Systemic Risks, Macroeconomic Shocks, and Financial Security in China

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Abstract—The Healthy development of China's economic and financial markets is crucial. This paper discusses in depth the macroeconomic factors and financial security environment that affect the systemic risk in China, and focuses on the regional research and analysis. The study discusses the relationship between macroeconomic factors and financial market performance and simulates the fragility and security conditions of the financial market through the detailed empirical facts. The loan scale, the transaction volume in financial markets, and the price performance of real estate are taken as the most important influential macroeconomic shocks to the systemic risk in China. The composite index for financial security is calculated by fully considering systemic risk based on factor analysis and finds significant regional differences in China. Through the method of stress testing, the study measures the different effects of macroeconomic shocks under different economic environments, time periods, and regions. The results of the stress testing suggest that the credit scale has the greatest impact on China's systemic risk, followed by the real estate market and the financial asset price. Besides, the most sensitive to the deterioration of the macroeconomic environment is the western region, followed by the middle region, the northeastern region, and the eastern region. Based on this, the study puts forward relevant suggestions for the healthy and stable development of financial markets in China.

Keywords-systemic risks;macroeconomic shocks; financial security; financial risk management

1 INTRODUCTION

The impact of financial development on economic growth has always been an important issue in the academic circles. A financial crisis usually occurs after bubbles arise in asset price. In recent years, the financial crisis is more closely related to real estate, stock markets, and credit risk, such as the financial crisis arising from the real estate and stock market bubbles in Japan in the 1980s and 1990s and the global economic crisis arising from the sub-prime crisis in the United States in 2008. Since the bankruptcy of Lehman Brothers Holdings (the fourth largest investment bank in the United States) on September 15,2008, the financial crisis has prevailed for 10 years. Over the past decade, economists have had more concrete reflections on the causes of the crisis. Financial liberalization and neo-liberalism have become the target of public criticism.

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The international economic environment that the emerging economies were confronted with at that time was also undergoing some significant changes, such as the increasing flow of transnational capital and financial liberalization. As a result, most of the emerging economies have relaxed the original financial repression policy and have turned to financial moderation. The excessive and inadequate financial repression and financial liberalization are perceived to have damaged economic growth. Moderation refers to finding a balance between the two. In order to find a better solution to the problem of financial moderation in the process of economic development, various financial reforms in China's financial market have recently been implemented with positive results. However, the stock market crash in China's capital market in 2015 caused the market value of the Chinese stock market to lose a total of 22 trillion yuan in just 3 weeks, which has aggravated the accumulation of systemic risks in China's financial system. The related problems of financial security have become the focus of the economic debate.

With the rapid development of China's economy, as well as the urgent need for financial markets to integrate into the progress of globalization, it has become quite essential to fully understand the development environment of China's financial markets, the level of risk and the ability to resist risk, and other real conditions. Based on such macroeconomic context, this paper attempts to carry out a comprehensive and crossover analysis of the impact of the economic shocks and the state of financial security on systemic risk in China. We adopt theoretical and empirical analyses to provide theoretical, data, and policy recommendations for the choice of a reasonable direction for adjustment and development of the financial structure in the future.

The paper is organized as follows: section 2 summarizes the review of related literature. Section 3 describes some empirical facts related to systemic risk in China. Section 4 builds the econometric models to calculate the composite index of financial security, and process macroeconomic stress tests to discuss the relationship among systemic risk, financial security and some key macroeconomic factors. Section 5 provides the concluding remarks and policy proposals.

2 REVIEW OF RELATED LITERATURE

The outbreak of the financial crisis in 2008 once again triggered widespread concern and in-depth studies on systemic risks by scholars. But, in the past, a consensus has almost been reached on the understanding and definition of systemic risks in academic circles and industry. Systemic risk refers to an uncontrollable risk that begins with the partial disruption of the financial system and gradually spreads to the total system, resulting in system disorder. This rapidly affects the real economy, leading to an economic recession and depression of the whole society that cannot be reversed in the short term [19]. In the process of research on systemic risks, the default rate of clients in financial institutions tends to be regarded as an indicator [10]. When the default rate of the client exceeds a certain cutoff point, the operations of financial institutions will become fragile and a slight economic shock will lead to their bankruptcy. In case defaults and bankruptcies occur to a large number of financial institutions simultaneously, the financial system will collapse completely. Thus, systemic risks are crucial to the regulators who are responsible for maintaining financial security. Unfortunately, the measurement and

analysis of systematic risk have been controversial due to the difficulty in developing a set of effective methods. Some studies argue that the failure to evaluate and measure systemic risks in an effective way is also one of the causes of the financial crisis [4].

One of the most important players concerned about systemic risks is the regulatory authority, which mainly regulated commercial banks [11][16]. Regulators are more willing to take into account both systemic and financial security, that is, to examine and quantify risks from a macro-prudential perspective. They observe the degree of occurrence of risk and the process of crisis outbreak at any time and benefit from receiving warnings in a timely manner so that they can take preventive measures to restrain the further spread of risk well in advance or just in time. However, such an idealized measurement method has not been well implemented[20].

Adrian and Shin (2010) pointed that, "the financial crisis reminds us that data predicts and transmits important information" [2]. The amount of credit, leverage, and money and the overall situation of cross-border financial affairs reflect the exposure of systemic risks and thus affect financial stability. An affective macro-prudential policy should pay attention to relevant data from all important sectors and departments at any time. A number of studies have pointed out the that the current banking regulation system lays particular stress on the individual financial institutions, while it has ignored to a great extent the externality and overall dynamics of the financial sector based on the macroeconomic cycles [15]. The purpose of macro-prudential regulation is to protect the entire financial system, as well as to lower the damage to the entire financial system and the costs of bankruptcy of the real sectors involved by restricting crisis [6][18], and to find specific solutions to the risks in the two dimensions of time and region [7][9].

At present, the measurement of systemic risks in the academic circles is mainly divided into two categories: Value at Risk (VaR) based on the default correlations and empirical analysis of market data and stress testing. These two methods have made unprecedented achievements, and a number of frontier branches have been derived [23], such as the CoVaR method based on specific market conditions and returns [3]. Acharya *et al*. (2009) develop a model in which capital shortages of individual financial institutions in periods of distress generate systemic risk in the economy [1]. Their measure is called the systemic expected shortfall and leverage. In addition, Brownlees and Engle (2015) constructed the SRISK index method, which aims to measure the anticipation of the future risk exposure of the financial intermediaries in the context of a downward trend in the market [8]. These methods provide a strong theoretical support for the in-depth and effective recognition of systemic risks and the maintenance of financial security by regulators.

The VaR method lays more stress on the empirical analysis with fewer theoretical restrictions, and thus, it is more likely to be accepted by the practitioners and managers in the financial sector. Stress testing is an effective risk management tool to assess the potential impact of extreme events on the banking or financial system. Similar to the stress testing of portfolios by a single institution, macro-stress testing can be used to test the robustness of the macroeconomy as a whole when it encounters the impact of a certain external or tail event, which can be used to measure the size of systemic risks [12]. The instrument of stress testing may be VaR [27], or a macro-model related to the driving factors of market risks [13]. In the macro-model, we can simulate the impact of all kinds of economic factors to get an appropriate variety of risk contexts, and in doing so, we will better understand the ability of the macroeconomic environment or financial environment of a country to resist stress. After the financial crisis in

2008, the regulatory authorities in various countries imposed macro-stress testing on the banking industry. For example, the regulatory authorities in the United States require financial institutions to report the condition of stress testing every year (see the Dodd-Frank Act in 2010 for details). The China Banking Regulatory Commission also explicitly stipulates that the banks in China should take stress testing as an important part of their assessment procedures for internal capital adequacy since 2012.

A considerable number of papers have conducted a joint study on systemic risks, financial vulnerability, and macro-prudential management [5][9][17][21][28]. Likewise, Chinese economists have carried out a number of studies and discussions regarding the characteristics of the financial market in China. Examples are the discussions concerning "Imbalance Adjustment, Macroeconomic Stability and Financial Risk Prevention" [30], the studies involving liquidity, stock market crash, and financial systemic risks [36], and the research on financial stability, systemic risks, and macro-prudential policies [14]; on financial development, real estate fluctuations, and monetary policy [25]; on asset price bubbles, economic openness, and financial risk management [22][26]; and so on. However, financial security is seldom mentioned in the studies on the above issues. The existing research has acknowledged the importance of financial security, and Chinese studies have been mostly devoted to this topic [24][35][31-32]; this research focus is closely related to the fact that China's national strategy has always laid emphasis on financial security.

3 EMPIRICAL FACTS IN CHINA

According to the history of financial crisis in western countries, the final signal of risk outbreak is the bankruptcy of commercial banks, which is closely related to the high non-performing loan rate. The past experience of developed countries also proves that systemic risk is directly related to the scale of loans of financial institutions and the price bubbles of financial assets. Are these key economic factors equally important to China's systemic risk? In this section, we intend to study the performance of systemic risk in China through some intuitive statistical description.

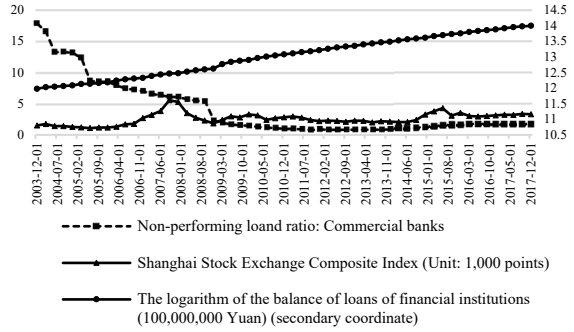


Figure 1. MAJOR INDICATORS OF THE FINANCIAL MARKET.

Source: Wind database.

In a strict sense, China has not experienced a devastating financial crisis. Even the 2015 stock market crash is still far from being a “devastating” crackdown. However, the uncoordinated development of the financial market in all aspects and the varying degrees of risks have hindered the high-quality economic development in China to a certain extent. With the acceleration of integration into the process of globalization, China faces new problems in the risks and resistance to stress of China's financial markets. In general, the non-performing loan rate is regarded as the most intuitive index to measure systemic risks. According to different regions and market environment, a certain safety value can be set, and the non-performing loan ratio beyond the warning line indicates the occurrence of a financial risk. We try to use Wind database of China's commercial banks and 2003-2017 China Statistical Yearbook data to perform a simple statistical analysis. Fig. 1 shows the quarterly data of the average non-performing loan ratio of commercial banks in China, the Shanghai Stock Exchange Composite Index, and the size of loans of financial institutions during the period from December 2003 to December 2017. As shown in Fig. 1, the loan scale of commercial banks continues to rise, the Shanghai Stock Exchange Index has experienced two peaks, and the peak period has been accompanied by a certain rise of the non-performing loan ratio.

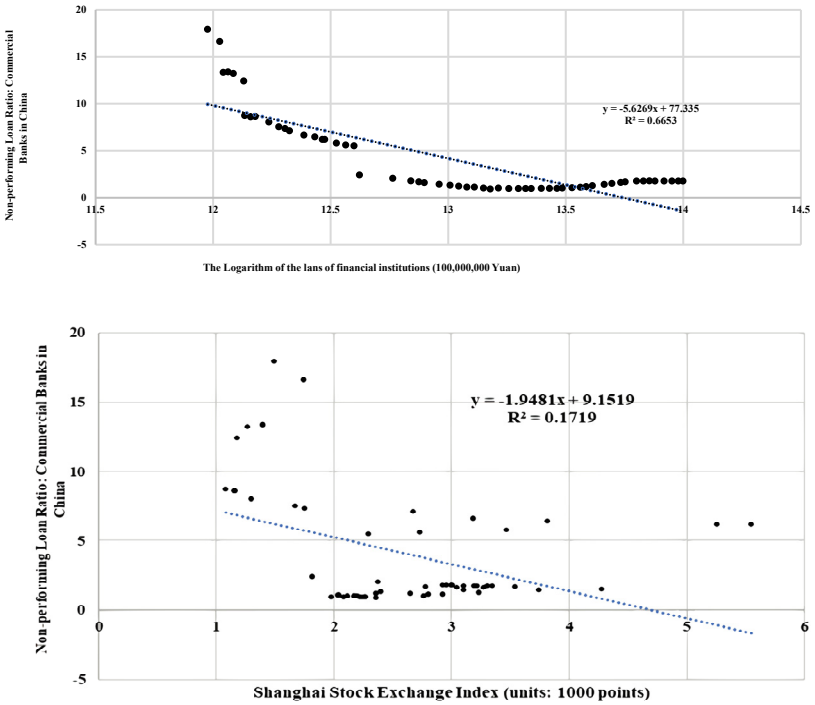


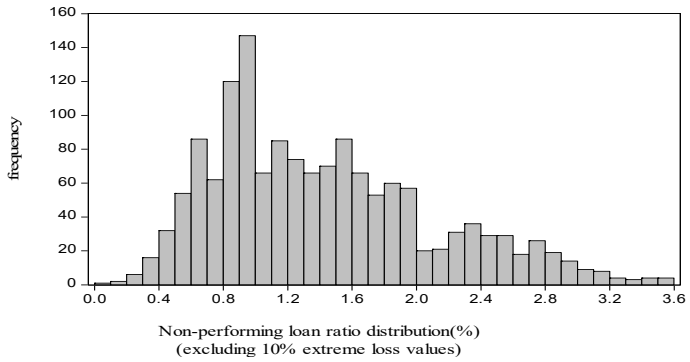
Figure 2. SCATTERPLOT OF THE NON-PERFORMING LOAN RATIO, THE LOAN SCALE, AN THE STOCK INDEX.

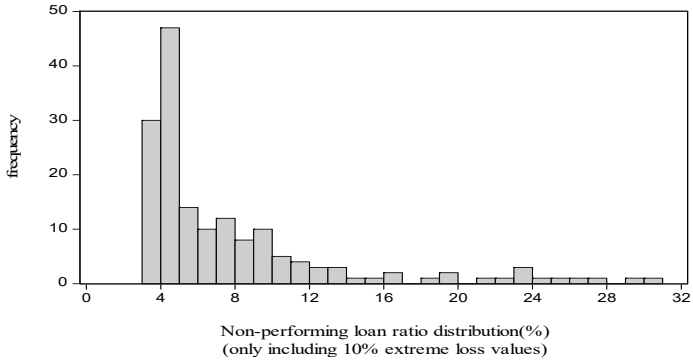
As shown in the scatterplot in Fig. 2, we can further examine whether the condition of the Chinese market is similar to the experience of western developed countries, that is, whether the

size of loans and the price of financial assets exert a key impact on the non-performing loan ratio, and thus ultimately affect the systemic risks of the entire financial market.

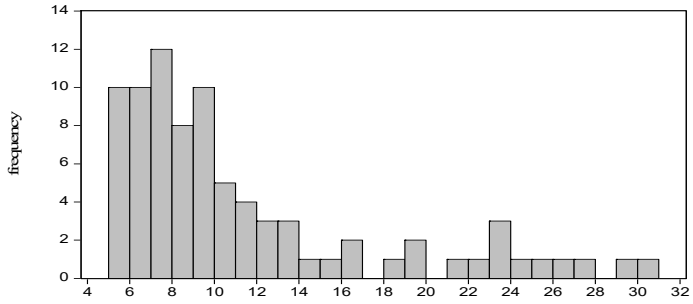
In the regression equation in Fig. 2, the dependent variables are the non-performing loan rates of commercial banks and the independent variables are the loan scale of financial institutions and the composite index of Shanghai Stock Exchange. The regression coefficients of independent variables in the two equations are significant at the 1% level. In case of an increase in the loan scale and the price of financial assets, the overall level of market default represented by the non-performing loan ratio will be reduced so that financial risks can be avoided. In theory, this can be explained by the fact that when the loan scale and asset price do not contain bubbles, the entire financial sector and the economy will automatically enter the mode of good development automatically. In such circumstances, appropriate financial liberalization will be conducive to the more efficient development of the Chinese economy. However, if the asset prices and loan expansion contain bubbles, the price of the financial assets and the credit scale have to be maintained at a higher level in order to avoid a high default rate. The hidden risk is that once the capital market collapses, a financial crisis cannot be avoided. The empirical facts of China are similar to those of developed countries, but the above analysis does not provide information about the level of financial security in the Chinese market. This needs to be further analyzed in what follows.

There has never been a long devastating financial crisis in the Chinese market, nor has there been bankruptcy of a bank in a strict sense. The financial regulation by the government and the central bank has always played an important role in the financial industry. Hence, it is difficult to define a critical value for financial security. But, some reference points can nevertheless be observed from Fig. 1. In September 2007 and June 2015, two peaks occurred in the stock market and the asset bubble reached its peak. Once the relevant economic stimulus occurs, the bubble will be broken in the absence of harsh financial regulation, and then a financial crisis will break out. The non-performing loan ratios corresponding to these two periods are 6.17 and 4.27, respectively. Systemic risks lead to an unsafe situation when the non-performing loan ratio exceeds the level of 4.27. In accordance with the Core Indicators for the Risk Management of Commercial Banks (for Trial Implementation) posed by the China Banking Regulatory Commission (2005), the non-performing loan ratio of commercial banks should not be higher than 5%, which also indirectly supports the above analysis.

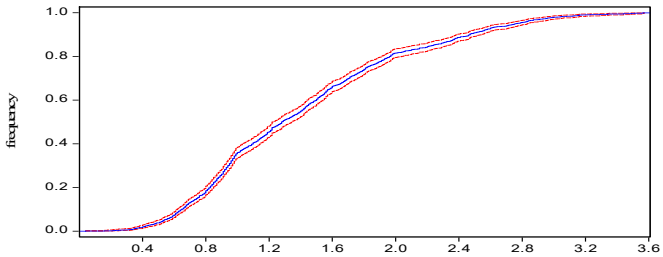




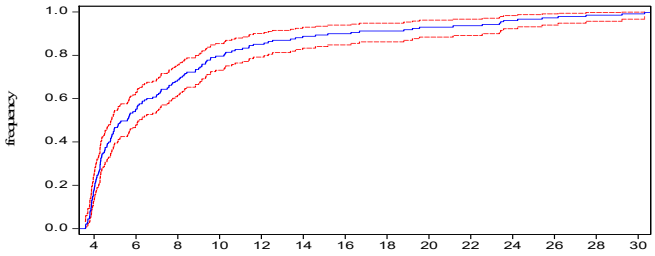
Non-performing loan ratio distribution(%)
(only including 10% extreme loss values)



Non-performing loan ratio distribution(%)
(only including 5% extreme loss values)



CDF of Non-performing loan ratio(%)
(excluding 10% extreme loss values)



CDF of Non-performing loan ratio(%)
(only including 10% extreme loss values)

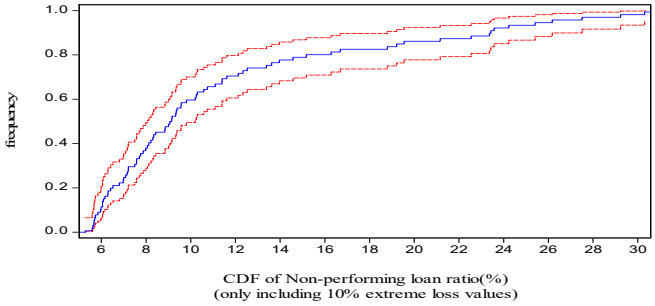


Figure 3. LOSS DISTRIBUTION OF THE NON-PERFORMING LOAN RATIOS IN COMMERCIAL BANKS.

Source: Wind database.

In order to have an additional understanding of the operational state of commercial banks in the Chinese market, we collected the data of 1,648 quarterly or annual non-performing loan ratios disclosed by 106 commercial banks from 1999 to 2017 in China, among which there are 31 listed banks, 31 urban commercial banks, and 44 rural commercial banks. Fig. 3 shows the distribution of the non-performing loan ratio of these commercial banks. It shows a histogram and an empirical cumulative distribution function (CDF) diagram of "loss distribution excluding 10% extreme values", "10% extreme loss distribution", and "5% extreme loss distribution" from top to bottom, respectively.

In Fig. 3, the non-performing loan ratios of 90% of commercial banks are all lower than 4%, and the shape of thick right tail and the slowly growing CDF chart offer a challenge to Chinese commercial banks to cope with extreme risk events. The extreme loss distributions show that 10% of the non-performing loan ratios of commercial banks have still exceeded 4% since 1999 and do not give the thin right tail feature of controllable losses. Among the extreme losses, more than 50% of the non-performing loan ratios exceed 5%, more than 20% of the non-performing loan ratios exceed 10%, and more than 5% of the non-performing loan ratios exceed 20%. Were it not for the fact that China has carried out financial repression policies for a long time, it would have been impossible for some vulnerable banks to avoid bankruptcy.

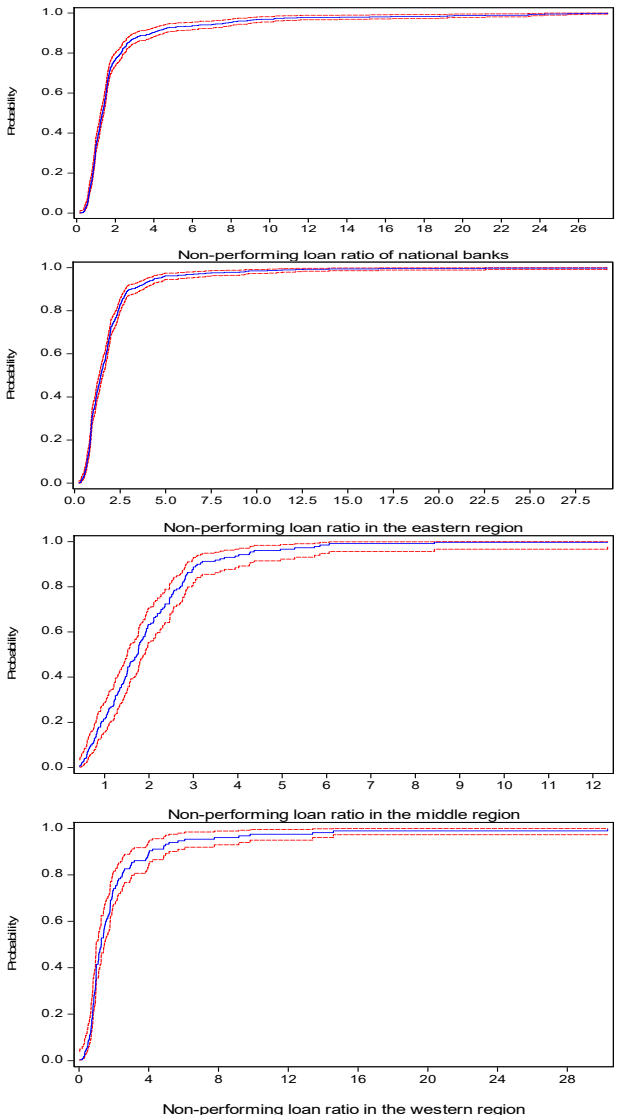


Figure 4. EMPIRICAL CUMULATIVE DISTRIBUTIONS OF THE NON-PERFORMING LOAN RATIOS OF REGIONAL COMMERCIAL BANKS.

The extreme imbalance of regional development in China is reflected in the development of the financial industry. To show that, we make a simple regional observation of the sample banks. Among them, a large number of banks, which have a long history, a large scale, and nationwide distribution in the business outlets, are classified as "national banks" because it is difficult to assign those banks to specific regions. The following are the four major banks in China: the Industrial and Commercial Bank of China, the Agricultural Bank of China, the China Construction Bank, and the Bank of China. Of the 1,648 banks in the sample, there are 622 commercial banks in the eastern region, 141 in the western region, 165 in the middle region, 68

in the northeast region, and 652 commercial banks nationwide. The cumulative empirical distribution of their non-performing loan ratios is shown in Fig. 4 (the data of the northeastern region are not separately listed).

According to the critical value of the loss distribution extreme value, the eastern region is in the best operating situation. In the past 20 years, 90% of the non-performing loan ratios have been below 3.12%. In the western region, 90% of the non-performing loan ratios have been below 4%; this level exceeds the average loss level nationwide, and its financial environment is sobering. The national banks exhibit good operating situation.

To sum up, in the Chinese market, where the financial markets are not fully liberalized and financial repression plays a dominant role, 10% of the non-performing loan ratios disclosed by commercial banks still exceed the required standard of the regulators throughout a long observation period.

In accordance with the 1996 Amendment of the Basel Committee on Banking Supervision, which was implemented in 1998, the banks are required not only to hold capital for credit risks but also to hold capital for market risks. The capital required for a bank's trading books is calculated by VaR on the basis of the historical values of catastrophic loss. If we followed this international practice, the non-performing loan ratio we have observed should be controlled within the range of 1-5% after taking into account the multiplier of at least three times.[1] Despite the absence of a major financial crisis in China's history, a gap with the international standards apparently exists.

4 EMPIRICAL ANALYSIS

According to financial theory, there are a variety of economic factors that trigger or aggravate financial risks. Different financial markets involve different determining factors. The same financial factors may be beneficial to financial security in some financial environments but stimulate financial risks in other cases. In this section, we will take full account of all kinds of possible factors in China's financial market by combining the reality of China the previous studies. We measure the relevant factors of security risks, the main indicators that constitute financial security, and the effects of the key macroeconomic factors on financial risks by means of an empirical analysis.

4.1 Buiding the Basic Systemic Risk Equation and Single-factor Influence Equation

We define the non-performing loan ratio of commercial banks as the dependent variable of the basic equation of systemic risks. The independent variables are the loan scale, the transaction volume of the securities market, the value added in the real estate industry, and other macroeconomic factors of interest. The development level of GDP and other factors that affect

[1] The capital required by the bank is equal to the number of *k* multiplied by VaR (additional adjustments required for other special risks), and the "*k*" is determined by the regulators. The value of *k* varies between different banks, but in any case, the value of *K* will not be less than 3. For banks with a well-established VaR detection system, it is highly possible for the *k* value of the bank to approach the minimum value of 3. However, for the banks that fail to establish a perfect VaR system, the value of *k* is likely to be higher.

the financial security environment are introduced into the panel equation as control variables. Based on the previous studies, a large number of financial security factors may be involved which may be correlated. If all these variables were introduced into the panel model as control variables, multicollinearity may hamper the estimation of the composite panel equation. Therefore, we first examine the impact of these factors on the non-performance loan ratio separately. Then we consider the overall impact of these factors to construct the composite index of financial security. Finally, we introduce the composite index as a control variable of aggregative indicator into the panel equation for analysis.

Through the analysis and comparison of the relevant statistics set by different models, this paper adopts the mixed section-time fixed effect model of panel data for analysis. The specific model is as follows:

$$y_{\mathrm{it}} = m + x_{ir}^{'}\beta + Y_t + \mu_{it}, \quad i = 1, 2\ldots, N, \ t = 1, 2, \ldots, T. \tag{1}$$

where y_{it} refers to the non-performing loan ratio in the area i at time t and x_{it} refers to the value of the economic variable i at time t, and β is the regression coefficient. The estimation of parameters is detailed in Appendix A.

TABLE I. DEFINITIONS AND STATISTICAL DESCRIPTIONS OF VARIABLES

Variable (definition)	**Descriptions of Variables**			
	Mean	*Standard deviation*	*Minimum*	*Maximum*
Default: Non-performing loan ratio				
	3.81	4.90	0.23	24.74
LnLoan: The logarithm of the balance of loans (100,000,000 yuan)				
	9.27	1.15	5.19	11.62
LnExcha: The logarithm of the total transaction volume of securities market (100,000,000 yuan)				
	9.67	1.90	1.93	14.48
LnGDP: The logarithm of GDP (100,000,000 yuan)				
	9.19	1.09	5.52	11.30
LnReAdd: The logarithm of the added value of real estate market (100,000,000 yuan)				
	5.92	1.55	2.30	8.74
LnPCGDP: The logarithm of GDP per capita (yuan)				
	10.31	0.62	8.59	11.68
LnFAdd: The logarithm of the added value in the financial sector (100,000,000 yuan)				
	6.10	1.29	1.86	8.72
LnConsumLe: The logarithm of consumption level of residents (yuan)				
	9.26	0.59	7.96	10.81
LnTrade: The logarithm of total imports and exports (1,000 US dollars)				
	17.08	1.74	12.23	20.81
LnCA: The logarithm of total current assets of privately owned and state-owned enterprises				

Variable (definition)	Descriptions of Variables			
	Mean	*Standard deviation*	*Minimum*	*Maximum*
(100,000,000 yuan)				
	8.04	1.25	3.13	10.17
F-S Index: Composite index for financial security				
	0.59	0.20	0.00	1.00

The data are mainly derived from the National Bureau of Statistics website and the Wind database. According to the availability of data, 372 groups of data are selected from 31 provinces between 2005 and 2016, of which there are 10 eastern provinces, six central provinces, 12 western provinces, and three northeastern provinces. The variables selected in this paper are mainly used in the correlation factor analysis of systemic risks, the building of composite index of financial security, and the stress testing of macroeconomic shocks. The definitions and statistical descriptions of related variables are shown in Tab. I. The calculation of the composite index for financial security F-S Index in the last line of Tab. I is described in detail in the next part of the analysis.

TABLE II. REGRESSION RESULTS OF THE MIXED "CROSS-SECTION AND TIME FIXED" EFFECT PANEL (BASIC EQUATION)

Variable	Regression Results					
	Intercept	*LnLoan*	*LnExcha*	*LnGDP*	*LnReAdd*	*F-S Index*
Model 1	6.341** (2.522)	-3.977*** (-6.564)	1.113*** (4.122)	3.851*** (6.697)	-1.994*** (-3.788)	
Model 2	3.656 (1.241)	-3.261*** (-4.458)	1.206*** (4.393)	3.534*** (5.874)	-1.861*** (-3.508)	-4.583* (-1.735)
Model 1: Adj. R^2: 0.737; F-statistic: 70.17; D-W value: 0.703. Model 2: Adj. R^2: 0.738; F-statistic: 66.34; D-W value: 0.707.						

Note: The period fixed effects are not listed in the table. The values in brackets are *t* statistics. *, **, and *** indicate that it is significant at the levels 10%, 5%, and 1%, respectively.

TABLE III. REGRESSION RESULTS OF THE MIXED "CROSS-SECTION AND TIME FIXED" EFFECT PANEL (SINGLE-FACTOR INFLUENCE EQUATION)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	23.02** (7.142)	9.835*** (12.484)	25.61*** (8.166)	12.75*** (8.941)	8.123*** (7.973)	7.415*** (13.899)
LnPCGDP	-1.86*** (-5.967)					
LnFAdd		-1.988*** (-7.768)				
LnConsumLe			-2.356*** (-6.959)			
LnTrade				-0.524*** (-6.301)		
LnCA					-0.537*** (-4.279)	

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
F-S Index						-6.067*** (-7.000)
Adj.R^2	0.699	0.717	0.709	0.702	0.686	0.709
F-statistic	72.900	79.344	76.240	73.966	68.392	76.389
D-W statistic	0.641	0.650	0.660	0.632	0.616	0.647

Note: The period fixed effects are not listed in the table. The values in brackets are *t*-statistics. *, **, and *** indicate that it is significant at the levels 10%, 5%, and 1%, respectively.

Eviews 8 software is used to conduct a significance test and regression analysis on the panel model. The application of the mixed "cross-section and time fixed" effect is supported to our analysis. The regression results are shown in Tab. II and III. Whether it is the regression result of the basic equation or that of the single-factor influence equation, most of the variables are closely related to the indicators of the default rate that mainly represent the systemic risks, and it is also consistent with our expectations. The basic equation (Tab. II) shows that during the observation period, the gradual expansion of the loan scale and the increase of the added value in the real estate industry are important factors to predict the occurrence of default, which also means that once the loan scale is tightened, a significant decline in the housing prices is likely to trigger a systemic risk. The regression results also show that when the trading scale of the securities market reaches a certain degree, it will also stimulate the occurrence of default. This shows the sensitivity of systemic risks to the value of the stock market to a certain extent. As a controlled variable, LnGDP is significantly positive, and it is different from the usual anticipation. When the economic level improves to a certain extent, it will easily breed the bubbles in the loan scale and the real estate expansion, which will lead to financial risk. The negative correlation of the composite index for financial security, F-S Index, indicates the importance of creating a healthy, orderly, and a safe financial security environment to avoid systemic risks.

Based on the previous studies, we consider the combined effects of GDP per capita, the development level of the financial sector, the situation of residents' consumption, the trade scale, and the amount of liquid assets in enterprises as the important indicators to calculate the composite index of financial security.

4.2 Calculation of Composite Index for Financial Security

The purpose of calculating the composite index of financial security is to evaluate the state of the financial environment. We calculate it based on the method of factor analysis. We select all the variables in different categories that have a significant impact on the non-performing loan ratios in the single-factor influence equation in Tab. IV for factor analysis. All the variables show a significant effect on the non-performing loan ratios. The composite index calculated by factor analysis is designed to follow the rule of "a higher value of the variable leads to a higher degree of financial security".

It is valued according to the common factor and processed by the 0-1 distribution in order to more intuitively observe the index more intuitively, so that the composite index for financial security can be obtained. The relevant statistical summary is shown in Tab. I. The composite index for financial security is substituted into the basic equation and the single-factor

influence equation separately, and the regression results prove that the composite index is set ideally. The regression results are shown in Tab II.

The composite index of financial security in this paper is a macro-level index. Its size corresponds to the financial risk environment of a certain market. Our research will give different boundaries of the index, representing the financial security level of “excellent”, “good”, and “low”. “Excellent” indicates the financial environment is healthy and risks can be well controlled. “Good” indicates the financial environment is normal and might need further improvement. “Low” implies the financial environment is risky and necessary measures should be taken to manage the risks.

This paper links the different boundaries of financial security with the regulated non-performing loan ratio. In order to allow the security boundaries not only to be adjusted dynamically with the time but also to vary with different regions, we add the dummy variables of the eastern, central and western regions (the northeastern region is the reference group) in Model 6 of the single-factor influence equation in Tab. III and then conduct regression on the non-performing loan ratio again. The results show that the regional dummy variables and the F-S Index are both significant at the 1% level, and that the value of R^2 of the equation is 0.75 and the F-statistic is 69.96 (the coefficients of the variables in the equation can be seen in the notes of Fig. 5-8). Therefore, we consider setting up a safe non-performance loan ratio and substituting it into our fitting equation. Finally, according to the requirements of different regions and time, we work out the safety margins of the financial security indexes under different circumstances. According to the provision mentioned in the preceding text that the non-performing loan ratio in the indicators of credit risk regulation in commercial banks should not be higher than 5%, coupled with the regulatory requirements of the Basel Accord for the default rate multiplied by 3, we take one-third of 5%, namely 1.67%, as the ideal value of the “excellent” level of financial security and one half of 5%, namely 2.5%, as the intermediate value of the “good” level of financial security, and 5% as the warning value of the “low” level of financial security.

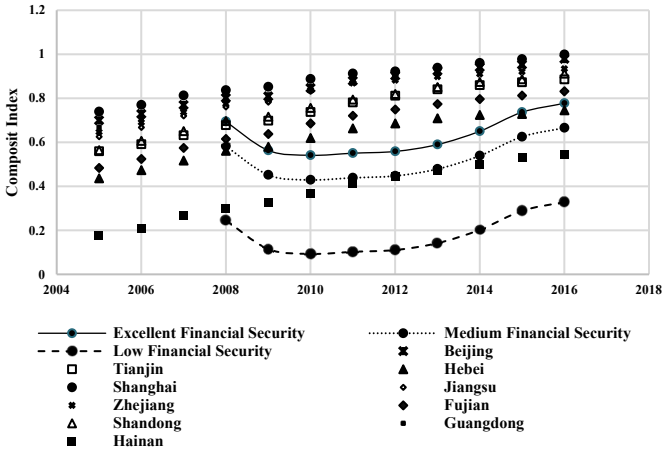


Figure 5. COMPOSITE INDEX OF FINANCIAL SECURITY IN THE EASTERN REGION OF CHINA.

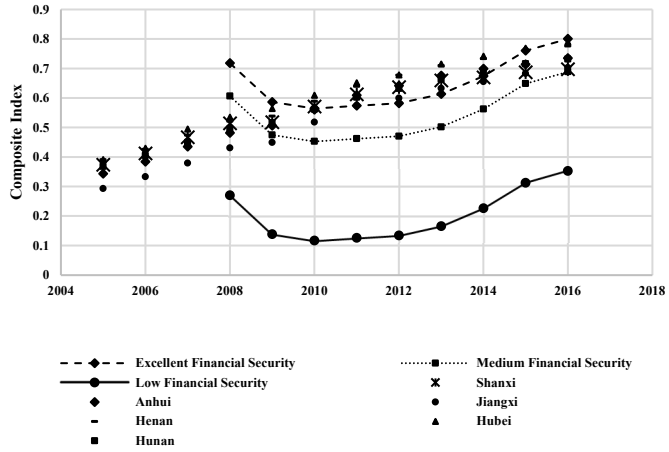


Figure 6. CONPOSITE INDEX OF FINANCIAL SECURITY IN THE MIDDLE REGION OF CHINA.

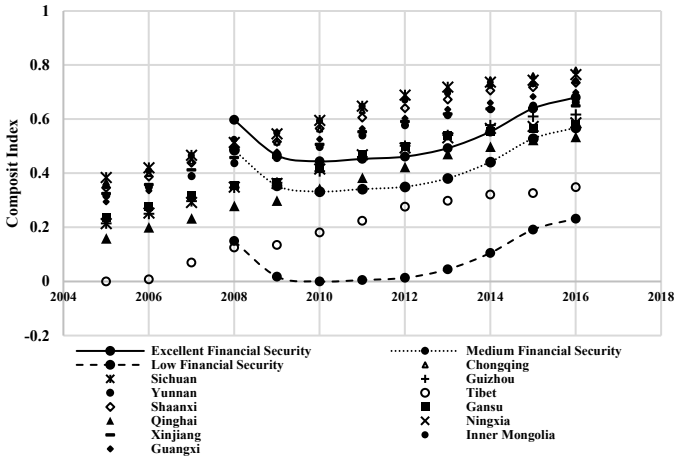


Figure 7. COMPOSITE INDEX OF FINANCIAL SECURITY IN THE WESTERN REGION OF CHINA.

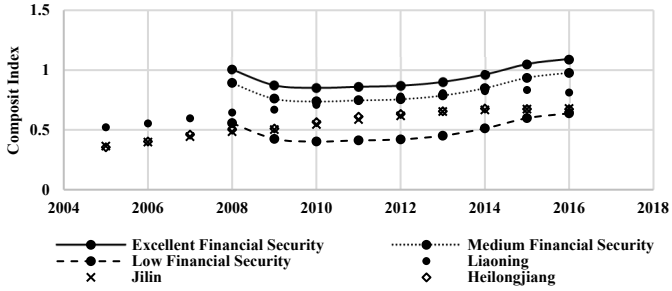


Figure 8. COMPOSITE INDEX OF FINANCIAL SECURITY IN THE NORTHESTERN REGION OF CHIN

Note for Fig. 5-Fig. 8: The regional financial security safety margins in the figure are worked out based on the fitting equation of "the fitted value of default = 2.304* the eastern region - 2.132* the middle region - 3.026* the western region - 7.433* F-S Index + 10.555 + period fixed effect". By setting the default value is 1.67 (excellent), 2.5 (medium) and 5 (low), the corresponding composite indexes for financial security can be worked out.

The scattered points in Fig. 5-8 are the values of the composite indexes for financial security in various regions from 2005 to 2016, and the smoothed lines refer to the financial safety margins at different levels in different periods. We define the values of composite indexes for financial security between 0 and 1, and the higher the value is, the safer the financial environment of the region will be. However, for different regions, there are different requirements for the excellent, medium, and low levels of financial safety margins in different periods. Therefore, there are different regulatory requirements for different regions, and when the scattered points are above the corresponding smoothed lines, we believe that the region has safe financial environment. By observing the distribution of scattered points, it can be seen that the value of security index in the eastern region is relatively the highest, and the lowest values are more distributed in the western region. Next, by observing the smoothed lines of financial safety margins in different regions, it can be inferred that the eastern region has the lowest requirements for financial safety margins, which means that the eastern region has the largest number of provinces above the safety margins as well as indirectly indicates that the eastern region has a relatively mature and stable macroeconomic environment for financial development. However, in the northeastern region, it is seen that in order to ensure a relatively low default rate to fully avoid the occurrence of the systemic risks, it must satisfy a high financial safety margin to achieve such default rate, which also means that the northeastern region has the smallest number of provinces above the safety margins, thereby showing the relatively weak financial environment in the northeastern region. From the figures, we can also observe that, irrespective of which region it is, the highest requirements for the value of the boundaries of financial security are at different levels in 2008, 2015, and 2016, which is closely related to the outbreak of the financial crisis and the stock market crash in these 3 years (2016 is a continuation of the impact of 2015). And it also verifies the reliability of our estimate of the index once again.

In this section, we focus on the calculation of financial security composite index in different regions of China. The index is composed of per capita GDP, the added value in the financial sector, consumption level of residents, trade scale, and current assets of enterprises which are highly related to the default rate of commercial banks. The boundaries of "excellent", "good", and "low" are different for different time periods. The results show that most of the provinces in the eastern region are located on the upper side of the curves "good" and "excellent", followed by the middle region, the western region, and the northeastern region. This order denotes that the eastern region has the best healthy financial environment and the middle region has the better one. The western region and the northeastern regions are less optimistic.

4.3 Macroeconomic shocks

The stress testing model which combines the credit risk with the macroeconomic factors has been relatively mature (Virolainen, 2004)[29]. The core idea is to link macroeconomic factors with the default rate represented by the non-performing loan ratio. In case of a reasonable setting of the model, the corresponding changes in the default rate can be observed by

generating a macroeconomic shock in the system, which is a simulation for the possible default rate in the future. The objective is to obtain the expected loss and extreme loss of a credit portfolio in the future under the prevailing macroeconomic conditions. This study refers to the model framework of Wilson (1997a, 1997b)[33-34].

The first step is to assume that the average default rate of commercial banks in region *i* can be defined in the form of a logistic equation as follows:

$$p_{i,t} = \frac{1}{1 + \exp(y_{i,t})}. \tag{2}$$

The logistic distribution form has been widely used in the research models on bank failure, and it can ensure that the estimated default rate is in the interval [0,1]. $p_{i,t}$ is the average default rate of the region *i* at time *t*, and $y_{i,t}$ is the index of the level of the development and operation of a bank in a specific region. The better the operation and development of a commercial bank is, the higher the value of $y_{i,t}$ will be, and the lower the default rate $p_{i,t}$ will be, and vice versa. The expression for $y_{i,t}$ can be easily obtained in the form of the logistic equation through the logit conversion:

$$L\left(p_{i,t}\right) = \ln\left(\frac{1-p_{i,t}}{p_{i,t}}\right) = y_{i,t}. \tag{3}$$

Since we can obtain the value of the default rate in the model represented by the non-performing loan ratio in advance, we can deduce the average value of the operating-level index of commercial banks in the region. If we fail to know the non-performance loan ratio, we can compile the operating level index and then estimate the default rate through the representative operating state of the commercial banks in the region.

In the model, $y_{i,t}$ is affected by a number of exogenous macroeconomic factors. In accordance with the mixed section-time fixed effect model adopted by the previously set panel, (1) can be expanded as follows:

$$y_{i,t} = \mathrm{m} + \beta_1 x_{1,it} + \beta_2 x_{2,it} + \ldots + \beta_\mathrm{n} x_{\mathrm{n},it} + \gamma_t + u_{it}. \tag{4}$$

where β_is are the coefficients of the related macroeconomic factors, which are presented in this paper as the loan scale, the value added of the real estate sector, the total trading volume of the securities market, and the composite index of financial security.

In the second step, similar to the approach of Virolainen (2004) [29], we can predict the expected value of each macroeconomic factor in the next stage by using a set of univariate autoregressive equations of order 2 (AR(2)), based on the time series data of each macroeconomic factor:

$$x_{it} = k_{i0} + k_{i1} X_{i\,t\text{-}1} + k_{i2} X_{i\,t\text{-}2} + \varepsilon_{it}. \tag{5}$$

where k_i represents the regression coefficient of the *i*th macroeconomic factor. ε_{it} is a random error term, and it is assumed that it obeys the independent normal distribution.

Equations (2)-(5) define the relationship between the default rate and the macroeconomic factors in the form of a joint equation, with the residual vector E of $(j+i)\times 1$ dimensions, and the variance and covariance matrices $\sum$ of the residual of $(j+i)\times(j+i)$ dimensions, which are defined as equation (6):

$$\mathrm{E}=\begin{pmatrix} u \\ \varepsilon \end{pmatrix} \sim N(0, \Sigma) \quad \Sigma = \begin{bmatrix} \sum_{u} & \sum_{u,\varepsilon} \\ \sum_{\varepsilon,u} & \sum_{\varepsilon} \end{bmatrix}. \tag{6}$$

The last step is to simulate the joint default rate of different regions based on the different time periods according to the system equations based on the combination of the estimation of each parameter and the residual term. According to the previous model settings, the macroeconomic factors that affect the default rate are independent of each other, so that we can conduct the stress testing of each economic shock on the model through the simulated data of the Monte Carlo model with a single variable on the premise that other economic conditions (variables) remain unchanged.

This paper selects the time fixed effect equation in the latest period to obtain the expected value of each macroeconomic factor for the next period and obtains the default rate in case of different extreme values simulated from the normal distribution based on the mean value and variance of each factor in the historical observation periods. The regression results of the vector autoregression model are shown in Tab. IV, and the simulated loss distribution of stress testing is shown in Tab. V.

The regional stress testing in this paper is targeted at the distribution in four major areas, and the expected values of different regions in the model are the mean provincial value in this region.

TABLE IV. REGRESSION RESULTS OF THE MACROECONOMIC FACTORS' VECTOR AUTOREGRESSION

Variable	*LnLoan*	*LnExcha*	*LnReAdd*	*LnGDP*	*F-S Index*
Intercept	0.183*** (7.033)	0.485*** (4.048)	0.268*** (12.027)	0.135*** (7.908)	0.043*** (11.344)
Lag Intervals (-1)	1.493*** (34.040)	0.895*** (19.593)	1.054*** (24.930)	1.534*** (37.834)	1.198* (20.382)
Lag Intervals (-2)	-0.504*** (-11.552)	0.083* (1.730)	-0.078* (-1.881)	-0.543*** (-13.481)	-0.230*** (-4.023)
Year	2005-2016	2002-2016	1999-2016	2001-2016	2007-2016
Adj. R^2	0.997	0.926	0.993	0.998	0.995
F-statistic	67,394	2,887.6	38,558	161,197	29,746

Note: The figure in brackets are t-statistics.***, **, and * indicate significance at the levels 1%, 5%, and 10%, respectively.

TABLE V. DISTRIBUTION TABLE OF REGIONAL LOSSES OF MACROECONOMIC SHOCK STRESS TESTING

Stress Testing	*Df.*	*LnLoan*	*Df.*	*Ln Excha*	*Df.*	*LnRe Add*	*Df.*	*F-S Index*
The Eastern Region of China								

Stress Testing	*Df.*	*LnLoan*	*Df.*	*Ln Excha*	*Df.*	*LnRe Add*	*Df.*	*F-S Index*
The Eastern Region of China								
Expected Value	1.01	10.88	1.01	12.71	1.01	7.60	1.01	0.90
10% Extreme Loss	4.99	9.67	3.90	15.10	3.88	6.06	1.93	0.70
5% Extreme Loss	6.23	9.28	4.66	15.73	4.71	5.61	2.23	0.63
1% Extreme Loss	9.00	8.43	5.91	16.77	6.31	4.75	2.56	0.56
The Middle Region of China								
Expected Value	2.24	10.38	2.24	11.70	2.24	7.06	2.24	0.76
10% Extreme Loss	4.75	9.61	4.47	13.55	4.47	5.87	2.84	0.63
5% Extreme Loss	5.65	9.33	4.98	13.97	5.11	5.52	3.01	0.60
1% Extreme Loss	6.98	8.92	6.38	15.13	6.10	4.99	3.25	0.54
The Western Region of China								
Expected Value	2.10	9.74	2.10	10.47	2.10	5.82	2.10	0.67
10% Extreme Loss	7.02	8.24	5.12	12.97	5.49	4.00	3.02	0.47
5% Extreme Loss	8.07	7.92	5.87	13.59	6.56	3.42	3.26	0.41
1% Extreme Loss	10.4	7.20	7.45	14.91	8.36	2.46	3.78	0.30
The Northeastern Region of China								
Expected Value	1.91	10.15	1.91	11.38	1.91	6.62	1.91	0.74
10% Extreme Loss	4.75	9.28	4.22	13.29	3.97	5.52	2.51	0.61
5% Extreme Loss	5.54	9.04	4.81	13.78	4.52	5.22	2.68	0.57
1% Extreme Loss	7.05	8.58	6.04	14.80	5.66	4.61	3.02	0.50

Note: Df. means Default rate.

Based on the 10,000 Monte Carlo simulations, the loss distribution of regional stress testing is shown in Tab. V.

First of all, the expected value of the default rate in each region is observed. It can be seen that the default rate of the middle region is at the highest level of 2.24 and that of the eastern region is at the lowest level of 1.01. However, stress testing intends to know more about what kind of shocks default risks will encounter when an extreme economic situation occurs. Throughout the four macroeconomic factors used for testing, the loan scale has the largest impact on the systemic risks or is the most sensitive to such risks, followed by the value added of the real estate industry, which means that in case of a sudden contraction in the scale of loans or a sudden drop in housing prices (we can obtain the corresponding range of drop according to the exponential values of the figures in Tab. V), it will lead to varying degrees of default, thereby resulting in a systemic risk. For example, in the real estate market of the eastern region under the circumstances of 1% extreme loss, when the LnReAdd value is 4.75, the default rate of commercial banks will reach 6.31, which indicates that for the regulatory authorities, the default rate of the commercial banks is likely to reach a high-risk level of 6.31% when the scale of the value added of the real estate industry in an eastern province shrinks to the exponential value of 11.558 billion yuan with the LnReAdd value of 4.75. The impact of the loan scale on the financial systems in China is most uncontrollable in the macro-impact factors shown in Tab. V. We can see that the non-performing loan ratio, triggered by the impact of the 1% extreme value of the factor, is at a very high default level (the minimum value is 6.98 for the middle region and the maximum value is 10.4 for the western region), which far exceeds the warning level that we set before. Furthermore, it is found that the two indicators of loan scale and housing price are the most sensitive in the western and eastern regions, while they are relatively stable in the middle and northeastern regions. Next, we observe the impact of the financial security environment in different regions on the default rate. Since the F-S Index is a composite index, there will be no significant fluctuations on the indicator in terms of the extreme value simulation. But, from the perspective of distribution, we can still find some regional differences. Taking the value of the F-S Index in case of 10% extreme loss as an example, the extreme conditions of financial security in the western region (the worst financial environment) have the greatest impact on the default rate, which is 3.02, followed by 2.84 in the middle region, 2.51 in the northeastern region, and 1.93 in the eastern region. The same sequence is shown in case of 5% and 1% catastrophic losses. It reflects the instability of the financial environment in the middle and western regions and indirectly verifies our previous conclusion that the eastern region has better financial security environment, but the excellent financial security environment in the eastern region highlights the hidden dangers and possible bubbles in the housing prices and the scale of loans.

This section mainly discusses the extreme impact of macroeconomic factors and the financial security index on systemic risk. From the perspective of individual macro-factors, the systemic risk caused by the contraction of loan scale is the most harmful and the risk in the western region is the most uncontrollable. Systematic risk caused by a shrinking real estate market also causes a tremendous damage. The western region still shows the biggest, uncontrollable risky situation followed by the eastern region, which implies that once the house price falls, the systematic risk caused may trigger economic panic. Our results also indicate that the risks from the price bubbles of financial assets are well managed in China at present. According to the stress test of financial security index, the risk of deterioration of

financial environment in the western region is largest, followed by the middle, northeastern, and eastern regions.

5 CONCLUSIONS AND POLICY PROPOSALS

In this paper, we focus on the non-performing loan rate of commercial banks to discuss the systemic risk of China. Through abundant data analysis, the systemic risk in China is closely related to credit scale, real estate markets, and financial asset prices. We design and calculate a composite index of financial security, which is composed of various macro-factors that significantly affect the non-performing loan rate of commercial banks. The objective of the index is to show that the financial environment assessment it represents is not only a comprehensive display of key macroeconomic factors, but also a prediction of possible systemic risks. Compared with the previous studies on financial security index conducted by Chinese scholars, the index constructed in this paper has dynamic characteristics and presents regional differences. According to the requirements of government financial supervision, we give the boundaries of “excellent”, “good” and “low”, which represent the different financial safety margins. Policymakers can take the requisite intervention measures to manage the corresponding levels of risks.

We test extreme value stress based on regional differences through the three indicators of systemic risk, namely credit scale, real estate prices, and financial asset prices. Taking 5% extreme value shocks as an example, assume that the non-performing loan rate exceeding 5% is the upper limit of regulatory capacity. The research conclusion states that the credit scale has the greatest impact on China's systemic risk, and the extreme consequences are beyond the scope of regulatory capacity in all regions, which is liable to trigger financial crisis. The real estate market has the second biggest impact on systemic risk, and the extreme risks also express greater harmfulness. The western and middle regions are beyond the scope of regulatory control. The extreme impact of financial asset price bubbles on systemic risks demonstrates that they are not beyond regulatory capacity except for the western region (which is very close to the regulatory threshold). For the four regions, the western region is the most exposed area to all the indicators. In addition, the eastern region has a higher credit risk, while the middle region has a higher real estate market risk.

According to the stress test of the financial security index composed of other macroeconomic factors, the most sensitive to the deterioration of the macroeconomic environment is the western region, followed by the middle region, the northeastern region, and the eastern region.

Based on the analysis discussed in this paper, we draw the following main conclusions. We should attach importance to the loan scale management of commercial banks and prudently use the tight credit policy. Slow credit expansion can prevent the rapid expansion of the credit bubble. China's real estate market has reached a certain scale, and further expansion needs to be carefully considered in combination with financial supervision. China's financial capital market still has flexible development space. China can be more in line with international financial markets, expand derivatives markets, and encourage diversified forms of capital flows, thus promoting faster maturity of China's financial markets. The western region of China has great potential financial risks, which need more detailed analysis of the relevant reasons, and has attracted the attention of the regulatory authorities.

The time for commercial banks in China starting market-oriented operation and information disclosure is relatively short. As a result, the available non-performing loan rate data have a short time span and the sample size is not large enough. Meanwhile, many commercial banks in China currently have a deviation in the concept of focusing on business while neglecting risk management, which restricts the development of China's stress testing practice to a certain extent. In the current turbulent global economic and financial situation, the scope and depth of the application of macro stress testing should be strengthened in future research, and the reference weight of stress testing result should be enhanced in relevant entities' decision-making process;

The relevant policy proposals are as follows: it is necessary to establish a dynamic comprehensive evaluation system and regulatory system on financial security in China. The development of economic and financial markets involves complicated macro-environment, it is necessary to set up specific regulatory requirements according to the specific economic and financial conditions and to set up a supporting regulatory system that is flexible, prudent, and highly effective. We should lay more emphasis on a differentiated financial risk management in various regions and enhance the overall early-warning mechanism of the relevant financial institutions. There are significant differences in China in terms of regional development and financial development. In view of the characteristics of regional development and the different policies for regional development in China, we should strengthen the overall early-warning mechanism from the perspective of financial institutions themselves, rather than excessively relying on the stress on the management functions of the central bank. In other words, we should establish appropriate regional financial instruments concerning financial risk management and innovation, which are used by the local governments. Macroeconomic and financial control policies should be adopted in a moderate and appropriate manner. Macroeconomic policies and financial policies play different regulatory roles in different periods, and their effectiveness varies in different regions. They should be used taking into account regional economic development, the orientation of economic objectives, and different regulatory requirements.

APPENDIX A. PARAMETER ESTIMATION OF MIXED SECTION-TIME FIXED EFFECT MODEL FOR PANEL DATA

The specific expression of the mixed section-time fixed effect model of panel data is shown in equation (A.1).

$$y_{\mathrm{it}} = m + x_{ir}^{'}\beta + Y_t + \mu_{it},\ i = 1, 2\ldots, N,\ t = 1, 2, \ldots, T, \tag{A.1}$$

The parameters are estimated as follows:

$$\hat{\beta}_{FE} = \left[\sum_{i=1}^{N} \sum_{t=1}^{T} (x_{it} - \bar{x}_l \bar{x}_t + \bar{x})\,(x_{it} - \bar{x}_l \bar{x}_t + \bar{x})' \right]^{-1}$$

$$\left[\sum_{i=1}^{N}\sum_{t=1}^{T}\left(x_{it}-\bar{x}_{l}\bar{x}_{t}+\bar{x}\right)\left(y_{it}-\bar{y}_{l}-\bar{y}_{t}+\bar{y}\right)'\right]^{-1}. \quad (A.2)$$

$$\hat{m}=\hat{y}-\bar{x}'\hat{\beta}_{FE}. \quad (A.3)$$

$$\hat{Y}_{t}=\left(\bar{y}_{t}-\bar{y}\right)-\left(\bar{x}_{t}-\bar{x}\right)'\hat{\beta}_{FE}. \quad (A.4)$$

where

$$\bar{x}_{i}=\frac{1}{T}\sum_{t=1}^{T}x_{it},\quad \bar{y}_{i}=\frac{1}{T}\sum_{t=1}^{T}y_{it},\quad \bar{x}=\frac{1}{NT}\left(\sum_{i=1}^{T}\sum_{t=1}^{T}x_{it}\right). \quad (A.5)$$

$$\bar{y}=\frac{1}{NT}\left(\sum_{i=1}^{T}\sum_{t=1}^{T}y_{it}\right),\quad \bar{x}_{t}=\frac{1}{N}\left(\sum_{t=1}^{T}x_{it}\right). \quad (A.6)$$

and

$$\bar{y}_{t}=\frac{1}{T}\left(\sum_{t=1}^{T}y_{it}\right). \quad (A.7)$$

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