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| Department: | Banking Business and Financial Technologies |
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# QUALIFYING MASTER'S THESIS

on the topic:
**STRESS TESTING OF FINANCIAL INSTITUTION AND ITS IMPROVEMENT**

higher education student **Wang Jian**

The qualifying master's thesis was accepted for defense by the decision of the Department of Banking Business and Financial Technologies

Protocol No. 4 dated 25.11.2024.
Head of Department
**Doctor of Economics, Professor**

_____________________ **Galyna Azarenkova**

Scientific Adviser
**PhD in Economics, Associate Professor**

____________________ **Kateryna Oriekhova**

Kharkiv - 2024

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
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Specialty **072 «Finance, Banking, Insurance and Banking Management»**
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APPROVED
Head of the Department
of Banking Business and Financial Technologies
Doctor of Economics, Professor

_____________ Galyna Azarenkova
**«** 25 **«** September 2024

TASK
FOR THE QUALIFYING MASTER'S THESIS

of Wang Jian

1.Topic of the work «STRESS TESTING OF FINANCIAL INSTITUTION AND ITS IMPROVEMENT»
Scientific adviser PhD in Economics, Associate Professor Kateryna Oriekhova
(surname, first name, patronymic, academic degree, academic title)

Approved by order of the university dated September 17, 2024 No. 4601-5/1025

2. Deadline for the student to submit the work November 18th 2024

3. List of issues to be developed:
In Chapter 1: to consider the content and definition of stress testing, as well as its progress, and present relevant methods.
In Chapter 2: to provide the current situation of stress testing in Chinese financial institutions, explore common issues in stress testing, and provide relevant cases and data for analysis.
In Chapter 3: to intended to discuss improvement methods for stress testing, propose method foundations, optimize relevant parameters, conduct scenario simulations, and validate them through risk quantification.

4. Work plan

| No. | Name of work stages |
|---|---|
| 1 | The choice of the topic of the qualifying master's thesis |
| 2 | Approval of the plan and tasks of the qualifying master's thesis |
| 3 | Completion of a qualifying master's thesis |
| 4 | Submission of the qualifying master's thesis to the scientific adviser |
| 5 | Signature of the qualified master's thesis by the scientific adviser |
| 6 | Submission of a qualifying master's thesis to the department to check for borrowings from other documents |
| 7 | Admission by the head of the department to the defense of a qualifying master's thesis |
| 8 | Defense of a qualifying master's thesis |

5. Date of the task issue September 25th, 2024

Student

Wang Jian

signature

Wang Jian
initials, surname

Scientific Adviser

signature

Kateryna Oriekhova
initials, surname

# ABSTRACT
# ON THE QUALIFYING MASTER'S THESIS
# “STRESS TESTING OF FINANCIAL INSTITUTION AND ITS IMPROVEMENT”
of Wang Jian

The qualifying master's thesis contains 87 pages, 9 tables, 2 figures, a list of 80 references.

**The object of research** is taking Chinese financial institutions as an example, this article explores the application and improvement of stress testing in financial institutions.

**The subject of research** is the research topic is to provide the current situation and improvement suggestions for financial institutions in stress testing

**The purpose of the qualifying master’s thesis** is to optimize the methods and practical suggestions for stress testing of financial institutions, improve their stress testing level and fit.

The tasks of the qualifying master's thesis are:

- to construction and evaluation of stress test framework;
- to analysis of stress test results;
- to use stress test results to optimize risk management strategies;
- to comparative study of international stress testing standards and domestic practice;
- to analyze the current situation of stress test of Chinese financial institutions;
- to considering the rapid changes in financial markets and the uncertainty of potential future risks;
- to make it more effective in responding to future market changes and risk challenges;
- to evaluate the effectiveness of the proposed recommendations.

**Based on the results of the research,** the author formulated theoretical and practical provisions and proposed parameter optimization and suggestions for financial institution stress testing.

**The obtained results** can further explore the stress testing process of financial institutions and guide them to optimize the current situation to improve the overall testing level.

**KEYWORDS:** FINANCIAL INSTITUTION STRESS TESTING, RISK QUANTIFICATION, RISK MANAGEMENT, PARAMETER OPTIMIZATION

**CONTENT**

# INTRODUCTION

With the frequent turbulence and financial crisis in the global financial market in recent years, the risks faced by financial institutions are increasing. The soundness of financial institutions is essential to maintain the stability of financial markets and the healthy development of the economy. In this context, financial institution stress tests have become a key tool to assess the capital adequacy and risk exposure of financial institutions under extreme but credible economic scenarios.

With the complexity of financial business and the innovation of financial products, it is difficult to fully grasp the risk status of financial institutions by relying only on traditional risk management methods. With its intuitive and forward-looking characteristics, stress test provides an effective way to measure the potential risks of financial institutions under different scenarios. However, there are some limitations and challenges in current stress testing methods, such as subjectivity of scenario setting, oversimplification of models and insufficient risk correlation treatment.

After the global financial crisis in 2008, international financial regulators strengthened their attention and requirements for the stress test of financial institutions. For example, the Basel III agreement, introduced by the Basel Committee on Banking Supervision, explicitly includes stress tests as part of bank capital planning. This not only requires banks to strengthen their risk management systems, but also encourages regulators to continuously seek to improve the scientific and effective stress tests.

With the continuous development of technology, the application of technologies such as big data and artificial intelligence provides new ideas and tools for improving stress testing. By integrating data from more sources and using advanced algorithms to simulate more complex economic scenarios, financial institutions can more accurately assess risks and develop appropriate response strategies.

The rapid development of China's financial market has also led to an increase in the demand for stress tests. China's regulatory authorities are also gradually establishing and improving the stress test system to promote financial institutions to strengthen internal risk management. However, the domestic research and application of financial institution stress test is not deep enough, and there is a certain gap compared with the international advanced level.

The significance of this study is that looking at the trend of global financial development, as an important regulatory tool, the research on the improvement of the scientific, accurate and regularized stress test of financial institutions has important practical significance. At the same time, with the rapid development of computing power and data processing technology, there is a very broad research space to explore new stress testing methods and improve the effectiveness of existing methods.

As an important tool to measure financial stability and risk management, the stress test of financial institutions has been widely concerned and deeply studied by the international community since the 2008 financial crisis. In China, with the continuous opening and improvement of the financial system, stress testing has gradually become an important part of regulatory policies. In 2010, Wu Yuhan published «Stress Testing: An Important Tool for Risk Management in Financial Institutions» in Consumer Guide, emphasizing the role of stress testing in identifying and controlling financial risks. In addition, Ren Xiangfen discussed the effectiveness and pertinence of the application of stress test in small and medium-sized financial institutions through the paper «Stress Test: The Impact of interest rate Factors on small and medium-sized corporate financial institutions» in Financial Research in 2008. At the same time, comparing international experience has become one of the key concerns of domestic researchers. In 2015, Chen Weidong, Zhang Xingrong and Xiong Qiyue published «International Experience and Inspiration of Financial Institution Stress Testing» in Financial Regulation Research, which deeply analyzed the practice and experience of financial institutions in developed countries in stress testing, and pointed out important enlightenment in building a stress testing system suitable for domestic financial environment.

This paper studies the stress test of financial institutions and its improvement, focusing on the stability of financial system and the assessment of financial institutions' ability to withstand potential risks. Through stress testing, this study aims to reveal the vulnerability of financial institutions in the face of extreme scenarios and propose ways to strengthen the resilience of the financial system to risks.

To achieve the goal, the following tasks must be completed:

- construction and evaluation of stress test framework;
- to analysis of stress test results;
- use stress test results to optimize risk management strategies;
- to comparative study of international stress testing standards and domestic practice;
- to analyze the current situation of stress test of Chinese financial institutions;
- to considering the rapid changes in financial markets and the uncertainty of potential future risks;
- to ensure the validity of stress test;
- to make it more effective in responding to future market changes and risk challenges;

The object of this study is stress testing of financial institutions, taking Chinese financial institutions and commercial banks as examples.

The theme of this study is stress testing and improvement of the financial system.

The theory and methodology of this study are banking business and financial technologies Concepts, regulations, and basic research of Chinese and foreign scientists Experts in the fields of banking, finance, and economics.

The information database of this study is represented by scientific publications, scientific conference reports, analytical and statistical materials.

Company, quantitative and qualitative research data, expert evaluation Internet resources, as well as national legislative acts and regulatory documents China's banking system and related financial institutions.

When achieving goals and solving tasks, the following methods were adopted:

Used: Building VAR models, Monte Carlo simulations, and complex network analysis, risk quantification.

The theoretical significance of this work result lies in.

Promote the systematization and technologization of risk management in financial institutions, in order to better identify risk points, optimize decision support, and further enhance the application efficiency of stress testing in financial institutions.

The practical value of this study lies in.

The application of financial technology and regulatory technology in stress testing promotes the deep integration and innovative development of risk management and regulation.

# CHAPTER 1
# OVERVIEW OF STRESS TESTING

## 1.1. Definition of stress testing

Stress testing, as a quantitative tool for measuring the risk carried by financial institutions in extreme economic situations, originated from the basic assessment of market risk and liquidity risk in financial practice operations in the early 20th century [10]. With the rise of financial engineering and the development of the financial derivatives market in the 1980s, stress testing gradually evolved into a systematic scientific method of risk management, focusing on capturing the losses of financial asset portfolios or financial institutions themselves in potential future macroeconomic and financial market extreme situations. Entering the 21st century, especially with the outbreak of the global financial crisis in 2008, stress testing has become a core tool of focus for financial regulatory authorities and institutions, reflected in regulatory policies and risk management practices worldwide [20].

In concept, stress testing refers to evaluating the value changes and related risks of financial institution assets and liabilities in a series of extreme but credible economic and financial scenarios [40]. It involves multiple financial fields, such as market risk, credit risk, liquidity risk, etc., and is usually combined with the capital adequacy assessment of financial institutions. From a practical and theoretical perspective, stress testing has evolved from simple historical data simulation to complex risk model construction, including the use of VaR (Value at Risk) models, decision tree analysis, Monte Carlo simulations, and other methods [50].

The stress testing in the 21st century is no longer limited to the capital assessment and liquidity prediction of financial institutions themselves, but rather starts from collecting micro level data and combines it with macroeconomic models to achieve systematic and dynamic financial risk modeling. Based on macroeconomic models, stress testing can incorporate multiple economic indicators such as economic growth, inflation, interest rate fluctuations, and exchange rate fluctuations when analyzing potential future risks, in order to establish a more comprehensive risk assessment model related to the operation of the financial system [62].

It is worth noting that there are differences in the understanding and application of stress testing both domestically and internationally [75]. International financial institutions and regulatory agencies, such as the Federal Reserve Bank of the United States, the European Banking Authority (EBA), and the Bank for International Settlements (BIS), focus on scenario design and model construction when designing stress tests. For example, they use the CCAR (Comprehensive Capital Analysis and Review) model to evaluate whether large banks' capital plans can withstand extreme economic environments. In contrast, the stress testing of Chinese financial institutions focuses more on a policy oriented approach, emphasizing the compliance of risk identification and management. Based on the relevant regulations and requirements issued by the China Banking Regulatory Commission, a stress testing model with Chinese characteristics is constructed [74].

With the advancement of technology and the development of big data analysis techniques, the methodology of stress testing is constantly innovating and expanding. In the past, stress testing relied heavily on qualitative analysis, such as expert evaluation and historical context analysis; Now, financial institutions are beginning to use more complex quantitative calculation models, such as predictive models based on big data analysis, to assist in the decision-making process. The application of these models not only improves the accuracy and reliability of stress testing, but also broadens the application prospects of stress testing in more financial risk management scenarios. The current stress testing methodology utilizes statistical models such as VAR (Vector Auto Regression) to identify and measure risk, as well as Monte Carlo simulations to analyze possible paths and risk distributions in financial markets [24].

The concept of stress testing has been evolving, and its application scope has gradually expanded from risk assessment of individual financial institutions to systematic risk assessment of the entire financial market. In the future, stress testing will continue to develop, integrating more financial theories and technological means, achieving effective integration between macroeconomic and micro decision-making, and making more important contributions to global financial stability [69].

As a key indicator for measuring the risk resistance ability of financial institutions, stress testing has significant differences in its definition at the international and domestic levels. Internationally, the definition of stress testing has gone through multiple stages of development and has now formed a quantitative analysis model centered on comprehensively simulating the debt situation and capital adequacy of banks in a financial crisis environment. International standard setting bodies, such as the Basel Committee on Banking Supervision (BCBS), have defined in detail in the Basel III Accord that stress testing must cover a wide range of risk types, including market risk, credit risk, and liquidity risk, emphasizing the overall resilience under the cross influence of multiple risk factors. In addition, both the International Monetary Fund (IMF) and the Financial Stability Board (FSB) have conducted comprehensive stress tests on financial institutions in member countries, covering multidimensional stress factors from macroeconomic levels to specific financial product levels, in order to more comprehensively predict and explain the reactions and vulnerabilities of financial institutions in different crisis scenarios [53].

In contrast, the definition of stress testing in China focuses on policy orientation. In China, with the rapid development and continuous deepening of the financial market, regulatory agencies such as the China Banking and Insurance Regulatory Commission have formulated relevant stress testing guidelines for different types of financial institutions, aiming to evaluate the stability of financial institutions in specific economic environments and systemic risk events. The domestic definition emphasizes strategic adjustments in policy response and risk management, and is implemented through two major strategies: «macro prudential management» and «micro prudential management» to ensure that financial institutions have sufficient capital and liquidity to maintain normal operations under external economic shocks. Specifically, domestic stress tests not only focus on the robustness of bank balance sheets and capital adequacy indicators, but also take into account the influence of macroeconomic factors, political risks, market sentiment, and other factors on the financial market [48].

At the application level, international definitions tend to use standardized models and methods, such as simulating scenarios of economic recession, market volatility, etc. with pre-set severity levels, and using highly complex economic and econometric models such as vector autoregression models (VAR), credit risk models, and Monte Carlo simulations for risk quantification and prediction. This method is beneficial for deeper integration and comparison of financial markets on an international scale. However, the stress testing models of domestic financial institutions may focus more on combining China's specific economic cyclical characteristics, market structure, and financial system settings to adapt to the actual environment of the domestic financial market, using relatively intuitive methods such as scenario analysis and historical data simulation to perform stress testing [49].

These two different levels of definitions reflect different methodologies and value orientations towards risk management and financial stability. The refinement and technologization of international definitions demonstrate a pursuit of systematic and scientific risk assessment standards, while domestically, there are more policy adjustment and response characteristics. In the context of the global financial environment, both have their rationality and necessity. International definitions are more conducive to cross-border financial activities and multilateral financial regulatory cooperation; The domestic definition is closer to the national conditions and helps establish a more effective communication mechanism between financial regulation and financial institutions. Although there are differences in the definition and application of stress testing both domestically and internationally, both parties share a common goal of ensuring the overall security of the financial system and preventing financial risks through stress testing [55].

Stress testing is widely used by financial institutions as an important tool to assess potential risk impacts and the effectiveness of response strategies in the process of risk management and internal control. Stress testing can simulate extreme but credible risk scenarios, helping financial institutions assess their vulnerability to intense market changes, sudden economic events, or other adverse environments, and adjust their capital structure and risk tolerance accordingly, thereby improving overall financial stability [70].

Specifically, the application of stress testing can be divided into three core areas: Capital Adequacy Testing, Liquidity Testing, and Credit Risk Measurement. By conducting stress tests on these key areas, financial institutions can more accurately identify and quantify their potential financial risks, providing support for effective risk management [30].

Capital adequacy testing is the most important part of stress testing, aimed at assessing whether financial institutions have sufficient capital levels to absorb losses and maintain operations in the face of sudden asset depreciation, increased credit risk, or market liquidity disruptions. In this process, financial institutions need to construct a comprehensive model of diversified risk factors and consider the correlation and volatility of various assets. By adopting indicators such as Risk Weighted Assets (RWA) and Leverage Ratio, financial institutions set stricter internal capital standards beyond the minimum capital requirements set by regulatory frameworks such as Basel III, ensuring that capital shortages do not occur in extreme but credible economic scenarios [25].

Liquidity testing focuses on the short-term liquidity pressure of financial institutions. In past financial storms, liquidity depletion was often a key trigger for crises. Therefore, liquidity analysis in stress testing often utilizes indicators such as Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR) to evaluate the cash flows and long-term stable funding sources of financial institutions in different market scenarios. By setting liquidity risk models with multiple time spans and different market shock factors, stress testing is used to simulate the ability of financial institutions to cope with extreme market conditions, ensuring that they have sufficient liquid reserves to withstand various liquidity risks [48].

In terms of credit risk measurement, stress testing focuses on assessing potential credit losses in the lending market. Financial institutions construct credit risk models by predicting the probability and potential losses of different credit events (such as defaults, rating downgrades, etc.), quantifying the losses that may be suffered under different stress conditions [54]. This includes predicting the Probability of Default (PD), Loss Given Default (LGD), and Exposure at Default (EAD). In addition, credit risk related models also involve responses to macroeconomic variables such as interest rates, exchange rates, inflation, and economic growth, all of which may affect changes in credit risk and must be considered in stress testing [78].

The above stress tests are all aimed at a core goal - to ensure that financial institutions can maintain normal operations and prevent systemic risks in the face of significant stress or extreme economic environments. Stress testing not only provides technical support for financial institutions' own risk management, but also provides important basis for regulatory agencies to formulate macro prudential policies. However, with the increasing complexity of financial markets, the methods and implementation of stress testing are gradually facing new challenges and shortcomings. Therefore, continuously improving the methodology of stress testing and enhancing the application efficiency of test results has become an urgent issue that the financial industry needs to explore and solve [46].

After the outbreak of the financial crisis, the reform and development of bank stress testing mechanisms by financial regulatory agencies in various countries have attracted widespread attention, especially in the context of increasingly integrated financial markets and continuous financial innovation. Stress testing has become a key tool for regulatory agencies to evaluate banks' risk tolerance and capital adequacy. From the development process of international bank stress testing, it can be seen that in the past few decades, market turbulence has continuously brought new challenges to the financial system, and the theory and practice of bank stress testing have made significant progress and innovation [45].

Internationally, the Comprehensive Capital Analysis and Review (CCAR) adopted by the United States is considered a benchmark for stress testing as an important annual review tool for banks by the Federal Reserve System. CCAR requires participating banks to submit their capital plans, including planned dividends and share repurchases, and to use multiple predictive models to estimate capital levels in different economic scenarios. These models involve thousands of macroeconomic variables and their estimated impact on bank finances, providing a comprehensive test of the internal risk management system of banks [19].

In Europe, after the 2008 financial crisis, the European Banking Authority (EBA) created a framework for EU bank stress testing aimed at assessing the resilience of banks to potential macroeconomic shocks. The testing of EBA places great emphasis on the assessment of asset quality and introduces a unified risk scenario to ensure comparability of testing among member countries [23].

Of course, there are various stress testing methods and processes internationally. The Prudential Regulation Authority (PRA) in the UK adopts a single economic scenario stress test that shifts towards the domestic financial system, emphasizing the financial system's ability to withstand risks. PRA testing not only covers credit risk and market risk, but also considers other types of risk factors such as operational risk and liquidity risk [65].

With the acceleration of globalization, stress testing has begun to expand to marginal financial systems and non bank financial institutions. Financial regulatory agencies around the world have also begun to pay attention to the impact of cross-border capital flows and macroeconomic policy shocks in stress testing, although research in this field is still in the exploratory stage. In addition, stress tests for emerging financial markets such as shadow banking have also been included in the research scope, with the aim of filling regulatory blind spots and strengthening overall risk management [45].

In terms of methodology, international stress testing increasingly emphasizes the complexity and accuracy of models and algorithms. Among them, some advanced financial technologies, such as artificial intelligence and machine learning, are beginning to play an important role in the stress testing models of banks, especially in areas such as asset valuation and default probability prediction. These technologies are completely changing traditional risk assessment methods [36].

In addition, with the advancement of data science, big data analysis techniques have also been widely applied in stress testing. The enhancement of real-time big data processing capabilities enables banks to monitor and respond to potential risks in real time, and take targeted measures to deal with possible risk events [32].

In general, the progress of international bank stress testing reflects the diversity and complexity of financial regulation. By continuously optimizing testing methods and improving the accuracy of risk assessment, financial regulatory agencies can better prepare for potential financial shocks in the future. Looking ahead to the future, with the continuous development of financial innovation, stress testing methods and practices will need to be continuously innovated and improved to adapt to new situations [24].

In the practical execution of stress tests for domestic financial institutions, the initial step involves defining the objectives and framework of the tests, which sets the course and parameters for subsequent evaluations. At this juncture, institutions must specify both the scope and depth of their assessments, targeting various business sectors and asset categories while developing appropriate evaluation systems. Following this, gathering relevant data becomes a critical task since high-quality and comprehensive data is essential for effective model assessment. However, due to market volatility and complex financial instruments, it often necessitates professional cleaning and adjustments to remove outliers, prevent information gaps, and ensure that the data remains authentic and usable [9].

Next in line is determining which test model will be utilized by financial institutions based on an implementation flowchart for stress testing. There are several models available in the marketplace - such as historical scenario simulations or Monte Carlo random path generation - each with its own suitable contexts along with distinct advantages and drawbacks [52]. Choosing a fitting model can help institutions more accurately forecast their performance during stressful conditions.

Following this selection process is setting up stress scenario parameters - a vital aspect of executing stress tests. These parameters should thoroughly account for potential fluctuations within financial markets by considering macroeconomic indicators alongside risk factors from those markets. The scenarios assumed should encompass not only past extreme events but also hypothetical severe situations [23].

During simulation exercises related to stress testing, this phase assesses whether previously established goals, datasets, models, and scenarios effectively represent how well financial institutions can withstand adverse conditions. Typically included in simulation outcomes are various risk indicators under stressed circumstances such as capital adequacy ratios or non-performing loan (NPL) ratios. Once simulations conclude, analyzing these results becomes crucial as it informs future strategies adopted by these institutions.

## 1.2. Progress of stress testing

After completing analysis efforts comes report generation - a summary reflecting feedback from all stages of the stress testing process. For domestic financial entities evaluating their results isn’t just about presenting raw data; rather it's about reassessing future strategic directions regarding development plans for capital allocation as well as frameworks for managing risks effectively. For instance, through detailed examination of findings from a stress test result analysis might lead a large state-owned bank A to realize that its ongoing credit risk exposure requires additional capital support while prompting city commercial bank C to enhance its loan approval criteria in response to interest rate threats. Throughout our investigation into these stress tests we developed an «Implementation Status table» capturing key metrics across different types of financial organizations during such evaluations - including numbers pertaining to test scenarios employed main risk categories shifts observed in capital adequacy ratios NPL rates plus specific actions taken following insights gained from test outcomes - for example when confronted with liquidity challenges joint-stock bank B opted towards bolstering liquidity reserves alongside refining internal control measures showcasing responsiveness adaptability derived directly from analyzed results (figure 1.1).

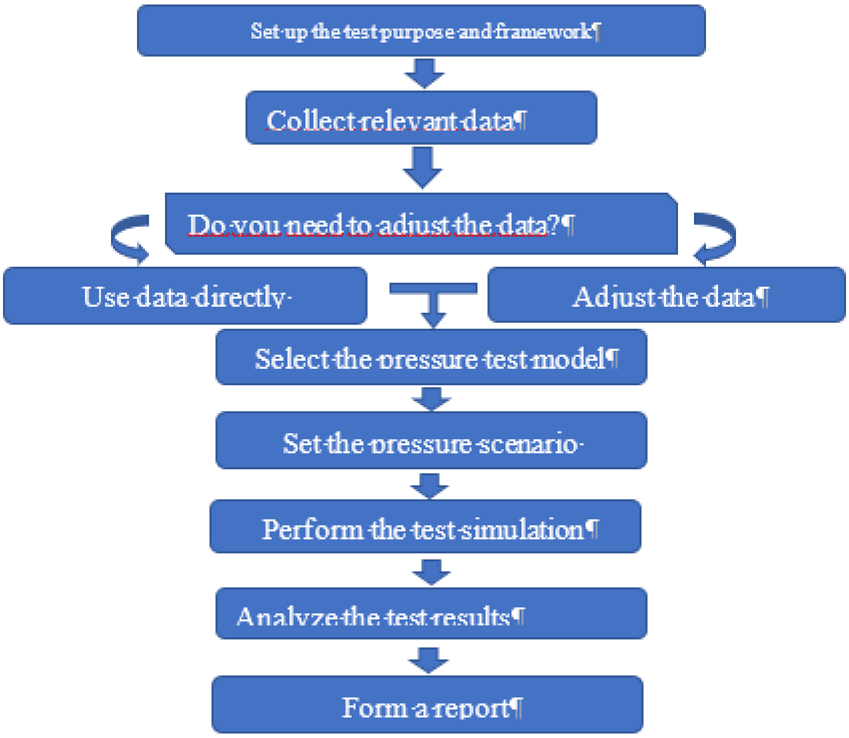


Figure 1.1. Domestic financial institution stress test

Overall through engaging practices surrounding these assessments domestic finance firms have exhibited progressively sophisticated refined capabilities concerning risk management whether dealing with aspects like processing data selecting models establishing scenarios or interpreting results faced against potential fiscal crises enterprises now possess tools enabling them mitigate impacts stemming from risks thereby enhancing overall stability via contingency planning rooted firmly within informed decision-making processes driven by empirical evidence gathered throughout analyses conducted (table 1.1).

Table 1.1

Implementation of stress tests for domestic financial institutions

| Financial institution | Year of stress test | Number of test scenarios | Principal Risk Types | Changes in capital adequacy ratio before and after (%) | NPL Ratio Change (%) | Test Results Response Measures |
|---|---|---|---|---|---|---|
| Large state-owned banks A | 2020 | 3 | Credit risk, market risk | -1.2 | 0.5 | Increase capital and optimize risk management |
| Joint-stock bank B | 2021 | 4 | Liquidity risk, operational risk | -0.8 | 0.3 | Enhancement of Liquidity Reserve and Improvement of Internal Control Process |
| City Commercial Bank C | 2019 | 2 | Credit risk, interest rate risk | -1.0 | 0.2 | Improving Loan Review Standards and Strengthening Interest Rate Risk Management |
| Rural Cooperative Bank D | 2022 | 3 | Credit risk, market risk | -1.5 | 0.6 | Asset structure adjustment and investment in risk mitigation tools |
| Non-bank financial institution E | 2020 | 3 | Liquidity risk, credit risk | -2.0 | 0.7 | Rapid asset liquidity conversion and enhanced credit risk control |
| Securities Company F | 2021 | 5 | Market risk, operational risk | -1.8 | - | Strengthen trading system security and risk exposure management |
| Insurance Company G | 2019 | 2 | Insurance risk, market risk | -0.9 | - | Pricing strategy adjustment, asset and liability management |

Continued of table 1.1

| Financial institution | Year of stress test | Number of test scenarios | Principal Risk Types | Changes in capital adequacy ratio before and after (%) | NPL Ratio Change (%) | Test Results Response Measures |
|---|---|---|---|---|---|---|
| Fund Management Company H | 2020 | 4 | Market risk, liquidity risk | -1.4 | - | Portfolio diversification and improved liquidity management capabilities |
| Financial institution | Year of stress test | Number of test scenarios | Principal Risk Types | Changes in capital adequacy ratio before and after (%) | NPL Ratio Change (%) | Test Results Response Measures |
| P2P Platform I | 2022 | 3 | Credit risk, liquidity risk | -2.5 | 1.0 | Strengthen borrower review and set up emergency fund pool |
| Internet Finance Corp. J | 2021 | 4 | Credit risk, operational risk | -1.6 | 0.9 | Encryption technology application, risk education enhancement |
| Foreign bank K | 2019 | 2 | Liquidity risk, foreign exchange risk | -1.1 | 0.4 | Foreign exchange exposure hedging and strengthening international liquidity management |
| Microfinance Corp. L | 2022 | 3 | Credit risk, market risk | -3.0 | 1.2 | Improve risk pricing capabilities and increase collateral coverage |

Stress testing is becoming increasingly crucial in the risk management practices of financial institutions, but traditional stress testing models and tools are facing unprecedented challenges in the face of increasingly complex financial markets and products [19].

To address these challenges, financial institutions have had to introduce various innovative methods in stress testing and explore new application areas to enhance the predictive ability of testing and the effectiveness of risk management.

As the complexity of interactions between financial instruments and market participants increases, stress testing needs to simulate the interactions in the financial system in greater detail. One innovative approach is to use Agent Based Models (ABM) to simulate the behavior of financial markets, which takes into account the diversity of individual behavior and feedback effects in the market environment. Through ABM, researchers can finely analyze the behavioral responses of various financial institutions during market crises and their impact on systemic risk [25].

Another prominent innovation is the use of big data technology and machine learning methods to improve the accuracy of stress testing. In the past, stress testing often relied on historical data for simulation, but in the era of big data, real-time monitoring of market dynamics and unstructured information such as social media and news can provide richer data sources for stress testing. For example, using Text Mining technology to analyze changes in market sentiment can promptly identify potential systemic risks. Similarly, machine learning methods such as deep learning and neural network models can automatically identify complex patterns in large-scale data processing, providing strong support for risk warning.

Another direction of stress testing is the effective combination of macro and micro levels. Macro stress testing focuses on the overall economic and financial market level, attempting to evaluate the impact of changes in macroeconomic variables on the stability of the entire financial system, while micro stress testing focuses more on the level of a single financial institution, assessing the impact of specific risks on individual financial institutions [35]. By effectively combining these two levels of stress testing, a systematic risk transmission path analysis from macro to micro can be achieved, and a more comprehensive risk assessment can be provided.

At the same time, the challenges faced by stress testing are also reflected in the comprehensiveness of risk identification and the dynamic updating ability of the model. With the continuous emergence of innovative products in the financial market, existing risk factors may no longer be applicable, and new potential risks are difficult to identify and quantify in a timely manner. At this point, it is necessary to regularly reassess the stress testing models used to ensure that financial institutions can promptly identify and respond to emerging risks and hazards [22].

Stress testing for financial institutions is developing through continuous innovation and challenges, which require both improving the technical content of testing tools and dynamically optimizing testing models. By utilizing innovative methods from multiple levels and perspectives, stress testing can more accurately reflect the true dynamics of financial markets, helping financial institutions better cope with complex and changing market environments, while also contributing to macroeconomic stability and sustainable growth.

## 1.3. Methodology of Stress Testing

Stress testing plays a central role in the risk management activities of financial institutions, and qualitative and quantitative methods are key components of its analytical framework. In the methodology of stress testing, qualitative methods mainly include expert review and scenario analysis, which focus on judgments based on experience and intuition, emphasizing understanding the background logic of potential risks and possible events. However, expert review may have subjective biases, and scenario analysis relies on assumptions about possible future events, which are often difficult to exhaust all possibilities [18].

Quantitative methods attempt to quantify and evaluate risks through mathematical models and statistical techniques. Among them, historical simulation methods consider extreme market volatility in history as future stress scenarios, but they ignore the fact that financial market structure and participant behavior change over time; The Value at Risk (VaR) model can quantify the potential maximum loss at a certain probability level, but there are issues with model risk and parameter robustness. In recent years, financial institutions have increasingly applied advanced technologies such as Monte Carlo simulation to improve the accuracy of risk assessment. By randomly generating a series of potential future market trends, Monte Carlo simulation can more comprehensively simulate the dynamic changes of financial markets in different scenarios, thereby providing a more comprehensive risk assessment. In addition, complex network analysis considering the propagation of systemic risks is emerging, which uses network theory to analyze the interdependence and chain reactions between financial institutions, providing a new perspective on systemic risks for stress testing [61].

The trade-off between model transparency and complexity is particularly crucial when selecting methods. Models with high transparency are easily understood by regulatory agencies and management, but may lack accuracy; Although models with high complexity can predict risks more accurately, they are likely to be questioned due to black box operations. At the same time, the difficulty of obtaining data is also an important factor that restricts the application of quantitative analysis methods. In many cases, financial institutions have very limited data samples for extreme risk events, which often leads to risk models being built on insufficient data, resulting in poor generalization ability and overfitting [15].

In addition, the interpretability of the model results cannot be ignored, as no matter how complex the model is, the results still need to be able to help management make decisions that align with risk management objectives. For example, when calculating conditional VaR, in addition to accurately reflecting the losses under specific conditions, the results should also be able to explain the sources and nature of risk exposure, as well as how related risks change with changes in the market environment. This requires the output of the model to have both quantitative accuracy and sufficient qualitative information support [20].

When financial institutions decide on appropriate stress testing methods, they need to consider both the scientificity and adaptability of their methodology, as well as evaluate the operability of these methods in practice and the decision support capabilities of management. This requires financial institutions to comprehensively consider the combination of macro and micro when choosing stress testing methods, in order to truly achieve effective risk identification and management through these methods [23].

The core technical model plays a crucial role in conducting stress tests for financial institutions. These models not only need to accurately simulate the dynamic characteristics of financial markets, but also have the ability to sensitively capture extreme situations to estimate the vulnerability of institutions under financial pressure. Common technical models include historical simulation, Monte Carlo simulation, and econometric models. Among these models, the Vector Autoregression (VAR) model is widely used in joint analysis of multiple economic variables due to its ability to capture dynamic relationships between variables. The VAR model can comprehensively depict the mutual influence and evolution process between financial variables by systematically expressing the linear relationship between variables [29].

In the application of stress testing, VAR models can be used to predict the impact of systemic financial risk events on multiple financial variables, such as changes in monetary policy, fluctuations in asset prices, and potential effects on bank credit capacity, capital adequacy ratio, and liquidity indicators. Considering the diversity and interactivity of financial institutions' participation in the market, different types of financial variables such as Gross Domestic Product (GDP), interest rates, exchange rates, stock indices, and other credit risk indicators need to be included when constructing VAR models to cover the main influencing factors of financial institution operations [15].

In addition, in order to enhance the model's ability to capture extreme financial shocks, the stress testing model will also introduce impulse response analysis. By applying one or more economic shocks (i.e. pulses) to the VAR model, analyzing the response trajectories and persistence of different financial variables to these shocks, the vulnerability or resilience of the financial system to external shocks can be evaluated. Impulse response analysis can provide regulators with an intuitive perspective on the behavioral responses and potential risks of financial institutions under specific stress scenarios [65].

In empirical analysis, VAR models are usually combined with Monte Carlo simulations to perform bootstrap error correction on parameter estimation and prediction. This method can improve the accuracy of predictions and provide corresponding confidence intervals for uncertainty, enhancing the robustness of the model. Through repeated sampling, financial stress testing can evaluate the loss distribution of financial institutions at different probability levels based on probability distribution, providing decision-makers with a more comprehensive risk assessment basis [47].

Overall, the use of VAR models and their derivative techniques is an important pillar in constructing and improving stress testing frameworks for financial institutions [16]. Through scientific parameter settings, precise model calibration, and detailed scenario analysis, financial regulators can better evaluate the stability of the financial system in the face of intense fluctuations and guide financial institutions to take reasonable risk management measures.

$$Y_t = c + \Phi_1 Y_{t-1} + \cdots + \Phi_p Y_{t-p} + \varepsilon_t. \qquad (1.1)$$

In the field of stress testing for financial institutions, method selection criteria are key to ensuring testing quality and efficiency. This standard mainly consists of three core dimensions: transparency and complexity of the model, ease of data acquisition, and interpretability of the model results. Thoroughly sorting out these standards can not only provide decision-making basis for financial institutions when facing various stress testing methods, but also promote transparent, efficient, and robust risk management practices at the regulatory level [45].

Firstly, model transparency refers to the knowledge of the model structure, assumptions, and decision logic to users. A highly transparent model can provide regulators and market participants with more confidence, as its potential «black box» effect is smaller and easier to understand and accept. However, transparency often shows an inverse relationship with model complexity. Models with high complexity, such as financial engineering models based on intelligent algorithms, can accurately capture subtle fluctuations and nonlinear features of financial markets. However, the opacity of their internal mechanisms may lead to misunderstandings and even decision-making errors between financial institutions and regulatory authorities. Therefore, balancing transparency and complexity is an essential factor that financial institutions must consider when choosing stress testing methods [64].

Secondly, the difficulty of data acquisition directly affects the operability of stress testing. Considering the diversity and dynamic changes of financial market data, it is crucial to obtain high-frequency and high-quality datasets quickly for the reliability of test results. In situations where data is scarce or acquisition costs are extremely high, stress testing methods based on historical data simulation may be superior to multi parameter complex simulations using real-time market data. For example, using Historical Scenario Analysis can avoid excessive reliance on real-time market data, thereby reducing the uncertainty of data accuracy in systematic risk estimation. In addition, compliance requirements cannot be ignored, and the use and processing of financial data must comply with relevant privacy and regulatory standards, such as GDPR and China's Personal Information Protection Law [14].

Finally, the interpretability of the model results determines whether the risk management department can develop targeted response measures based on the test results. A highly explanatory model can provide clear sources and transmission pathways of risk, which helps decision-makers to gain a deeper understanding of the response mechanisms of financial markets under stress scenarios. In terms of model selection, the Value at Risk (VaR) model can be integrated to extract the contribution of a single risk factor to potential losses, or Bayesian Networks can be used to intuitively represent the dependency relationships between different risk nodes. In addition, the interpretability of the model is closely related to its ability to provide strategic guidance. Appropriate risk management decision support can enable the model to not only stay at the theoretical level, but also transform into feasible risk control measures [14].

When selecting stress testing methods for financial institutions, it is necessary to comprehensively evaluate the interaction between model transparency and complexity, the practical feasibility of data acquisition, and the interpretability of model results. This not only ensures the accuracy and practicality of test results, but also serves as an effective way for financial institutions to respond to regulatory policies, proactively identify and manage risks. At the same time, the selection of methods should also take into account the latest developments in international regulation, technological trends, and the actual needs of the institution, in order to ensure continuous innovation and improvement in stress testing and contribute to financial stability.

# CHAPTER 2
# ANALYSIS OF THE CURRENT SITUATION OF STRESS TESTING IN FINANCIAL INSTITUTIONS

## 2.1. Overview of Stress Tests for Chinese Financial Institutions

Current architecture. The stress test system of China's financial institutions is characterized by the differentiation of regulatory levels, forming a dual track regulatory stress test system led by the People's Bank of China and the CBRC. In this system, financial institutions at different levels are assigned corresponding stress testing tasks and requirements, and there are significant differences in the scope and depth of stress testing imposed by regulatory authorities on various institutions. For example, large state-owned banks and important systemic financial institutions need to undergo stricter stress tests, including but not limited to multidimensional stress scenarios such as cross market risk transmission, liquidity shocks, and changes in liability composition. In contrast, small and medium-sized financial institutions mainly conduct customized stress tests based on their unique asset quality, credit risk, and other factors [17].

Financial groups have a special positioning in the stress testing system, where the above-mentioned institutions attach great importance to evaluating the risk linkage effects between subsidiaries within the group through simulating risk transmission paths. This move aims to capture potential group effects and assess and monitor the systemic impact on overall financial stability. In terms of specific testing implementation, the financial group further evaluates the overall risk tolerance and operational sustainability at the group level based on the completion of individual stress tests for each subsidiary [22].

It is worth noting that the implementation of stress testing in Chinese financial institutions presents a clear hierarchical structure. Based on the size and type of different financial institutions, regulatory authorities will adapt corresponding stress testing frameworks and standards, and set specific testing indicators and parameters according to different risk points [26]. This layered stress testing adaptation mechanism ensures the pertinence of testing and the feasibility of execution, while avoiding resource waste and execution difficulties caused by a one size fits all regulatory approach (table 2.1).

Table 2.1

Basic situation of participating banks' ratings in the second quarter of 2023

| Institution type | Number of institutions | Rating results (Level) |
|---|---|---|
| Development and policy banks | 3 | 1-7 |
| State owned commercial banks | 6 | |
| Joint stock commercial bank | 12 | |
| City Commercial Bank | 125 | 2-10 |
| Rural Commercial Bank | 1608 | 2-10 |
| Rural Cooperative Bank | 23 | 5-9 |
| Rural Credit Cooperatives | 509 | 2-10 |
| Rural Bank | 1643 | 3-10 |
| Private banks and other | 21 | 2-7 |
| Foreign legal entity bank | 42 | 2-6 |
| Total | 3992 | - |

In terms of the application of stress test results, financial institutions exhibit significant differences in risk management and decision support based on test results. Some large banks are able to guide strategic adjustments, capital planning, and establish risk warning mechanisms based on stress test outputs, while most small and medium-sized institutions only consider stress test results as a routine procedure to meet regulatory requirements, and their results are rarely applied in actual risk management [55]. The reason for this phenomenon is that small and medium-sized financial institutions generally lack professional risk management teams and sufficient technical support, and have not effectively transformed stress test results into risk management and performance growth drivers for the institutions [60].

Further analysis shows that financial institutions often face multiple technical challenges during the implementation of stress testing, such as setting risk assessment parameters, selecting influencing factors, and designing testing scenarios. For example, financial institutions need to consider various factors such as asset portfolio characteristics, changes in market conditions, and regulatory policy adjustments when promoting stress testing, which requires institutions to have high risk quantification modeling and comprehensive evaluation capabilities. In addition, predicting potential changes in future financial markets and setting stress scenarios rely on accurate data analysis and advanced econometric models. Therefore, improving the scientific and targeted design of stress tests has become a key link in strengthening risk management of financial institutions and enhancing regulatory effectiveness [22].

Test implementation level. Financial institution stress testing has become an important component of financial regulation in China, with its coverage and implementation continuously expanding, reflecting the regulatory authorities' high emphasis on risk prevention and control capabilities. According to statistics from the China Banking and Insurance Regulatory Commission and the People's Bank of China, various levels of banking institutions in China have generally conducted stress tests, and the tests have gradually evolved from initial capital adequacy ratio tests to comprehensive response capability tests covering liquidity risk, credit risk, and market risk. Through in-depth analysis of test results over the years, this section will explore the extent to which stress testing is implemented in Chinese financial institutions, as well as the effectiveness and shortcomings demonstrated in the face of complex financial environments [18].

In terms of the implementation level of stress testing, large state-owned banks and joint-stock banks in China are in a leading position in implementing stress testing, and most of them have formed periodic and institutionalized evaluation mechanisms. According to the latest research report, all five major state-owned commercial banks and twelve major joint-stock commercial banks have established regular stress testing systems that comply with regulatory requirements, with frequency mostly quarterly or semi annually. The test results serve as important risk assessment tools and directly participate in strategic decision-making and risk management. However, due to limitations in funds, technology, and talent, small and medium-sized banks have begun implementing relevant tests, but their performance in terms of testing frequency, breadth, depth, and precision is not satisfactory, often meeting the minimum regulatory standards [20].

In terms of testing scope, the vast majority of financial institutions have extended stress testing to multidimensional risk indicators, which not only include traditional credit risk and market risk, but also comprehensive risk assessments such as liquidity risk and operational risk. Especially in recent years, with the rapid development of financial innovation and the increasing volatility of financial markets, the diversification and complexity of stress testing have become an inevitable trend. Especially in emerging business fields such as asset securitization and Internet financial products, more and more financial institutions have begun to introduce specific stress test models to adapt to the specific risk characteristics of these new fields [19].

From the results of the capital adequacy ratio test, most financial institutions demonstrate good capital reserve capabilities and potential capital to withstand risks. On this basis, more institutions have begun to pay attention to liquidity risk testing, by setting simulation scenarios of short-term financial pressure and long-term financial stability, to assess the vulnerability of institutional financial conditions in extreme situations. However, there are significant differences in the selection and parameter settings of liquidity risk models among different institutions during this process, which has a certain impact on the consistency and comparability of the results [29].

It is worth noting that although the implementation level of stress testing is constantly improving, the overall system still presents some shortcomings: firstly, stress testing often uses static historical data for simulation, which may not fully reflect potential and dynamic risk factors and market changes in the future; Secondly, due to resource limitations, some small financial institutions rely on simplified methods in selecting models and algorithms, which may not accurately capture the risk characteristics of specific businesses; Finally, there is a time lag in the application of stress testing results, and the test results cannot be timely fed back to the institution's risk prevention and control, which reduces the effectiveness of the testing [33].

According to the requirements of the regulatory authorities, in the future, the stress testing of financial institutions in China should further increase the frequency of testing, deepen the content of testing, expand the scope of testing, and make innovations and improvements in the application of test results and the improvement of risk management level. Further strengthen the testing of emerging financial products, increase the predictability and foresight of testing, conduct cross cycle testing, and ensure that financial stability can be maintained even in more challenging environments. At the same time, improve the transparency of stress test results and closely integrate them with capital planning, risk management, and liquidity management, making them a part of daily decision-making and increasing the resilience of the entire financial system to potential future risks [36].

Application of test results. Once the results of financial institution stress tests are released, they play a crucial role in improving decision support mechanisms, identifying systemic risk points, and formulating precise response strategies. Empirical research has shown that financial institutions at all levels use test results in multiple dimensions and levels. This section will delve into the application of test results and their impact on financial institution governance [78].

Due to the diverse and rich financial variables involved in stress testing, the effective application of stress test results lies in how to translate them into specific practices in supervision and management, risk control, and capital planning. Financial institutions typically use stress test results from the following dimensions: Firstly, as a decision support tool, stress test results play an important guiding role in identifying potential capital gaps and liquidity risks. Institutions can optimize their balance sheet structure, adjust their credit strategies, and even reshape their business models based on this. Secondly, the test results help to reveal the exposure points of risks. Financial institutions can track the root causes of risks by comparing historical data with the current situation, thereby avoiding the recurrence of similar risks in financial product design and market positioning. Finally, the test results prompted financial institutions to develop and optimize response measures, such as developing emergency capital and liquidity support plans, establishing risk warning systems and response mechanisms, in order to enhance their ability to withstand pressure when the future economy is on the brink of collapse [64].

In terms of practical application scenarios, financial institutions exhibit certain limitations when using stress test results. For example, in the banking industry, a common practice is to use stress tests to dynamically predict capital adequacy ratios as the primary criterion for measuring internal capital adequacy. However, in some cases, a high capital adequacy ratio does not necessarily mean that the institution has sufficient risk resistance, and other factors such as asset quality, profitability, and cost of funds need to be considered. In the insurance industry, stress testing focuses more on the matching risk between insurance liability and investment assets, but it does not fully reflect market risk and easily overlooks the impact of interest rate and market price changes on asset revaluation. In the asset management industry, although stress testing can assess the risk of investment portfolios in specific scenarios, the test results often heavily rely on the accuracy of benchmark assumptions and parameter settings. Once the actual situation deviates from the assumptions, the guiding significance of the test results will be greatly reduced [22].

It is worth noting that some financial institutions have demonstrated advanced ways of applying test results, such as combining machine learning and big data technology to deeply mine stress test results. This not only identifies the source of risk, but also predicts potential risk transmission paths and monitors the trend of risk level changes in real time. In addition, the organic structure will combine the test results with financial innovation projects, set up an intelligent warning system based on various indicators output from the test, and enhance the adaptive adjustment ability of financial products and services [33].

The above analysis clearly depicts the current situation of the application of stress test results in Chinese financial institutions, reflecting the practical value and application limitations of test results in practical environments, and providing in-depth insights for further improving the effectiveness and accuracy of test result application. In the future, financial institutions' work in this area will become more refined and technological, and the application of stress test results will be closer to real-time response mechanisms, which can better serve risk management and decision support.

## 2.2. Common Issues in Stress Testing

Test parameter settings. Financial institutions generally face parameter setting issues during the implementation of stress testing, which directly affects the accuracy and practicality of test results. Among the many parameters, the setting of correlation coefficients, estimation of shock amplitude, and prediction of policy response time are particularly critical. Inappropriate setting of these parameters may lead to underestimation or overestimation of potential financial risks to a certain extent [5].

The incorrect setting of correlation coefficient is a common problem. In stress testing, the correlation coefficient is used to determine the correlation between different financial products or markets, and its accurate setting is crucial for the reliability of the test results. However, in practice, the setting of correlation coefficients often relies on historical data and ignores changes in market structure and behavior patterns, which may result in the original correlation no longer being applicable in the new financial environment. In fact, the rapidly changing financial market requires that the correlation coefficient should be adjusted based on real-time data and dynamic models [13].

The estimation of the impact amplitude is equally crucial. In stress testing, the shock amplitude is used to simulate extreme situations that may occur in the financial market and is a core parameter for evaluating the risk resistance ability of financial institutions [15]. However, many institutions often set the impact range based on their understanding of past financial crises, while ignoring the influence of new factors such as financial innovation and regulatory changes. Therefore, the setting of the impact amplitude needs to comprehensively consider market dynamics and potential risk factors, and adapt to the new characteristics of market development.

The prediction of policy response time is a more difficult variable to grasp. Effective policy responses can buffer or even avoid the manifestation of financial risks, thereby affecting the scope and results of stress testing. In reality, the speed of policy response is influenced by multiple factors, including government decision-making efficiency, the effectiveness of regulatory warning mechanisms, and the complexity of cross institutional coordination. Currently, most financial institutions tend to be too conservative or optimistic when estimating policy response time, lacking dynamic prediction mechanisms based on real policy cycles [18].

Improving the parameter settings in stress testing requires establishing a more scientific and dynamic parameter adjustment system. The first priority is to use dynamic correlation models such as the Dynamic Conditional Correlation (DCC) model, as well as time series methods based on high-frequency data, to improve the flexibility and accuracy of correlation coefficient settings. At the same time, a dynamic stochastic general equilibrium model of the economy and financial markets should be constructed to continuously optimize the prediction mode of the impact amplitude, incorporating potential risk factors and dynamic changes in macroeconomic indicators into the model prediction system [20].

In addition, advanced technologies such as machine learning can be used to conduct in-depth analysis of historical policy change data, establish policy response prediction models, and combine policy makers' decision-making habits and market behavior reactions to predict policy response time in a more refined and real-time manner. At the same time, it is recommended that financial institutions and regulatory agencies strengthen communication and exchange, share information resources, and achieve real-time updates and calibration of policy response time prediction parameters [22].

The parameter setting issues faced by financial institutions in stress testing need to be addressed through technological innovation and model optimization. This not only helps to enhance the scientific and practical nature of stress testing, but also has important practical significance for accurately assessing financial risks and formulating effective response strategies. Research in this area still needs to be continuously deepened and developed to ensure the stability and development momentum of the financial system [44].

Insufficient risk identification. The crucial step for financial institutions in conducting stress tests is to accurately understand and assess potential risks. However, in practical operation, due to various constraints such as method selection, model setting, and data analysis, Chinese financial institutions face a common problem of insufficient risk identification in stress testing [75].

Firstly, the multi-level structure and cross market risks of China's financial market are often overlooked in model construction. Previous stress testing models often tended to focus on a single type of risk, such as credit risk, market risk, etc., while ignoring the correlation and transmission mechanism between different risk types within the financial market. For example, the joint distribution model of default probability (PD) and default loss rate (LGD) has not been widely applied in China. The panoramic identification of various risk factors and their interactions is not comprehensive enough, making it difficult to reflect the intensifying effects of various risks in complex financial systems [56].

Secondly, in the current era of constantly emerging financial innovation products, new financial instruments and trading methods often bring new risk points, which are rarely addressed in the current stress testing system. For example, the risk attributes of complex barrier options and swap contracts applied in the OTC derivatives market may undergo sharp changes due to factors such as implied volatility and changes in associated asset prices, but these situations are often weakened or ignored in stress testing [29].

Furthermore, leverage is an important feature of modern financial markets and a significant source of risk. However, many financial institutions have not fully considered the factors affecting leverage when conducting stress tests. Especially the mismatch between internal debt and assets of financial institutions, as well as the leverage effect of financial derivatives, which are not included in the variables of stress testing, can lead to test results that cannot truly reflect the liquidity crisis and liquidation risk faced by financial institutions [45].

In addition, the measurement of systemic risks and the integration of stress testing are new trends in the development of stress testing. Systemic risk indicators such as CoVaR and SRISK have been widely used abroad to monitor the vulnerability and potential risks of the financial system. However, Chinese financial institutions have not yet effectively integrated these advanced systemic risk measurement tools in the risk identification process, resulting in the inability to comprehensively assess the true extent of damage suffered by financial institutions in systemic financial crises [14].

To overcome the above problems, the stress testing models of financial institutions need to integrate macro and micro perspectives, cross industry analysis, and consider the multi asset linkage effects. In terms of data, it is necessary to expand the sources of data, such as synchronously considering the financial derivatives market and bond market, and conducting cross analysis with real economy data. When constructing the model, network theory based models such as GVAR model, macro network model, etc. can be introduced to simulate the risk diffusion path and potential impact under sudden events. At the same time, strengthen risk monitoring and quantitative evaluation of non-traditional financial activities such as shadow banking, asset management products, and non-standard credit instruments, in order to more accurately reflect the true level of risk [18].

By improving model construction, expanding data dimensions, and enhancing the ability to identify systemic risks, it not only helps to improve the scientific and accurate stress testing of financial institutions, but also has important significance for regulatory authorities to formulate effective risk prevention policies and financial stability measures [11].

Result application restrictions. Financial institutions often face several constraints when applying stress test results, which not only limit the practical effectiveness of stress testing as a risk management tool, but also affect the scientific and forward-looking nature of financial regulation. The insufficient ability to provide decision support, limitations in identifying risk exposure points, and time delays in formulating countermeasures have all become bottlenecks in the application of stress test results in domestic financial institutions [16].

In terms of decision support, the application of stress test results often fails to enter the strategic and operational levels of institutions in a timely manner. Some financial institutions still lack mechanisms to integrate stress test results with core banking businesses such as capital planning and liquidity management. The test results often exist as a static report and have not been fully transformed into a dynamic process of strategic adjustment and risk mitigation. Therefore, although the model output shows potential risk pressures, actual capital decisions and market actions slowly follow up, affecting the timeliness and effectiveness of decisions [19].

In identifying risk exposure points, most financial institutions use traditional risk indicators and historical data based judgment methods during stress testing. Indicators such as Value at Risk (VaR) and Expected Shortfall (ES) can to some extent reflect market risk, but often overlook the tail risk and its nonlinear characteristics in extreme situations. In addition, some potential risk points, such as the vulnerability of the shadow banking system, the transmission effect of derivative markets, and the inherent credit risk of complex financial instruments, are difficult to grasp in traditional quantitative models, leading to underestimation of actual risks [20].

When it comes to the response of formulating countermeasures, the application of results is also limited by institutional and operational factors. In practical operations, financial institutions often choose conservative measures to avoid aggressive execution of countermeasures due to concerns that adverse results of stress tests may trigger market panic or a crisis of trust. At the regulatory level, there is also excessive caution towards the results of stress tests, leading to regulatory agencies being overly cautious in their responses and slowly updating regulatory frameworks and policy measures. This phenomenon to some extent weakens the effectiveness of applying stress test results, preventing them from becoming a powerful tool for developing risk management strategies in a timely manner [23].

The above conclusion is not an unfounded inference, but is based on in-depth empirical research. By comparing the implementation and application modes of stress testing in domestic and foreign financial institutions, we found that there are still problems such as low integration of stress testing methodology and practical application, and weak connection between operational and decision-making levels in domestic financial institutions. Especially in terms of automation and systematization of stress test results application, domestic financial institutions still have significant room for improvement compared to international advanced banking systems. Therefore, in-depth analysis and optimization improvement of the application limitations of results have become the key to promoting the development of risk management in financial institutions [24].

Based on international best practices, it is urgent to establish a more efficient, transparent, and multidimensional mechanism for the application of stress test results to address the limitations of the aforementioned achievements. Specifically, financial institutions should establish a rapid response mechanism for stress test results and decisions, improve risk identification tools to more accurately capture market and systemic risks, optimize decision-making processes, and achieve real-time dynamic monitoring of test results and rapid activation of emergency plans. At the regulatory level, we advocate for an open and transparent mechanism for disclosing test results, effectively enhancing the regulatory guidance and warning functions of stress testing tools, ensuring that test results can provide strong support for regulatory decision-making and timely feedback to market regulatory practices.

The existence and underlying reasons for the limitations in the application of stress test results reveal the shortcomings of domestic financial institutions in risk management and regulatory practices, and also point out the direction for future improvement and application enhancement of stress testing. Through continuous institutional innovation and technological application, financial institutions are expected to fully tap into the potential value of stress testing and make new and greater contributions to financial stability and sustained and healthy economic development.

## 2.3. Case analysis

Typical Financial Institution Cases. As a key tool for risk management in financial institutions, stress testing often demonstrates its effectiveness through case analysis of typical institutions. This study selected state-owned large banks, joint-stock banks, local banks, and foreign banks as case studies to compare and analyze their similarities and differences in stress testing implementation. When analyzing the stress test results of various financial institutions, various factors such as the asset size, market positioning, asset liability structure, and domestic and international operating environment of the corresponding financial institutions were considered.

Stress scenario . The solvency macro scenario stress test sets three stress scenarios: mild, moderate and severe. The macro scenario indicators include the year-on-year growth of GDP (table 2.2), CPI growth, short-term and long-term market interest rates, the year-on-year growth of total retail sales of social consumer goods, the year-on-year growth of industrial added value, the year-on-year growth of completed fixed assets investment and the exchange rate of RMB against the U.S. dollar. The solvency sensitivity stress test uses the non-performing loan ratio, non-performing asset ratio, loss rate, and yield curve changes of overall credit assets and key areas as stress indicators (table 2.3).

Table 2.2

GDP year-on-year growth rate in macro scenario stress test of solvency

| Year | Mild stress scenario | Moderate stress scenario | High-stress scenario |
|---|---|---|---|
| 2023 | 3.50% | 2.80% | 1.10% |
| 2024 | 3.20% | 2.60% | 2.90% |
| 2025 | 3.70% | 3.40% | 3.20% |

Note: Other macroeconomic indicators are set based on macroeconomic econometric models

Table 2.3

Solvency Stress Test Scenarios

| Test content | Stressful situation |
|---|---|
| Overall credit assets risk | Shock 1: Overall non-performing loan ratio increases by 100%;<br>Shock 2: Overall non-performing loan ratio increases by 200%;<br>Shock 3: Overall non-performing loan ratio increases by 400%;<br>Shock 4: 50% of special-mentioned loans are transferred to non-performing loans;<br>Shock 5: 100% of special-mentioned loans are transferred to non-performing loans. |
| Real estate financing risk | Shock 1: The non-performing loan ratio of real estate development loans increases by 5 percentage points, the non-performing loan ratio of home purchase and other loans increases by 3 percentage points, the non-performing asset ratio of standardized real estate assets increases by 3 percentage points, and the non-performing asset ratio of non-standardized real estate assets increases by 5 percentage points; |

Continued of table 2.3

| Test content | Stressful situation |
| --- | --- |
| Real estate financing risk | Shock 2: The non-performing loan ratio of real estate development loans increases by 10 percentage points, the non-performing loan ratio of home purchase and other loans increases by 6 percentage points, the non-performing asset ratio of standardized real estate assets increases by 6 percentage points, and the non-performing asset ratio of non-standardized real estate assets increases by 10 percentage points;<br>Shock 3: The non-performing loan ratio of real estate development loans increases by 15 percentage points, the non-performing loan ratio of home purchase and other loans increases by 9 percentage points, the non-performing asset ratio of standardized real estate assets increases by 9 percentage points, and the non-performing asset ratio of non-standardized real estate assets increases by 15 percentage points. |
| 5<br>Small and medium-sized enterprises and individual operational loans risk | Impact 1: The non-performing loan ratio for small, medium, and micro enterprises and individual businesses increases by 200%;<br>Impact 2: The non-performing loan ratio for small, medium, and micro enterprises and individual businesses increases by 400%;<br>Impact 3: The non-performing loan ratio for small, medium, and micro enterprises and individual businesses increases by 600%. |
| 6<br>Local government financing platform risks | Shock 1: The original non-performing asset ratio rises to 5%;<br>Shock 2: The original non-performing asset ratio rises to 10%;<br>Shock 3: The original non-performing asset ratio rises to 15%. |
| Customer concentration risk | Shock 1: Maximum default of 1 non-industry group customer, loss given default rate is 60%;<br>Shock 2: Maximum default of 3 non-industry group customers, loss given default rate is 60%;<br>Shock 3: Maximum default of 5 non-industry group customers, loss given default rate is 60%. |

Continued of table 2.3

| Test content | Stressful situation |
|---|---|
| Counterparty credit risk | Shock 1: Maximum 1 counterparty in the same industry defaults, default loss rate is 60%;<br>Shock 2: Maximum 3 counterparties in the same industry default, default loss rate is 60%;<br>Shock 3: Maximum 5 counterparties in the same industry default, default loss rate is 60%. |
| Investment loss risk | Shock 1: The yield curve for interest rate bonds (including treasury bonds, local government bonds, central bank bills, and policy financial bonds) shifts upward by 250 basis points;<br>Shock 2: The yield curve for commercial financial bonds and interbank negotiable certificates of deposit shifts upward by 400 basis points;<br>Shock 3: The yield curve for non-financial corporate bonds shifts upward by 400 basis points;<br>Shock 4: A 10% loss in the book value of SPV investment accounts;<br>Shock 5: All four of the above shocks occur simultaneously. |
| Bond default risk | Shock 1: The default of the bond with the largest book value;<br>Shock 2: The default of the 3 bonds with the largest book value;<br>Shock 3: The default of the 5 bonds with the largest book value;<br>Shock 4: The default of the 10 bonds with the largest book value. |
| 7 Off-balance sheet business credit risk | Shock 1: The balance of off-balance-sheet business exposure accounts for 30%, with an expected loss rate of 90% after the advance payment;<br>Shock 2: The balance of off-balance-sheet business exposure accounts for 40%, with an expected loss rate of 90% after the advance payment;<br>Shock 3: The balance of off-balance-sheet business exposure accounts for 50%, with an expected loss rate of 90% after the advance payment. |

Note:

1 - Assuming the initial non-performing loan (NPL) ratio is X%, after an increase of n%, the NPL ratio becomes X% (1 + n%).

2 - Real estate development loans include land development loans and housing development loans.

3 - Housing purchase and other loans include commercial property purchase loans, individual housing loans, operational property loans, real estate leasing

operation loans, real estate M&A loans, and real estate intermediary service loans, etc.

4 - Assuming the initial non-performing loan ratio is X%, after an increase of n percentage points, the NPL ratio becomes (X + n)%.

5 - The classification standards for small, medium, and micro enterprises refer to the regulations in the «Notice on Printing and Distributing the Standards for the Classification of Small and Medium-sized Enterprises» (No. 300 of the Ministry of Industry and Information Technology [2011]).

6 - The risk exposure of local government financing platforms includes loans to local government financing platforms, investments in bond-type financing instruments of local government financing platforms, and other on-balance-sheet credit funds supporting local government financing platforms.

7 - Off-balance-sheet business credit risk exposure includes credit business equivalent to loans and contingent projects related to transactions, such as bank acceptance bills, financial and non-financial guarantees.

The liquidity risk stress test sets mild and severe stress scenarios, and sets different inflow or outflow rates for on balance sheet assets, liabilities, and contingent financing obligations with different maturity periods to calculate the net cash flow gap under different maturities. The infectious risk stress test sets three stress scenarios to examine the potential risk spillover effects on other participating banks when a credit default occurs and interbank funds are withdrawn (table 2.4).

Basic assumptions. The solvency stress test assumes that the bank's asset liability structure remains unchanged, the provision coverage ratio meets 100%, and the income tax rate is 25%. When the net profit is positive and the capital adequacy ratio at all levels still meets regulatory requirements after dividends, dividends will be distributed at 30%. During the testing period, macro policy support, disposal of non-performing loans, and external capital supplementation will not be considered. The liquidity stress test assumes that the bank will continue to operate, meaning that the bank will not harm its relationships with important customers or cause significant business disruptions [75].

Table 2.4

Infectious Risk Stress Test Scenarios

| | |
|---|---|
| Scenario 1 | Assuming that participating banks experience credit defaults (default and withdraw interbank lending funds, hereinafter the same), examine the potential spillover effects that may arise. |
| Scenario 2 | Assume that non-bank financial institutions in the banking sector are the first to default. The participating banks incur losses on their interbank assets held with non-bank financial institutions in the banking sector, which are directly deducted from the net core tier one capital. Then, the potential spillover effects are examined when the remaining participating banks experience credit defaults. |
| Scenario 3 | Assuming that securities and insurance financial institutions are the first to default, the participating banks would suffer losses on their interbank assets to securities and insurance financial institutions, which would be directly deducted from the net core tier one capital. Then, the potential spillover effects from credit defaults occurring in the remaining participating banks would be examined. |

The infectious risk stress test assumes that a participating bank defaults on its interbank counterparty and withdraws funds from interbank lending. If other participating banks fail the stress test due to interbank fund losses during this process, the bank will continue to default and withdraw funds until no more banks continue to default, and this round of contagion process will end. The other participating banks repeated the default shock process mentioned above [66].

By standards. For the macro scenario stress test of solvency, if any of the core Tier 1 capital adequacy ratio, Tier 1 capital adequacy ratio, or capital adequacy ratio of the participating bank after being impacted is lower than regulatory requirements (including 2.5% reserve capital requirement and D-SIBs additional capital requirement - 1), it has not passed the stress test. For the solvency sensitivity stress test, if the capital adequacy ratio of the participating bank after being impacted is lower than the regulatory requirements, it will not pass the stress test (table 2.5).

Table 2.5

Balance Sheet of Chinese-funded Large (End-of-period balance)

| Project | First Quarter | Second quarter | Third quarter | Fourth quarter |
|---|---|---|---|---|
| Foreign assets | 39254.73 | 41384.38 | 41692.01 | 40564.99 |
| Reserve assets | 116847.32 | 113572.55 | 117562.92 | 120858.13 |
| Reserve deposits | 114164.71 | 111030.86 | 115037.84 | 118318.40 |
| Cash on hand | 2682.61 | 2541.69 | 2525.08 | 2539.73 |
| Government claims | 250405.48 | 267637.38 | 267487.30 | 272865.95 |
| Wherein: the central government | 250405.48 | 267637.38 | 267487.30 | 272865.95 |
| Claims on the central bank | 6.06 | 58.97 | 78.08 | 72.01 |
| Claims on other deposit-taking corporations | 106299.43 | 113496.57 | 118385.28 | 121434.39 |
| Claims on other financial companies | 63433.18 | 65647.53 | 67127.41 | 65104.64 |
| Non-financial corporate debt | 671888.33 | 693459.08 | 716900.71 | 726698.14 |
| Claims on other resident sectors | 350928.08 | 354558.25 | 358966.46 | 359976.86 |
| Other assets | 57870.96 | 58847.19 | 57980.33 | 52033.07 |
| Total Assets | 1656933.57 | 1708661.91 | 1746180.49 | 1759608.19 |
| Liabilities to non-financial institutions and households | 1091073.74 | 1114419.54 | 1137645.34 | 1138268.57 |
| Deposits included in broad money | 1014587.40 | 1041336.77 | 1065573.35 | 1071964.43 |
| Current account deposits | 258062.91 | 269374.50 | 267545.21 | 264619.13 |
| Fixed-term deposit | 163713.56 | 169891.36 | 178911.71 | 169729.57 |
| Personal savings | 592810.92 | 602070.90 | 619116.43 | 637615.72 |
| Deposits not included in broad money | 31481.79 | 31750.64 | 31653.44 | 30654.92 |

Continued of table 2.5

| Project | First Quarter | Second quarter | Third quarter | Fourth quarter |
|---|---|---|---|---|
| Transferable Deposit | 12834.50 | 12130.93 | 11176.92 | 11471.17 |
| Other Deposits | 18647.29 | 19619.71 | 20476.52 | 19183.75 |
| Other liabilities | 45004.55 | 41332.14 | 40418.55 | 35649.22 |
| Liabilities to the central bank | 53555.97 | 54352.53 | 54874.57 | 64236.59 |
| Liabilities to other deposit-taking corporations | 27707.94 | 31551.07 | 29961.29 | 33765.04 |
| Liabilities to other financial companies | 100089.97 | 112751.95 | 117371.57 | 115942.89 |
| Wherein: Deposits included in broad money | 98801.63 | 111279.81 | 116045.14 | 114482.60 |
| Foreign debt | 5155.01 | 5411.26 | 6972.90 | 5491.65 |
| Bond issuance | 157565.71 | 163440.59 | 168994.14 | 170028.87 |
| Paid-in Capital | 33254.15 | 33901.67 | 34122.88 | 34122.88 |
| Other liabilities | 188531.08 | 192833.30 | 196237.80 | 197751.70 |
| Total liabilities | 1656933.57 | 1708661.91 | 1746180.49 | 1759608.19 |

For liquidity risk stress testing, when a participating bank experiences a cash flow gap (cash outflow exceeds cash inflow) under stress scenarios, the bank should take measures to liquidate or pledge qualified high-quality liquid assets to the central bank to obtain liquidity to make up for the gap. If all available qualified high-quality liquid assets have been exhausted and cannot make up for the gap, the stress test has not been passed. For the infectious risk stress test, if the core Tier 1 capital adequacy ratio of the participating bank after being impacted is less than 5%, it will not pass the stress test [44].

State owned large banks face significant systemic risks due to their vast asset size and coverage. Therefore, they adopted more complex and comprehensive risk scenarios and parameter settings in stress testing [27]. The test results have a particularly significant role in decision support, which can effectively guide asset liability management and liquidity risk control (table 2.6).

Table 2.6

Chinese-owned small bank balance sheets (End-of-period balance)

| Project | First Quarter | Second quarter | Third quarter | Fourth quarter |
|---|---|---|---|---|
| Foreign assets | 29162.23 | 30106.50 | 30502.03 | 29902.28 |
| Reserve assets | 36784.38 | 36761.42 | 35723.06 | 38405.30 |
| Reserve deposits | 36326.91 | 36296.62 | 35261.70 | 37902.45 |
| Cash on hand | 457.48 | 464.79 | 461.36 | 502.85 |
| Government claims | 82906.77 | 86420.44 | 88755.74 | 91843.04 |
| Wherein: the central government | 82906.77 | 86420.44 | 88755.74 | 91843.04 |
| Claims on the central bank | 11.29 | 23.27 | 25.43 | 6.62 |
| Claims on other deposit-taking corporations | 44391.32 | 42258.32 | 43579.35 | 49829.77 |
| Claims on other financial companies | 95727.44 | 95916.58 | 92535.91 | 94529.57 |
| Non-financial corporate debt | 340615.73 | 348050.22 | 356650.56 | 360432.89 |
| Claims on other resident sectors | 167636.57 | 170100.41 | 172918.84 | 173928.65 |
| Other assets | 24134.52 | 24354.21 | 24315.39 | 22282.68 |
| Total Assets | 821370.25 | 833991.37 | 845006.32 | 861160.81 |
| Liabilities to non-financial institutions and households | 383042.13 | 399751.37 | 404891.57 | 408133.87 |
| Deposits included in broad money | 360906.06 | 378017.19 | 382496.89 | 389387.23 |
| Current account deposits | 130934.86 | 136309.35 | 133996.02 | 130751.54 |
| Fixed-term deposit | 132048.25 | 138887.03 | 143203.82 | 139736.73 |
| Personal savings | 97922.94 | 102820.82 | 105297.04 | 118898.96 |
| Deposits not included in broad money | 18936.89 | 18285.96 | 16616.93 | 14562.58 |
| Transferable Deposit | 7776.58 | 7725.23 | 6436.00 | 6261.88 |
| Other Deposits | 11160.30 | 10560.73 | 10180.93 | 8300.69 |
| Other liabilities | 3199.18 | 3448.22 | 5777.74 | 4184.06 |
| Liabilities to the central bank | 33451.20 | 30024.81 | 32124.01 | 36448.44 |
| Liabilities to other deposit-taking corporations | 31789.92 | 34871.99 | 34376.66 | 34842.14 |

Continued of table 2.6

| Project | First Quarter | Second quarter | Third quarter | Fourth quarter |
|---|---|---|---|---|
| Liabilities to other financial companies | 103395.83 | 97776.83 | 95279.70 | 99574.45 |
| Wherein: Deposits included in broad money | 102617.08 | 96975.16 | 94670.70 | 98961.31 |
| Foreign debt | 3761.64 | 3650.27 | 4258.84 | 4296.65 |
| Bond issuance | 162419.54 | 163424.21 | 167429.36 | 171990.68 |
| Paid-in Capital | 14493.45 | 14546.55 | 14663.76 | 14668.33 |
| Other liabilities | 89016.54 | 89945.33 | 91982.43 | 91206.23 |
| Total liabilities | 821370.25 | 833991.37 | 845006.32 | 861160.81 |

For example, in recent stress tests, state-owned banks often introduce dynamic models based on Macro financial variables to evaluate their capital tolerance and liquidity coverage in extreme economic recession or inflation scenarios. In testing implementation, such banks are usually able to respond more sensitively to credit and market risks, and adjust credit policies and investment strategies accordingly [15]. Joint stock banks have demonstrated good innovation capabilities in stress testing applications. Due to their different risk tolerance compared to state-owned banks, joint-stock banks place greater emphasis on considering credit risks for small and medium-sized enterprises, market liquidity risks for non-standard assets, and international financial risks for cross-border capital flows when designing stress tests. In addition, joint-stock banks are relatively flexible in the application of stress test results, frequently using measures such as checking capital shortages and optimizing asset structures to make rapid adjustments [23].

The stress testing of local banks faces problems such as insufficient basic data and technical deficiencies. Local banks generally lack professional risk management teams and high-end risk assessment tools, making it difficult for them to compete with large banks in terms of testing parameter settings and result analysis. However, the specificity of these institutions in the areas of local government debt, financing for small and medium-sized enterprises, and rural financial services also requires targeted stress testing (table 2.7).

Table 2.7

Balance Sheet of Chinese-funded Small Banks (End-of-period balance)

| Project | First Quarter | Second quarter | Third quarter | Fourth quarter |
|---|---|---|---|---|
| Foreign assets | 3714.76 | 4219.52 | 4379.97 | 4289.46 |
| Reserve assets | 59972.66 | 59489.64 | 59099.13 | 64421.91 |
| Reserve deposits | 57796.10 | 57516.70 | 56972.07 | 62374.32 |
| Cash on hand | 2176.56 | 1972.94 | 2127.06 | 2047.58 |
| Government claims | 87413.44 | 94513.28 | 98059.67 | 101430.16 |
| Wherein: the central government | 87413.44 | 94513.28 | 98059.67 | 101430.16 |
| Claims on the central bank | 7.17 | 11.69 | 54.18 | 54.38 |
| Claims on other deposit-taking corporations | 120586.03 | 121568.72 | 120552.68 | 121272.63 |
| Claims on other financial companies | 83830.94 | 85010.54 | 85077.78 | 83352.46 |
| Non-financial corporate debt | 329872.47 | 340446.02 | 344192.39 | 349077.95 |
| Claims on other resident sectors | 180319.55 | 183570.97 | 188646.12 | 191194.60 |
| Other assets | 32025.70 | 32236.73 | 34086.46 | 33596.48 |
| Total Assets | 897742.71 | 921067.12 | 934148.37 | 948690.03 |
| Liabilities to non-financial institutions and households | 618899.28 | 638071.72 | 647436.01 | 658509.24 |
| Deposits included in broad money | 610259.06 | 629593.89 | 639159.52 | 651021.02 |
| Current account deposits | 121583.17 | 126709.98 | 123160.09 | 121026.82 |
| Fixed-term deposit | 104987.31 | 108672.80 | 112730.98 | 112415.46 |
| Personal savings | 383688.57 | 394211.10 | 403268.44 | 417578.74 |
| Deposits not included in broad money | 6655.01 | 6456.41 | 5601.62 | 4881.10 |
| Transferable Deposit | 2337.97 | 2415.76 | 1942.77 | 2056.74 |
| Other Deposits | 4317.04 | 4040.65 | 3658.85 | 2824.37 |
| Other liabilities | 1985.22 | 2021.42 | 2674.87 | 2607.12 |
| Liabilities to the central bank | 32110.40 | 31829.26 | 31074.24 | 32724.77 |
| Liabilities to other deposit-taking corporations | 40686.77 | 42504.19 | 43805.82 | 43488.66 |
| Liabilities to other financial companies | 53852.20 | 53509.18 | 53780.05 | 56089.47 |
| Wherein: Deposits included in broad money | 52823.90 | 52722.38 | 52635.34 | 54409.44 |
| Foreign debt | 647.55 | 747.15 | 750.89 | 881.78 |
| Bond issuance | 40039.98 | 40896.76 | 40376.50 | 39478.76 |
| Paid-in Capital | 23926.11 | 24431.33 | 24744.73 | 24968.98 |
| Other liabilities | 87580.42 | 89077.54 | 92180.13 | 92548.36 |
| Total liabilities | 897742.71 | 921067.12 | 934148.37 | 948690.03 |

In a case study of a local bank, the impact of local government debt default on the bank's capital adequacy ratio was evaluated by combining a self built credit risk scoring model with a Monte Carlo model in the context of regional economic depression [76].

In the process of localization management, foreign banks usually combine their parent bank's international risk management experience with the actual situation in the Chinese market. They not only focus on legality and compliance in the application of stress test results, but also emphasize the coordination between international rules and domestic policies. For example, a foreign bank referred to the strict process of Comprehensive Capital Analysis and Review (CCAR) during stress testing, analyzed the impact of foreign exchange fluctuations and the US China trade war on the bank's cross-border asset quality, and then formulated corresponding hedging strategies [51].

The case analysis of typical financial institutions shows that the industry has achieved certain results in stress testing, especially in risk identification, business structure adjustment, and cross cycle risk management. However, there are also shortcomings such as insufficient data transparency and explanatory difficulties caused by models relying too heavily on quantitative analysis. The analysis also points out that banks need to gradually establish a more structured stress testing process based on their own characteristics, enhance risk management culture, and strengthen the application analysis of test results. By deeply analyzing the differences in actual operations, banks can more effectively identify and manage risks in various economic situations, continuously improving the overall stability of the financial system [26].

Analysis of stress test results. After conducting stress tests on specific financial institutions, analyzing their results is a key step in measuring the effectiveness of stress tests and improving risk management levels. Through in-depth analysis of the effectiveness of stress tests conducted by state-owned banks, joint-stock banks, local banks, and foreign banks, we can gain insight into the performance and adaptability of the entire financial industry in the face of intense market fluctuations, especially under systemic risks and liquidity pressure tests (figure 2.1).

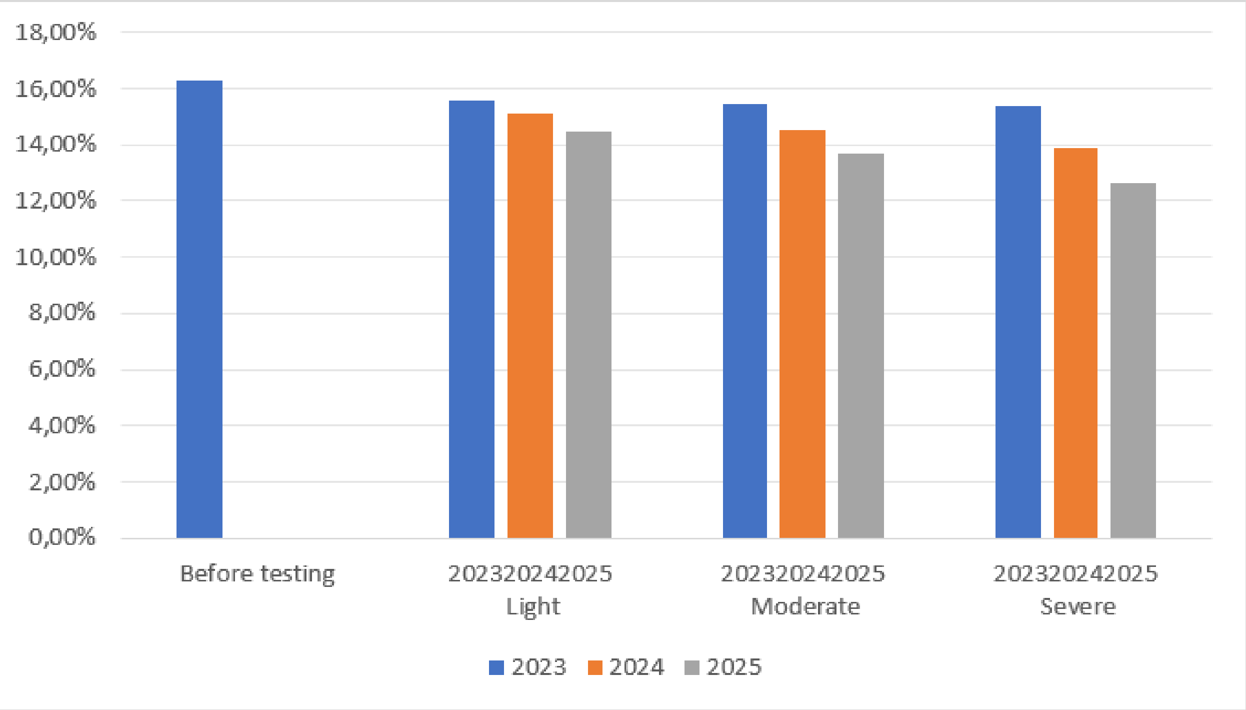


Figure 2.1. Overall Capital Adequacy Ratio of Macro Scenario Stress Test

As of the end of 2022, there were 3985 participating banks with a total loan balance of 186.78 trillion yuan. The overall non-performing loan ratio is 1.71%, while the overall capital adequacy ratio is 15.07%. Among them, 19 banks classified as D-SIBs (domestic systemically important banks) have a loan balance of 133.26 trillion yuan, a non-performing loan ratio of 1.30%, and a capital adequacy ratio of 16.29%; In addition, the total loan balance of 3966 non D-SIBs (i.e. non systemically important banks) is 53.52 trillion yuan. These banks have a high non-performing loan ratio of 2.74%, while their capital adequacy ratio is relatively low at 12.42%.

In the case of a state-owned large bank, two methods of measuring risk exposure, Value at Risk (VaR) and Expected Shortfall (ES), were used, combined with the Dynamic Conditional Value at Risk Model (DCC-GARCH) to analyze the risk exposure of its global asset portfolio. Taking into account the integrated scenarios of exchange rate fluctuations, interest rate hedging, and credit defaults, the response speed and elasticity of capital adequacy ratio to shocks were evaluated.

19 D-SIBs have strong overall impact resistance. The macro scenario stress test results show that the overall capital adequacy level of 19 D-SIBs is relatively high and their operation is stable. As of the end of 2022, the overall capital adequacy ratio of 19 D-SIBs was 16.29%. Under mild stress scenario, the capital adequacy ratio at the end of 2025 is 14.46%; Under moderate stress scenario, the capital adequacy ratio at the end of 2025 is 13.71%; Under severe stress scenarios, the capital adequacy ratio at the end of 2025 is 12.66%, indicating that the 19 D-SIBs as a whole have strong resilience to macroeconomic shocks

In the case of a joint-stock bank, a more forward-looking institution specific economic capital (EC) model was adopted, combined with Stress Vector analysis techniques to identify high-risk business areas in stress testing. Special attention was paid to the areas of loans to small and medium-sized enterprises (SMEs), real estate related investments, and non-performing loan treatment, which may increase credit losses, and the effects of different policy interventions were simulated in testing. Through stress testing, joint-stock banks have clearly identified and alerted potential credit risk issues, providing quantitative decision support for subsequent risk management and capital optimization [46].

Local banks are typically operating in more complex environments, facing pressures from various factors such as geopolitics, microeconomic changes, and regulatory framework adjustments. The Multifactor Model, which realistically simulates the impact of changes in local economic conditions and industry development trends on local bank finances, calculates multiple indicators including liquidity coverage ratio (LCR), stable funding ratio (NSFR), and loan loss reserve ratio. The results show that local banks are vulnerable to scenarios such as rapid capital outflows, declining housing prices, and rising corporate defaults, but at the same time, they also reflect their important supporting role in the local economy and their response strategies when facing risks.

In contrast, foreign banks have adopted a combined analysis method of Dynamic Stochastic General Equilibrium (DSGE) model and sovereign credit risk assessment due to their international business coverage and cross-border regulatory needs. This method not only covers market risk, credit risk, operational risk, and liquidity risk, but also examines the impact of cross-border capital flows on banks' own capital and external macroeconomic uncertainty. The stress tests of foreign banks have demonstrated their asset quality and capital adequacy in the global financial environment, verifying their ability to adjust strategies in a timely manner through a multi-level risk management system to respond to various norms and requirements set by multinational regulatory agencies [41].

Through the above case analysis, it can be found that different types of financial institutions not only reflect their own risk management characteristics in stress testing, but also highlight the common progress of the financial industry in risk identification, assessment, and response capabilities. Especially in cross cycle comparisons, it is evident that financial institutions have improved their adaptability to market dynamics, and the optimization and adjustment of business structures have gradually effectively controlled high-risk points. The shortcoming is that there are still differences between experimental stress testing and real-life operations, and the data quality and risk management culture still need to be further improved. Overcoming these shortcomings is necessary to ensure that the results of stress tests are better translated into practical actions to enhance the resilience of financial institutions [71].

Shortcomings and Lessons Learned. Stress testing, as an important tool for evaluating the capital adequacy and liquidity of financial institutions in extreme environments, has shown significant limitations and deficiencies in practical operations. Based on the analysis of multiple typical cases of financial institutions facing systemic risks, we can find that even in carefully designed and strictly executed stress tests, there are still significant deficiencies and lessons to be learned that cannot be ignored. These reflections and reviews help us to more accurately examine the adaptability of current models and methods, and further promote the improvement and development of stress testing methods for financial institutions.

Firstly, there is a significant difference between laboratory settings and actual operations. Stress testing in laboratory environments of financial institutions such as state-owned banks often uses relatively idealized model parameters and assumptions. However, when these tests are exposed to the complexity of the real world, many assumptions are often difficult to accurately verify. For example, local banks often use historical data for retrospective analysis when conducting stress tests, but historical extreme events cannot fully predict future market behavior, and changes in market conditions and macroeconomic environment can also lead to model failure [75].

Secondly, the impact of data quality on stress test results cannot be ignored. Financial institutions, including foreign banks, face a large number of unstructured data processing problems and difficulties in data quality control, especially in Internet financial enterprises. The incompleteness, errors, and lack of timeliness of this data can all lead to inaccurate stress test results, which are particularly prominent in the rapidly changing financial market context [74].

Furthermore, the culture of risk management needs to be further cultivated. In the case of joint-stock banks, although stress testing provides identification of risk exposure points, it is difficult to achieve consistent action across departments in implementing corresponding risk management measures. Cultural neglect often leads to the neglect of test results, resulting in significant losses when actual risks arise. This cultural flaw is closely related to the management's lack of awareness of the importance of stress testing [78].

In the research on improving stress testing methods for financial institutions, more originality and innovation are needed at the strategic level. In response to the limitations of existing methods, it is necessary to consider introducing models based on system dynamics and behavioral finance, which can better simulate and predict the dynamic behavior of financial markets in stressful environments. At the same time, the risk transmission pathways under the interaction of multiple factors and the accumulation of systemic risks also need to be fully considered. In terms of parameter selection, parameter sensitivity analysis must receive deeper attention and research. The determination of economic capital (EC), the setting of key parameters such as loss determination and long-term risk-free return rate should be based on more rigorous theoretical derivation and market observation. In terms of risk quantification, existing methods such as Value at Risk (VaR) and Expected Loss (EL) need to be calibrated and optimized based on the actual business characteristics of financial institutions, with emphasis on model backtesting and the establishment of a sound model validation system and criteria [47].

Financial institutions also need to continuously improve their application of stress testing. Both the core risk management department and the organizational structure of the entire organization need targeted adjustments and optimizations to ensure that stress test results can be more effectively integrated into practical business such as decision support, risk management, and emergency fund pool construction. In addition, with the development of financial technology, technologies such as big data and cloud computing should be more widely integrated into the implementation and analysis of stress testing to improve testing efficiency and transparency. In summary, it can be seen that financial institution stress testing has encountered various difficulties in empirical analysis. Solving these problems not only requires innovation in technology and methods, but also synchronous improvement in the culture and governance structure of financial institutions.

# CHAPTER 3
# IMPROVEMENT IN STRESS TESTING APPLICATION FOR FINANCIAL INSTITUTIONS

## 3.1. Improved methodological foundation

Limitations of existing methods. Financial institution stress testing, as a key tool for assessing potential financial risks, has shown significant importance during past financial crises, but it has shown clear limitations in dealing with more complex and volatile financial environments. Traditional stress testing methods often assume a stable market environment and ignore the nonlinear characteristics of financial markets and their dynamic evolution under extreme market conditions, which affects the accuracy and reliability of test results [71].

A core limitation of existing methods is that they are mostly based on linear assumptions, which assume that the correlations between financial assets and their responses to external shocks remain constant under various market conditions. However, actual market observations indicate that during financial crises or abnormal market fluctuations, the correlation between assets undergoes structural changes, and traditional static correlation indicators such as Pearson correlation coefficient cannot accurately capture this dynamic change. In addition, the scenario design in stress testing often only considers probability distributions within a certain range, while the assessment and simulation of tail risks are relatively lacking. Tail risk reflects rare but destructive extreme events in financial markets, which often lead to significant financial losses [12].

Furthermore, in terms of considering systemic risks, traditional stress tests typically focus on the risk tolerance of a single institution, while ignoring the overall fragility of the financial system. Systemic risk typically arises from the intricate interconnections between financial institutions, such as credit networks, payment systems, and capital markets, which can trigger chain reactions in extreme cases, amplifying the impact on individual financial institutions and leading to overall financial market instability. Therefore, stress testing methods need to further consider the structure of financial networks and their dynamic evolution under external shocks to ensure a more comprehensive capture of systemic risks [18].

The parameter setting of stress testing is also one of the limitations of existing methods, often using fixed parameters to simulate the profit and loss scenarios of financial institutions. However, this approach lacks adaptability to the dynamic characteristics of financial markets and ignores the real-time impact of financial market conditions on parameters. For example, the impact of market liquidity on current market value and the long-term impact of changes in credit policies within the banking system on asset quality have not been reflected. If a fixed capital adequacy ratio parameter is used, it cannot reflect the changes in countercyclical capital buffer requirements in the actual regulatory environment, resulting in overly optimistic or pessimistic evaluations of institutional risk resistance capabilities [15].

To address these challenges and limitations, stress testing methods need to introduce more advanced and refined theories. For example, complex systems theory provides powerful tools for understanding and analyzing the nonlinear characteristics of financial markets, and Agent based models can be used to simulate the behavior and interactions of financial market participants. In addition, the risk measurement method based on Extreme Value Theory (EVT) can better quantify tail risk, while Network Theory helps to analyze the complex relationships between financial institutions, thereby more accurately assessing systemic risk [11].

The improved methods should also include machine learning algorithms to enhance the accuracy and dynamism of parameter estimation. For example, using deep learning to train historical data, identifying potential signals of market state transitions and nonlinear features reflecting asset price fluctuations, while adjusting asset correlations and stress testing scenarios through reinforcement learning. In addition, the introduction of multi-stage stress testing allows for the phased assessment of the robustness of financial markets in a continuously changing macroeconomic and regulatory environment within a continuous time frame [15].

Although traditional stress testing methods provide a foundation for financial risk management, they show significant limitations in dealing with the current highly dynamic and uncertain financial market. The development and adoption of innovative methods is a key focus of stress testing improvement for financial institutions, which requires the integration of more financial engineering, economic principles, complex system theory, and the latest computing technologies to provide more refined and comprehensive risk assessments [19].

Theoretical basis for improvement. In the exploration of improving stress testing methods for financial institutions, the establishment of theoretical basis is particularly important, especially in model assumptions, system risk assessment, and financial market behavior analysis. Traditional stress testing relies on classic financial market models such as CAPM (Asset Pricing Model) and MPT (Modern Portfolio Theory) to estimate the risk exposure of financial institutions. However, these models often exhibit structural maladjustment when faced with extreme market volatility and nonlinear behavior. With the increasing complexity of financial market structures and the innovation of financial instruments, the limitations of traditional theories have gradually become apparent, prompting the academic community to further improve and expand the theoretical foundation of stress testing [25]. In the process of improving the theoretical foundation of stress testing, the perspective of behavioral finance provides a new angle. For example, psychological biases such as overconfidence, herd behavior, and market sentiment fluctuations of decision-makers may trigger irrational behavior patterns in financial markets, thereby having an undeniable impact on the risk situation of financial institutions. The addition of these psychological and behavioral factors makes the assumptions of the stress testing model closer to real market behavior, improving the accuracy and effectiveness of the model's warning [26].

The application of system dynamics methods has further deepened the theoretical framework of stress testing. The core of system dynamics is to analyze and simulate the interactions between various elements within a system and their dynamic processes over time. In financial institution stress testing, system dynamics provides theoretical tools for simulating the immediate response of market shocks to financial institution balance sheets, liquidity risk transmission pathways, and dynamic changes in capital adequacy ratios. By constructing a complex network model that includes multiple market participants and financial instruments, stress testing can more comprehensively capture the systemic risks of the market as a whole [29].

The extended application of economic principles is also one of the basis for the improvement of stress testing theory. Traditional static equilibrium theory cannot effectively predict and explain the dynamic processes in financial crises. Therefore, introducing non-equilibrium economic theory, especially utilizing group game theory, market microstructure theory, and extreme value theory, can enable stress testing to more accurately evaluate the risk resistance of financial institutions in non-equilibrium states. The introduction of these theories not only enables financial institutions to better understand the nonlinear characteristics of the market and its risk concentration, but also helps to more effectively consider the probability and potential impact of extreme market events when formulating risk hedging strategies.

In addition, the application of econometric methods in stress testing is also receiving increasing attention, which enables risk estimation to be quantitatively expressed based on empirical data. For example, predicting the volatility of financial assets through GARCH models, exploring long-term relationships between different financial assets using Cointegration Test, and analyzing causal relationships between market variables using Granger Causality Test. The widespread use of these measurement methods provides a rigid statistical basis for stress testing, enhancing the scientific and logical nature of risk prediction models [24].

Overall, the improvement of stress testing methods for financial institutions cannot be achieved without the continuous enrichment and expansion of theoretical foundations. By drawing on modern financial theory, introducing a behavioral finance perspective, combining system dynamics methods, and utilizing advanced econometric techniques, stress testing methods can be effectively optimized to enhance the application value of test results in financial decision-making and risk management. In today's increasingly complex and uncertain risk environment, improved stress testing will continue to assist banks and regulatory agencies in better warning and managing financial risks [21].

Propose innovative methods. In the complex environment of macroeconomic fluctuations, market structure changes, and continuous promotion of financial innovation, traditional stress testing methods are no longer able to fully reflect potential financial risks for financial institutions. Therefore, this study proposes innovative measures to improve stress testing methods, aiming to enhance the risk resistance ability of financial institutions and improve their risk management level. The key to proposing innovative methods lies in surpassing the limitations of existing models and integrating interdisciplinary theories and technologies to improve the predictive accuracy and adaptability of the models [29].

In terms of methodology, the primary task is to strengthen the evaluation of the interaction between macro and micro environmental variables and financial institutions. To this end, multi factor market models from economics, such as Agent Based Modeling (ABM) and Network Analysis, have been introduced to simulate the behavioral changes of market entities under different shocks and their impact on the financial system. This model, with its flexibility and adaptability, can capture the complex dynamics and evolution process of financial markets [12].

Secondly, considering the diversity and continuous innovation of financial instruments, it is proposed to combine the concept of behavioral finance to analyze the adaptation and response of market entities to new financial products. The scenario designed on this basis should be able to include diverse financial instruments and innovative strategies, as well as market participants' perceptions and usage patterns of these tools and strategies, in order to evaluate the impact of these financial innovations on financial stability [19].

Once again, strengthen the application of system dynamics methods by introducing the System Dynamics (SD) model, integrating the dynamic interaction effects of various risk factors, and examining financial risks from a global perspective of the system. The SD model accurately identifies and characterizes the positive and negative feedback loops between risk factors, reveals the internal operating mechanisms and possible nonlinear behaviors of the financial system, and provides a more comprehensive explanation for stress test results [39].

In the process of model construction, a highly flexible and scalable model architecture was adopted, taking into account multiple factors and nonlinear characteristics. Combining deep learning analysis of financial time series data, such as Recurrent Neural Networks (RNN) and Long Short Term Memory networks (LSTM), dynamic tracking and high-precision prediction of financial risk evolution trends have been achieved [45].

Through a multi-level and multi-dimensional risk management simulation platform, a new stress testing scenario was designed in highly uncertain macroeconomic scenarios, including severe market volatility, emerging market risk exposure, major geopolitical events, etc. This scenario analysis based simulation platform can effectively evaluate the risk exposure and effectiveness of response strategies of financial institutions in various extreme scenarios [65].

It is worth mentioning that this study also innovatively proposed a stress testing framework tailored to the characteristics of specific financial institutions. By combining the business model, capital structure, market positioning, and historical experience of the institution, a stress testing scenario and indicator system that fits its characteristics have been designed. This customized approach can more accurately identify the unique risk points faced by institutions and provide targeted risk assessment and management recommendations for regulatory authorities [64].

To further enhance the applicability and effectiveness of stress testing, this study promotes the integration with emergency planning practices. By simulating the initiation and execution process of various emergency plans during a financial crisis, the immediacy and effectiveness of emergency response in the actual operation of financial institutions were tested, promoting the optimization of their own risk management system and response mechanisms [12].

Therefore based on the above methods, the new perspective of financial risk management revealed in this study not only provides more accurate methodological support for financial institution stress testing, but also further promotes the transformation of financial institution stress testing from static point based evaluation to dynamic and continuous evaluation. These innovative methods demonstrate their important theoretical and practical significance in improving risk prediction and management in financial institutions.

### 3.2. Parameter optimization and scene simulation

Parameter sensitivity analysis. In the research and application of stress testing in financial institutions, parameter optimization and scenario simulation have built the core technical framework. Especially in the sensitivity analysis of the model, parameter settings have a decisive impact on the accuracy and adaptability of the results. Through parameter sensitivity analysis, it is possible to gain insight into the impact of changes in different economic variables on the overall risk situation of financial institutions, and adjust the application strategies of the model accordingly, thereby improving the effectiveness and warning capabilities of stress testing [16].

The core of sensitivity analysis lies in identifying and quantifying the impact of major parameter changes on the systemic risk of financial institutions. At the operational level, the Beta coefficient is used to quantitatively analyze the correlation between various assets and market indices, in order to monitor the risk exposure of asset portfolios under different market conditions. In addition, the slope of the win rate curve is used to evaluate the probability distribution of profit and loss under stress testing scenarios by integrating the changes in profit and loss of various assets or business lines. When measuring the loss of credit risk, a long-term risk-free return rate is set as a benchmark to analyze the potential loss scale of various credit investment portfolios in stress events [45].

The optimization of parameter selection is the core task of the entire sensitivity analysis. The parameter of sufficient liquidity buffer is an important indicator to measure the ability of financial institutions to resist large-scale fund withdrawals in the short term, and its precise setting is crucial for evaluating the liquidity risk of institutions. Meanwhile, the fixed impact of capital adequacy ratio is equally important in assessing the ability of institutions to withstand long-term risks. The control of credit expansion speed is directly related to the formation speed of potential non-performing assets in the future, and has direct guiding significance for the business strategy and policy formulation of financial institutions [19].

In the scenario setting of stress testing, simulation testing based on historical extreme events provides the possibility of simulating complex real-life scenarios. For example, simulations of events such as the 2008 financial crisis can enable financial institutions to assess their risk tolerance in similar extreme situations. The stress testing scenarios generated using artificial intelligence technology can make intelligent judgments more efficiently among potential risk factors, predict potential risk events in the future, and develop appropriate evaluation models based on this.

Meanwhile, parameter sensitivity analysis should pay attention to the adaptability between model selection and application scenarios during the operation process. The application of diversified risk models, such as the Value at Risk (VaR) model under liquidity risk, the Expected Loss (EL) model under credit risk, and the Delta Normal method under market risk, provides different focused analytical approaches for quantifying different types of risks. By comparing with actual data in scene simulation, it is possible to verify the predictive accuracy of the model and track and detect potential model design deficiencies [13].

Although parameter sensitivity analysis plays an important role in stress testing, there are also many challenges. For example, when faced with complex financial instruments and increasingly delicate financial market structures, past methods may struggle to capture emerging risk points. Therefore, further development of stress testing tools and technologies with highly adaptive capabilities will be an inevitable trend in future research in the field of financial security. By introducing new risk measurement indicators such as debt to equity ratio and debt service coverage, the model can help capture more subtle market changes and improve the comprehensiveness and accuracy of stress testing [20].

Parameter optimization and scenario simulation play an indispensable role in stress testing. Through systematic and scientific sensitivity analysis, not only can financial institutions improve their understanding of existing risks, but they can also provide powerful warning information for potential market changes in the future. These optimization measures further build a solid foundation for risk management for financial institutions, enhance their ability to resist unknown risks, and ensure their sustainable and healthy development in a complex and changing economic environment [25].

Selection of optimization parameters. Parameter optimization is a key step for financial institutions to improve the accuracy and effectiveness of stress testing. In response to the insufficient parameter selection of commonly used stress testing models in financial institutions and the challenges of dealing with complex financial market environments, this study focuses on proposing an optimized parameter selection framework to enhance the predictive ability and risk sensitivity of the model, thereby better evaluating and managing potential financial risks (table 3.1).

When selecting optimization parameters, this study first considered liquidity buffer indicators, such as the ratio of high-quality liquid assets (HQLA) to total liquidity demand, which can effectively reflect the short-term liquidity situation of financial institutions in the face of market turbulence. When selecting optimization parameters, this study first considered liquidity buffer indicators, such as the ratio of high-quality liquid assets (HQLA) to total liquidity demand, which can effectively reflect the short-term liquidity situation of financial institutions in the face of market turbulence.

Liquidity coverage ratio (LCR) and net stable funding ratio (NSFR) are also considered, as they are widely used to reflect an institution's liquidity risk tolerance.

Meanwhile, regarding the capital adequacy ratio, this study adopts the Common Equity Tier 1 (CET1) ratio in Basel III regulations as the core evaluation parameter, which is of great significance for measuring the inherent ability of financial institutions to withstand extreme market conditions.

Table 3.1

Regional Commercial Banks Stress Test Selection Factors

| Region | Hong Kong, China | Taiwan, China | Norway | Finland | Sweden |
|---|---|---|---|---|---|
| Variable name | HIBOR | Stock Index | Interest rate change ratio | Market interest rate | Actual interest rate level |
| | Real Estate Price Index | GDP growth rate | Asset prices | Asset prices | Inflation trends and expectations |
| | Nominal GDP Growth Rate | Export value | GDP growth rate | Savings and Investment | Loan Growth Rate |
| | Real GDP Growth Rate | | Loan Growth Rate | Total money supply | Trends in intermediary competition |
| | | | | Balance of Payments Exchange Rate | |

The control of credit expansion speed is another key factor in parameter selection. In this study, the gap between credit growth rate and GDP growth is used as an observation window to ensure that the speed of credit expansion is coordinated with the pace of economic growth. Rapid credit growth often indicates potential credit risk aggregation in the future. Quantitative analysis of credit risk through sensitivity testing can help financial institutions adjust their lending strategies in a timely manner [25].

Under conditions of unstable macroeconomic environment or significant market fluctuations, macroeconomic pressure indicators such as changes in unemployment rate, fluctuations in industrial production index, and changes in real estate market prices are considered key variables for optimization selection. The dynamic changes of these macro variables can provide forward-looking indications for systemic risks in financial markets [31].

In addition, interest rate risk, as another important dimension of risk, plays a crucial role in optimizing parameters. The dynamic change of the slope of treasury bond yield curve and the fluctuation of interest margin can provide an important decision-making basis for asset liability management, and are indispensable factors in the stress test of financial institutions [48].

For market risk, this study utilized tools such as Historical Value at Risk (VaR) and Conditional Value at Risk (CVaR) to analyze the sensitivity of market risk parameters to stress testing, focusing on keywords such as financial asset price fluctuations and maximum potential losses within the holding period. This provides guidance for financial asset portfolio selection and risk control [50].

In empirical research, this study applied multivariate statistical analysis, machine learning algorithms, and complex network theory to optimize parameters in stress testing. Through these advanced data analysis techniques, deep structures and patterns hidden within the data can be revealed, thereby assisting financial institutions in more accurately capturing risk exposures. Parameter optimization not only stays at the theoretical and model level, but also reflects in the accuracy and operability of empirical results [59].

In short, the selection of optimization parameters not only needs to consider static historical data, but also dynamic market changes and the impact of macroeconomic environment. By comprehensively utilizing various quantitative models and advanced data analysis tools, we can provide a more scientific, detailed, and accurate parameter optimization plan for stress testing of financial institutions, thereby promoting the improvement of risk management capabilities and the maintenance of financial stability [63].

Scene setting and simulation testing. The continuous improvement of stress testing methods for financial institutions plays an indispensable role in maintaining financial stability, especially in the current global financial environment full of uncertainty. In the optimization of stress testing methods, scenario setting and simulation testing are the core parts of building a risk assessment system for financial institutions, which directly affect the authenticity of test results, warning capabilities, and the practicality of response strategies [14].

The primary task of scenario setting is to restore or construct scenarios of macroeconomic, financial market, and industry-specific variables that may affect the stability of financial institutions. The simulated scenarios include regular economic fluctuations, abnormal fluctuations in financial markets, and major policy adjustments. In terms of specific operations, multidimensional scenarios involving domestic and international macroeconomic indicators, financial market indices, asset prices, exchange rate fluctuations, and other factors should be comprehensively developed based on historical experience and industry expert opinions. The setting of key parameters such as GDP growth rate, inflation rate, interest rate level, stock market volatility, etc., needs to be flexibly adjusted according to domestic and international economic trends and policy guidance, and the probability distribution should be used to quantify the likelihood of different scenarios occurring. Based on this, «benchmark scenarios» and «extreme scenarios» can be set [25].

Simulation testing conducts comprehensive risk testing on financial institutions based on the set scenarios, using advanced quantitative models such as Vector Auto regression (VAR) model, dynamic stochastic general equilibrium model (DSGE), econometric model, etc., to evaluate the losses of financial institutions in various scenarios. Simulation testing should also consider the balance sheet structure, capital buffering capacity, and liquidity situation of financial institutions, identify key nodes that may become risk transmission pathways, and simulate the transmission of shocks. Modern simulation processes rely on high-performance computing capabilities and enhance the accuracy and applicability of simulations through simulation techniques such as Monte Carlo methods [24].

It is worth noting that scenario setting should not only rely on traditional economic variables, but also incorporate non economic factors such as climate change, geopolitical events, public health emergencies, as well as the impact of changes in fields such as technological development and regulatory policy adjustments on financial institution risks. Such cross-border integration considerations can more comprehensively capture potential risks and effectively identify non-traditional risk sources, such as cybersecurity and the challenges posed by FinTech innovation to financial institutions. For emerging market countries, the impact of factors such as land market volatility and international capital inflows and outflows on the stability of the financial system should also be included in scenario analysis [29].

The technical challenges in the simulation testing process should not be underestimated. For example, when conducting financial market risk analysis, it is necessary to dynamically simulate the term structure of interest rates and changes in credit risk ratings. At the same time, it is necessary to compare the pricing and trading strategy assumptions of derivative financial instruments to ensure the reliability of the results. In the simulation of liquidity risk, the simulation testing of fund flow and financing structure needs to have a high degree of flexibility and adaptability to simulate liquidity freezing in different extreme situations of financial markets. For operational risks, simulation testing needs to combine the probability distribution of factors such as human errors, system failures, and internal management deficiencies to evaluate risk events that may cause significant losses.

Gross, parameter optimization needs to start from reality, combine macroeconomic indicators, financial market data, industry dynamics, and regulatory requirements, adopt innovative models and calculation methods, and improve the accuracy and applicability of stress testing. The rigor of scenario setting and simulation testing work will directly affect the effectiveness of the risk assessment system of financial institutions. It is necessary to consider the actual causes and characteristics of potential future impacts, strengthen the predictive power of the model, and enhance its ability to resist risks.

## 3.3. Risk quantification and model validation

Methods for risk quantification. Risk quantification is one of the key steps in ensuring the stability of financial institutions during stress testing. Through scientific risk quantification methods, we can accurately assess the resistance of financial institutions to potential financial fluctuations. In this section of the study, we adopt various advanced quantitative models to quantitatively evaluate multidimensional financial risks such as market risk, credit risk, and liquidity risk, providing a more comprehensive and in-depth analysis basis for stress testing [70].

In the quantification of market risk, we focused on studying the Value at Risk (VaR) model. The VaR model is a widely used risk quantification tool in the financial field, which can measure the potential maximum loss under normal market conditions and a given confidence level [65].

The quantification of credit risk is also a focus of our research. We used credit transfer matrices and survival models to determine the relationship between default probability and potential losses in lending relationships. During the parameter calibration process of the credit risk model, we conducted extensive data analysis to deeply mine and learn historical default data, in order to improve the predictive accuracy of the model [22].

In terms of quantifying liquidity risk, this study adopts a liquidity adjusted VaR model, integrating the influencing factors of liquidity risk into the VaR model and further optimizing the traditional VaR calculation method. The liquidity risk in financial markets is closely related to market conditions, and the discontinuity and uncertainty of the market pose challenges to accurately measuring liquidity risk. To overcome this challenge, we have comprehensively considered factors such as market depth, bid ask spread, and recovery time of market shocks to revise the VaR model, in order to achieve a more accurate measurement of liquidity risk [33].

Model validation is also a necessary step to ensure the reliability of stress test results. We conducted a series of posterior analysis of the model to test its predictive ability, including backtesting, gross sensitivity analysis, and extreme case analysis. Through these verification steps, we can validate the model's ability to fit past data and its resilience to future uncertainty. We combine factors such as heteroscedasticity effects and tail dependence to further improve the predictive accuracy of the model [22].

This study delves into various methods and models for risk quantification and their validation processes, providing strong theoretical support and practical guidance for financial institutions to develop stress testing strategies. By continuously optimizing model parameters and verification methods, financial institutions can more accurately quantify potential risks, thereby maintaining stability in complex and volatile financial markets.

$$\mathrm{VaR} = \mathrm{Z}_{\alpha} \cdot \sigma \cdot \sqrt{\mathrm{t}} \tag{3.1}$$

VaR - Value at Risk.

Implementation of verification methods. The accuracy and credibility of financial institution stress testing largely rely on rigorous validation of relevant risk models. In the process of risk quantification and model validation, the implementation of validation methods is a key step that determines the reliability of the model and the actual usability of future stress test results. Given this, the backtesting, benchmarking, and stress testing verification of the model have become the focus of attention for both researchers and practitioners. Developing a rigorous implementation mechanism through these methods is an important means of improving the scientific and accurate nature of stress testing methods for financial institutions.

When performing posterior validation, researchers need to pay attention to using historical data to test the risk value (VaR) and other indicators produced by the model, and check their predictive ability in actual financial crises one by one. The strategy adopted includes comparing the VaR values generated by the model with the extreme loss values or loss distributions in actual market operations, and verifying the matching of the model's overdue probability at different confidence levels. This type of verification provides feedback on the accuracy and practicality of the model by comparing the frequency and amplitude of predicted and actual events. However, various empirical studies have shown that most risk models struggle to accurately capture extreme risks during systemic financial shocks. Therefore, researchers continue to pursue more advanced posterior verification techniques that combine non parametric estimation methods with extreme value theory [45].

During the benchmarking process, researchers typically choose to compare with static or simplified risk models that are similar to the model or have been adopted by typical financial institutions. The core of this process is to establish an acceptable benchmark or standard point, and then use it as a basis to evaluate the overall performance of the current model. Especially in today's ever-changing market environment and rapid innovation of financial products, comparing with other models can often help regulators and risk managers distinguish the applicability and limitations of specific risk models in specific environments [65].

The key to empirical testing in stress testing is to identify a scenario that can simulate potential financial environmental pressures in the future and comprehensively predict the impact of various risk factors on the stability of financial institutions. This not only involves the setting of macroeconomic variables, but also requires in-depth analysis of internal risk factors related to the characteristics of financial institutions, such as credit risk, market risk, liquidity risk, etc. To further improve empirical testing and promote the application of artificial intelligence in scenario generation, identifying potential risk patterns through learning historical data has undoubtedly become a new direction for enhancing the scientificity of stress testing. By introducing more sophisticated machine learning and data mining techniques, financial institutions can more accurately simulate potential stress scenarios they may encounter in the future, thereby developing more precise and efficient risk management strategies [78].

So the validation of stress testing models cannot be limited to mathematical calculations or internal self consistency, but requires empirical testing of model stability and warning capabilities. Through multidimensional methods such as posterior verification, benchmark testing, and empirical testing of stress testing, the model can effectively reflect the real pressure faced by financial institutions. At the same time, the accuracy of the model should be continuously tracked and its predictive ability improved to ensure that stress test results can truly guide financial institutions to make wise decisions when facing future financial risks. Only in this way can the depth, scientificity, and practical guidance of doctoral level research on stress testing and improvement of financial institutions be reflected [90].

Validity evaluation of verification results. When financial institutions verify stress test results, they need to comprehensively consider multiple factors such as testing frequency adjustment, error analysis, and data updates, which directly affect the robustness and effectiveness of the stress test model. In practical operations, financial institutions often use methods such as backtesting, benchmarking, and stress testing rituals to ensure the rationality and accuracy of model validation. And among them, the validity evaluation of the verification results is the core link to ensure that financial institutions can cope with current and future potential risks.

In the validity evaluation of the verification results, it is necessary to first determine the verification frequency. The validation of models should not be a one-time task, but a continuous process. Periodic validation helps ensure that the model can continuously and accurately reflect the risk situation faced by financial institutions. In determining the frequency, institutions can refer to the availability of historical data, the speed of changes in market conditions, regulatory requirements, and their own risk management needs to set it. Some financial institutions may tend to conduct model validation on a quarterly or even monthly basis, which can quickly identify and correct model limitations, but frequent validation can also increase operating costs and work complexity. Therefore, when formulating the verification frequency, it is necessary to find a balance between risk management requirements and cost-effectiveness [45].

Furthermore, error term analysis is a key component in evaluating the accuracy of the model. Financial institutions need to carefully analyze the error sources generated during the verification process, which may be inaccurate model assumptions, unpredictable market dynamics, or inaccurate data processing. For example, in the Value at Risk (VaR) model, an abnormally volatile market environment may cause the model to systematically overestimate or underestimate risk. In this case, institutions need to delve into the reasons for errors and adjust the parameters or assumptions in the model in a timely manner. For the existing error terms, institutions should also consider using techniques such as data fusion and model integration to enhance the predictive performance and robustness of the model [23].

Finally, data updates play a decisive role in model validation. Financial institutions should continuously monitor and obtain the latest market and internal data to ensure that the input information of the model is up-to-date and effectively reflects market conditions. The adaptive model mechanism can automatically adjust model parameters when new data arrives, thereby enhancing the model's ability to predict future risks. In addition, financial institutions should pay attention to data quality management and ensure the integrity and reliability of data through measures such as data cleaning, verification, and completion [32].

Overall, by scientifically setting the frequency of model validation, conducting in-depth analysis of error terms, and ensuring timely data updates, financial institutions can continuously improve the validity of stress test results and make them powerful tools for risk management and decision-making. In the innovation and improvement of stress testing methods, future financial institutions should draw on advanced technologies such as artificial intelligence and cloud computing, combined with macroeconomic models and systematic risk analysis frameworks, to form a new stress testing system that can balance accuracy and practicality, in order to meet the needs of increasingly complex financial markets and regulatory environments.

# CONCLUSIONS

As a result of the qualifying master's work, we will consider the degree of solving the tasks set at the beginning of the work.

The in-depth exploration in the field of stress testing for financial institutions has yielded remarkable results, evolving into a series of milestone studies. This study conducted a comprehensive analysis of the improvement and application enhancement of stress testing in financial institutions. Combining the current development status and innovative practices at home and abroad, a comprehensive research framework was constructed, which includes methodological upgrading, risk quantification, implementation system optimization, and demand-oriented innovation. The summary of research results and prospects for future development provide highly operational risk management strategies and decision-making references for financial institutions.

In terms of improving stress testing methods, the reconstructed theoretical framework introduces system dynamics methods on the basis of traditional quantitative models, significantly enhancing the accuracy and predictive ability of stress testing. By introducing the perspective of behavioral finance, the examination of micro subject behavior in financial markets has been increased, enabling stress testing to analyze how irrational factors will affect financial markets in times of crisis. The multi factor interactive evaluation model proposed by innovation simulates the performance of financial institutions in various complex economic scenarios by introducing macroeconomic variables and financial market data, enhancing the applicability and robustness of stress testing in extreme situations.

In the risk quantification and model validation stage of stress testing, complex network analysis is introduced to gain insight into the linkage effects between financial institutions and the systemic risk propagation path. The verification mechanism for stress test results is more refined. With the help of Backtesting and Benchmarking methods, the testing model has been rigorously empirically tested, greatly reducing the risk of overfitting and ensuring the efficiency and applicability of the test output.

In the field of enhancing stress testing applications, focus on optimizing the internal risk management processes and decision-making mechanisms of financial institutions. We have created an information system supported by technology and big data, which automates data collection, risk monitoring, and result reporting, greatly improving the efficiency and timeliness of risk management. The optimization of the internal organizational structure of financial institutions ensures the organic collaboration between the risk management department and the finance department, and enhances the application value of stress test results in business decision-making.

In terms of future development, this article proposes various possibilities for the application of financial technology in stress testing, such as the application of artificial intelligence and machine learning in scenario simulation and risk prediction, and the role of financial technology products in stress testing parameter optimization and result analysis. It is expected to greatly promote stress testing towards a more accurate and forward-looking direction. Meanwhile, the continuous development of regulatory technology will facilitate efficient collaboration between risk management and regulation, further strengthening the solid defense line of financial institutions in the face of systemic financial risks.

This study provides strong intellectual support for financial institutions and relevant regulatory agencies through its profound theoretical insights, precise empirical techniques, and innovative practical applications. The in-depth exploration and improvement proposals for stress testing and risk management models of financial institutions will effectively guide the continuous optimization and innovation of financial institutions in the fields of risk prediction, control, and management. With the rapid changes in the financial environment and the continuous advancement of emerging financial technologies, the stress testing and related risk management work of financial institutions will inevitably usher in broader development prospects.

The rapid development of financial technology is profoundly changing various aspects of the financial field, among which stress testing, as an important tool for evaluating the risk resistance ability of financial institutions, has a particularly broad application prospect. Future stress testing will leverage cutting-edge technologies such as artificial intelligence, big data analysis, cloud computing, and blockchain to further improve its accuracy, real-time performance, and predictive capabilities, providing stronger support for risk management of financial institutions and decision-making of regulatory authorities.

With the deep integration of financial technology, the automation and intelligence of stress testing is an irreversible trend. Machine learning algorithms can recognize patterns by training large amounts of historical data to predict potential risk exposures in new economic situations, accelerating the generation of stress testing scenarios and risk assessment processes. Deep learning networks are capable of processing structured and unstructured data and discovering complex nonlinear relationships in high-dimensional data, which is crucial for understanding and predicting the complex dynamics of financial markets.

Cloud computing provides unparalleled computing power, making large-scale stress testing possible. Financial institutions can rely on cloud services to quickly expand their computing resources when needed, conduct extensive simulation experiments, and ensure the robustness of test results. At the same time, this also means that stress tests can be conducted more frequently, strengthening the emergency response capabilities of financial institutions to unexpected events.

Blockchain technology can enhance the transparency of information and traceability of results in stress testing. Automatically execute stress testing scenarios and parameter settings through smart contracts to ensure consistency and credibility of test results. Different financial institutions and regulatory authorities can collaborate based on the same distributed ledger data to achieve information sharing and regulatory linkage, enhancing the transparency and regulatory efficiency of the entire financial system.

The development of regulatory technology will also promote the popularization and standardization of stress testing. Regulatory agencies can use technological means to implement more refined supervision, such as directly obtaining stress test data and results of financial institutions through API interfaces. This not only reduces the problem of information asymmetry between regulatory authorities and financial institutions, but also enables real-time monitoring of stress test results, providing regulatory authorities with more immediate risk assessment.

The role of stress testing in risk management will become increasingly prominent in the future, and it is expected to help financial institutions better adapt to the constantly changing market environment through improved risk management, control, and response mechanisms. Furthermore, by integrating the advantages of machine learning, cloud computing, blockchain, and regulatory technology, stress testing in the financial industry will evolve into a comprehensive and dynamic risk management framework, enabling financial institutions and regulatory authorities to more effectively identify, measure, monitor, and mitigate various risks.

On this basis, integrating financial technology into stress testing can promote its standardization, systematization, and refinement. Thus, stress testing can not only better evaluate the robustness of financial institutions, but also help regulatory agencies make more rapid and effective policy responses when there are substantial changes in the global economic environment. The penetration and application of these technological means indicate the coordinated reform of risk management and regulation in the future, which will create a more intelligent, interconnected, and predictive financial ecosystem.

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Онлайн сервіс створення та перевірки кваліфікованого та удосконаленого електронного підпису

ПРОТОКОЛ
створення та перевірки кваліфікованого та удосконаленого електронного підпису

Дата та час: 22:36:11 16.12.2024

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Підписувач - 1: ОРЄХОВА КАТЕРИНА ВІТАЛІЇВНА
П.І.Б.: ОРЄХОВА КАТЕРИНА ВІТАЛІЇВНА
Країна: Україна
РНОКПП: 2980818183
Організація (установа): ФІЗИЧНА ОСОБА
Час підпису (підтверджено кваліфікованою позначкою часу для підпису від Надавача): 22:03:47 27.11.2024
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Алгоритм підпису: ДСТУ 4145
Тип підпису: Удосконалений
Тип контейнера: Підпис та дані в одному файлі (CAdES enveloped)
Формат підпису: З повними даними ЦСК для перевірки (CAdES-X Long)
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Підписувач - 2: АЗАРЕНКОВА ГАЛИНА МИХАЙЛІВНА
П.І.Б.: АЗАРЕНКОВА ГАЛИНА МИХАЙЛІВНА
Країна: Україна
РНОКПП: 2571514226
Організація (установа): ФІЗИЧНА ОСОБА
Час підпису (підтверджено кваліфікованою позначкою часу для підпису від Надавача): 21:20:49 30.11.2024
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Сертифікат: Кваліфікований

Підписувач - 3: Омеляненко Денис Олегович
П.І.Б.: Омеляненко Денис Олегович
Країна: Україна
РНОКПП: 3634714115
Час підпису (підтверджено кваліфікованою позначкою часу для підпису від Надавача): 11:43:04 16.12.2024
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Тип контейнера: Підпис та дані в одному файлі (CAdES enveloped)
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Версія від: 2024.11.25 13:00