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Develop Macro Stress-testing Framework for Financial Stability Assessment

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한국은행 dongguk UNIVERSITY 산학협력단 NEPAL RASTRA BANK नेपाल राष्ट्र बैंक

Contents

List of Tables

List of Figures

List of Boxes

Executive Summary

The Nepal economy has made significant progress in terms of poverty reduction and shared prosperity in the last two decades. Although Nepal's economic fundamentals have been relatively sound, recently the Nepali economy is facing pressure on external and fiscal fronts after COVID 19 shock. In a situation where various difficulties and risks are emerging, stress testing is expected to be helpful in finding the right policy. Stress testing is a quantitative technique to measure the impact on a financial company or system in the event of exceptional but plausible incidents.

Nepal has already been using stress tests for over 10 years. Stress Testing Guidelines 2012, issued by Nepal Rastra Bank, has played a pivotal role in shaping stress testing practices within the country's banking sector. The current stress testing framework primarily employs sensitivity analysis, focusing on micro stress testing at the individual bank level. Despite the recent amendments that signify progress, a notable gap still exists i.e. the absence of macroeconomic considerations in stress testing. In order to bridge this critical gap, it is imperative for the inclusion of macroeconomic factors in stress testing methodologies. The incorporation of macro stress testing in Nepal's Stress Testing framework is essential to comprehensively evaluate the resilience of BFIs as well as the financial system against adverse macro-economic scenarios. The inclusion of macro stress testing will not only be a regulatory enhancement but a starting point to fortify the assessment of resilience of banks and the overall financial ecosystem against the complexities of the macro economic landscape.

Korea's experience in establishing and developing a macro stress test system is expected to be helpful to Nepal. There are two types of macro stress tests: top-down and bottom-up, and Korea is conducting both. This report not only introduces Korea's experience with macroeconmic stress testing system, but also explores Nepal's macro stress test introduction strategy and specific model construction plans. In addition, we design a macro stress test model based on data provided by the Central Bank of Nepal and introduce the estimation results.

In particular, a concrete strategy must be formulated in order to introduce macroeconomic stress testing. In the context of Nepal's introduction strategy for stress testing, we will focus on the differentiation between macroprudential and microprudential stress testing, decisions on top-down and bottom-up stress testing, and the seven decision challenges pointed out by Herring and Schuermann (2022).

Based on the direction in this report, we also review ways to build a specific model. This report has constructed a credit loss model, the interest income ratio (IIR) and interest expense ratio (IER). However, a separate model for market risks could not be constructed because relevant data has not been provided. The solvency stress test is to estimate the future financial statements under a stress scenario and evaluate the capital adequacy by calculating the capital ratio. Since there is a lack of data on the time series of trading profits and losses of commercial banks in Nepal and the composition of equity ratios, we calculated the stressed capital ratios based on the base year financial statements.

Scenario design and estimation method is the starting point and the most important step of macro stress testing. To model initial shocks for Nepal's macro stress test, this study employs the GaR (Growth at Risk) framework, a probabilistic scenario model first proposed by the IMF (2017a). Using the three steps suggested by Prasad et al. (2019), we estimated the correlation between current macrofinancial conditions and future GDP growth rate and used this to derive the conditional distribution of future GDP growth rate. And we estimated a Bayesian VAR model using quarterly Nepalese macro data for about 10 years from Q3 2013 to Q4 2022.

This output, which is based on Korea's experiences and the skills and data of the Nepal Rastra Bank, seems to be a result of desirable collaboration. However, it has a number of limitations, including the limited availability of relevant statistical data. In addition, there is a need to secure manpower to develop and operate stress testing models and to continue education and training for them.

I. Introduction

The Nepal economy has made significant progress in terms of poverty reduction and shared prosperity in the last two decades. The proportion of Nepali households living in poverty has declined significantly. The progress in poverty reduction and shared prosperity can be attributable to high levels of remittances inflows. Nepal is scheduled to graduate from the Least Developed Country (LDC) category in 2026. Although Nepal's economic fundamentals have been relatively sound, recently the Nepali economy is facing pressure on external and fiscal fronts after COVID 19 shock. There has been reversal in trend due to the large-scale post-earthquake reconstruction, rapid expansion of government expenditure due to the transition to federal system, expanding social security net and the cost associated with COVID-19 pandemic.

In a situation where various difficulties and risks are emerging, stress testing is expected to be helpful in finding the right policy. Stress testing is a quantitative technique to measure the impact on a financial company or system in the event of exceptional but plausible incidents. Macro stress testing, as a methodology of macroprudential analysis for assessing system risk as part of a financial stability supervisory role, is widely used to evaluate financial stability in the event of exogenous shocks.

Nepal has already been using stress tests for over 10 years. Stress Testing Guidelines 2012, issued by Nepal Rastra Bank, has played a pivotal role in shaping stress testing practices within the country's banking sector. Mandating stress testing for credit risk, market risk, and liquidity risk, the guidelines has been instrumental in using stress testing as a tool for risk analysis and management among banks. The guidelines has also encouraged banks and financial institutions to explore advanced stress testing techniques, aligning with the regulatory framework while enhancing their internal risk management capabilities.

The current stress testing framework primarily employs sensitivity analysis, focusing on micro stress testing at the individual bank level. Despite the recent amendments that signify progress, a notable gap still exists i.e. the absence of macroeconomic considerations in stress testing. Banks and financial institutions and the overall financial system are inherently intertwined with macroeconomic conditions. The interconnectedness implies that adverse macroeconomic scenarios can significantly impact banks and financial institutions, affecting overall financial stability in the country.

Hence, to bridge this critical gap, it is imperative for the inclusion of macroeconomic factors in stress testing methodologies. The incorporation of macro stress testing in Nepal's Stress Testing framework is essential to comprehensively evaluate the resilience of BFIs as well as the financial system against adverse macro-economic scenarios. By conducting stress tests that encompass macroeconomic variables, NRB and Banks and financial institutions will be able to proactively identify vulnerabilities, enabling timely interventions to safeguard the stability of the institutions and overall banking system. The macro stress test is also essential to decide on the stressed capital requirements.

In essence, the evolution of stress testing practices in Nepal's banking industry must transcend the micro-level and embrace a holistic approach. The inclusion of macro stress testing will not only be a regulatory enhancement but a starting point to fortify the assessment of resilience of banks and the overall financial ecosystem against the complexities of the macro economic landscape.

Korea's experience in establishing and developing a macro stress test system is expected to be helpful to Nepal. There are two types of macro stress tests: top-down and bottom-up, and Korea is conducting both. The top-down stress test utilizes a stress test system developed by regulatory authorities, which incorporates data, scenarios, assumptions, and models, and is used for financial supervisory purposes. This approach evaluates the resilience of the entire financial system through estimating credit risks such as the probability of default (PD) and loss given default (LGD), using financial data from financial

institutions. Conversely, the bottom-up stress test is conducted by financial institutions using their self-developed scenarios and models, or by performing tests based on common scenarios provided by the authorities, with results reported back to the financial authorities.

This report not only introduces Korea's experience in establishing and developing a macro stress test system, but also explores Nepal's macro stress test introduction strategy and specific model construction plans. In addition, we design a macro stress test model based on data provided by the Central Bank of Nepal and introduce the estimation results. However, macro stress testing requires a vast amount of data, which is difficult to obtain in a short period of time, so the macro stress testing model presented in this report has not been completed.

First of all, a concrete strategy must be formulated in order to introduce macroeconomic stress testing. It is important to decide whether macroeconomic stress testing will be designed based on microprudential stress testing. Second of all, decisions need to be made regarding the conduct of top-down and bottom-up stress testing. Moreover, Herring and Schuermann (2022) identified seven key issues that need to be addressed when conducting stress testing, including: (1) designing stress scenarios, (2) selecting risk factors, (3) considering stress scenarios to mitigate banks' procyclicality, (4) setting stress test pass/fail criteria, (5) determining the scope, duration, and frequency of stress testing, (6) selecting models, and (7) communication strategies. In the context of Nepal's introduction strategy for stress testing, we will focus on the differentiation between macroprudential and microprudential stress testing, decisions on top-down and bottom-up stress testing, and the seven decision challenges pointed out by Herring and Schuermann (2022).

Regarding the issue of microprudential and macroprudential stress testing, a phased approach could be considered in the case of Nepal. Starting with a microprudential stress test centered around liquidity capacity and subsequently incorporating macroprudential elements such as transmission effects could be a practical approach.

With regard to the choice of top-down vs bottom-up approaches, it is considered necessary to first develop a downward stress testing model that takes into account available data and then establish minimum standards for stress testing methodologies through discussions with banks. Banks can then conduct upward stress testing using their own models, and the results can be used for validation by the Central Bank of Nepal.

In Nepal, there is no known instance of financial crises with available statistical data in the past. Consequently, there may be limitations to scenario design based on statistical techniques. Nonetheless, despite these challenges, a statistical approach serves as a crucial starting point for scenario analysis. Initially, attempts can be made to design scenarios based on GaR within the possible scope. Second, expert opinions on significant risk factors, such as the linkage with the Indian economy, fixed exchange rates, and remittances from overseas workers, can be considered to complement scenarios. Finally, if these methods prove to be infeasible, the option of scenario design through reverse stress testing may be explored.

In addition, the focus of th Nepali macro stress testing should primarily be on developing solvency stress tests with an emphasis on credit risk. Market risk and interest rate risk should also be included, with consideration given to adopting Basel III's Interest Rate Risk in the Banking Book (IRRBB) standard method, an upgrade from the current business reporting for monitoring interest rate risk. Regarding liquidity risk, Nepal has established a system to monitor detailed risk profiles through business reporting. However, there is a need to consider implementing Basel III's Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR) regulations to align with international standards. Additionally, the introduction of macroprudential models can be considered once solvency stress tests are refined, which is also in line with the current experimental stage of the Financial Supervisory Service in South Korea.

This report also considers the issues of stress scenarios to mitigate banks' procyclicality, setting stress test pass/fail criteria, determining the scope, duration,

and frequency of stress testing, selecting models, and communication strategies.

Based on this direction, this report also reviews ways to build a specific model. This report has constructed a credit loss model explaining variations in the credit cost ratio, centered around various variables. The dependent variable is the credit cost ratio, which is the ratio of the moving average of credit costs over four quarters to the outstanding loan balance of 20 commercial banks. Explanatory variables are divided into real, financial, and overseas indicators to estimate a panel data model. We have also constructed and estimated the interest income ratio (IIR) and interest expense ratio (IER). However, a separate model for market risks could not be constructed because relevant data has not been provided.

The solvency stress test is to estimate the future financial statements under a stress scenario and evaluate the capital adequacy by calculating the capital ratio. To do this, we need to estimate the income statement and balance sheet. However, there is a lack of data on the time series of trading profits and losses of commercial banks in Nepal and the composition of equity ratios. Therefore, in this paper, we first calculate the stressed capital ratios based on the base year financial statements.

The next chapter is about scenario design and estimation method, which is the starting point and the most important step of macro stress testing. To model initial shocks for Nepal's macro stress test, this study employs the GaR (Growth at Risk) framework, a probabilistic scenario model first proposed by the IMF (2017a). GaR, conceived as a tool to gauge and monitor the possibility and severity of abrupt economic downturns by predicting the future GDP growth rate distribution, takes inspiration from the VaR (Value at Risk) concept, a popular risk management tool used in financial companies.

This report uses Prasad et al. for estimation of the GaR model. (2019), based on the three steps proposed, we found the correlation between current macrofinancial conditions and future GDP growth rate and used this to derive the conditional distribution of future GDP growth rate.

After identifying the initial shock to GDP, which is required for scenario analysis through the Growth at Risk (GaR) framework, a multivariate time series model of the macro variables of the Nepalese economy needs to be constructed to determine the behavior of other macro variables in response to the initial shock. In this study, we decided to use Bayesian VAR model for scenario analysis of macro stress test of Nepalese economy and estimated Bayesian VAR model using quarterly Nepalese macro data for about 10 years from Q3 2013 to Q4 2022.

This report explains these contents in the following four chapters. Chapter II touches economic trends and financial environment in Nepal and chapter III explains Korean and Nepali macro stress test systems and development experiences. Chapter IV proposes a macro stress testing framework for Nepal. Chapter V is about macro stress test design and estimation methodology. Chapter VI concludes.

II. Economic Trends and Financial Environment in Nepal

Nepal's economic fundamentals have been relatively sound, although recently Nepalese economy is facing pressure on external and fiscal fronts after COVID 19 shock. The inflation has been in single digit for the most part of the last decade. Government's fiscal balances have remained modest leading to a reduction of public debt compared to level decade of 2000s but recently there has been reversal in trend due to the large-scale post-earthquake reconstruction, rapid expansion of government expenditure due to the transition to federal system, expanding social security net and the cost associated with COVID-19 pandemic. The financial sector for the most part has been stable and external balances has remained at comfortable levels with exception in 2020/21 and 2021/22. Moreover, significant progress has been made in terms of poverty reduction and shared prosperity in the last two decades. The proportion of Nepalese households living in poverty has declined significantly. The progress in poverty reduction and shared prosperity can be attributable to high levels of remittances inflows. Nepal is scheduled to graduate from the Least Developed Country (LDC) category in 2026.

1. Economic Growth and Inflation

A. Economic Growth

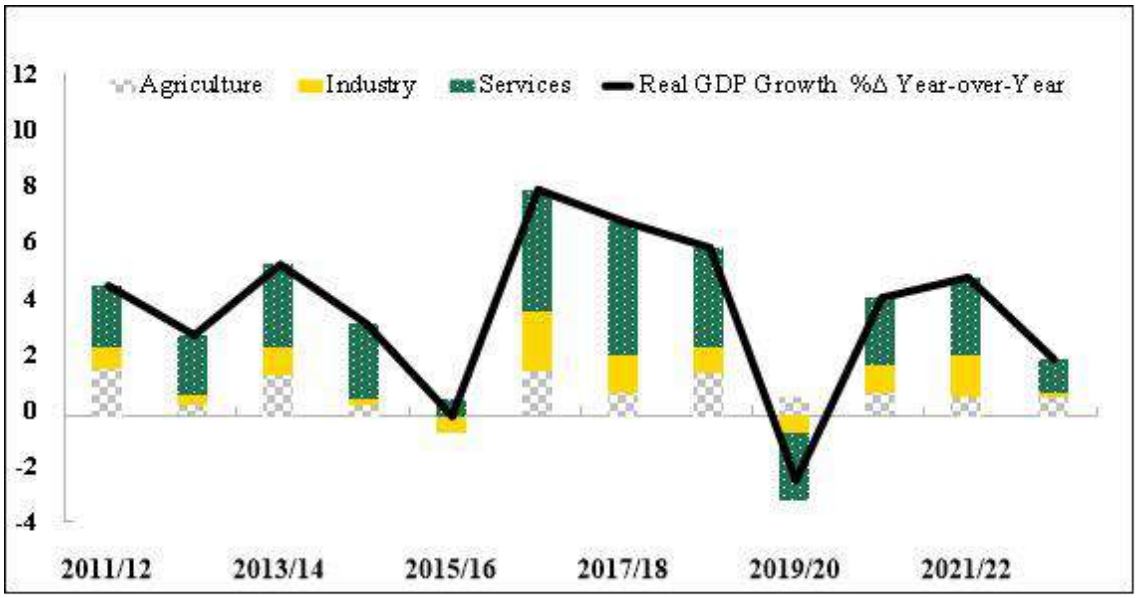
Historically, the economic growth of Nepal has remained low and volatile. In the last three decades, the economy grew by 4.4 percent on average from 1990/91 to 2022/23. The performance of the Nepalese economy right after the restoration of multi-party democracy in 1990 remained phenomenal on the background of the establishment of democratic government and sweeping reforms. The average growth rate stood at 5.0 percent during the 1990s. Since 1991, the government of Nepal pursued liberalized policies and accelerated structural

reforms to support development and economic growth. The economy fared relatively better in the first half of 1990s. But following the decade-long domestic conflict, due to political and economic uncertainty, underdeveloped infrastructure and the prolonged political transition towards a federalism, the productive capacity of the economy remained rather limited, consequently the economic growth rate also slowed down. The average growth rate stood at 4.0 percent during the 2000s.

During the last 13 years (2010/11- 2022/23), Nepal's GDP growth has been modest with the growth rate of 4.2 percent on average. Nepal's growth has been lower than that of other regional economies. Moreover, the growth rate has fluctuated from -2.4 percent in 2019/20 to 9.0 percent in 2016/17 indicating the volatility in economic growth. Despite the decline in share of the agricultural sector from 33.4 percent of GDP (at basic price) in 2010/11[1)] to 24.1 percent in 2022/23, it still continues to play a large role in economic growth trajectory. However, the agriculture sector is susceptible (Figure 2.1) to climate related factors such as monsoon (heavily dependent on rainfall for irrigation) and other natural disasters. The service sector has emerged as an important sector and remains the key driver for the economic growth whereas the industrial sector, particularly manufacturing, has remained stagnant during the period.

1) Mid-July 2010 to Mid-July, 2011 represents a fiscal year 2010-11.

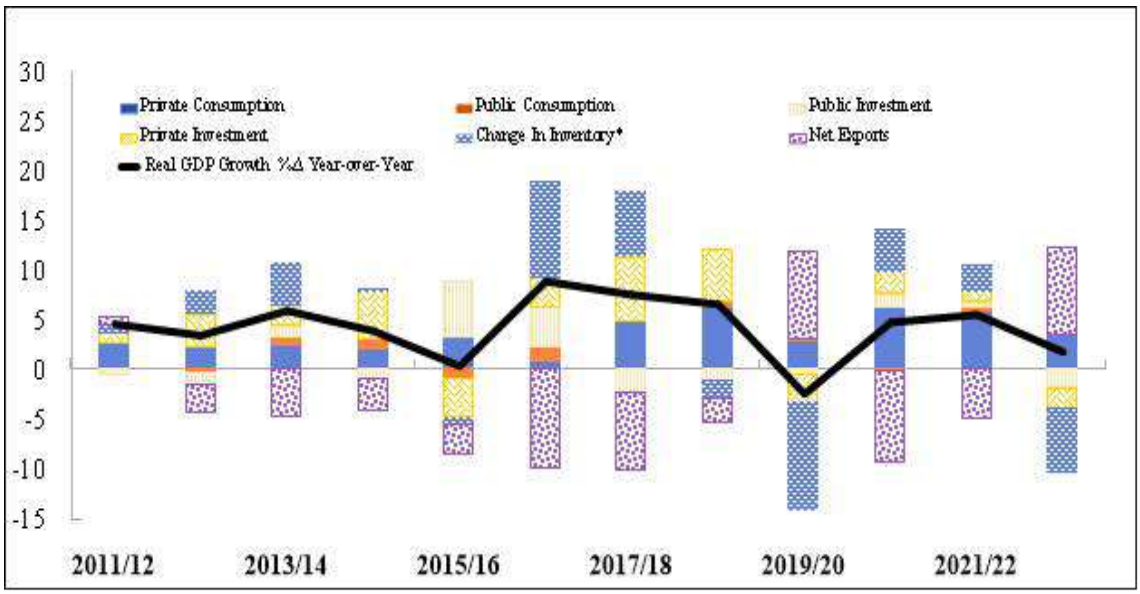
<Figure 2-1> Contribution to Real GDP growth by Sector



Source: National Statistics Office

Figure 2-1 shows that Nepal's economic growth has not only been low but also volatile. The existence of such volatility in economic growth also indicates susceptibility of the economy to frequent exogenous shocks. The more recent slowdown was caused by the earthquake and trade disruptions in 2015 and COVID-19 pandemic. During 2015/16, the growth rate was 0.4 percent due to earthquake and trade disruptions along the southern border, which had a huge impact on the economy. The growth rebounded as domestic economic activity gradually recovered and reconstruction activities gained momentum. Subsequently, the growth averaged 7.8 percent from 2016/17 to 2018/19, supported by favorable monsoon, accommodative monetary policy, post-earthquake reconstruction activity and rising government spending due to transition towards a fiscal federalism system. The COVID-19 pandemic also severely impacted Nepal’s economy. The economy contracted by 2.4 percent in 2019/20 due to sharp decline in overall domestic economic activity, tourism and other services sector in the context of restrictions due to COVID-19.

<Figure 2-2> Contribution to Real GDP growth by Expenditure



Source: National Statistics Office

The growth averaged around 5.2 percent in 2020/21 to 2021/22 reflecting a strong post-pandemic rebound in credit growth and domestic demand and return of normalcy to domestic economic activity. But, following pressure on external sector; burgeoning current account deficit, depleting foreign exchange reserve and inflationary pressure, domestic tightening of monetary policy has moderated the growth in 2022/23 as domestic demand and credit growth slowed down. In Nepal, consumption expenditure compared to gross domestic production is very high. During the last 12 years, the ratio of consumption expenditure to GDP was around 91.0 percent on average. Historically, this ratio has remained high. Generally, higher consumption ratio implies unavailability of resources for investment in capital goods to enhance productive capacity. The private consumption has driven growth (Figure 2.2) while public investment has remained limited, resulting in slow capital accumulation. Exports have struggle to grow while imports have remained high, due to steady influx of remittances. In the past decade, the workers' remittances have grown in importance.

B. Inflation

Low and stable inflation enhance both economic growth and economic stability. So, price stability is an important goal of monetary policy around the world. Nepal Rastra Bank Act, 2002 has given the mandate of maintaining price stability to the NRB. Similarly, a study by NRB shows that inflation higher than 6.5 percent may negatively affect economic growth in Nepal. Therefore, monetary policy focuses on price and external sector stability along with providing support to achieve high and sustainable economic growth. The Government of Nepal generally announces the inflation target through the annual budget. NRB accordingly, formulates monetary policy and conducts monetary management to contain inflation within the given target.

<Table 2-1> Inflation in Nepal (Period Average)

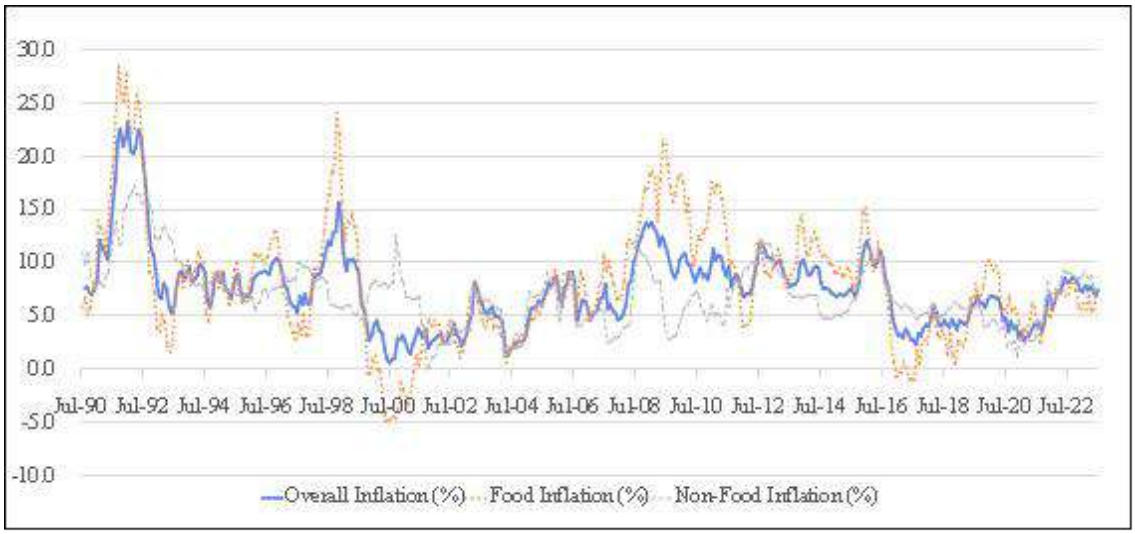
Period	Overall	Food	Non-Food
1990/91-1999/00	9.6	9.9	9.1
2000/01-2010/11	6.1	7.0	5.6
2011/12-2022/23	7.0	7.5	6.6

Source: Nepal Rastra Bank

Historically inflation has remained high and volatile for most of the period. The inflation in Nepal tends to be driven due to supply shocks and price development in India. Due to strong trade integration and fixed exchange rate regime with India, inflation rate tends to be highly correlated with India and broadly follows price development in India. But, the inflation in Nepal appears to be driven exclusively by higher correlation in food inflation rates between Nepal and India. (Blagrave, 2019). But it has remained stable for the most part of the last decade. Figure 2.3 shows the movement of food, non-food, and overall CPI inflation for the period 2010/11-2022/23. Inflation averaged 7.0 percent during that period. Similarly, food and non-food averaged 7.5 and 6.6 percent respectively. Food inflation contributed more to overall inflation in early

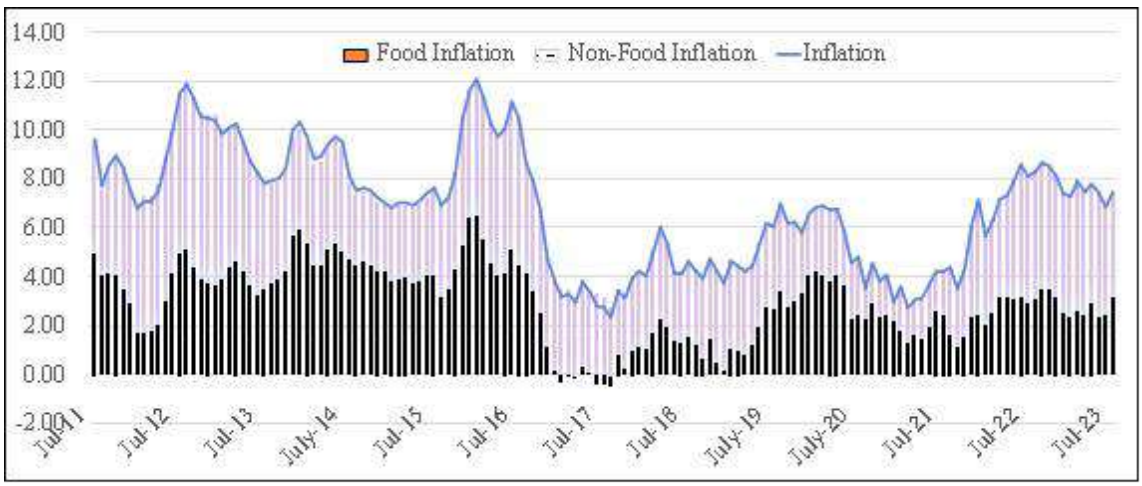
part of the last decade (Figure 2.4). Lately, non-food inflation is more prominent than food inflation.

<Figure 2-3> Food, Non-Food, and Overall CPI Inflation (y-o-y, in percent)



Source: Nepal Rastra Bank

<Figure 2-4> Contribution to Inflation



Source: Nepal Rastra Bank

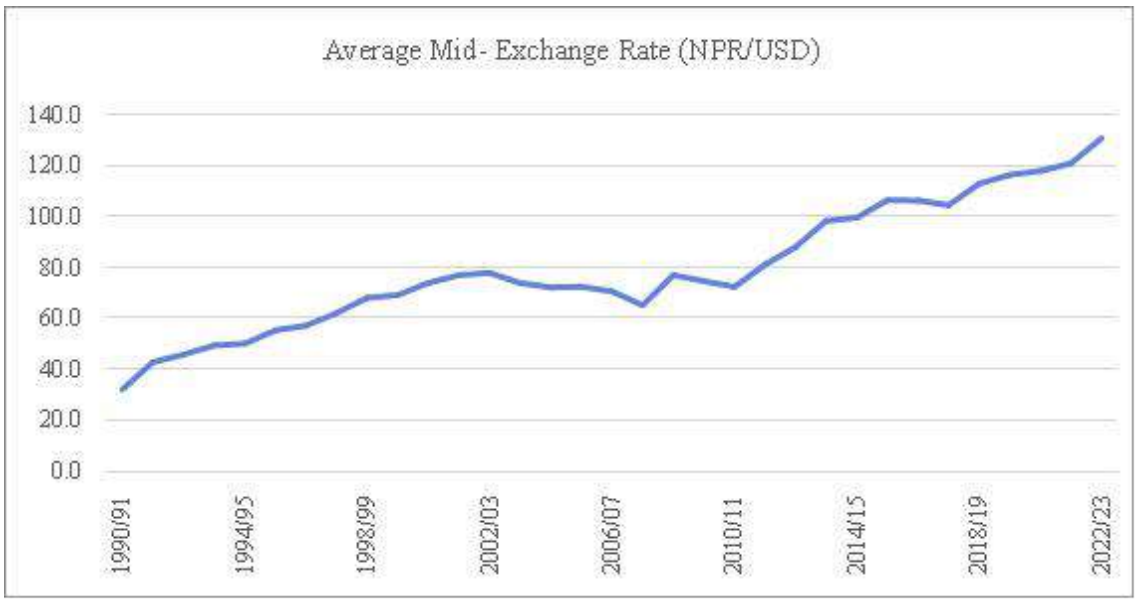
After the COVID-19 pandemic, inflation increased to reach 6.2 percent in 2019/20 due to disruption in global supply chain and restrictions related to pandemic. In 2020/21, it moderated to reach 3.6 percent. More recently, since March 2022, inflation has increased and reached 8.6 percent in June 2022 as

higher oil and food prices globally exerted inflationary pressure. The inflation has remained elevated as the annual average consumer price inflation stood at 7.74 percent in 2022/23 compared to 6.32 percent in 2021/22. NRB pushed policy rates upward to anchor inflationary expectation and reduce rising current account deficit.

2. External Sector

The exchange rate arrangement of Nepal is a conventional peg to a single currency unit (Indian rupee). Nepal has formally adopted a pegged exchange rate regime with the Indian Rupee since the 1960s. The existing fixed exchange rate is 1.6 Nepalese rupee (NPR) per one Indian rupee (INR) and has continued to remain at that level since February 1993.

<Figure 2-5> Exchange Rate (NPR/USD)



Source: Nepal Rastra Bank

The exchange rate peg to Indian rupee is considered as the nominal anchor of the monetary policy and reduces the exchange rate uncertainty for investment and trade with Nepal's major trading partner, India (accounts for 62 percent of

total import on average in last two decades). Figure 2.5 depicts the depreciation of NPR against United States Dollar (USD) since the last 30 years. The depreciation of INR against USD led to weaken NPR reflecting the existing peg to the Indian rupee.

Nepal’s financial account remains mostly closed. However, Nepal has gradually opened up inflows of foreign capital through foreign direct investment (FDI), external borrowing by Banks and Financial Institutions (BFIs), and private sector in recent years. However, there is limit on such foreign borrowings. The FDI inflows has been small and portfolio inflows are negligible. The financial inflows mostly consist of long-term concessional borrowings by government from development partners, followed by external borrowing from BFIs and private sector. The financial outflows remain restricted. As Nepal maintains restrictions on financial account transactions, volatilities associated with capital flows are limited. However, there is no restrictions on current account transactions as Nepal has accepted the obligations of IMF's Article of Agreement (Article VIII, Sections 2, 3, and 4). Currently, merchandise (except for a goods restricted for security, health or related reasons) can be imported free of restrictions. It is evident by the share of imports in percent of GDP.

The size of exports has remained low due to loss of competitiveness in international market, low productivity and low industrial base while imports have remained high. It indicates that Nepal's trade balance has deteriorated in the recent decade. The share of Nepal’s exports (goods and services) remained 7.2 percent of GDP in 2022/23 compared to 36.5 percent of GDP for imports. In terms of commodities, the major exports of Nepal largely cover primary commodities such as agricultural materials, food items, herbs and metal exports whereas the major imports include petroleum products, essential food items, medicines, raw and intermediate materials, machinery and capital-intensive goods. The export structure of Nepal is narrow and less diversified. To some extent, the lack of diversification is associated with relatively small share of manufacturing in Nepal's GDP. Due to landlock nature, international trade is difficult and

expensive. The cost associated with imports and exports are on average higher.

<Table 2-2> Nepal's Trade Balance

(in percent of GDP)

Year	Imports of Goods	Imports of Goods and Services	Exports of Goods	Exports of Goods and Services
2010/11	25.4	28.5	4.1	7.8
2011/12	26.3	29.2	4.2	8.8
2012/13	28.6	32.6	3.9	9.3
2013/14	32.0	35.9	4.1	10.1
2014/15	32.0	36.5	3.5	10.2
2015/16	29.7	33.9	2.7	8.2
2016/17	32.2	36.8	2.4	7.8
2017/18	36.0	40.6	2.4	7.8
2018/19	36.8	41.5	2.5	7.8
2019/20	30.8	34.1	2.5	6.8
2020/21	35.4	37.9	3.2	5.1
2021/22	38.9	42.6	4.1	6.8
2022/23	30.0	36.5	2.9	7.2

Source: National Statistics Office and Department of Customs

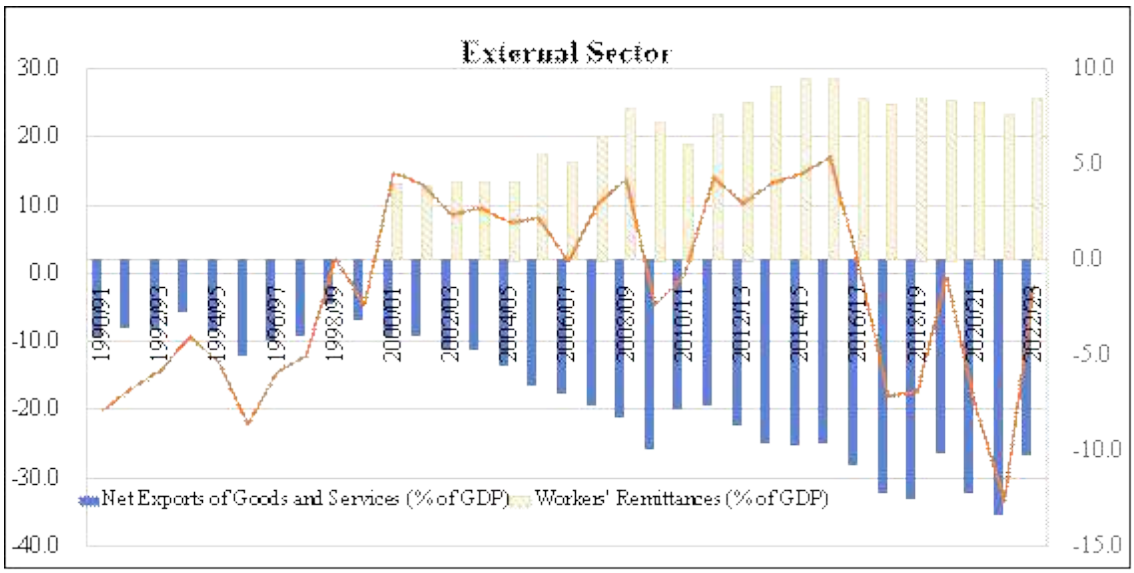
The trade structure of Nepal is also less diversified in terms of trading partners. Nepal is closely integrated with India in terms of cross border trade and investment. India remains the major trading partner of Nepal as the merchandise imports from India accounts for around 64 percent of the total merchandise imports (2022/23) and merchandise exports to India accounts for 68 percent of total merchandise exports. In addition, Nepal has to rely on India as transit for trade with rest of the world. Nepal's extensive trade and investment linkages with India generally lead to spillover effect from Indian economy. China also remains a major trading partner as it accounts for 14 percent of total merchandise imports. The other major trading partner includes Indonesia, United States, and United Arab Emirates.

<Figure 2-6> Nepal's Trade Structure with India

Source: Nepal Rastra Bank

The rise of imports in recent years and weak export performance have led to sharp deterioration in trade balance and put pressure on the current account (CA). Following trend of current account surpluses in the recent decade driving by steady inflows of workers' remittances, the current account turned deficit and reached 7.1 percent of GDP in 2017/18 due to strong import demand on the backdrop of post-earthquake reconstruction and transition to federal system. It reached 6.9 percent of GDP in 2018/19. The premature deindustrialization and the changing demographic structures also reflect into trade and current account deficits. The CA deficit narrowed to 0.9 percent of GDP in 2019/20 during the pandemic but again increased to reach 7.7 percent of GDP in 2020/21 as economy recovered following the relaxation of pandemic measures. It reached 12.6 percent of GDP in 2021/22 as the imports increased significantly amidst of accommodative monetary policy, strong domestic credit growth and elevated commodity prices due to the disruption in global supply chain and Russia-Ukraine war.

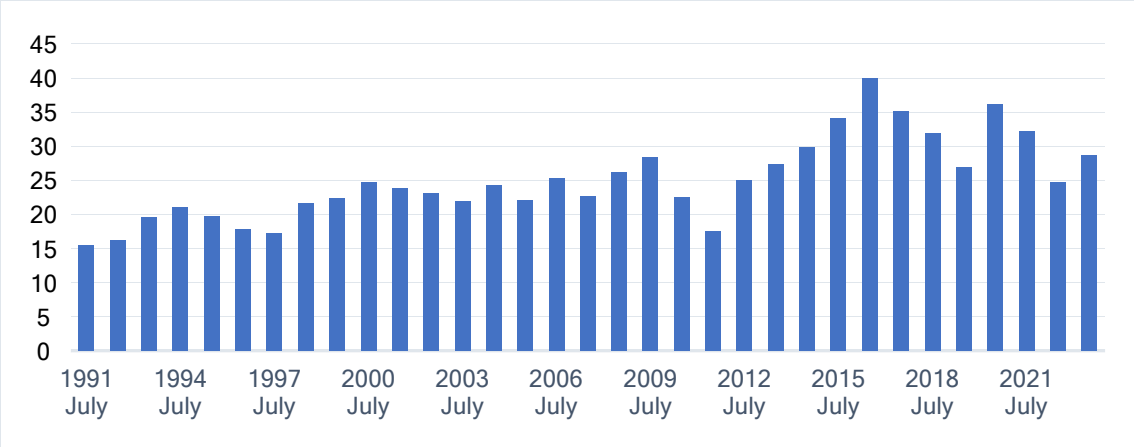
<Figure 2-7> Net Exports, Remittances and Current Account



Source: Nepal Rastra Bank

Workers' remittances play an important role in the Nepalese economy as it has increased significantly during the last decade due to the movement of migrant workers mainly to Gulf Cooperation Council (GCC) countries and Malaysia other than the traditional labor market, India. Workers' remittances reached USD 9.3 billion in 2022/23. This corresponds to a 22.7 percent of GDP. It remains the largest component in the current account balance of Nepal, helping to close the large trade deficit. It is now the single largest source of foreign exchange inflows and less volatile than other sources. It has helped to boost the national income, consumption and contributed to reduction in poverty at household level. Remittances has contributed to increase the valuation of domestic property but with weak impact on the value added of the national output.

<Figure 2-8> Nepal's Gross Foreign Exchange Reserves (in percent of GDP)



Source: Nepal Rastra Bank

With a peg exchange rate regime, maintaining an adequate level of reserves is prerequisite for Nepal for anchoring inflation and ensuring stability. One of the goals of the monetary policy is to keep the foreign exchange reserves at an adequate level that is sufficient to cover at least specified[2] months' imports of goods and services. The foreign exchange reserves have grown significantly in the last decade, primarily boosted by strong inflow of workers' remittances. The foreign exchange reserves have remained mostly above the adequacy target set by the monetary policy.

Gross foreign exchange reserves reached the peak of USD 12.8 billion in mid-January 2021, on the back of a sharp drop in imports due to pandemic, steady workers' remittances inflow, and concessional borrowing by government of Nepal from development partners. With the resumption of economy after the relaxation of pandemic related social restrictions, the reserves declined to USD 9.5 billion by mid-July 2022 due to strong import growth, moderation in remittances inflows, and strong credit growth. Due to policy intervention by authorities, the foreign exchange reserves have stabilized and started to increase in recent months. But the recent drawn down of foreign exchange reserves in

2) The current monetary policy set the target of at least 7 months' imports of goods and services.

post-pandemic recovery phase indicate the vulnerability of Nepal's external sector. The foreign exchange reserves are likely to remain under some pressure when current account deficits remain large.

3. Monetary Sector

After the enactment of NRB Act 2002, Nepal Rastra Bank has started presenting annual monetary policy for every fiscal year. The quarterly reviews of monetary policy are also made public. This has been a crucial step to enhance monetary policy transparency and make the NRB accountable towards its commitment. The quarterly review enables the NRB to communicate economic and financial condition at a higher frequency and adjust policy stance in a timely manner according to the changed economic condition. Within the Monetary Policy Framework, the ultimate goal of the monetary policy is to facilitate economic growth through maintaining price and external sector stability. The pegged exchange rate of the Nepalese Rupee to Indian Rupee is kept as a nominal anchor of the monetary policy. The goals of the monetary policy are to keep the foreign exchange reserves at an adequate level that is sufficient to cover at least specified months' imports of goods and services and contain inflation within the target.

The NRB has introduced an explicit monetary policy rule in 2022/2023 which links the policy rate with the endogenous variable such as inflation target and import capacity of foreign exchange reserves. This condition is necessary to uniquely determine the time path of the policy variable. The rule makes the public understand the condition on which the NRB will take decisions on interest rate changes. Therefore, public change their behavior looking at data on inflation and reserve level without even changing the policy rate actually. So, the impact is timely and orderly. This rule is intended to outline the interest rate path and guide the behavior of economic agents according to economic condition.

The above policy rule responds to inflation and reserve capacity where i is the policy rate, is the inflation gap and is the reserve capacity gap. The policy

interest rate is calibrated according to inflation gap and gap in reserve capacity which are endogenously determined. Besides this, quantity variables such as growth of money supply and credit growth are used as indicators to assess the situation of the monetary policy stance. Weighted average interbank rate is the operational target of the monetary policy with explicit interest rate corridor in place. The movement of the corridor serves to communicate the stance of the monetary policy. The NRB indirectly influences the short-term interest through open market operations. Similarly, the liquidity monitoring and forecasting framework (LMFF) has been made operational from July 15, 2004 to monitor and forecast short-term liquidity position and guide monetary operations.

The empirical findings in the case of Nepal shows that high powered money (H) or the reserve money is one of the major determinants of monetary aggregates (i.e., money supply, M2). Given the pegged regime, the money supply process is partly endogenous and partly exogenous. The contribution of Net Foreign Assets (NFA) to the reserve money has increased significantly in recent years with the gradual opening up of economy and steady flows of remittances which indicate that external developments affect money supply and authorities' control over the money supply. In such context, NRB has been using the OMO instruments to control money supply and liquidity in the system. The fixed exchange rate, fully convertible current account and limited capital/financial account mobility of Nepal characterizes the classical case of small open economy. Due to fixed exchange rate, nominal exchange rate channel of monetary policy to influence aggregate demand is completely switched off. When the economy is hit by shock, the burden of adjustment rests on the interest rate in short run and interest rate has the risk of being highly volatile in the pegged exchange rate regime.

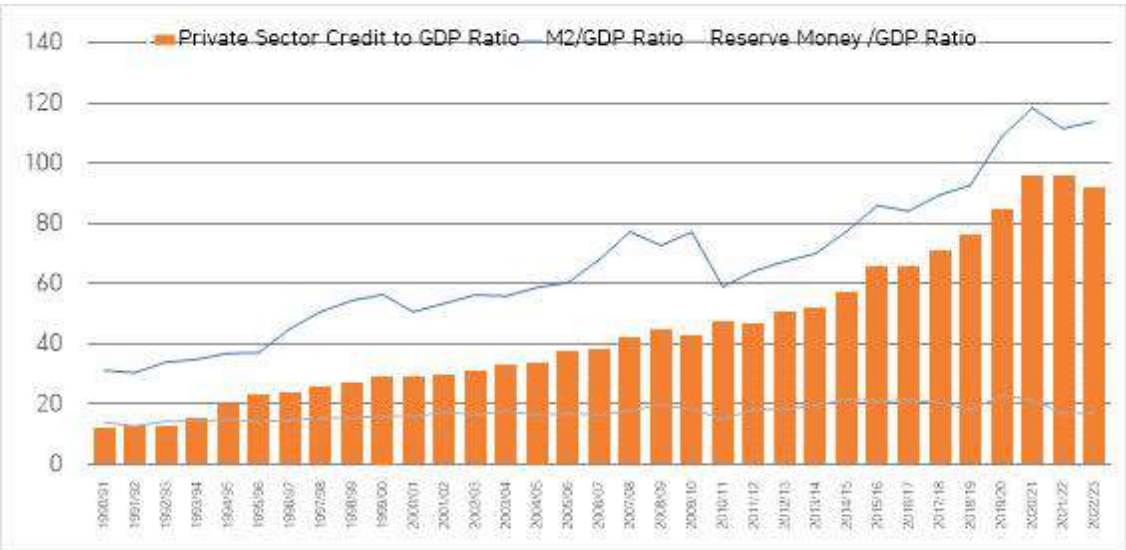
With the objective to stabilize the short-term interest rates and modernize monetary management, the Interest Rate Corridor (IRC) was introduced by the NRB through Monetary Policy 2016/17. The IRC allows the exogenous shocks to the external sector to pass through on interest rate slowly and gradually so that the economic adjustment is not sharp. Under the IRC system, the standing

liquidity facility (SLF) rate is kept as the upper bound whereas deposit collection rate is kept as the lower bound and repo rate as the policy rate. The corridor has been gradually trimmed to minimize the fluctuations in the short-term market interest rate. With the implementation of IRC, the target of current monetary policy is to maintain such weighted average interbank rate within the interest rate corridor. Similarly, open market operations (OMOs) for monetary management are conducted by monitoring the excess liquidity of the BFIs through LMFF. Since 2022/23, the NRB has started to avail overnight liquidity facility to improve the efficacy of the IRC.

4. Financial Deepening

The standard indicators to measure financial deepening: broad money (M2) in percent of GDP and Private Sector Credit to GDP also shows gradual increase since 1990. Broad Money (M2) in percent of GDP has reached 113.9 in 2022/23 from 31.3 percent in 1990/91, implying process of monetization has increased in the economy along with deepening of financial system.

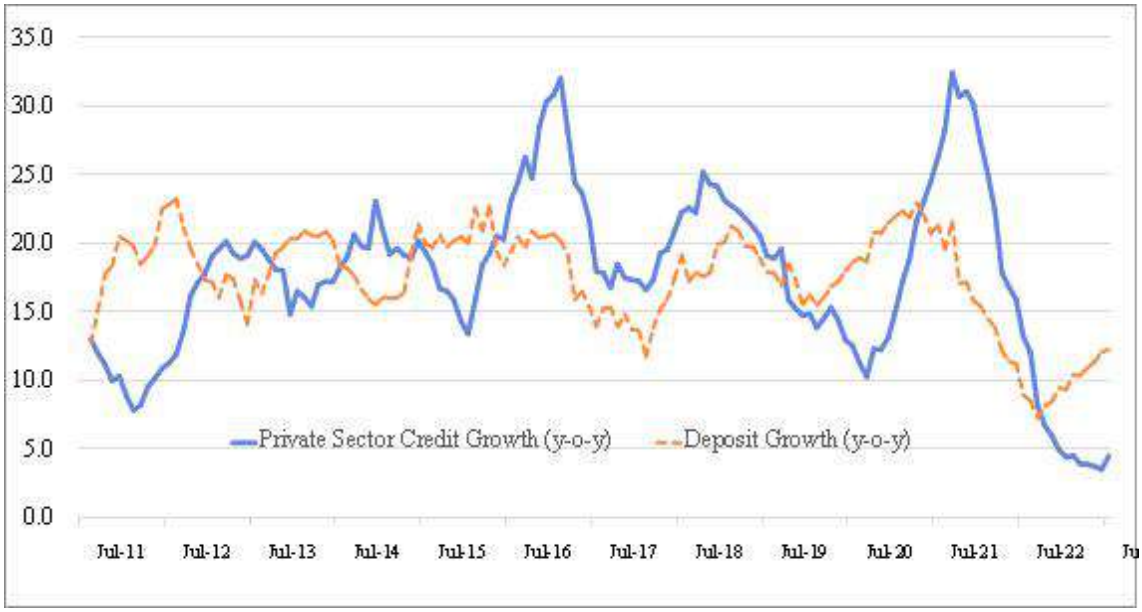
<Figure 2-9> Broad Money and Private Sector Credit (in percent of GDP)



Source: Nepal Rastra Bank

The ratio of private sector credit to GDP, which is still a relevant component of financial development, is high indicating deepening of financial institutions. However, the period of high credit growth has caused the private sector credit to GDP to reach higher level. Moreover, private sector credit-to-GDP ratio in Nepal remains among the highest in its peer group (IMF, 2023).

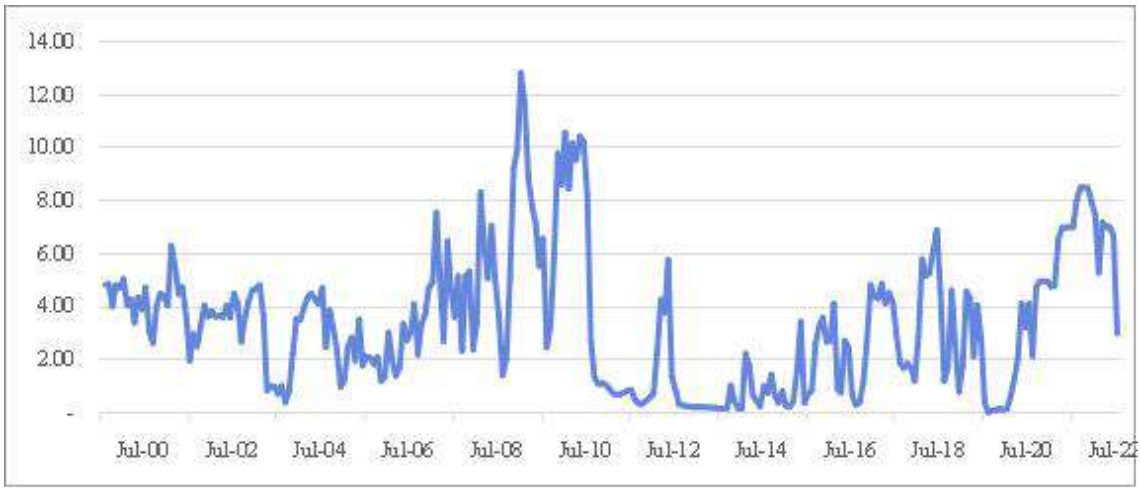
<Figure 2-10> Credit and Deposit Growth (in percent)



Source: Nepal Rastra Bank

There have been episodes in which the credit growth exceeds the deposit growth (Figure 2.10) which has pushed the credit to deposit ratio higher and subsequently exert pressure on the liquidity in banking system. The interbank rate tends to increase during those episodes (Figure 2.11). The experience of rapid credit growth during 2009-10 that fueled asset price booms (real estate and stock prices) suggests that excessive credit growth tend to increase the financial vulnerability of the banking system by building up significant credit and liquidity risks. In the post-pandemic recovery when the credit growth exceeded the deposit growth, there was liquidity shortage in the banking system. As a result, the interbank rate increased.

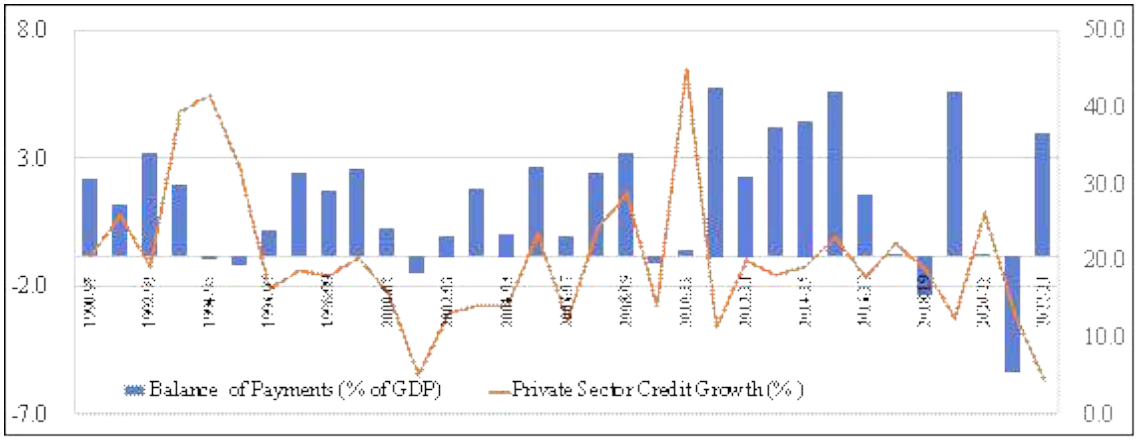
<Figure 2-11> Interbank rate (in percent)



Source: Nepal Rastra Bank

Due to fixed exchange rate regime with Indian rupees, balance of payments is endogenously determined. The empirical analysis of monetary approach to balance of payments in Nepalese context shows that changes in domestic component of money supply can have significant impact on balance of payments and there is negative relationship between the balance of payment and domestic component of money supply (Khatiwada, 1992). Low interest rates and strong credit growth generally lead to surge in imports resulting in deteriorating trade balance, widening current account deficit and subsequent decline in foreign exchange reserves. Expansionary monetary policy causes the central bank to lose foreign exchange reserves ultimately along with the negative impact on productivity and international competitiveness. Nominal expansion has mostly fueled up property prices rather than real gain in terms of productivity and employment. There have been recent episodes in which the excessive credit growth has led to pressure in external sector (Figure 2.12).

<Figure 2-12> Private Sector Credit Growth[3] and Balance of Payments

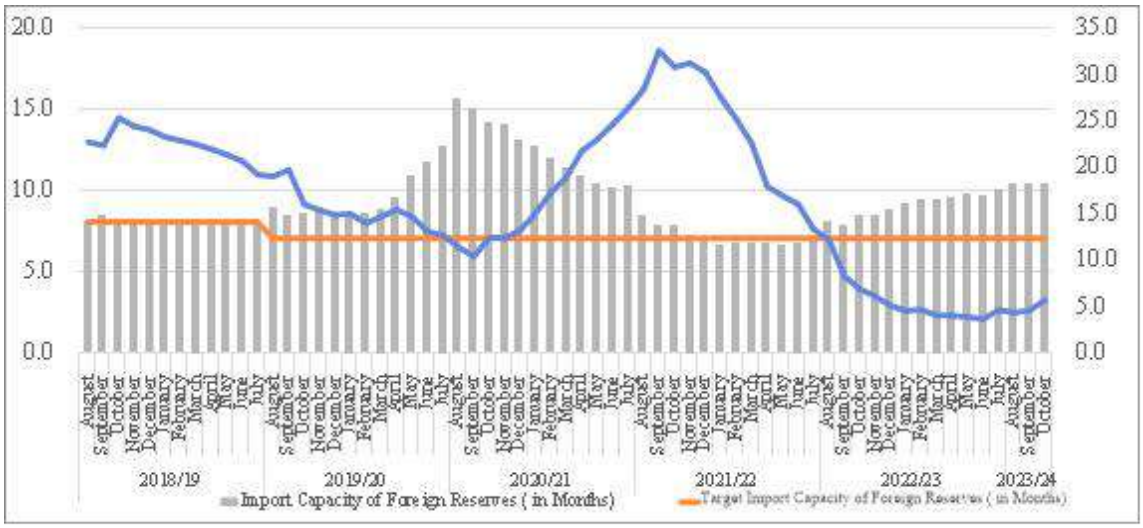


Source: Nepal Rastra Bank

As a response to COVID-19 shock to economy, NRB adopted an accommodative monetary policy along with relaxation in macro prudential measures, leading to strong growth in private sector credit. Accommodative monetary policy, excess liquidity in financial system and higher credit growth led to strong import growth, that ultimately led to stress in external sector of Nepal and increase the buildup of financial sector risks. However, recently NRB has gradually withdrawn most of the relaxations measures and tightened macro prudential policies, as a result, credit growth has moderated and depletion in foreign exchange reserves stabilized and started to increase in recent months (Figure 2.13).

3) The sharp growth in 2010/11 is due to the inclusion of private sector credit growth of development banks and finance companies.

<Figure 2-13> Private Sector Credit Growth and Foreign Exchange Reserve Adequacy

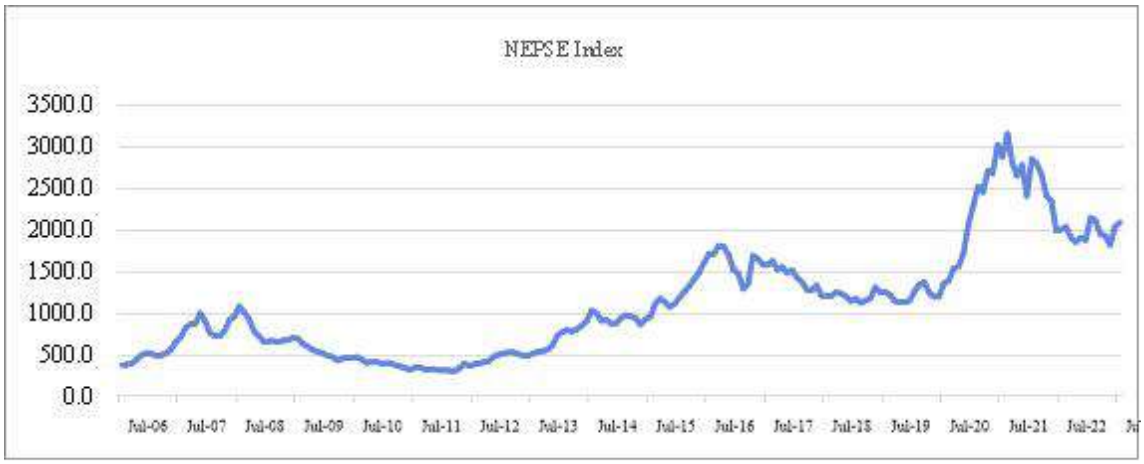


Source: Nepal Rastra Bank

5. Capital Market

Capital market remains an integral part of financial system. In the last two decades, the securities market has undergone structural reforms with changes in legal provision, gradual introduction of automation, gradual increase in presence of participants providing securities related services, and implementation of online trading system. Figure 2.14 depicts the movement of stock market in Nepal. However, the rapid credit growth has coincided with a sharp rise in stock market. The pandemic and policy responses to economic and financial stress related to COVID-19 led to the surge in stock market. NRB's decisions to cut interest rates and regulatory relaxations to support economic growth and excess liquidity in the financial system, lower interest rate prompted the stock prices to rise substantially.

<Figure 2-14> Stock Market Index



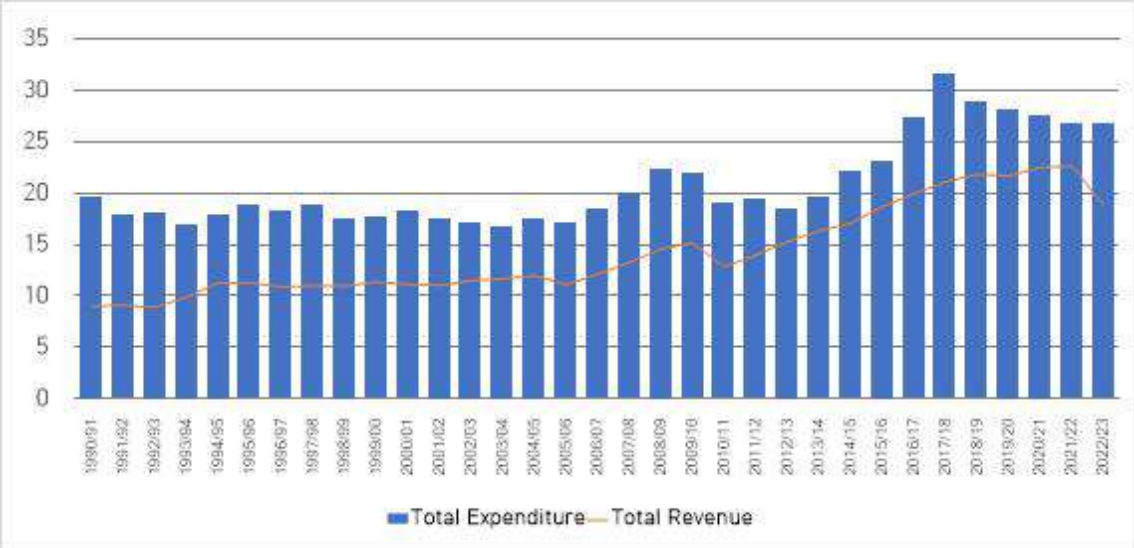
However, with gradual withdrawal of most of the COVID-19 related relaxations in policy measures and tightened monetary policy instance, the performance of stock market has slowed down.

6. Fiscal Sector

Despite relatively modest economic growth in the last three decades, the public revenue[4] collection in percent of GDP has reached 22.6 percent in 2021/22 from 8.9 percent in 1990/91. As the government of Nepal pursued liberalized policies in the early 1990s, the tax system was modernized gradually along with other structural reforms. The introduction of Value Added Tax (VAT) marked a significant step towards the modern tax system and enhance revenue mobilization. Moreover, revenue administration reforms in Department of Customs and Inland Revenue Department targeted at broadening tax base and reducing tax evasion have also contributed to the growth in revenue. The tax revenue in percent of GDP has also increased from 6.8 percent in 1990/91 to 20.0 percent in 2021/22. VAT, income tax, custom and excise taxes accounted for more than 90 percent of tax revenues on average.

4) Including other receipts

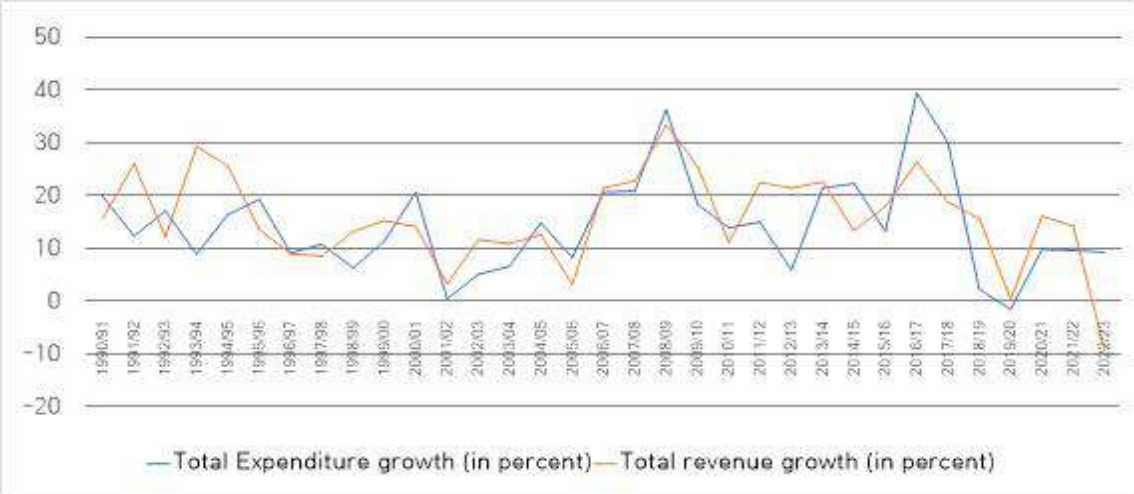
<Figure 2-15> Government's Revenues and Expenditure (in percent of GDP)



Source: Nepal Rastra Bank

Total government expenditure in percent of GDP remained 20.7 percent on average during 1990/91-2022/23. Total government expenditure, which was 19.6 percent of GDP in 1990/91 reached 31.5 percent in 2017/18. The rising trend of government expenditure after 2015 was mainly driven by post-earthquake reconstruction and transition towards federal system (Figure 2.15). The composition of government spending had reversed during the period of three decades. Earlier the capital expenditure was major component of the government's expenditure. The capital expenditure in percent of GDP has declined from 13.3 percent in 1990/91 to 4.3 percent in 2022/23 which is concern because such spending is essential to address large infrastructural gaps. Due to increasing expenditure related to administration of state and its apparatus, pension and other social security liability, the share of recurrent expenditure in percent of GDP has increased. It has reached 18.7 percent of GDP in 2022/23 from 5.7 percent in 1990/91.

<Figure 2-16> Revenues and Expenditure Growth Rate



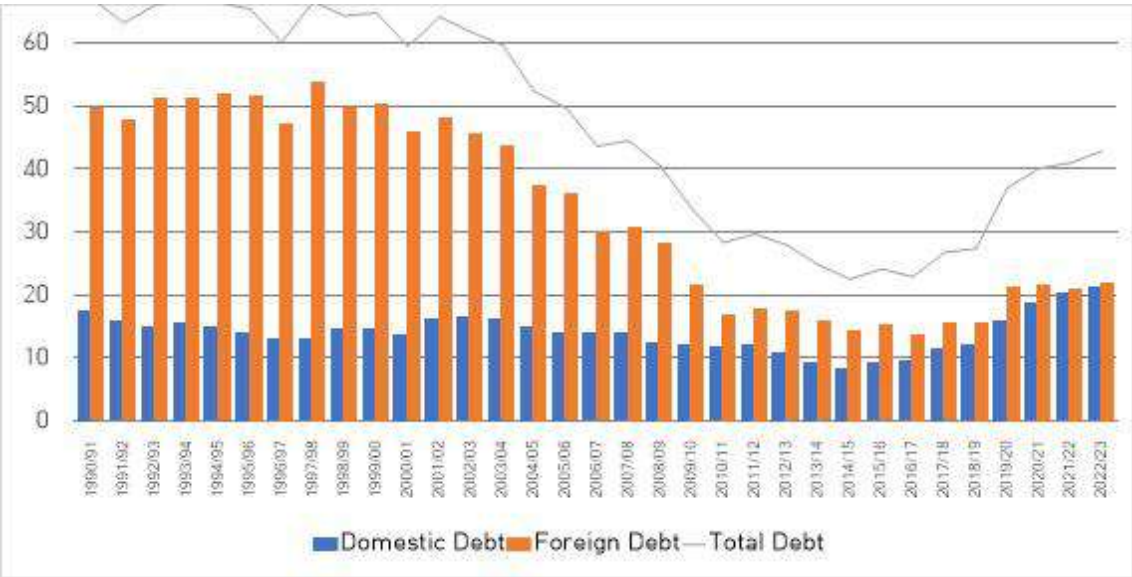
Source: Nepal Rastra Bank

To finance budgetary gap, the government has been mobilizing domestic as well as external loans. The public debt-to-GDP ratio dropped significantly from 66.8 percent in 1990/91 to 22.7 percent in 2016/17, depicting persistent downward trend in Nepal's public debt to GDP ratio. Likewise, total foreign debt has fallen from 53.6 percent of GDP in 1997/98 to 13.5 percent in 2016/17. Strong revenue growth, prudent fiscal policy and bottlenecks on budget implementation related to capital expenditure has led to gradual reduction in public debt level.

<Figure 2-17> Recurrent and Capital Expenditure (in percent of GDP)

Source: Nepal Rastra Bank

<Figure 2-18> Outstanding Public Debt (in percent of GDP)



Source: Nepal Rastra Bank and Public Debt Management Office

But due to transition to fiscal federalism and decision to expand social security net, the government expenditure increased substantially that led to expand fiscal deficit and increase in public debt. The substantial increase in level of public debt in 2019/20 is driven due to the impact of and responses to the pandemic. Moreover, foreign public debt increased by 5.7 percent of GDP in 2019/20, partially reflecting the support of development partners in Nepal's response and measures to the pandemic. The foreign public debt is mostly owed to official development partners at concessional terms and conditions. The total stock of public debt in Nepal stands around 42.7 percent of GDP by the end of 2022/23. External public debt stood at 21.7 percent of GDP whereas the domestic public debt stood at 20.9 percent of GDP by the end of 2022/23. The public debt has grown more than 22 percent in last five years on average. The rapid growth of public debt could entail a higher risk to inflation and interest rate in the future.

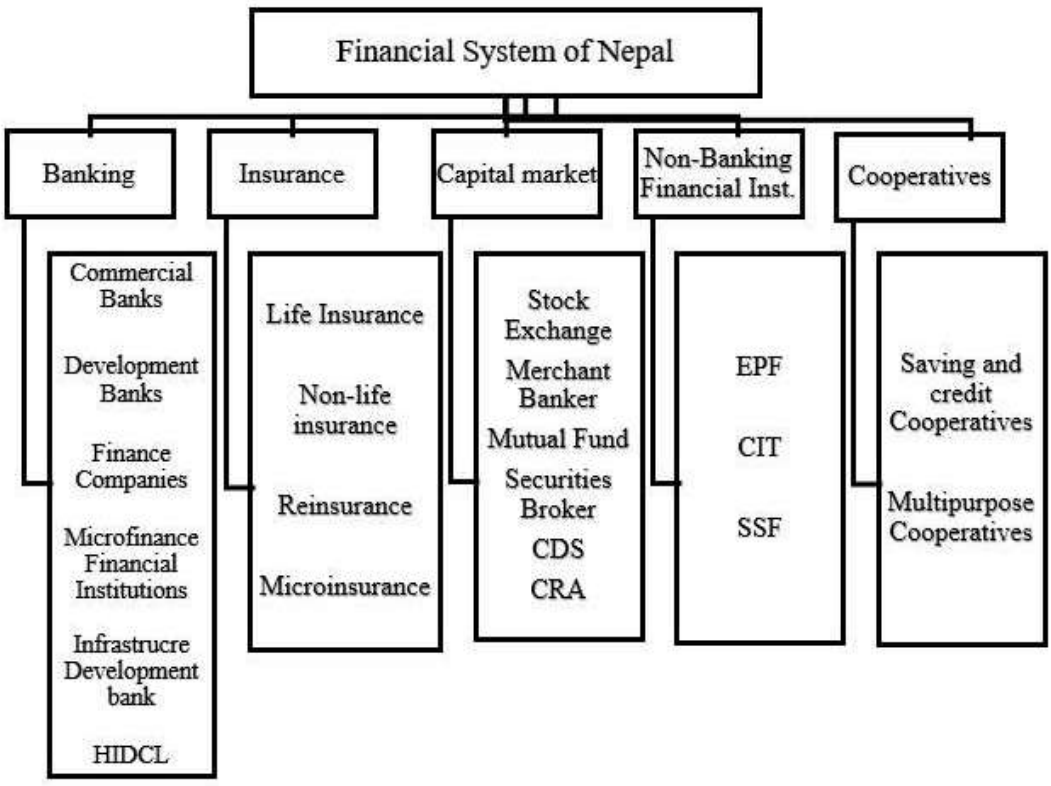
7. Financial System

The financial system of Nepal consists of five major sectors: banking,

insurance, capital markets, non-banking financial institutions, and cooperatives. The banking sector accounts for approximately 86.6 percent of the total financial system assets, making it the largest segment, while the non-banking financial institutions, (EPF and CIT) comprise of 6.88 percent of the total financial system assets. The insurance market has been expanding gradually, covering about 6.55 percent of the total financial system assets. Cooperatives have been instrumental in providing financial services to a large number of people, with over 31,373 cooperative institutions, as of mid-March 2023 (Ministry of Finance, 2023b). Similarly, the capital markets have witnessed growth, driven by advancements in technology and increased access to financial services.

The overall structure of the Nepalese Financial System can be depicted as:

<Figure 2-19> Financial System of Nepal



1. **Banking Sector:** The banking sector forms the backbone of Nepal's financial system, catering to the financial needs of individuals, businesses, and the government. The banking sector consists of 20 Commercial Banks

(Class A), 17 Development Banks (Class B), 17 Finance Companies (Class C), 57 Microfinance Institutions (Class D) and an Infrastructure Development Bank, dedicated institution for infrastructure development as of mid-July 2023 (NRB, 2023). Similarly, on a financial access side, the number of branches of BFIs stands at 11,589, and the population per branch stands at 2,517 (including MFIs) as of mid-July 2023.

2. **Non-Banking Sector:** Contractual Saving institutions in each of Employee Provident Fund (EPF), Citizen Investment Trust (CIT) and Social Security Fund (SSF) form the non-banking sector in the Nepalese economy and are regulated by the Ministry of Finance.

3. **Capital Markets**: Nepal's capital markets have experienced growth and development over the years, providing opportunities for businesses to raise capital and individuals to invest. The Securities Exchange Board of Nepal (SEBON) is the regulatory authority overseeing the securities market in Nepal. It regulates securities issuance, trading, and related activities to ensure market integrity and protect the interests of investors. The securities market in Nepal comprises the NEPSE (Nepal Stock Exchange), listed companies, central depository services (CDS), stockbrokers, merchant bankers, credit rating agencies (CRA), mutual funds, applications supported by blocked amount (ASBA) members, and depository participants.

4. **Insurance Sector**: Under the Nepalese Insurance sector, as of mid-July 2023 there are 15 Life insurance companies, 14 non-life insurance companies, 2 reinsurance companies and 2 micro insurance companies operating in Nepal and are regulated by the Nepal Insurance Authority.

5. **Cooperatives**: Cooperatives in Nepal have a long-standing tradition of supporting local communities and promoting financial inclusion. The cooperatives are regulated by the Department of Cooperatives and are 31,373 in number as of mid-March 2023 (Ministry of Finance, 2023 b).

Development in Banking System

The gradual reforms in financial system had a far-reaching impact in the development of the financial sector in Nepal. Since 1980s, various initiatives were taken to mark the beginning of liberalization of financial sector in Nepal.

The most notable liberalization measure was opening up of banking sector to foreign investors through amendment in Commercial Bank Act in 1984. Following this, three joint venture commercial banks were established in Nepal during 1984-87. The opening up of banking sector to foreign investors enhanced competitive environment in banking sector, increased the participation of private sector in financial sector, and helped to modernize the banking services.

Similarly, various reforms were initiated to deregulate interest rate structure. Earlier, the deposits and interest rates were tightly regulated by Nepal Rastra Bank. But, in 1986, NRB deregulated existing interest rate regime by allowing commercial banks to set interest rate to any extent above the fixed minimum level (Shrestha, 2004). In 1989, the interest rates were completely deregulated as the commercial banks were allowed to determine their deposit and lending rates on their discretion to keep real deposit rate positive and stimulate savings.

In the meantime, NRB gradually strengthened its regulation and supervision of BFIs. NRB further introduced a set of prudential norms, including capital adequacy requirement, loan classification, loan loss provisioning, single borrower limit, and account disclosure norm (Ozaki, 2014). The emphasis on establishment of prudential norms in Nepal can be seen as early as 1989 when the NRB began setting single borrower limits with the aim of reducing the risk factors of over-concentration of bank resources in the hands of selected people (Pant, 2005). Some of another measure includes the following (Pant, 2005):

- NRB directed commercial banks with respect to classification of loans into four categories (good, substandard, doubtful and bad) to improve asset quality. Likewise, the commercial banks were directed to maintain sufficient reserve fund out of their profit on the basis of these four categories.
- Capital adequacy ratio was initially introduced by linking it to the total deposits of commercial banks. NRB directed the commercial banks to maintain their capital base (paid-up capital, general reserve and undistributed profit) to at least 2.5 percent of total deposits by mid-July 1989, 3.5 percent by mid-July 1990, 4.5 percent by mid-July 1991 and

5.5 percent thereafter.

- In March 22, 1991 commercial banks loans were reclassified into six categories (good loans, acceptable loans, 2 types of substandard loans, doubtful loans, and bad loans)

NRB took a significant step towards strengthening the capital base of BFIs and enhance their resilience to potential risks. In response to the evolving financial landscape, regulatory norms for were developed incrementally to align with international standard. These measures included eliminating the Statutory Liquidity Ratio (SLR) requirement (1993), establishing loan classification and provisioning standards (1996), defining core and supplementary capital (1996), and increasing capital requirements (1996).

Furthermore, after the restoration of democracy, with pursue of liberal economic policy, the government of Nepal gave more emphasis on the liberalization of the financial sector. As a result, the financial sector grew very rapidly since 1990s. The number of commercial banks increased from 5 in 199 1[5] to 13 in 2000. Similarly, there were 7 development banks and 47 finance companies and 7 microfinance financial institutions by 2000. Apart from increase in the number of BFIs, the standard indicators to measure financial deepening: M2 to GDP and Private Sector Credit to GDP also showed growth trend during the period. M2 to GDP increased from 32.3 percent from 1991 to 56.5 percent in 2000. Similarly, private sector credit to GDP also increased from 11.7 percent to 28.8 percent during the same period.

However, NPL ratio of the state-owned banks (Nepal Bank Limited, Rastriya Banijya Bank Limited, and Agriculture Development Bank Limited) were substantially higher than the overall banking sector average, CARs were all negative and these banks had financial, managerial and organizational problems. Taking into account underlying problems at the state-owned banks and necessity to strengthen NRB's regulatory and supervisory capacity, the government adopted the Financial Sector Strategy Statement (FSSS) in December 2000 (Shrestha,

5) The fiscal year in Nepal normally ends around mid-July. 1991 means mid-July 1991.

2004). The specific agenda in FSSS included modernizing finance sector legislation to strengthen autonomy and authority of NRB, strengthening NRB's supervisory and regulatory capacities and inspection, strengthening banking sector's accounting and auditing standards, and restructuring of troubled stated-owned banks. In 2003, the government of Nepal adopted the 10th Five Year Plan/Poverty Reduction Strategy Paper which also emphasized on strengthening the ongoing financial reforms and introducing new reforms in financial sector to support economic reforms for growth and development.

Keeping in line with development of new financial products and services, evolution of BFIs and increasing integration of technology in financial sector, several financial sector policies were undertaken by NRB to strengthen the institutions through regulations on risk management. Some of them are discussed below.

- Capital Adequacy Framework: With a view of adopting international best practices, Nepal started implementing Basel framework. In 2007, NRB issued a Capital Adequacy Framework 2007, for commercial banks in accordance to Basel II. This framework introduced a more scientific approach to risk assessment and capital requirements, reflecting the growing complexity of the financial sector. The framework was replaced with a new Capital Adequacy Framework 2015, based on the reforms prescribed by the Basel Committee on Banking Supervision (BCBS) under Basel III, to be effective from July 2016. The new framework incorporates aspects capital requirements which focuses on both micro-prudential and macro-prudential aspects of regulation. Countercyclical buffer requirement has been set for commercial banks as part of implementing Basel III standard.
- Internal Capital Adequacy Assessment Process (ICAAP): In order to address risk identified by BASEL II and inherent risk associated with individual banks, guidelines on Internal Capital Adequacy Assessment Process (ICAAP) have been issued. As per the guidelines, banks are required to set policies, methodologies and procedures for assessing its capital adequacy relative to its risk profile. Stress Testing remains a core element of ICAAP.
- Financial Consolidation: Post Global Financial Crisis, the focus of the central

banks around the world has been on strengthening financial sector. NRB also focused on the strengthening of financial sector by consolidation through various measures ranging from maintaining moratorium on new licensing of BFIs, advocating policy for merger and acquisitions of BFIs, increasing capital base to implementing BASEL principles. Merger Bylaws, 2011[6] has been issued along with other incentives to encourage merger and acquisitions of BFIs. Moreover, the level of minimum paid up capital has been increased for licensed financial institutions. These measures aim to strengthen financial soundness of BFIs by establishing highly capitalized bank with wider capital base to absorb external shocks.

- Directives and Circulars: The directives and circulars issued by NRB includes regulations relating to capital, asset quality, liquidity, corporate governance, risk management etc. The objectives of these regulations are to strengthen the health and soundness of the banks and financial institutions, enhance public confidence and ultimately contribute in maintaining stability in the financial system. With the recognition that risk management is essential for the safety and soundness of BFIs, NRB has issued numerous risk management-related circulars in its unified directives. These circulars are issued for identification, assessment, management of risk by BFIs and to reduce their likelihood and mitigate the impact of losses.
- Deposit Insurance: NRB has introduced policy provisions with the motive of enhancing public confidence towards the financial system, for insuring deposit up to NPR 0.5 million.
- Risk Management Guidelines for Banks and Financial Institutions were issued in 2018 to encourage BFIs to adopt and implement sound risk management framework and provide minimum standard for risk management practices. The guidelines cover a wide range of topics, such as having a clear and comprehensive risk management policy, establishing risk limits and controls, implementing a risk monitoring and reporting system, and conducting regular stress tests.
- Environmental and Social Risk Management: Guideline on Environmental &

6) Merger bylaw 2011was amended in 2012. Moreover, NRB implemented Acquisition Bylaw 2013. Later, the two were integrated into Merger and Acquisition bylaw 2016.

Social Risk Management (ESRM) For Banks and Financial Institutions, 2022 was issued. The core objective of the ESRM Guidelines is to require BFIs to integrate environmental and social risk management into their overall credit risk management process.

- Payment Systems Department (PSD) of NRB has issued several directives to payments-related institutions on risk management. These directives are designed to ensure that payments-related institutions have robust risk management frameworks in place to identify, assess, and mitigate the risks they face. These directives cover a wide range of risk management topics, including corporate governance, risk identification and assessment, risk mitigation, risk monitoring, and reporting.
- In addition, a comprehensive "Financial Sector Development Strategy (FSDS) 2017-2021" was implemented with vision of "An Effective, efficient, inclusive and stable financial sector contributing to broader economic growth". Second Financial Sector Development Strategy is expected to be implemented in coming years (Ministry of Finance, 2023 a).

Along with the adoption of various Basel standards, NRB has implemented various measures to strengthen the regulatory framework for BFIs. These include:

- Establishment of the Credit Information Bureau in 2005 to facilitate credit risk assessment.
- Issuance of Prompt Corrective Action Bylaws in 2008, focusing on capital adequacy, and these bylaws were later amended in 2017.
- Enactment of the Money Laundering Prevention Act 2008 to combat financial crimes.
- Issuance of Act on Recovery of Debts of Banks and Financial Institutions, 2002 and Banking Offence and Punishment Act, 2008.
- NRB fixed the credit to core capital and deposit (CCD) ratio for BFIs at 80 percent in 2009/10. This was a significant policy decision aimed at regulating the growth of credit in the economy.
- Issuance of Stress Testing Guidelines in 2012 (updated on 2023) to assess the resilience of BFIs to potential shocks.
- Introduction of merger and acquisition bylaws 2016.
- Amendment of Nepal Rastra Bank Act, 2002.

- Issuance of Bank and Financial Institutions Act 2017 replacing earlier Act Bank and Financial Institutions Act, 2006.

The financial sector reform programs since mid-1980s have helped to enhance NRB's supervisory and regulatory capacity along with development of essential financial legislations and finance sector infrastructure.

However, the liberal licensing policies and participation of private sector in banking industry contributed to the proliferation of BFIs during 2000s. The number of commercial banks increased from 13 in 2000 to 27 in 2010. Similarly, there were 79 development banks and 79 finance companies and 18 microfinance financial institutions in 2010. The number of commercial banks reached 32 in 2012 and there were 88 development banks and 70 finance companies and 24 microfinance financial institutions by 2012.

To ensure financial sector stability, NRB has pursued the policy to consolidate the financial sector through maintaining moratorium on new licensing[7] of financial institutions, issuing new paid-up requirement, and issuing Merger and Acquisition Bylaw to facilitate mergers of financial institutions to strengthen the financial sector. These regulatory changes were aimed to streamline the sector and create a more robust and efficient banking system. As a result, the number of commercial banks has shrunk to 20 in 2023. Similarly, the number of development banks has come down to 17 in 2023 from 88 in 2012 and there are 17 finance companies and 54 microfinance financial institutions by 2023.

<Table 2-3> Number of BFIs

Type of BFIs	1990	2000	2010	2015	2020	2023
Commercial Banks	5	13	27	30	27	20
Development Banks	2	7	79	76	20	17
Finance Companies	-	47	79	47	22	17
Microfinance Financial Institutions	-	7	18	38	85	57

Source: Nepal Rastra Bank

7) Earlier moratorium on new licensing of commercial banks, development banks and finance companies were in place. Later it was extended to Microfinance as well.

The growth in BFIs in recent decades has led to increased complexity and interconnectedness within the financial system emphasizing the need for prudential regulations to safeguard the financial system. Nepal Rastra Bank (NRB) has played a pivotal role in shaping the regulatory landscape and ensuring the stability and soundness of the financial system. NRB has implemented BASEL III framework yet in a simplified form with appropriate level of customization since July 2016. Besides the regulatory framework, stress testing, prompt corrective actions (PCA), consolidated supervision and risk based supervisory mechanism are some of the key tools in practice to ensure the financial sector stability. The regulatory framework for banks and financial institutions in Nepal has evolved continuously over the years, adapting to the changing dynamics of the financial sector and the emerging risks. NRB's commitment to implementing international standards and fostering a robust regulatory environment has been instrumental in maintaining financial stability and supporting economic growth.

8. Macroprudential policy in Nepal

Macroprudential policy is a forward-looking type of financial regulation that aims to mitigate systemic risk to the financial system and address potential risks before they materialize. Nepal Rastra Bank has been actively engaged in developing and enacting a range of macroprudential measures aimed at reducing systemic risks in Nepal. Before the 2008 global financial crisis, financial regulation in Nepal were conventional prudential measures, like capital adequacy requirements, risk management, governance guidelines etc. Primarily the focus of these guidelines was on safeguarding the stability of individual financial institutions rather than addressing systemic risks that could impact the entire financial system. Nevertheless, certain macroprudential policy elements, such as reserve requirements, sectoral credit limit, and liquidity related regulations were in place.

Following the global financial crisis, a more dynamic inter-linkages among financial institutions emerged and the necessity for various macroprudential measures were internalized. In the same context, the NRB embraced international developments and introduced various new macroprudential measures. The NRB has consistently implemented various measures, driven by both domestic considerations and regulatory guidance from the Basel Committee on Banking Supervision (BCBS). Some of the measures are discussed below.

Legal and Institutional arrangements

The legal framework for macroprudential policy in Nepal is primarily established through the Nepal Rastra Bank (NRB) Act 2002 and the Banking and Financial Institutions Act (BAFIA) 2017. These acts empower the NRB to implement macroprudential measures aimed at maintaining financial stability and mitigating systemic risks. The institutional arrangement for macroprudential policy in Nepal comprises a multi-layered structure that provides effective coordination and oversight of systemic risks. At the apex is the Financial Sector Coordination Committee (FSCC), chaired by the Finance Minister, which analyzes the overall financial system and provides guidance and direction on macroprudential policy matters. The FSCC brings together key stakeholders from the government, the NRB, and other regulatory agencies to ensure a holistic approach to financial stability. Further, there is a committee setup within the NRB i.e., Financial Stability Oversight Committee (FSOC), which is chaired by the senior deputy governor of the NRB. The FSOC is responsible for identifying, monitoring, and assessing the overall risks in the financial system. The FSOC has representatives from various departments within the NRB as well as from other financial system and experts, enabling a robust risk assessment and policy formulation.

Similarly, there is a financial stability sub-committee (FSS) within the NRB which provides technical support and analysis for the FSOC and contributes to the formulation and implementation of macroprudential policies. There is also a separate Financial Stability Unit (FSU) which serves as a dedicated unit within

the Regulation Department of NRB. The FSU conducts in-depth monitoring and analysis of risks in the financial system and develops macroprudential policy proposals.

Macroprudential Policy Tools

NRB has issued various macro prudential policy tools, both broad-based and sectoral tools. These include capital-based tools, asset-side/loan tools and liquidity-related macroprudential policy tools.

i. Broad-based/ Capital Tools: These tools consist of a range of policy measures aimed at safeguarding financial stability as a whole. Under the broad-based tools, the NRB has adopted various capital-related measures. Over the years, capital requirements for banks and financial institutions have been calibrated in such a way that it can withstand possible losses in the context in which they are operating. Currently, the capital requirements vary based on their type, ensuring adequate financial strength to withstand potential losses (NPR. 8 billion for commercial banks, up to NPR. 2.5 billion for development bank, up to NPR. 800 million for finance companies and up to NPR. 100 million for microfinance institutions). Similarly, the countercyclical buffer has been made effective for commercial banks and currently commercial banks have to hold 0.5 percent additional capital by July 2024. A capital conservation buffer is also in place which is kept at 2.5 percent. The capital conservation buffer further strengthens banks' resilience, while a leverage ratio of 4 percent is in place which limits excessive risk-taking. These measures are calibrated according to need of the financial system and hence are useful in promoting financial stability and protect the financial system from potential shocks.

ii. Household sector tools: NRB has implemented some tools to meet the current macroeconomic situation as well as to be in line with international norms and guidelines. The debt service to gross income ratio, which is set at 50 percent, ensures that borrowers can comfortably manage their loan obligations. Additionally, loan-to-value ratio is kept at 50 percent while the single sector

limit is kept at 40 percent of total loans which not only helps diversify the loan portfolio but also helps minimize the impact of any downturns in any particular sector. Furthermore, the credit to real estate and housing sector limit of 25 percent prevents excessive buildup to a single sector, reducing the concentration risk associated with fluctuations in the real estate market.

iii. Corporate Sector Tools: To address potential risks that could originate from the interconnectedness and spillover effects within the financial sector, cap on the loan-to-value ratio for commercial real estate credit is set which stands at 60 percent currently.

iv. Liquidity-related tools: The Cash Reserve Ratio (CRR) is one of the conventional tools relating to liquidity which has been calibrated from time to time by NRB to meet the liquidity needs in the banking system. Currently, the CRR stands at 4 percent. Additionally, the credit deposit ratio is set at 90 percent. Furthermore, the minimum ratio of liquid assets to total assets of 20 percent ensures that banks are in a comfortable position at any given time.

In other measures, NRB is taking steps to enhance financial stability by implementing two key measures of BASEL III norms: the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR). These ratios aim to ensure that banks have sufficient liquid assets to meet their short-term obligations as well as meet their funding sources over a period of time. Some of the macroprudential measures of NRB are presented in the table below.

<Table 2-4> Status of Macroprudential Policies in Nepal Rastra Bank

SN	Macro Prudential Policies	Status	Remarks
	Loan to Value Ratio	Yes	
	Limits on Lending-Single Obligor Limit	Yes	
	Debt to Income Ratio	Yes	
	Limits on FC lending	Yes	
	Limits on Maturity Mismatch	Yes	CD Ratio
	FC Mismatches	Yes	
	Liquidity Tools	Yes	CRR, SLR, NSFR, LCR
	Stress Testing	Yes	
	Early Warning System	Yes	Indicator based Basic EWS
	Risk Based System	Yes	
	Capital standard	Yes	
	Countercyclical element	Yes	
	Dynamic provision element	No	
	Control over dividend	Yes	
	Minimum equity capital requirement	Yes	
	Restriction on interconnectedness	No	
	Restriction on credit to risk takers	Yes	
	Clear macro prudential policy objective approved	No	
	Deposit Insurance	Yes	
	Identification of SIFIs	No	

Macroprudential regulations along with other financial sector regulations in Nepal have played a crucial role in maintaining financial stability as well as promoting economic growth. By internalizing and adopting a forward-looking approach to the risks and emphasizing on systemic risks that could arise from the financial system, these regulations have helped mitigate the buildup of excessive leverage in the system, monitor and address emerging vulnerabilities, and promote sound financial system.

<Box 2-1>

Impacts of COVID-19 on Nepalese Economy

The pandemic affected the worldwide economy and the impact was similar in the Nepalese economy as many businesses struggled to survive. In the initial days, only 4.00 percent of the businesses were fully operational while 61.03 percent of businesses were completely shut down (NRB, 2021). The urgency was to safeguard well-being, rather than recovery of economic activities which caused a decline in the GDP growth rate. The impact was felt on all the economic sectors of the Nepalese economy.

1. **Real sector**

- Economic Growth: Prior to the pandemic, Nepal was experiencing rapid economic growth. The pandemic and related restrictions had a significant impact on domestic economic activity as GDP contracted by 2.37 percent in 2019/20 as compared to growth of 6.66 percent in 2018/19 and 7.62 percent in 2017/18. The accommodation and food service sector contracted by 36.78 percent whereas transportation and storage sector and wholesale and retail trade sector contacted by 11.79 and 11.39 percent in 2019/20. Moreover, the manufacturing sector also contracted by 9.03 percent
- Tourism Sector: The tourism sector, which is a major source of foreign exchange earnings for Nepal, was particularly hard hit. Arrivals went down from the levels of 1.2 million in 2019 to 0.23 million in 2020, 0.15 million in 2021. The tourism sector is rebounding with 0.61 million tourists in 2022 (Economic Survey, 2022/23) and signs are encouraging in terms of tourism arrivals amidst global economic downturns.
- Inflation: Inflation has remained generally stable. Inflation remained low during the COVID-19 period due to low levels of economic activity and slack in demand for goods and services. However, due to disruption in global supply chain and strong aggregated demand after lifting of restriction exerted some inflationary pressure. As a result, the yearly average inflation reached 6.15 percent in 2019/20 from 4.64 percent in 2018/19.

2. **External sector**

- Import and Export: Restriction measures implemented around the world and the nationwide restrictions on movement have significantly disrupted

international trade. Prior to COVID, imports have been constantly increasing while the exports have not expanded at the same rate causing the trade balance deficit to increase. Due to economic slowdown, imports decreased by 15.63 percent in 2019/20 as imports reached NPR.1294.51 billion from NPR.1515.6 billion in 2018/19.

- Remittance inflows: The remittance inflows, the major source of foreign exchange earnings, declined significantly during the early stages of the pandemic. However, it started to stabilize thereafter and as a result, the remittance inflows declined by marginal 0.49 percent in 2019/20 in contrast to earlier expectation about significant decline.
- Balance of Payments: As a result of restricted movement of goods and services across borders and economic slowdown due to the COVID-19 pandemic and narrowing of current account deficit (0.87 percent in percent of GDP in 2019/20 as compared to 6.92 percent of GDP in 2018/19), BOP remained in surplus. It remained at a surplus of NPR. 282.41 billion (7.26 percent of GDP) in 2019/20 against a deficit of NPR. 67.40 billion (1.75 percent of GDP) in 2018/19.
- Reserve: Foreign exchange reserves accumulated during COVID-19 phase due to temporary factors such as mobilization of COVID-19 related official loans from development partners, limited expenditure capacity due to the lockdowns, steady inflows of remittances. The reserve position was sufficient to cover the import of merchandise and services for up to 15.6 months (mid-August 2020) during the peak of the pandemic. The reserve coverage started to decline amidst strong demand for goods and services in post-pandemic revival of the economy. The external sector was in stressed in 2021/22 as the reserve adequacy to cover merchandise and services import reached 6.6 months by mid-May 2022.

3. **Monetary sector**

- Credit Growth: In 2019/20, the credit growth declined to 12.60 percent from 19.14 percent in 2018/19 due to slowdown in domestic economic activities amidst the pandemic. In 2020/21, on the backdrop of accommodative policy stance and strong aggregate demand in post-COVID recovery, there was rapid expansion in credit disbursement with a growth rate of 26.33 percent. However, in recent years the credit growth has

moderated.

- Assets Quality of the Banking System: The resiliency of the banking system was tested during COVID-19, but the banks and financial institutions performed remarkably well during the phase. This was also partially due to various policies adopted by NRB (moratorium, grace period etc.). There is a recent degradation in the quality of the assets in the financial system, which is due to the slowdown in the economy, but the level of NPL and LLP are at a manageable level.
- Structure of Interest rate: The interest rates remained low due to excess liquidity in the financial system as well as active policy intervention to keep the interest rate low to stimulate the economic activities. The weighted average deposit rate of Commercial Banks declined from 6.60 percent in mid-July 2019 to 4.65 percent in mid-July 2021. Similarly, the weighted average lending rate of commercial banks declined from 12.13 percent in mid-July 2019 to 8.43 percent mid-July 2021. The decline was also due to the policy intervention by NRB to facilitate economic activities by reducing policy rate, Cash Reserve Ratio (CRR), and Statutory Liquidity Ratio (SLR) rates among others.
- Refinance Facility: This facility was aimed to assist economic recovery for certain period of time by making this facility available temporarily at concessional rate to the businesses affected by the COVID-19. The amount of refinance provided by the NRB increased significantly during the COVID-19 pandemic. In 2020/21, the NRB provided a total of NPR. 148.75 billion in refinance, which was significantly higher than the amount provided in the previous year. With the normalization of economic activities and easing of restrictions, the refinancing facility was gradually withdrawn and as a result, the outstanding refinance amount stood at NPR. 1.49 billion as of mid-July 2023.

4. **Fiscal sector:**

The pandemic placed significant strain on the government's resources and capacities, as it had to swiftly respond to the health crisis while managing the economic and social repercussions. The government allocated substantial funds towards healthcare infrastructure, testing, and medical supplies to combat the virus's spread. Lockdowns and restrictions imposed to curb the

outbreak led to disruptions in economic activity, resulting in decreased revenue collection and increased fiscal deficits. The government had to reallocate budgets to address urgent needs, diverting resources from other sectors. Additionally, the pandemic exposed vulnerabilities in social safety nets, prompting the government to enhance support systems for vulnerable populations. The impact of COVID-19 on government budgetary operations is discussed below.

- Government Revenue: Government revenue was sharply affected due to a combination of factors including a slowdown in economic activity, reduced import related taxes, tax breaks, and deferrals provided to businesses. The growth rate of government's revenue was 0.20 percent in 2019/20 as compared to 15.54 percent in 2018/19.
- Government Expenditure: The government expenditure declined by 1.72 percent in 2019/20 as compared to 2018/19. The capital expenditure of government was significantly affected by the pandemic as the government was unable to implement infrastructure project due to the restrictions. With the immediate priority of government to deal with human and economic impact, government's expenditure increased by 9.65 percent in 2020/21 to support additional health spending such as importing additional medical supplies and equipment, setting up quarantine centers and temporary hospitals.
- Foreign Assistance: Foreign assistance from development partners including World Bank, Asian Development Bank, IMF made substantial contribution to bridge the fiscal and external financing needs due to the COVID-19. As a result, the mobilization of foreign loans increased by 48.27 percent in 2020/21.

III. Korean and Nepali Macro Stress Test Systems and Development Experiences

1. Overview of Macro Stress Test

A. Overview

Stress testing is a quantitative technique to measure the impact on a financial company or system in the event of exceptional but plausible incidents. Micro stress testing, conducted from the risk management perspective of individual financial companies, primarily focuses on evaluating the impact of specific events or exogenous shocks on individual financial companies. Financial institutions utilize stress testing for risk management, capital management, and business planning. Micro stress testing is also used as a proactive supervisory tool to evaluate the capital (or liquidity) adequacy of individual financial institutions based on portfolio risk. The key supervisory objective in this context is the "test-passing ability" of the bank and any additional supervisory actions needed if the test is not passed.

Macro stress testing, as a methodology of macroprudential analysis for assessing system risk as part of a financial stability supervisory role, is widely used to evaluate financial stability in the event of exogenous shocks. This test sets potential adverse scenarios, measures the resilience of the financial system, and utilizes this as a basis to propose policies for maintaining/recovering financial stability.

The importance of macro stress testing as a tool to evaluate the impact of financial crises and economic shocks on financial institutions and the entire financial system has been gradually increasing, but the significance of these tests is not a recent phenomenon. Stress testing methodologies have evolved over a long period, influenced by various economic events. The concept of stress testing was first introduced in the 1980s and the initial tests, primarily based on

scenario analysis, were used as risk management tools for individual financial institutions. The necessity and importance of stress testing increased with the rapid integration of global financial markets and advancements in financial innovations in the 1990s, especially after the financial crises in Asia in 1997 and Russia in 1998.

Entering the 2000s, the methodologies for stress testing became more sophisticated, introducing advanced statistical techniques like Monte Carlo simulations and VaR (Value at Risk). Additionally, central banks and financial supervisory authorities began utilizing stress testing as a macroprudential policy tool. The 2007-2008 global financial crisis was a turning point that established stress testing as an essential tool for analyzing the soundness of financial markets or institutions. As a result, the methodologies for stress testing were significantly reevaluated. The scope, utilized scenarios, and assumptions of the tests became more sophisticated and comprehensively expanded.

After the global financial crisis, stress testing has become a main tool for evaluating the macroprudential soundness of the overall financial system. International organizations like the IMF and World Bank have exerted efforts in developing and standardizing the methodologies of the tests. Recently, technologies like artificial intelligence, big data analytics, and machine learning have begun to be incorporated into the methodologies of stress testing. Financial institutions, central banks, and international organizations are collaborating to develop integrated stress testing methodologies.

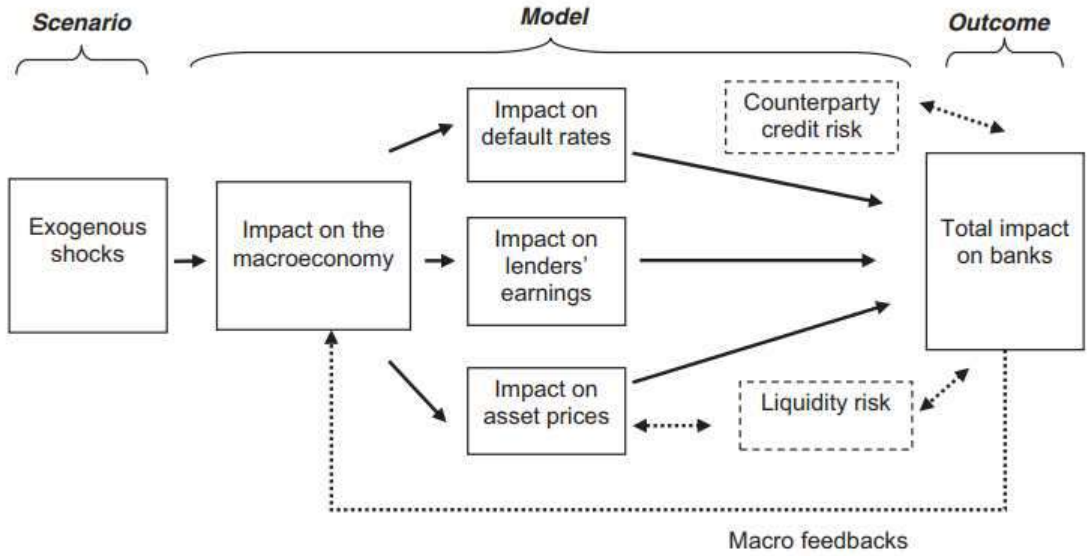
Macroprudential stress testing focuses on financial vulnerabilities that can generate systemic risk. Financial vulnerabilities refer to imbalances and other financial characteristics (e.g., high leverage, mispricing, risk concentration, poor liquidity management, etc.) in the financial environment that can amplify adverse shocks. While the primary purpose of macro stress testing is to evaluate the health of individual financial institutions, it assesses whether identified vulnerabilities can threaten financial stability for the entire economy rather than determining whether individual financial institutions are adequately capitalized.

Such analytical results are used to support financial authorities in assessing financial stability and making recommendations. Recommendations may include the need to strengthen capital buffers, but can also encompass the adoption of other macroprudential measures like actions targeting credit demand (debt-to-income or loan-to-value ratios), additional levies (countercyclical or risk-specific levies), or liquidity requirements.

IMF, FSB, and BIS (2009) define systemic risk during the occurrence of a global financial crisis as the risk of disruption in financial service provision resulting from impairments to the entire or parts of the financial system, and conduct vulnerability analysis related to vulnerabilities that can lead to a financial crisis. Recently, the IMF's Financial Stability Test not only identifies financial vulnerabilities in advance to prevent them from leading to a financial crisis but also estimates financial vulnerabilities that can create downside risks to sustainable economic growth even if they do not lead to a financial crisis. This is because, as well as systemic financial risk, the reversal of financial vulnerabilities can generate downside risks to growth. Therefore, the goal of the IMF's financial surveillance function and the current stress testing is not only to evaluate the systemic failure risk of significant financial institutions but also to identify financial vulnerabilities that can generate risks to sustainable economic growth even if those vulnerabilities do not lead to a financial crisis.

General components of a macro stress test include: firstly, setting a scenario for external shocks. The policy authorities, as test participants, assume the possibility of a recession and estimate the impact on related macro-financial variables. Secondly, there are risk exposures that are directly exposed to external shocks under the set scenarios. For financial institutions, risk factors are amounts on the financial statement and income statement. Thirdly, a statistical model estimates how the shock is amplified through the financial system to affect financial institutions and markets. Lastly, indicators showing the final analysis results of the test would be the soundness indicators of the banks.

<Figure 3-1> Structure of Macro Stress Test



* Source: Borio, Drehmann and Tsatsaronis (2014)

IMF stress tests are primarily applied to deposit-taking institutions, particularly to systemically important financial institutions (SIFIs). Banks are institutions that are likely to cause systemic risk through maturity and liquidity transformation or credit risk channels. The IMF often includes non-banks in the FSAP (Financial Sector Assessment Program) stress test, based on stress estimates for insurance and asset management companies, non-financial corporations, and households, after identifying specific causes of systemic risk. Unlike national institutions that focus on one or a limited number of national financial sectors over time, the IMF uses stress testing as part of financial stability assessments in 12-14 different financial systems each year. Additionally, the IMF supports about 18 other financial systems annually through financial sector stability reviews and other technical support tasks that help develop the capacity of national authorities in the field of stress testing. Although this schedule helps countries gain experience in understanding the causes of vulnerabilities, it also raises the need to adapt to various types of threats to financial stability, uneven data availability, and the various complexities of financial systems. To benefit from local knowledge, stress testing at the IMF usually involves top-down stress testing

(sometimes conducted by IMF staff in collaboration with national supervisory authorities) and bottom-up stress testing (generated by financial institutions).

B. Principles and Best Practices of Macro Stress Test

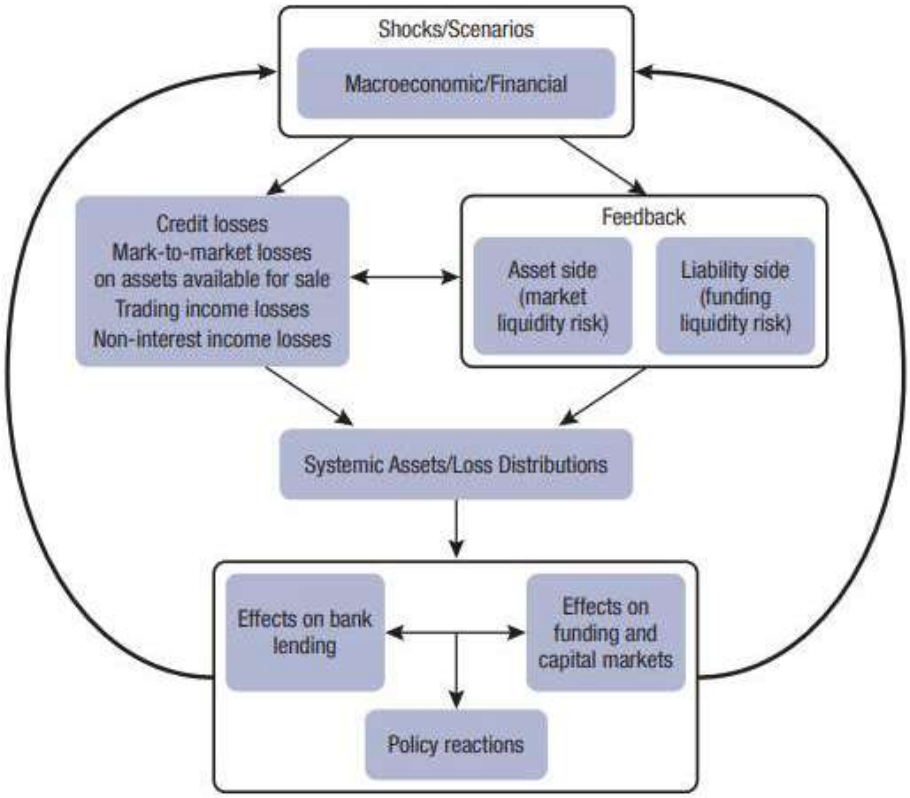
The IMF Policy Paper (IMF 2012b) introduces principles and best practices for macro stress tests as follows:

Principle 1 (Coverage): Define Appropriately the Institutional Perimeter for the Tests

This principle is necessary to determine which institutions to include in the stress test by evaluating which banks have systemic importance, based on the potential to trigger or amplify systemic risk. The size, substitutability, complexity, and interconnectivity of institutions are criteria used to assess the systemic importance of internationally active banks (IMF/BIS/FSB 2009; BCBS 2011). The larger a bank's contractual debt network, the more likely its bankruptcy will significantly impact the bankruptcy potential of other institutions. To apply this principle, a deep understanding of the main characteristics of the system is required before conducting the stress test, demanding knowledge not only of relevant market participants but also of their operations, business models, transaction types, risk concentration areas, and possible paths of risk transmission.

Principle 2 (Risk Transmission): Identify All Relevant Channels of Risk Propagation

In addition to network effects among financial intermediaries as a cause of systemic risk in financial markets, there are shock propagation paths that connect financial intermediaries to each other and to other economic entities, as shown in the figure below.



* Source: IMF policy paper (2012b)

The design of stress testing necessitates a meticulous examination of transmission paths and a robust understanding of how financial markets and individual financial institutions respond to various shocks. In reality, market participants have a very limited understanding of the role of interactions between the real economy and the financial sector, as well as FMI (financial market infrastructures) and business practices, in amplifying and transmitting adverse shocks. Therefore, the principle is about feedback effects between the real and financial sectors. Reliable stress testing requires the identification and calibration of transmission paths (based on historical information or expert judgment), incorporating them during the design and implementation of stress tests under incomplete information. This includes handling tail risks arising from 'unknown unknowns'.

Principle 3 (Scope): Material Risks and Buffers

The key to obtaining reliable stress test results is capturing all quantifiable risks. Until the global financial crisis occurred, stress tests generally focused on credit risk from customer loans and securities risk in the capital market. The financial crisis revealed that such coverage was incomplete, prompting the inclusion of other risk factors in stress tests, such as sovereign risk, funding risk, systemic liquidity risk, and counterparty risk, to expand coverage of potential shock sources. For global financial institutions, it became crucial to include cross-border exposures, off-balance-sheet credit and market risk, and funding (including funding and liquidity transfers between parent and subsidiary companies). Nevertheless, there are limits to the range of risk factors to be included in stress tests. Some risks (e.g., government bonds) may be too large and difficult to hedge, having a substantial impact on financial institutions and especially the financial system, but mitigating or alleviating them (e.g., injecting additional capital) may be too costly to implement. Regardless of the validity of such debates, it is vital to include all risks in stress tests to obtain a complete picture and provide guidance for finding risk mitigation solutions. Not all potential risks need to be addressed with additional capital, and comprehensive and candid stress tests can assist in evaluating the results of inaction or delays (e.g., addressing the sustainability of sovereign debt).

Modeling the transmission channels between macro stress and non-impaired income components is a challenging task, especially in top-down tests, due to: (1) a lack of sufficiently granular information; (2) complexity in the sources of bank income; (3) the possibility of banks changing their behavior under stress to protect financial soundness (e.g., many banks try to protect profitability through higher fees and commissions during a downturn).

Principle 4 (Interpretation): Make Use of the Investor's Viewpoint in the Design of Stress Tests

Capital adequacy in financial markets and perceived asset value are crucial elements in the design of stress tests. Before the global financial crisis, banks

generally had a much higher dependence on short-term wholesale funding than on deposits. During the global financial crisis, uncertainties in the valuation of agency risks and unsecured funding mechanisms triggered confidence shocks, leading to major bank crises. With a large proportion of financial institution debt being uninsured, the market closed banks as national risk increased, imposing higher funding costs on banks and, in extreme cases, not providing additional funding to banks at all. The discipline imposed by such a market impacted bank performance through higher losses, the need to reduce leverage, and additional damage that could occur through second-round effects.

These operational implications suggest that market views should complement stress tests based on regulatory and accounting standards. This principle also has implications for the disclosure of stress test results. Disclosing the results of stress tests can remove asymmetric information under uncertainty and restore market confidence. Even for stress tests conducted for surveillance purposes during non-crisis periods, public communication of results can heighten risk awareness, promote more realistic risk pricing, and strengthen market discipline. However, to gain these benefits by disclosing results, the stress tests must provide an honest assessment of risks, clearly delineate their scope and limitations, and the announcement of results must be accompanied by measures that can convincingly address all vulnerabilities revealed by the tests."

Principle 5 (Calibration): Focus on Tail Risks

The empirical rule of stress testing has traditionally been to apply "extreme but plausible" shocks, but there is no systematic way to determine this. Typically, the size of the shock is defined by qualitative properties, such as a measure unit or a "once in ten years" event, a "1% probability" tail event, or an "x-times standard deviation" shock calibrated against historical scenarios for one or more (macro) variables. The problem with this approach is that historical experience varies between countries and changes over time. Another constraint, particularly relevant for stress tests conducted before crises, is calibrating adverse shocks for

new financial products due to insufficient historical pricing information. Approaches based on historical data do not work when considering events that have not occurred. BCBS (2004) provided some quantitative guidelines for determining tail risk for single-factor shock stress tests. However, there are no comparable guidelines for macroeconomic scenarios.

These concerns are especially pertinent when stress tests are conducted during or just before crises. In such cases, a financial institution or system is already experiencing significant stress, so some supervisory authorities might hesitate to apply overly negative tail scenarios to an already stressed baseline outlook. Announcing stress test results, including extreme scenarios, in such situations can be self-fulfilling in terms of triggering a crisis. Political economy and legal constraints can also be considered when choosing scenarios, especially when results are used as a basis for determining solutions, such as restructuring failed banks, deciding on public-sector support, etc. Conversely, compromising on the severity of the scenario can undermine the credibility of the exercise and prolong the crisis. Effective stress testing during crisis onset should not compromise on the severity of the scenario but should instead be complemented with credible support measures to mitigate any possible negative market impact.

Principle 6 (Communication): When Communicating Stress Test Results, Speak Smarter, Not Just Louder

The experience of the global crisis has underscored the importance of effectively communicating the results of stress tests. Central banks and supervisory authorities in various countries have been disclosing stress test results in financial stability reports even before the crisis, albeit with varying content and degrees across countries. After the financial crisis, financial authorities in various countries enhanced the disclosure of stress test results, particularly in the US and Europe, viewing this as a means to reinforce market confidence. In the US, the disclosure of stress test results was mandated by law, significantly heightening public interest and scrutiny of stress testing.

While the disclosure of stress tests can bring considerable benefits, it is not, naturally, a panacea for financial crises. The SCAP in the United States successfully restored market confidence in the banking sector, enabling investors to differentiate between banks and helping to raise additional capital from private sources. In contrast, the EU's 2011 system-wide stress test did not fully achieve these objectives. The discrepancy in outcomes was not due to differences in the degree of disclosure between the two standards, as the EU test was transparent, but rather to differences in the design of the stress test and the context in which the results were announced. The SCAP setup was credible, clearly communicated, and pre-prepared, while the EU stress test was considered mild and did not fully capture the risk profile of the banking system. More importantly, subsequent actions for failed banks and policy backstops were considered ambiguous.

In some cases, disclosure may induce difficult trade-offs. Public disclosure of stress test methodology, underlying exposures, assumptions, and results can (1) help elevate public awareness of risks; (2) promote more realistic risk pricing, reducing the probability of future sudden reversals in investor sentiment by strengthening market discipline; and (3) provide information for more effective financial stability policies. Even if the results are weak, public communication can have a positive impact if it is accompanied by credible contingency plans and support measures for failing financial institutions. This reflects the authorities recognizing the problem and committing to financial stability. More disclosure carries risks. It (1) allows financial institutions to "game" the test, inducing portfolio choices; (2) can increase moral hazard problems and foster complacency if investors overly rely on the disclosed stress test results, which are always subject to a margin of error, sacrificing other bank soundness indicators; and (3) can erode confidence if the necessary support measures (for political economy or other reasons) are absent.

Principle 7 (Limitations): Beware of the "Black Swan"

Regardless of the range of risk factors, the granularity of analysis models, the

severity of shocks included in the stress test, and the meticulousness of communication strategies, there is always a risk that "unthinkable" events will occur. Stress tests measure the resilience of a financial institution or system to given shocks but cannot predict the future. However, future shocks can arise from new sources and unexpected events, events that have historically been low in volatility or have not occurred for a long time and have been forgotten (e.g., sovereign defaults in advanced markets). How can these factors be practically integrated into the design of stress tests?

One approach is to design hypothetical scenarios based on expert judgment and available new information instead of relying solely on history. The Bank of England (Haldane, Hall, Pezzini 2007) has suggested using current vulnerabilities as a guide to choosing hypothetical shocks, which means, for instance, a system concentrated in real estate should be stress-tested for a large drop in real estate prices, regardless of the probability of such a shock. Alternatively, the U.S. Federal Reserve typically uses two scenarios for stress testing, one unique to each institution and one common to the market. In this way, institutions are evaluated under scenarios they themselves consider particularly harmful. Reverse stress testing by individual institutions and surveys of such exercises between institutions may help expand the frontier of tail risks.

Another approach is to apply distribution theory to the scenario itself instead of choosing a single adverse scenario at present. This approach assumes that the future is probabilistic and can be represented by a combination of events, each associated with a realization probability. The scenario distribution approach was used by IMF staff for the first FSAP for South Africa, where each scenario was represented by a combination of price changes, including credit spreads used to revalue bank assets, using Monte Carlo simulation based on the statistical properties of historical distributions of price changes. The final result was a distribution of bank capital ratios for each bank, with each point on the distribution associated with a particular scenario. Ultimately, the principle of recognizing "black swans" pertains more to the context of stress test scenarios

than the mechanics of their design and implementation. It serves as a reminder that stress tests should not be conducted in isolation and their results should not be taken literally. No matter how hard analysts try, there will always be a margin of error in stress tests, and their results will always be optimistic or pessimistic in hindsight. Moreover, model risk will always be present, and there can be an underestimation of shock severity due to incomplete data access. Thus, stress test results should be set in a broader context.

In summary, the IMF Policy Paper (IMF 2012b) emphasizes the importance of setting realistic expectations about what stress testing can and cannot achieve. Stress tests are forward-looking tools to evaluate the solvency and liquidity of financial institutions and the resilience of the entire financial system under plausible adverse scenarios, but they do not predict the likelihood of these scenarios materializing. The results of the tests should always remain speculative statements, regardless of the detail and improvement, and thus should not be used in isolation. Moreover, this report highlights several important decision points in the design and implementation of stress tests. These decisions include (1) the scope and severity of risk scenarios in terms of the range of all relevant risk factors; (2) the type of test, including all relevant transmission channels and realistic assumptions about buffers; and (3) the choice of appropriate hurdle rates. These are very important in terms of the efficacy of stress tests and the credibility of their results.

The success of stress testing cannot be summarized by the selection of a few parameters but must be viewed in a broader context designed by principles. This context includes (1) a clear understanding of the scope and objectives of stress testing; (2) knowledge about major individual financial institutions within the system, their business models, and key risk transmission channels; (3) appropriate decisions about the boundaries and scope of the test; (4) consideration of buffer assessment tools; (5) a communication strategy tailored to the context and purpose of the test; and (6) a credible commitment to take necessary measures to address vulnerabilities discovered by the test.

C. IMF's GST (Global Bank Stress Test)

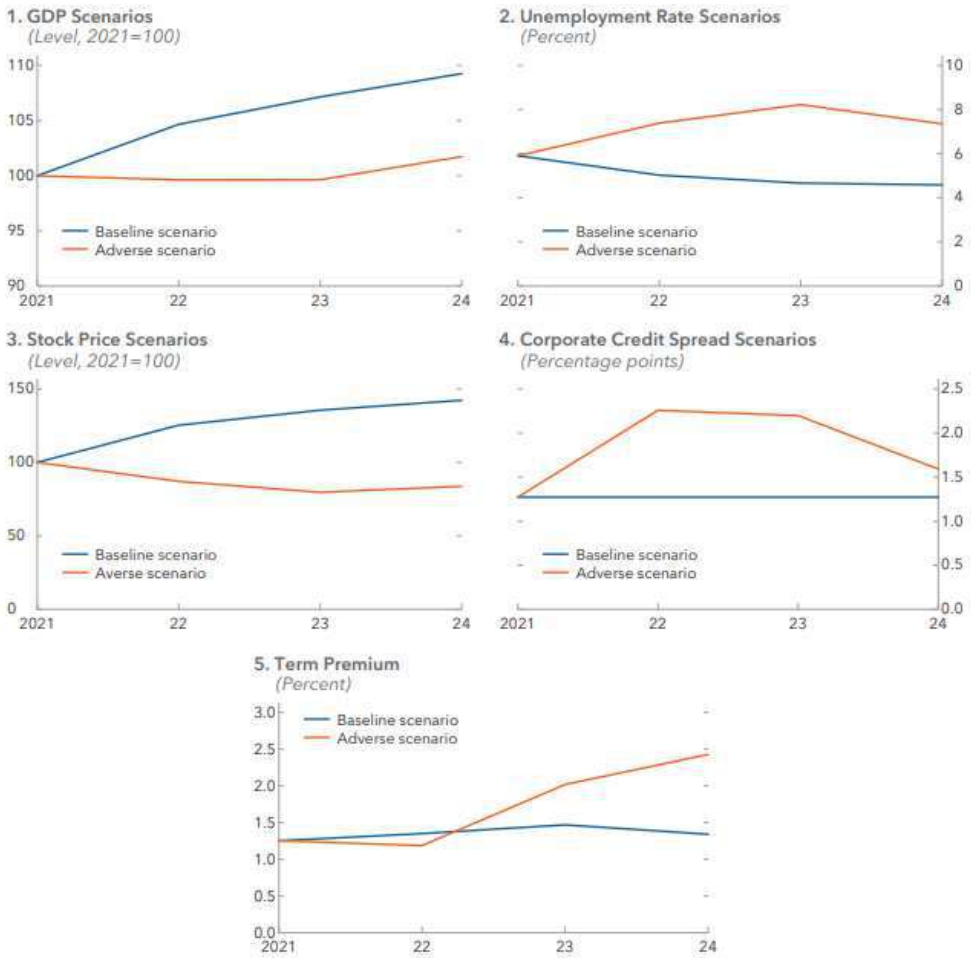
The IMF evaluates systemic risks as part of its monitoring of global financial stability. Such risks are analyzed at a multilateral level in the GFSR (Global Financial Stability Report) and at the national level in the context of Article IV supervision and FSAPs (Financial Sector Assessment Programs). Assessing the impact of global shocks is a highly complex task. Especially in situations like COVID-19, global shocks can have vastly different impacts across countries and economic sectors.

Against this backdrop, the IMF developed the GST, presented in the October 2020 GFSR, to analyze the impact of the pandemic. The GST is the first framework to analyze banks' resilience using consistent cross-country scenarios and a common methodology. The GST methodology differs from supervisory top-down or bottom-up stress test approaches. The use of public data imposes limitations on the methodology, scope, and interpretation of results. Public data is less granular and limited in scope compared to supervisory data used mainly in FSAP stress tests or authorities' stress tests. Therefore, the GST methodology is more straightforward and aggregated, capturing high-level dynamics of bank balance sheets. The results should be interpreted cautiously when compared to exercises based on more detailed supervisory data. The GST includes the largest banks in 24 advanced economies and five emerging economies. The bank sector assets of these 29 countries account for 70% of global bank assets. In each economy, the GST includes banks covering at least 80% of the total assets of the individual bank system. Overall, the sample comprises 53 banks in emerging economies and 204 banks in advanced economies.

The GST introduces several innovations to the global top-down stress test, and this methodology analyzes the financial statements of banks in various countries consistently. The baseline scenario for each economy reflects consistent forecasts for each country's macro and financial variables developed by IMF economists and presented in the WEO. Adverse scenarios were designed using the IMF's

Flexible System of Global Models (Andrle et al. 2016), a type of general equilibrium model between countries that ensures the internal consistency of scenarios. Using country-specific scenarios derived from the IMF's global general equilibrium modeling framework is especially important when considering large-scale global shocks. Each scenario is characterized by two macro variables (real GDP growth and unemployment rate) and six financial variables (short-term interest rates, term spread, two measures of risk premiums (VIX and corporate spreads), and country-specific equity returns) and global oil price growth.

<Figure 3-2> Global Stress Test Macroeconomic Scenarios (29 Countries)



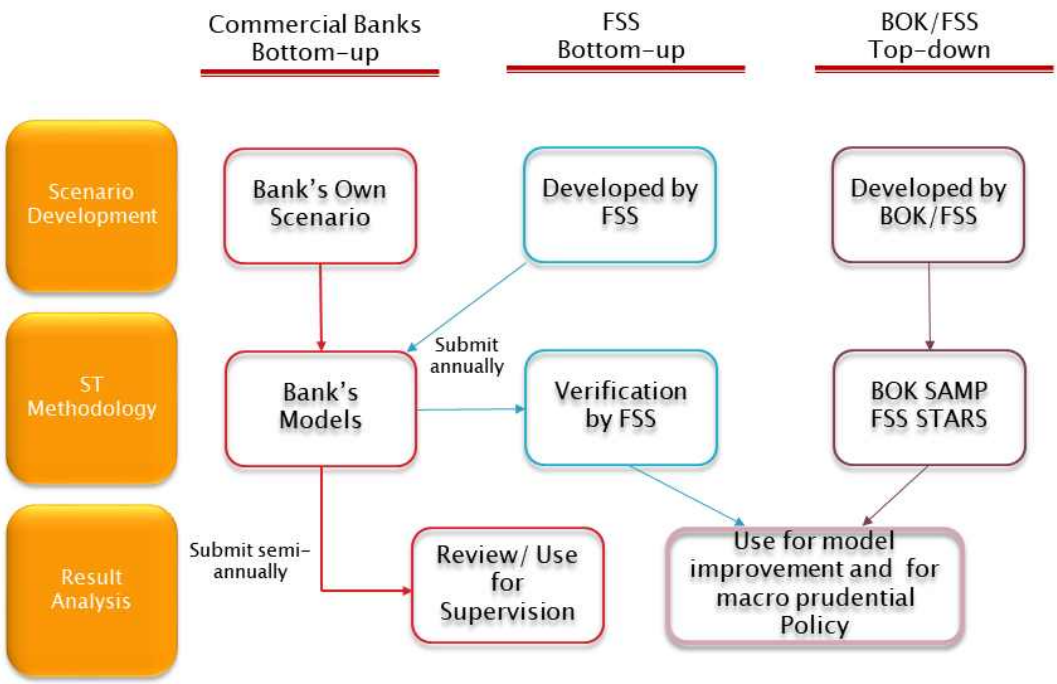
Source: IMF, Oct 2021 World Economic Outlook

2. Korea's Macro Stress Test System and Development Experiences

A. Overview

Macro stress tests can be classified into two types: top-down and bottom-up approaches. The top-down stress test utilizes a stress test system developed by regulatory authorities, which incorporates data, scenarios, assumptions, and models, and is used for financial supervisory purposes. This approach evaluates the resilience of the entire financial system through estimating credit risks such as the probability of default (PD) and loss given default (LGD), using financial data from financial institutions. Conversely, the bottom-up stress test is conducted by financial institutions using their self-developed scenarios and models, or by performing tests based on common scenarios provided by the authorities, with results reported back to the financial authorities. Korea conducts both top-down and bottom-up stress tests, as depicted in the figure below.

<Figure 3-3> Bottom-UP & Top-down Stress Tests in Korea

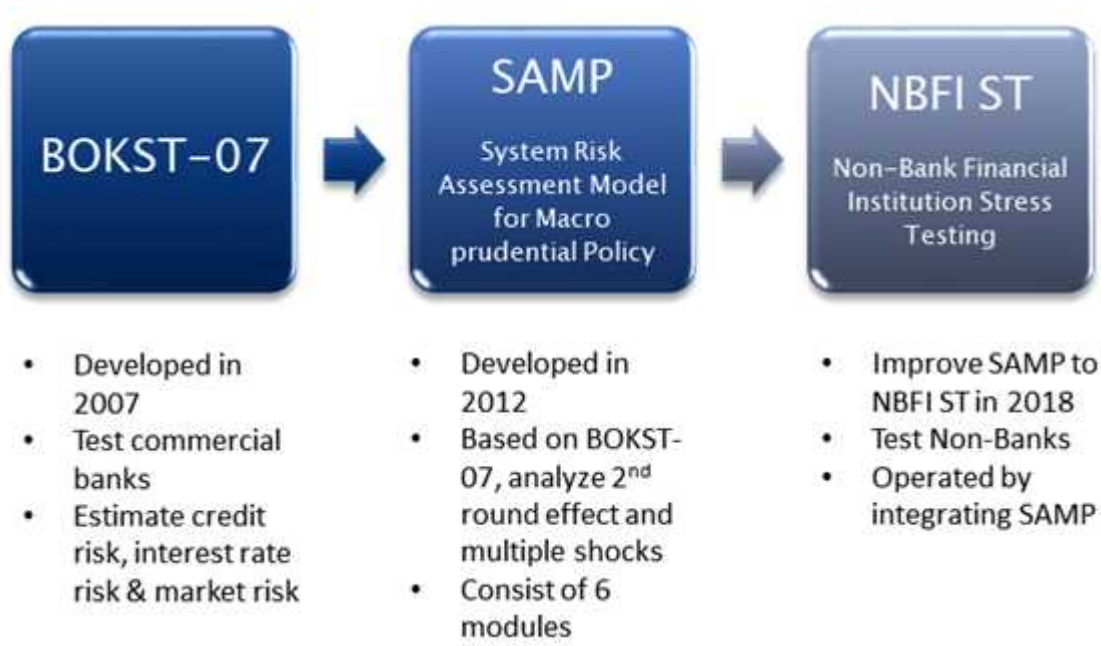


* Source : Authors

B. The Bank of Korea's Macro Stress Test

Following the Asian financial crisis, the IMF and central banks of various countries began to utilize financial system stress tests as a crucial quantitative evaluation method for assessing financial system stability. In Korea, until the early 2000s, the approach was micro-oriented, constrained by fundamental data required for testing, such as default rates, and lacked a well-developed quantitative model for stress testing to comprehensively evaluate the impact of external shock factors on the financial system. In response, the Bank of Korea, utilizing a macro-quantitative model (BOK04), developed a stress test model (BOKST-07) suitable for Korea's economic structure and financial environment in December 2007, beginning its work in 2006. Furthermore, after the global financial crisis in 2008, the need for a more sophisticated and comprehensive model to measure the systemic risk in the Korean financial market emerged. Consequently, in 2012, a unified macro stress test model, SAMP (Systemic Risk Assessment Model for Macroprudential Policy), was developed.

<Figure 3-4> Stress Tests of BOK



* Source : Authors

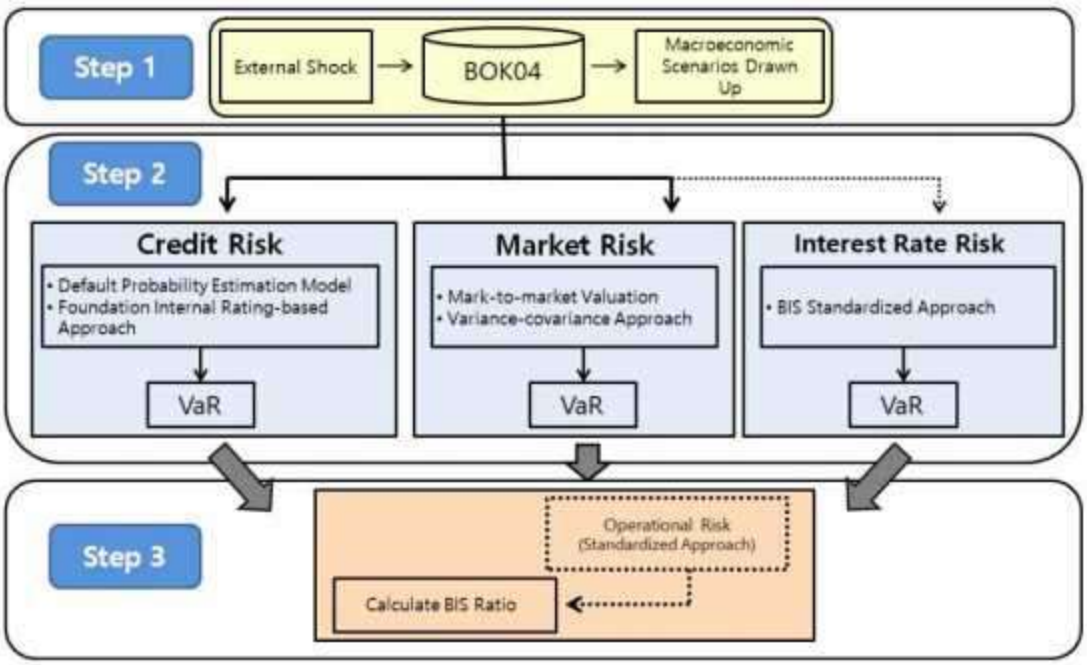
(BOKST-07)

In the late 1990s, following the Asian financial crisis, the IMF and central banks began utilizing financial system stress tests as a key quantitative evaluation method for financial system stability, leading to an expansion of research on financial system stress tests in Korea. In 2007, the Bank of Korea (BOK) developed a stress test model, BOKST-07, suitable for South Korea's economic structure and financial environment by utilizing the existing macro-quantitative model (BOK04). This model was employed to conduct stress tests to evaluate the stability of the domestic financial system and check for vulnerabilities.

BOKST-07, officially named "Bank of Korea Financial System Stress Test Model," was developed through a process in which the BOK surveyed banks' stress test preparation processes and gathered ideas for model formulation. The BOK also collected data needed for the test and received consulting from the Bank of England. Ultimately, the BOK conducted a test in the 4th quarter of 2007 and completed development in December 2007.

The BOKST-07 model evaluates the stability and resilience of the Korean financial system. Specifically, it compares the degree of risk exposure to financial institutions (seven national banks, two state-owned banks, and three local banks) in response to macroeconomic shocks. To do this, it adopts a quantitative measurement model to estimate financial risks such as credit risk, interest rate risk, and market risk, as illustrated below. Bond assets on a bank's balance sheet are considered when estimating market and interest rate risks. Operational risk is only used in calculating risk-weighted assets. The BOK-04 macroeconomic forecasting model is used to formulate scenarios.

<Figure 3-5> The Basic Structure of the BOKST-07 Model



* Source : BOK press release(2007.12)

BOKST-07 follows a typical stress test procedure, including ① initial shock setting, ② generating macroeconomic scenarios based on the initial shock, ③ measuring changes in the financial system's risk amount per scenario, and ④ checking the stability of the financial system according to risk amount changes. Among these, the second step (generating macroeconomic scenarios) and the third step (measuring scenario-based financial system risk changes) can be considered core steps in the quantitative model of the stress test.

The models used at each test stage in BOKST-07 are as follows. Firstly, the Bank of Korea's macro-quantitative model (BOK04) is utilized to estimate changes in major macroeconomic variables according to the initial shock during the macroeconomic scenario setting stage, and the financial system's risk amount changes are measured for each scenario. Next, for measuring credit risk, a default probability estimation model and the basic internal rating approach of the new BIS agreement are used. The default probability estimation model estimates a long-term equilibrium formula that connects the default rate and

macroeconomic variables for exposures like enterprises, SMEs, and retail using a panel model. Additionally, credit risk is calculated using the basic internal rating approach of the new BIS agreement, with the default probability estimated by the default probability model as an input variable. Lastly, market and interest rate risk measurement uses the VaR (Value at Risk) measurement technique.

(BOK SAMP)

In 2012, the Bank of Korea developed the SAMP (Systemic Risk Assessment Model for Macroprudential Policy), the first of its kind among Asian central banks, to comprehensively and systematically analyze and evaluate the financial stability situation. The model provides a holistic and systematic approach to assess and navigate financial stability conditions, incorporating a macroprudential policy perspective, and it was a pioneering initiative within Asian central banks at the time of its development. Comprehensive quantitative analysis system in the field of financial stability, SAMP, has been constructed to conduct systemic risk assessment and stress testing under a consistent system. SAMP, designed for systemic crisis detection, not only models the primary effects directly impacting the financial system from macro shocks but also comprises the following six modules to model secondary effects (2nd round effects) where risk is amplified and spread through bank contagion, fire sales, credit crunches, and deleveraging.

① Macro Risk Factor Probability Distribution Module: Estimates the probability distribution of macro risk factors affecting bank profits and losses.

② Bank Profit and Loss Module: Estimates bank profits and losses, such as credit losses, market losses, interest and non-interest income, in response to changes in macro risk factors.

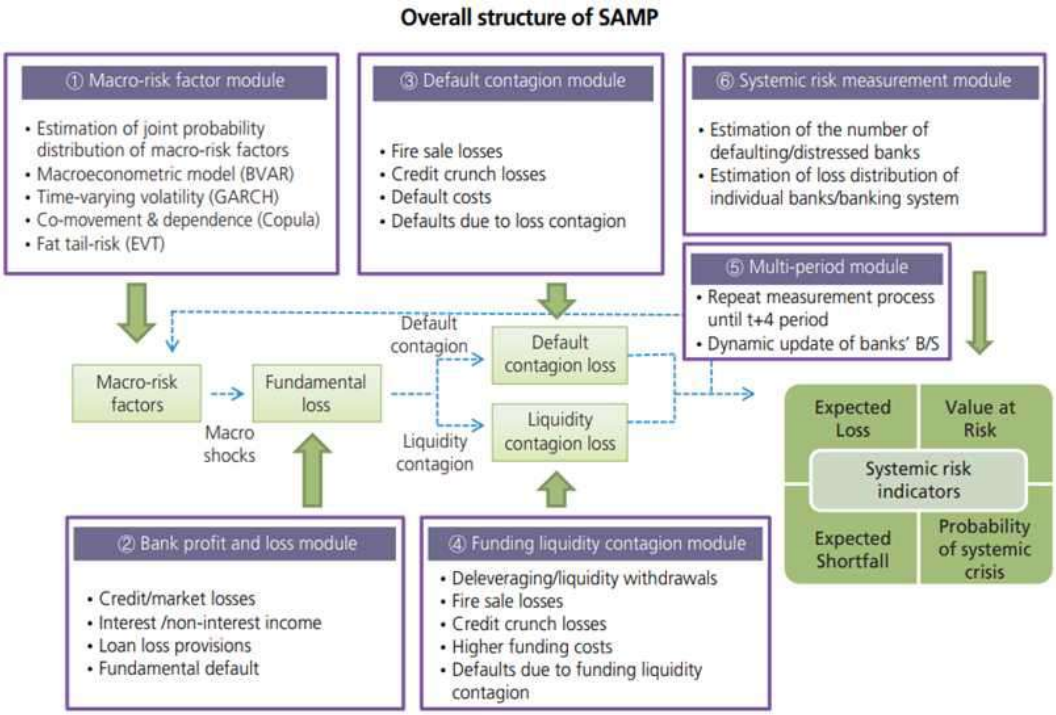
③ Insolvency Loss Contagion Module: Measures effects such as insolvency contagion due to interbank interconnectedness, and macro-financial feedback effects due to fire sales and credit crunches.

④ Funding Liquidity Contagion Module: Measures effects like liquidity exhaustion in the wholesale funding market, deleveraging, and deposit withdrawals during crises.

⑤ Multi-Period Loss Module: Updates financial statements and measures dynamic risk.

⑥ Systemic Risk Indicator Module: Calculates various systemic risk indicators using the probability distribution of total banking system losses.

<Figure 3-6> Overall Structure of SAMP



* Source : BOK press release(2012.9)

When compared with systemic risk models of central banks in other countries, SAMP possesses comparative advantages in several areas, such as enhancing the accuracy of tail risk measurement, estimating contagion effects of funding liquidity risk, estimating credit crunch losses due to macro-financial feedback effects, and multi-period model configuration. The specific comparative results between models across countries are presented in the table below.

<Table 3-1> Comparison of Systemic Risk Models Among Major Central Banks

	Korea (SAMP)	Korea (BOKST-07)	U.K (RAMS)	Austria (SRM)	Canada (MFRAF)
Name of model	Systemic Risk Assessment Model for Macroprudential Policy		Risk Assessment Model for Systemic Institutions	Systemic Risk Monitor	Macro-Financial Risk Assessment Framework
Time of development	2012	2007	2011	2006	2012
Macro model	○	○	○	○	○
	(BVAR)	(Simultaneous equations model)	(BVAR)	(VAR)	(DSGE)
Fat tail-risk	○ (EVT, GARCH)	×	×	0 (EVT, GARCH)	×
Probability of default (PD)	○ (5 exposures)	○ (3 exposures)	○ (4 exposures)	○ (11 industries)	○ (7 exposures)
Loss given default (LGD)	○ (S&P model)	×	○	×	×
Market loss	○ (Mark-to-market)	○ (Mark-to-market)	○ (Mark-to-market)	○ (Mark-to-market)	×
Income	○ (Interest/Non-interest income)	×	○ (Interest/Non-interest income)	×	×
Loss contagion	○ (Network model)	×	○ (Network model)	○ (Network model)	○ (Network model)
Funding liquidity	○ (Contagion effect reflected)	×	△ (Contagion effect not reflected)	×	△ (Contagion effect not reflected)
Macro-financial feedbacks	△ (Credit crunch reflected)	×	× (Under development)	×	×
Multi-period model	○ (Dynamic B/S update)	×	○ (Dynamic B/S update)	×	△ (No B/S adjustment)
Time horizon	1 year	1 year	Longer than 1 year	1 quarter	1 year

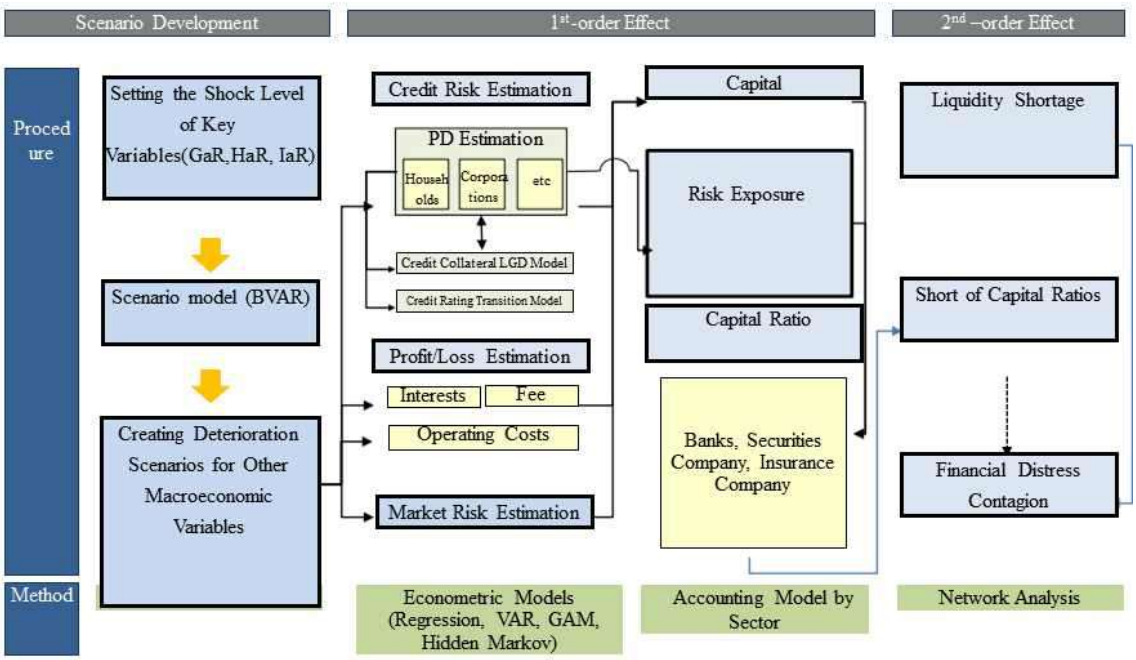
* Source : BOK SAMP(Systemic Risk Assessment Model for Macroprudential Policy) (2014)

C. Financial Supervisory Service's Macro Stress Test

The Financial Supervisory Service (FSS) of Korea developed STARS-I (Stress Test for Assessing Resilience and Stability of the financial system Version 1) in 2018, as a top-down stress test model intended for supervisory stress testing across all financial sectors. This development emerged particularly after the 2008 financial crisis, where the importance of stress testing as a primary supervisory tool was highlighted. The initiative was driven by limitations in utilizing the results from initial-stage tests, which were in use at the time, as guidelines for the capital management of financial institutions. Notably, in 2013, the IMF recommended improvements to the stress test model for financial supervision during its FSAP (Financial Stability Assessment Program) evaluation of South Korea.

STARS is a top-down model that the FSS can quickly execute on its own, without the participation of individual financial companies, covering not only banks but also insurance, securities investment, savings banks, and mutual credit and credit unions across the entire financial system. The analysis results are utilized as a foundation for validating test results conducted by individual financial companies and as a basis for supervisory actions. STARS is structured in a modular fashion to encompass various risk areas, as depicted in the following diagram.

<Figure 3-7> Structure of FSS's STARS



* Source : FSS Press release (2021.1)

STARS aims to analyze the impact of crisis scenarios on the financial statements of banks and bank holdings, estimating the BIS ratio by assessing the credit, market risks, and operating profits of each bank and holding. For credit risk, expected losses (EL), probability of default (PD), transition rates, and loss given default (LGD) for six portfolios - large corporations, SMEs, individual proprietors, mortgage-backed, other retail, and public/others - are estimated to calculate credit risk-weighted assets and loss costs during a crisis. Here, long-term default rate time-series information, which encompasses the entire economic cycle, including the IMF foreign exchange crisis, is employed, reflecting the characteristics of each bank (observed default rate, asset correlation coefficient, etc.). To estimate operating profits, variations in interest income and costs due to interest rate changes, an increase in non-interest-bearing loans for each bank and holding, and increased funding costs due to a decline in the capital ratio are estimated. For market risk, the valuation gains and losses of trading accounts and available-for-sale securities are estimated. Meanwhile, in the 2019 Financial Sector Assessment Program (FSAP), the IMF and the Financial

Supervisory Service (FSS) conducted stress tests using their respective models. The assessment results were quite similar, with model deviations of 0.1% to 0.5%. The IMF validated STARS, rating it as "well-developed" and an appropriate method to measure loss-absorbing capacity.

D. Korean Depository Insurance Corp.(KDIC)'s Macro Stress Test

KDIC began a project for stress testing in the financial sector in July 2015. The project was initiated to develop distinct models for various financial services sectors, including banks, life insurers, non-life insurers, investment firms, and savings banks. The Korea Fixed Income Research Institute was commissioned in October 2015 to lead this project. In terms of operation, risk monitoring teams assigned to each financial sector conducted quarterly stress tests. The results from these tests were then integrated into the risk monitoring processes for individual firms and other related activities.

In May 2021, KDIC developed the Macroprudential Stress Test Model which was designed to simultaneously cover all the financial services sectors. Since its inception, the team responsible for industry-wide risk analysis has been conducting quarterly stress tests. The outcomes of these tests are crucial for the risk monitoring of individual firms and for informing broader activities within the financial sector. These developments reflect a comprehensive and evolving approach to risk assessment and management within the Korean financial sector, adapting to the dynamic nature of financial risks and regulatory requirements.

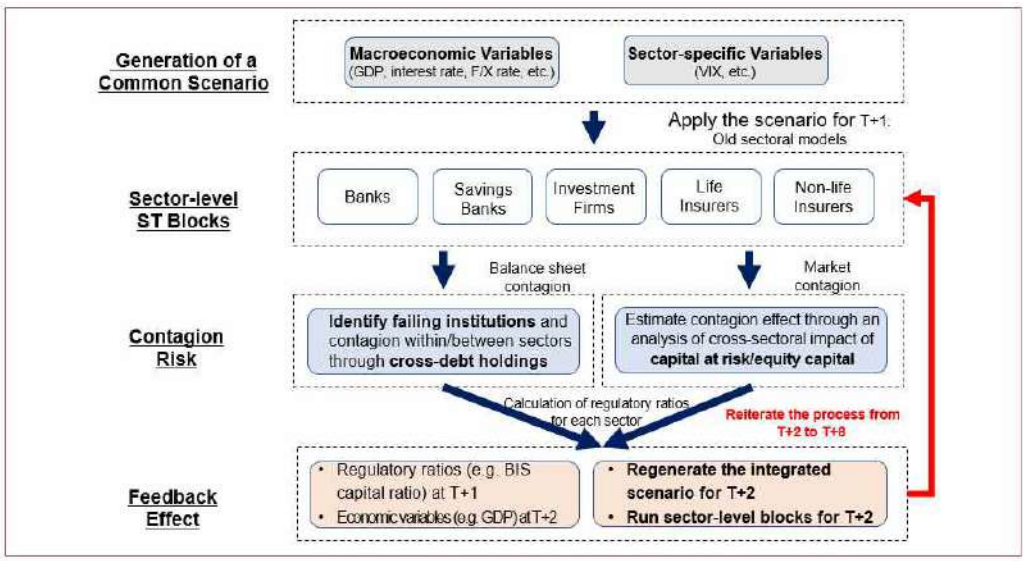
The existing stress test models in financial regulation primarily focus on regulatory ratios and are used to supervise various financial sectors. These models aim to identify the impact of sector-specific scenarios on individual financial sectors. A critical limitation of these models is their inability to reflect the growing complexity and interconnectedness in financial markets. In response, the Macroprudential Stress Test Model has been developed, taking a broader approach by accounting for system-wide risks. This model estimates contagion

risk and feedback effects, employing a common scenario across all sectors to ensure a comprehensive understanding of risks at member institutions.

The development strategy for the Macroprudential model involves several key components. Firstly, it generates a common scenario using the Bayesian Vector Autoregression model, differing from the sector-specific scenarios of current models. Secondly, the model incorporates existing sectoral stress test models. This inclusion allows for the comparison of outcomes between the macroprudential model and the traditional sectoral models. Lastly, new elements have been added to assess contagion risk and feedback effects. The first element of contagion risk evaluates the risk emanating from a firm's failure using balance sheet data. The second element assesses contagion risks associated with risk assets and capital in each sector, based on the methodology developed by Diebold & Yilmaz (2014). The feedback effect component adjusts macroeconomic variables of subsequent quarters, considering the level of risks at the five largest commercial banks and investment banks.

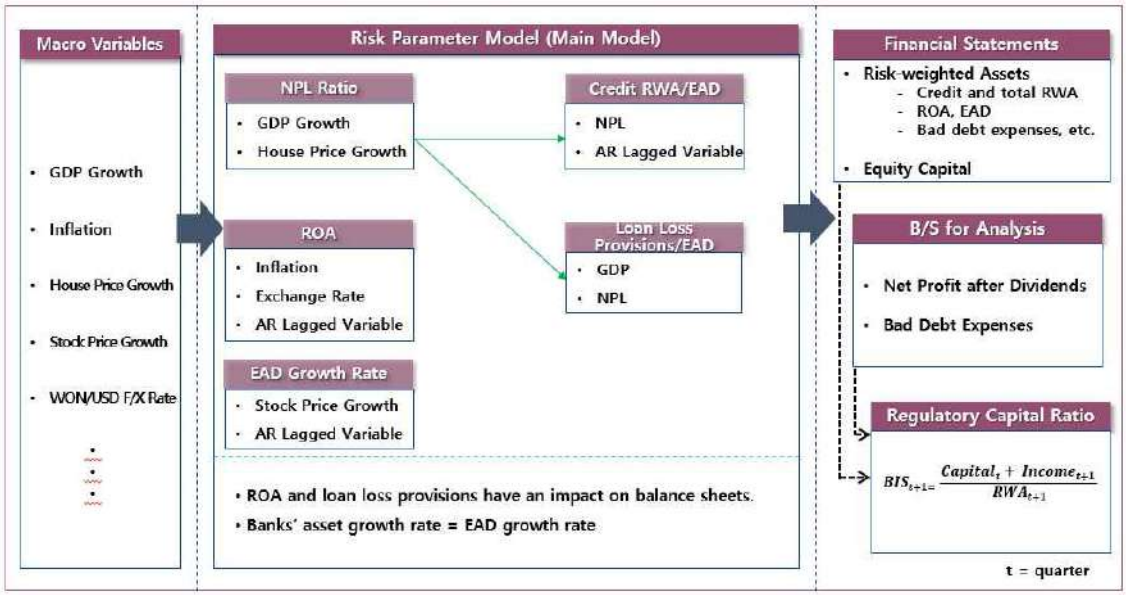
The following figures summaries the structure of KDIC's Macroprudential Stress Test Model as well as the model for the commercial bank industry.

<Figure 3-8> Structure of KDIC's Macroprudential Stress Test Model



*Source: Overview of KDIC's Macroprudential Stress Test Model(2023)

<Figure 3-9> Structure of KDIC's Macroprudential Stress Test Model – Commercial Banks



*Source: Overview of KDIC's Macroprudential Stress Test Model(2023)

The model examines contagion effects at the balance sheet level, which occur when a financial institution is unable to meet its debt obligations. In the absence of direct data on inter-institutional exposure, the total amount of assets that an institution holds against a sector is used as a proxy. For estimating exposures, reliance is placed on reports from the Bank of Korea, such as ES007 (deposit statement) and ES010 (list of securities holdings), to determine the amount of deposits, bonds, and other securities held by an institution against each sector. When imposing losses on a failed institution's deposit and bond holdings, these are calculated in proportion to the share of the institution's total assets relative to the total assets in the relevant sector.

In addition to balance sheet contagion, the model also delves into market contagion risks. These risks, including asset price declines, stem from the interconnectedness of financial markets and are not directly related to changes in macroeconomic variables. To estimate additional changes in capital at risk and equity capital due to cross-sectoral effects, the Diebold-Yilmaz model (2014) is utilized. This model helps in estimating sensitivity coefficients, which measure the impact that a change in the regulatory capital ratio of one sector can have

on another. The sectors considered for this analysis include the five largest banks, other banks, investment banks (IBs), other investment firms, life insurers, non-life insurers, and savings banks.

The model also addresses the feedback effect, which pertains to the impact of shocks from the previous period on the next quarter's macroeconomic variables. This part of the study focuses on shocks endured by large financial institutions, such as the five largest commercial banks and IBs. To establish whether changes in these institutions' regulatory capital ratios can predict future changes in major macroeconomic variables, a standard VAR model is applied. This model incorporates the BIS capital ratios of the five largest commercial banks, net capital ratios (NCRs) of IBs, GDP, call rate, KOSPI, and exchange rate. The results, which confirm statistical significance, are then scaled to model the feedback effect.

3. Stress Testing History and Practices in Nepal

A. Introduction

Nepal Rastra Bank (NRB) has developed Stress Testing Guidelines, 2012 for conducting stress testing for banks and financial institutions (BFIs) in Nepal. NRB conducts stress testing of all BFIs as per the guidelines. Similarly, BFIs, at minimum, are required to conduct stress testing as per the scenarios prescribed in the guidelines. Moreover, BFIs are also encouraged to introduce more complex and advanced techniques of stress testing to improve their own internal risk management practices.

The inception of stress testing in Nepal begun with the introduction of the Stress Testing Guidelines in 2012. The guidelines were issued to gauge the resilience of BFIs in terms of solvency and liquidity when subjected to various shocks encompassing credit risk, market risk, and liquidity risk. Initially, only

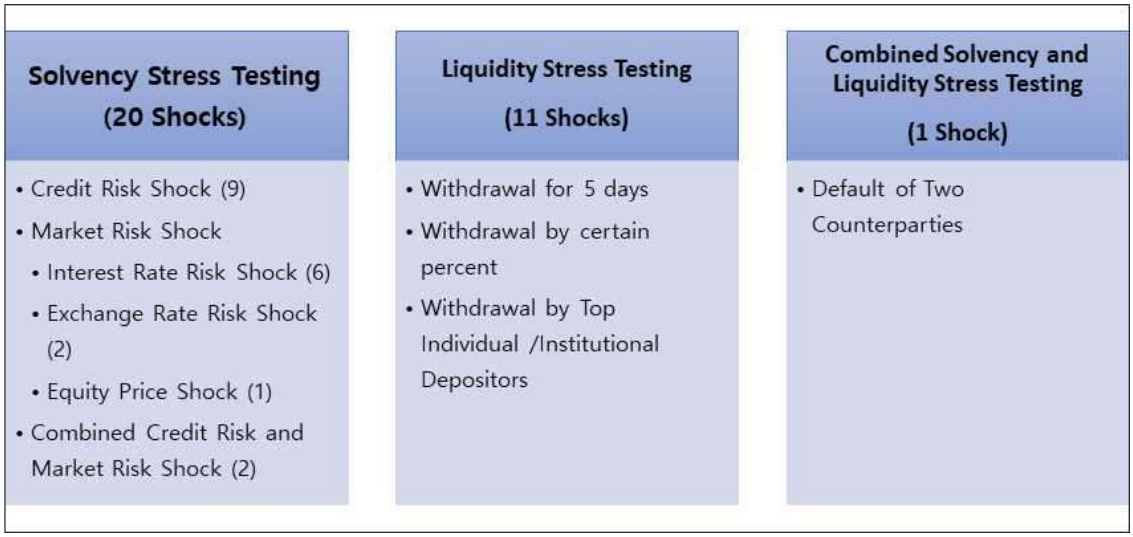
commercial banks were under purview of the guidelines. Gradually it was applicable to development banks (B class of BFIs) as well as finance companies. With recent changes in banking landscape, evolving risk analysis and management practices along with stress testing practices and to encompass all the elements of sound stress testing framework, NRB has issued Stress Testing Guidelines, 2023 on October 2023 with some enhancement in current stress testing guidelines. The guidelines provide the benchmark for Supervisory Stress Testing and encouraging BFIs to develop their own stress testing model with shocks assumed in supervisor stress testing and encompassing other shocks based on their respective risk appetite, business complexities, future strategies, etc. This section of the report highlights the stress testing practices in Nepal on the basis of Stress Testing Guideline 2012 along with the key amendments in Stress Testing Guidelines 2023.

B. Key Features of Stress Testing Guidelines, 2012

Stress testing is mainly focused on assessing the resilience in terms of solvency and liquidity of BFIs against various shocks related to credit risk, market risk and liquidity risk. At present, stress tests are micro stress testing in nature which analyzes the effect of various shocks related to credit risk, market risk and liquidity risk in individual banks without focusing on the systemic risk and the linkage with macroeconomic variables. The stress testing practice is conducted on a quarterly basis. Key features of Stress Testing Guidelines 2012 are as follows:

- Stress testing is conducted for various shock scenarios related to credit risk, market risk and liquidity risk.
- Stress testing encompasses a total 32 shock scenarios where 20 shock scenarios relate to Solvency Stress Test, 11 shock scenarios to Liquidity Stress Test and 1 to Combined Solvency and Liquidity Stress Test as depicted in Figure 3.10.

<Figure 3-10> Overview of Stress Testing Framework



- **Solvency Stress Testing:** This assesses the impact on solvency through 9 credit risk-related shock scenarios, 9 market risk-related shock scenarios, and 2 combined credit and market risk-related shocks. Post-shock capital adequacy is considered as a key metric in Solvency Stress Testing.
- **Liquidity Stress Testing:** To evaluate liquidity resilience, 11 shocks associated with liquidity stress scenarios ensued from deposit withdrawal are examined. Post-shock liquidity position and net liquidity ratio are key metrics in liquidity stress testing.
- **Combined Solvency and Liquidity Stress Testing:** This involves a combined shock scenario that tests solvency and liquidity stress in a scenario where two counterparties default.
- BFIs, at minimum, are required to conduct stress testing based on the shock scenario outlined in the guidelines.
- BFIs are required to conduct stress testing on quarterly basis and the result should be discussed at Board and Senior Management Level.
- Stress testing is a crucial component of the Internal Capital Adequacy Assessment Process (ICAAP) of BFIs.
- BFIs are required to report the result of their stress test conducted as per the guidelines along with data to NRB on quarterly basis. NRB also conducts the stress testing of BFIs as per the Stress Testing Guidelines. The results of

individual bank and financial institutions' stress tests are discussed at Senior Management Level and Financial Stability Oversight Committee of the NRB. In addition, stress testing results are published in the Annual Financial Stability Report of the NRB.

(1) Solvency Stress Testing

① Credit Risk

Solvency stress testing involves a sensitivity analysis incorporating nine distinct credit risk shock scenarios. These scenarios are based on what if approach, i.e. what if non-performing loan goes up or what if there is migration of certain percentage of loan from one category to more adverse category. Such migration will trigger additional loan loss provisioning and will adversely impact profit of the bank. This, in consequence, impact capital fund, risk-weighted assets and ultimately capital adequacy ratio.

BFIs in Nepal follow the prudential loan loss provisioning regulations set forth by the NRB. These regulations necessitate BFIs to classify their loans into seven distinct buckets, primarily based on number of Past Due Days.

S.N.	Loan Category	Past Due Days	Provision %
A.	**Performing Loans**		
i.	Pass Loans	Up to 1 Month	1.3%
ii.	Watch list Loans	1 Month to 3 Months	5%
iii.	Restructured Loans – Performing		5%
B.	**Non-Performing Loans**		
iv.	Restructured Loan		12.5%
v.	Substandard Loans	3 Months to 6 Months	25%
vi.	Doubtful Loans	6 Months to 1 Year	50%
vii.	Loss Loans	Above 1 Year	100%

This categorization serves as a foundation for developing the shock scenarios and assessing the risk and provisioning requirements for loan portfolio during stress testing. Credit risk stress testing involves an exploration of various scenarios to understand the potential impact on a bank's solvency. These

scenarios encompass study of what happens if:

- Certain percent of Performing Loans deteriorated to Substandard loan.
- Certain percent of Substandard Loans deteriorated to Doubtful loan.
- Certain percent of Doubtful Loans deteriorated to Loss loan.
- Certain percent of Performing loans deteriorated to Loss loan.
- All NPLs under Substandard category downgraded to Doubtful loan.
- All NPLs under Doubtful category downgraded to Loss loan.
- Certain percent of performing loan of Real Estate loan directly downgraded to Doubtful category of NPLs.
- Certain Percent of performing loan of Real Estate loan directly downgraded to Loss category of NPLs.
- Large exposures downgraded from Performing to Substandard or Loss.

② Market Risk

Shocks related to market risk aim to assess how the changes in market risk factors impact bank's capital position. These changes are typically associated with fluctuations in interest rates, equity prices, and exchange rates. The following market risk scenarios are considered:

- **Interest Rate Shock:** This scenario involves increasing the interest rates on deposits by 1%, 1.5%, and 2%, as well as decreasing the interest rates on loans and advances by the same percentage point. Six scenarios are tested to evaluate their impact on profit and the capital adequacy.
- **Exchange Rate Shock:** Two scenarios are examined; appreciation and depreciation of the domestic currency, evaluating their impact on profit and the capital adequacy. Exchange rate risk impact is measured by applying changes in the exchange rate of the Nepalese Rupee (NPR) against the USD in bank's foreign currency net open position.
- **Equity Price Shock:** This scenario assesses the impact of a fall in stock prices on profit and the capital adequacy.

(2) Liquidity Stress Testing

Liquidity stress testing encompasses eleven predefined scenarios, each representing different types of large customer deposit withdrawals that need to be covered by liquid assets. These scenarios include:

- A 5-day liquidity stress test simulating withdrawals of deposits by 2%, 5%, 10%, 10%, and 10% for five consecutive days to assess liquidity stress.
- "What if" scenarios considering the withdrawal of a certain percentage of deposits and the withdrawal of deposits by the top 2, 3, and 5 individual and institutional depositors. The impact of these stress scenarios on the net liquidity ratio of BFIs is evaluated.

(3) Combined Solvency and Liquidity Stress Testing

This scenario combines both solvency and liquidity shocks. It assumes that the top 2 interbank loans of each bank transition from performing to non-performing (loss) status, affecting both solvency (credit losses) and liquidity (a drop in net liquid assets, as interbank loans are included in them).

C. Stress Testing Practices in Nepalese Banking Industry

BFIs are required to conduct stress testing exercises, adhering to the predefined scenarios outlined in the aforementioned guidelines. However, the framework also encourages BFIs to explore more advanced stress testing techniques.

The prevailing stress testing practice in BFIs reveals that a significant proportion of banks predominantly rely on the scenarios outlined in NRB Stress Testing Guidelines, 2012. These prescribed scenarios serve as a foundational framework for evaluating the impact of various stress factors on their financial stability. Nonetheless, a few banks have taken the initiative to design and incorporate additional stress scenarios into their stress testing practices. Similarly, some joint venture banks have also developed forward-looking macro financial stress testing which is conducted annually as important component of Internal Capital Adequacy Assessment Process (ICAAP).

In summary, Nepal's banking and financial institutions exhibit a spectrum of approaches to stress testing, ranging from the foundational compliance with regulatory scenarios to the adoption of forward-looking stress testing practices.

D. Result of Stress Test of Commercial Bank

Resiliency of the commercial banks to credit shock, liquidity shock, market shock and combined shocks were assessed by the stress tests presented in following table:

<Table 3-2> Results of Stress Test of Commercial Bank as of Mid-July 2023

		Number of Banks with CAR		
		< 0%	0% - < 11%	>=11%
Pre Shock		**0**	**0**	**20**
Post Shock				
A. Credit Shock		**Number of Banks with CAR**		
S.N.	**Scenario**	**< 0%**	**0% - < 11%**	**>=11%**
C-1 a	15 percent of performing loan deteriorated to substandard	0	15	5
C-1 b	15 percent of substandard loan deteriorated to doubtful loan	0	0	20
C-1 c	25 percent of doubtful loan deteriorated to loss loan.	0	0	20
C-1 d	5 percent of performing loan deteriorated to loss loan	0	18	2
C-2	All NPLs under substandard category downgraded to doubtful.	0	0	20
C-2	All NPLs under doubtful category downgraded to loss.	0	0	20
C-3	25 percent of performing loan of Real Estate loan directly downgraded to substandard category of NPLs.	0	0	20
C-4	25 percent of performing loan of Real Estate loan directly downgraded to loss category of NPLs.	0	2	18
C-5	Top 2 large exposures downgraded: performing to loss category	0	1	19
B. Market Shock				
I. Interest Rate Shocks				
IR-1a	Deposits interest rate change (+,-) by 1% on an average.	0	0	20
IR-1b	Deposits interest rate change (+,-) by	0	0	20

	1.5% on an average.			
IR-1c	Deposits interest rate change (+,-) by 2% on an average.	0	0	20
IR-2a	Loan interest rate change (+,-) by -1% on an average.	0	0	20
IR-2b	Loan interest rate change (+,-) by -1.5% on an average.	0	0	20
IR-2c	Loan interest rate change (+,-) by -2% on an average.	0	0	20
II. Exchange Rate Shocks				
ER-1a	Depreciation of currency exchange rate by 20%	0	0	20
ER-1b	Appreciation of currency exchange rate by 25%	0	0	20
III. Equity Price Shocks				
Eq-1	Fall in the equity prices by 50%	0	0	20
C. Combined Credit and Market Shocks				
Comb1	25 Percent of performing loan of Real Estate loan directly downgraded to substandard category of NPLs. and Fall in the equity prices by 50%	0	1	19
Comb2	15 Percent of Performing loans deteriorated to substandard, 15 Percent of Substandard loans deteriorated to doubtful loans, 25 Percent of Doubtful loans deteriorated to loss loans. and Fall in the equity prices by 50%	0	19	1

D. Liquidity Shock		**Number of Banks becoming illiquid after shock of**		
S.N.	**Scenario**	**3 days**	**4 days**	**5 days**
L-1	Withdrawal of customer deposits by 2% 5% 10% 10% and 10% for five consecutive days respectively.	**0**	**0**	**11**
		Number of Banks with Liquid Assets to Deposit Ratio		
		< 0%	**0% - < 20%**	**>=20%**
	Pre-Shock	0	0	20
	Post-Shock			
L-2-a	Withdrawal of deposits by 5%	0	2	18
L-2-b	Withdrawal of deposits by 10%	0	7	13
L-2-c	Withdrawal of deposits by 15%	0	15	5
L-2-c	Withdrawal of deposits by 20%	0	17	3
L-3a	Withdrawal of deposits by top 2 institutional depositors.	0	3	17
L-3b	Withdrawal of deposits by top 3 institutional depositors.	0	6	14

L-3c	Withdrawal of deposits by top 5 institutional depositors.	0	9	11
L-3d	Withdrawal of deposits by top 2 individual depositors.	0	0	20
L-3e	Withdrawal of deposits by top 3 individual depositors.	0	0	20
L-3f	Withdrawal of deposits by top 5 individual depositors.	0	0	20
		< 0%	**0% - < 11%**	**>=11%**
L-4	Top 2 Inter Bank Lending goes bad Number of Banks with CAR	0	0	20
		< 0%	**0% - < 20%**	**>=20%**
	Number of Banks with Liquid Assets to Deposit Ratio	0	0	20

Source: Nepal Rastra Bank (2023)

E. Recent Change in Stress Testing Guidelines

In an effort to enhance the robustness of the current Stress Testing Guidelines, several amendments have been made recently by issuing new Stress Testing Guidelines, 2023 on October, 2023. The key amendments in new Stress Testing Guidelines 2023 include:

- **Adoption of BCBS Principles:** The new guidelines embrace the stress testing principles outlined by the Basel Committee on Banking Supervision (BCBS) in October 2018, to align Nepalese practices with international standards.
- **Credit Risk Enhancements in Solvency Stress Test:** Notable changes have been made to the solvency stress testing approach. The amendments introduce additional credit risk shocks, including dynamic sectoral shocks, providing a more detailed understanding of how sector-specific vulnerabilities can impact credit risk. Importantly, new guidelines remove the shock related to real estate loan deterioration.
- **Inclusion of Off-Balance Sheet Exposure Shock:** The new guideline now incorporates off-balance sheet exposure shock scenarios under credit risk shock allowing for a more comprehensive evaluation of potential risks.
- **Operational Risk Integration:** Operational risk, is formally included in the new guidelines. This step acknowledges the significance of operational risk in

stress testing exercises, ensuring a more comprehensive risk assessment.

- **Liquidity Risk Enhancement in Liquidity Stress Test:** The new guidelines introduce new shock scenario related to conversion of irrevocable credit commitment to loans. This addition facilitates an assessment of how such conversion impact on credit to deposit ratio. The new guidelines also refine existing liquidity-related shocks, adopting a more realistic approach by assessing stress scenario of deposit withdrawal on deposits excluding fixed deposits. Previously, the stress scenario for deposit withdrawal encompassed all types of deposits.
- **Introduction of Reverse Stress Testing:** The introduction of reverse stress testing is an important amendment in new Stress Testing Guidelines. This approach enables the identification of extreme stress scenarios by working backward from adverse outcome of breached capital adequacy ratio and rising non-performing loans first and then to identify the possible scenario that can lead to that adverse outcomes.
- **Supervisory Stress Test and Internal Stress Test:** The new guidelines lay foundation to carry out stress test in two ways i.e. Supervisory Stress Tests conducted by the NRB based on prescribed scenarios in the guidelines, and Internal Stress Tests developed by individual BFIs. BFIs are required to develop their own internal stress testing model to conduct stress test which must include, at a minimum, the shocks assumed in supervisory stress tests and may incorporate other shocks based on their respective risk appetite, business complexities, and future strategies. BFI's internal stress test model should also include the reverse stress test analysis.

F. Conclusion

Stress Testing Guidelines 2012, issued by Nepal Rastra Bank, has played a pivotal role in shaping stress testing practices within the country's banking sector. Mandating stress testing for credit risk, market risk, and liquidity risk, the guidelines has been instrumental in using stress testing as a tool for risk analysis and management among banks. The guidelines has also encouraged banks and financial institutions to explore advanced stress testing techniques, aligning with

the regulatory framework while enhancing their internal risk management capabilities.

The current stress testing framework primarily employs sensitivity analysis, focusing on micro stress testing at the individual bank level. Despite the recent amendments that signify progress, a notable gap still exists i.e. the absence of macroeconomic considerations in stress testing. Banks and financial institutions and the overall financial system are inherently intertwined with macroeconomic conditions. The interconnectedness implies that adverse macroeconomic scenarios can significantly impact banks and financial institutions, affecting overall financial stability in the country.

Hence, to bridge this critical gap, it is imperative for the inclusion of macroeconomic factors in stress testing methodologies. The incorporation of macro stress testing in Nepal's Stress Testing framework is essential to comprehensively evaluate the resilience of BFIs as well as the financial system against adverse macro-economic scenarios. By conducting stress tests that encompass macroeconomic variables, NRB and Banks and financial institutions will be able to proactively identify vulnerabilities, enabling timely interventions to safeguard the stability of the institutions and overall banking system. The macro stress test is also essential to decide on the stressed capital requirements.

In essence, the evolution of stress testing practices in Nepal's banking industry must transcend the micro-level and embrace a holistic approach. The inclusion of macro stress testing will not only be a regulatory enhancement but a starting point to fortify the assessment of resilience of banks and the overall financial ecosystem against the complexities of the macro economic landscape.

IV. Proposed Macro Stress-Test Framework for Nepal

1. Overview of Stress-Test

A. Concept and History of Stress-Test

(1) Concept of Stress-Test

Stress testing refers to a set of activities designed to assess the solvency or liquidity of financial firms or the financial system as a whole under severe but plausible crisis scenarios. These assessments are used as a tool for the supervision/inspection of individual financial firms or for the identification of risk vulnerabilities in the financial system as a whole. The use of stress tests to assess the stability of the banking financial system became prominent in the aftermath of the global financial crisis, particularly in major industrialised countries such as the United States. The history of stress testing can be summarised as follows, with reference to Das et al. (2022).

(2) Emergence of Banks' own Stress-Tests

Modern stress testing, which analyses the impact of clearly defined adverse scenarios on a bank's balance sheet and profitability, first emerged in the early 1990s as a risk management technique for the trading books of large international banks. Early stress testing was used by trading desk managers to assess their exposure to market risk, i.e. the risk of loss from adverse movements in market prices. The nature and use of stress scenarios varied considerably across banks. While most banks used stress testing to estimate maximum losses and set exposure limits for trades, some went further to decide on contingency plans or the allocation of capital across business lines in response to market stress (CGFS, 2000).

However, stress testing for credit risk has lagged significantly behind market risk. According to a 1999 BCBS report on the credit risk modelling of large international banks, hardly any institutions conducted stress testing for credit risk, and those that did so did so only sporadically. Surveys of stress testing practices (CGFS, 2000, 2001, 2005) indicate that the development of credit risk stress testing has lagged far behind that of market risk, with no cases of integration of market and credit risk stress testing. Factors hindering credit risk stress-testing included difficulties in marking-to-market loan portfolios and insufficient time series of data.

(3) Utilization of Bank-Executed Stress-Tests as Supervisory Tools

Initially used as a market risk management technique in private banks, stress testing was introduced as a supervisory tool by the Basel Committee on Banking Supervision (BCBS) in 1996 through a revised proposal on capital standards for market risk, which required banks using internal model approaches to conduct stress tests on their market risk positions (BCBS, 1996). Similarly, for credit risk, with the finalisation of Basel II in 2004, the BCBS required banks using internal ratings-based approaches to conduct stress tests on their credit risk models, with the results subject to supervisory review (BCBS, 2004). Thus, banks wishing to use internal rating-based approaches were required to establish stress testing programmes for credit risk.

However, the global financial crisis of 2008 revealed serious shortcomings in the design and scope of the stress tests conducted by banks. According to a BCBS report, stress testing relied excessively on historical information and statistical relationships derived under benign pre-crisis economic operating conditions (BCBS, 2009). The introduction and proper implementation of credit risk stress testing requirements came too late to have a meaningful impact, leading to the 2008 global financial crisis. Moreover, a 2009 BCBS survey found that while stress testing for market risk was well established prior to the

GFC, stress testing for credit risk was still in its infancy (BCBS, 2009).

In line with these developments, the Basel Committee on Banking Supervision (BCBS) established principles for sound stress testing practices and supervision in 2009, and emphasised in Basel III in 2011 the requirements for banks using the internal ratings-based (IRB) approach to conduct stress tests for credit and market risk (BCBS, 2011). According to a BCBS report in 2016, stress testing for credit risk has become standard industry practice, and it was found that all banks surveyed included both credit and market risks in their stress tests (BCBS, 2017). However, some banks still perceived stress testing as merely a regulatory compliance procedure, and integration with routine risk monitoring and management was not properly achieved. Therefore, the BCBS introduced revised stress testing principles in 2018, emphasising that stress testing should be used as a tool for banks' portfolio management and capital allocation in line with risk appetite and business decisions (<Box 4-1>).

<Box 4-1>

BCBS Stress Testing Principles (2018) Key Contents

1. **The stress testing framework should have clearly defined and formally adopted objectives.**

- Assess capital or liquidity levels of supervised banks
- Promote banks' own stress testing and risk management capabilities
- Support other supervisory activities (e.g. on-site inspections, deeper analysis)
- Quantitative assessment of banks' risk profiles for individual banks and the banking system as a whole
- Enhance market confidence or market disciplineAssessing capital or liquidity levels of supervised banks

2. **The stress testing framework should include an effective governance structure.**

- The roles and responsibilities of senior management, supervisory bodies and individuals responsible for the day-to-day operation of the stress testing framework should be clearly defined.
- The bank's board of directors should have ultimate responsibility for the overall stress testing framework.
- Governance structures should support coordination between micro-prudential and macro-prudential supervisory functions, as stress testing often involves multiple entities within the jurisdiction.
- Stress testing should be used as a risk management tool and to inform business decisions.

3. A clear understanding of the key assumptions and limitations, and regular testing.

- Stress testing can be used for macroprudential purposes to
  - Identify and assess system-level risks and vulnerabilities. Additional sources of stress (e.g. feedback/secondary effects) can be included.
  - Quantitative estimation of system-level capital requirements in crisis situations.
  - Provide information to complement macroprudential policies and tools.
- The stress testing framework should capture important and relevant risks and apply sufficiently severe stress.

4. Scenarios should be sufficiently severe but plausible.

- Reverse stress testing helps identify banks' core vulnerabilities and explores scenarios leading to bank failure.
- Consider individual bank characteristics (e.g. risk profile & business model) or those of the banking sector as a whole.
- Assess whether common scenarios can be applied across the banking sector or whether tailored scenarios are more appropriate for specific parts of the banking sector.

5. Resources and organisational structures should be adequate to meet the objectives of the stress testing framework.

- As stress testing becomes more sophisticated over time, the need for specialised staff, systems and IT infrastructure increases.

6. Stress testing should be supported by accurate and sufficiently detailed data and robust IT systems.

7. Models and methodologies for assessing the impact of scenarios and sensitivities should be fit for purpose.

- Consider the linkages between solvency and liquidity stress.
- Use a degree of expert judgement, including assumptions within models or methodologies.
- Include system-wide feedback or contagion in models, consistent with macroprudential objectives.

8. Stress testing models, results and frameworks should be subject to challenge and regular review.

- Challenging assumptions and results in business lines provides benefits in the interpretation of results and ensures that stress testing is not a purely statistical or hypothetical exercise.
- Independent audit functions should regularly review the bank's stress testing framework and its execution.
- Regularly review the bank's internal stress testing framework.

9. Stress testing practices and results should be communicated across countries and regions.

- Disclosure of stress test results by banks or authorities can help improve market discipline and confidence in the resilience of the banking sector to identified risks.
- The sharing of stress testing information within supervisory colleges should be encouraged.

Source: BCBS (2018)

(4) The introduction of stress testing procedures by supervisory authorities

TThe introduction of direct supervisory stress testing regimes was driven by the recognition that existing bank soundness regulations and risk management practices were insufficient to identify and address serious problems within banks. This shift was prompted by the realisation that Prompt Corrective Action (PCA), despite its name, was often inadequate for taking timely supervisory action. Stress testing has attracted attention as an important supervisory tool to overcome this shortcoming (Yoon and Choi, 20-23).

The United States experienced the Savings and Loan (S&L) crisis in the 1980s, during which the leniency of regulators delayed a rigorous response to troubled banks. As a result, substantial public funds were injected into these banks much later than would have been ideal. To minimise the use of taxpayer funds for troubled banks, the Prompt Corrective Action (PCA) regime was introduced in 1991. Under PCA, if a bank's capital ratio falls below a certain level, supervisors are required to initiate pre-defined procedures for recovery or resolution without exercising discretion. Subsequently, the PCA framework became a standard supervisory regime for global regulation. However, the 2008 Global Financial Crisis (GFC) revealed the limitations of the PCA in providing an effective and timely response. The actual insolvency of banks progressed too quickly due to the complexity of financial instruments such as derivatives. Even for banks that were already considered troubled by the market, their capital ratios, which formed the basis for PCA, remained at high levels for some time, making it difficult to initiate resolution proceedings in a timely manner under existing rules (GAO, 2012). In response, US supervisors supplemented PCA-based prompt corrective action with supervisory stress testing, which allowed them to impose capital replenishment and dividend restrictions based on stress test results. The stress tests introduced in the United States in 2009 were instrumental in overcoming the financial crisis by replenishing bank capital and restoring market confidence, and have become an internationally recognised

supervisory approach.

It is widely believed that the adoption of stress testing as a supervisory tool in the United States can be traced to the development of comprehensive stress analysis methodologies in the International Monetary Fund (IMF) and World Bank's Financial Sector Assessment Programme (FSAP). During the Global Financial Crisis (GFC), stress testing was introduced into the FSAP as a means of assessing the capital adequacy of major banks and banking systems under plausible stress scenarios. The objectives were twofold: (1) to identify banks that were not sufficiently capitalised to meet minimum capital requirements under stress scenarios, and (2) to require banks to address capital shortfalls promptly through retained earnings, market or government support funds, thereby restoring confidence in the banking system (Herring and Schuermann, 20-22).

With the introduction of stress testing in the Financial Sector Assessment Program (FSAP), many central banks and supervisory authorities around the world began to conduct their own bank stress tests. While some countries simply updated the FSAP stress tests, others set out to develop their own independent stress testing methodologies. Ultimately, this approach evolved into the concurrent stress testing frameworks that are widely used by central banks and supervisors today. The sophistication and use of supervisory stress testing has evolved significantly since the Global Financial Crisis (GFC). They have evolved from small, isolated exercises to comprehensive risk assessment programs, often followed by direct policy responses. The evolution of supervisory stress testing has been enabled by a significant increase in the human and physical resources devoted to it.

A notable example of this advanced supervisory stress testing is the aforementioned US Supervisory Capital Assessment Program (SCAP), which was launched in 2009. SCAP published results on a bank-by-bank basis. Banks identified as needing capital were given a six-month period to raise capital, and if they were unable to do so through market means, the U.S. Treasury established a regulatory backstop to provide support. SCAP is widely regarded as

a turning point in restoring confidence in the badly damaged US financial system, because it did not adequately distinguish between relatively sound and vulnerable banks, which traditional minimum capital requirements failed to do. This success led to efforts in other countries to use stress testing as a means of restoring confidence in their banking systems, even under normal financial conditions, and stress testing has become a key tool of prudential supervision.

Stress testing has also been introduced in Europe as a crisis management tool, with the Committee of European Banking Supervisors (CEBS) launching a stress test for the EU banking sector in May 2009 (CEBS, 2009). Unlike the SCAP, the results of the 2009 CEBS stress tests were not published on a bank-by-bank basis, no funding measures were taken as a result of the tests, and CEBS could not force undercapitalised banks to raise capital. As a result, the European stress tests conducted in 2010 and 2011 are judged to have failed to restore sufficient market confidence. The lesson is that supervisors must be able and willing to take swift corrective action against banks that do not have sufficient capacity to absorb stress losses, and that credible and rigorous stress tests must be conducted.

The use of concurrent stress testing as a crisis management tool following the Global Financial Crisis (GFC) has led to a proliferation of published concurrent stress testing frameworks by national supervisors. In response to the crisis, the United States used the Supervisory Capital Assessment Program (SCAP) in 2009 to measure banks' capital shortfalls under stress scenarios and require them to raise capital, thereby restoring market confidence. In 2011, the Federal Reserve introduced the Comprehensive Capital Analysis and Review (CCAR), which focuses on capital planning and distribution to assess whether banks can operate stably under future stress scenarios. US bank holding companies with assets of $50 billion or more were subject to the CCAR stress test, and the results are presented on a bank-by-bank basis. CCAR complements the quantitative assessments of capital adequacy in the stress tests with qualitative assessments of the adequacy of banks' risk management processes.

In 2014, the European Banking Authority (EBA) started to conduct concurrent stress tests for large European banks every two years. The EBA stress tests target large banks in each EU member state, with no single inclusion threshold, but banks with total assets of at least EUR 30 billion are considered for inclusion. EBA tests are conducted on a static-balance-sheet basis, which effectively prevents banks from mitigating the impact of stress by deleveraging. There are no minimum capital requirements for EBA stress tests and banks must take corrective action at the discretion of their national supervisors. Results are reported on a bank-by-bank basis.

In December 2014, the Bank of England introduced concurrent stress testing and currently conducts it for all UK banks with retail deposits in excess of £500 million.The stress test uses a dual scenario approach, comprising an annual 'macroeconomic and financial market stress scenario' and a biennial 'exploratory scenario', which is used to explore emerging threats to financial stability. The Bank of England's tests are conducted on a dynamic-balance-sheet basis, and banks are required to produce annual forecasts for a period of five years from the start of the stress scenario. The Bank of England's approach is closer to that of the EBA than to that of the Federal Reserve, with banks' internal stress forecasts forming the basis of the stress test results. The Bank of England's model is used to challenge and inform banks' initial capital projections. Banks that fall below the hurdle rates (minimum CET1, Tier 1 leverage and global and domestic systemic importance buffer capital requirements) are required to submit new capital plans explaining how they will address their capital shortfalls. The results of the Bank of England's stress tests are reported on an individual bank basis and are used to inform both macro- and micro-prudential policy.

In parallel, the Financial Sector Assessment Program (FSAP) stress testing framework has also evolved in response to the lessons of the GFC. It has shifted its focus from the supervision of individual financial firms to macroprudential supervision in order to better identify macro-financial risk channels and contagion. The FSAP integrates assessments of systemic risk and

the interconnectedness of firms within the financial market.

<Table 4-1> Key Historical Developments in Stress Testing

Early 1990s	Banks conduct small-scale stress tests on their trading accounts.
1996	Introduction of stress testing in the Basel I market risk amendments.
1999	Introduction of the Financial Sector Assessment Program (FSAP) by the IMF and the World Bank, including stress testing.
Early 2000s	Development of stress testing by central banks and supervisory authorities in various countries.
2004	Incorporation of stress testing requirements for credit risk in Basel II.
2009	Implementation of the Supervisory Capital Assessment Program (SCAP) by the U.S. Federal Reserve; initiation of stress tests by the Committee of European Banking Supervisors (CEBS) for the EU.
2010	Introduction of capital buffers to absorb stress impacts in Basel III.
2011	The European Banking Authority (EBA) conducts the Comprehensive Capital Analysis and Review (CCAR) for the EU.
2014	Introduction of an annual stress testing program by the Bank of England (BOE).

Source: Dent et al. (2016). Reprinted from Das et al. (2022).

B. The Causes and Lessons from the Failure of Stress Testing During the Global Financial Crisis (GFC)

The Basel Committee on Banking Supervision introduced stress testing as a regulatory tool for market risk in 1996 and extended it to credit risk in 2004. In addition, the International Monetary Fund (IMF) emphasised stress testing in its 1999 Financial Sector Assessment Program (FSAP), which led to major supervisors developing their own stress testing programs in the early 2000s. However, these early stress tests proved unsuccessful in preparing for and responding to the 2008 global financial crisis due to a combination of three complex factors identified by Anderson et al. (2022):

① Disaster Myopia

In the decade leading up to the crisis, the economic environment was

exceptionally favourable by historical standards. As a result, risk-takers and risk managers, as well as financial authorities, believed that "this time is different" and were convinced that extremely adverse scenarios were impossible. This unwavering belief in the unlikelihood of severe shocks led to a lack of imagination about what could happen if the "impossible" became a reality.

② Financial System Complexity

The increasing interconnectedness of the financial system, coupled with the lack of data on these interconnections, made it a monumental challenge to understand and think through how shocks would propagate and amplify in severe stress conditions.

③ Misaligned Incentives

Given that individual banks had a limited view of the broader financial system, stress situations that escalated within the complex financial system were beyond the capacity of individual banks to manage. Moreover, there were no incentives for banks to conduct stress tests for severe shocks. This lack of incentive was due to the belief that the financial authorities would step in to provide support in the event of a severe shock. In addition, bank employees had a disincentive to conduct stress tests, as severe shocks could lead to loss of bonuses and job insecurity. While financial authorities were motivated to conduct enhanced stress tests, they often failed to consider funding risk and market liquidity risk, focusing primarily on bank solvency.

Anderson et al. (2022) draw lessons from the failure of stress tests prior to the GFC and suggest five key considerations to ensure that stress tests do not fail in the future:

① Comprehensive stress scenario setting for tail events, ② Regular assessment of the impact of concurrent stress scenarios, ③ Assessment of secondary effects: Contagion and spillovers, ④ Integration of stress testing into banks' risk

management frameworks and capital and liquidity planning, ⑤ Public disclosure of stress testing frameworks, results and linkages to supervisory actions. The main contents are as follows.

① Comprehensive Stress Scenario Setting for Tail Events

Prior to the global financial crisis, it was common for banks to take the lead in setting stress scenarios, much like students setting their own exam questions. There was a tendency to include only mild shocks in these scenarios, with loss estimates typically not exceeding a quarter of profits (BCBS, 2009). Reflecting this, supervisory authorities have taken charge of scenario setting in the aftermath of the global financial crisis, and there has been a push to incorporate more extreme scenarios. For example, in the 2018 US Comprehensive Capital Analysis and Review (CCAR), the worst-case scenario assumed a 7.5% decline in real GDP, a markedly more severe level than the GDP decline of just over 4% during the recent financial crisis. However, the precise design of appropriate 'tail events' can vary over time, particularly depending on the state of the financial cycle (BOE, 2015). For example, during economic expansions characterised by rapid credit and asset price growth and compressed risk premia, the left tail of the distribution becomes fatter relative to the normal risk environment. The UK's Financial Policy Committee (FPC) assesses potential imbalances in credit, asset prices, and household and corporate balance sheets to gauge whether risks could increase, and consequently adjusts the severity of scenarios when indicators suggest potential imbalances. More recently, the International Monetary Fund (IMF) has begun to include assessments of a similar concept, called 'GDP at risk', in its Global Financial Stability Report (IMF, 2017).

② Regular Assessment of the Impact of Concurrent Stress Scenarios

The introduction of concurrent stress testing is a prominent feature of post-crisis regulatory reform. Conducting concurrent stress tests has several

advantages.

First, it facilitates peer review and benchmarking. The following table summarises the financial institutions covered by the most recent stress tests conducted by major national supervisors. While there are differences between countries, a common feature is the establishment of criteria for including the largest banks from each country in the stress tests. This is in line with the IMF's proposal to include systemically important institutions in macroprudential stress tests (IMF, 2012).

<Table 4-2> Scope of Recent Stress Tests in Major Countries

	Criteria for Inclusion	Number of Included Banks	Percentage within the Banking Sector
Bank of England (BOE)	Retail deposits of £5 billion	7	Approximately 80%
Federal Reserve (Fed)	Total assets of $50 billion	35	Approximately 80%
European Banking Authority (EBA) / (SSM)	Total assets of €30 billion	48	Approximately 70%
Reserve Bank of New Zealand (RBNZ)	4 major banks	4	Approximately 90%
Reserve Bank of Australia (RBA)	13 major banks	13	Almost 90%

Source: Dent et al. (2016). Reprinted from Das et al. (2022).

Second, conducting simultaneous stress tests allows an assessment of the overall resilience of the system. This is because it can identify common vulnerabilities across banks and the build-up of risks in specific economic and financial sectors.

Third, by allowing supervisors to consider potential amplification mechanisms that may arise from banks' responses to adverse shocks, concurrent stress testing allows for a more comprehensive examination of systemic stability risks (Bank of England, 2013).

③ Assessment of Secondary Effects: Contagion and Spillover

When the impact of secondary effects is considered, the analysis shows that around $300 billion of losses related to subprime mortgages escalated to over $2.5 trillion of potential losses in the global banking sector in just one year (Brazier, 2017). Efforts have been made to model direct contagion through contractual obligations, but direct losses from contagion are generally not large enough to trigger a crisis, and this approach ignores the reality that shocks can propagate before defaults occur. Solvency shocks can reduce the value of interbank exposures without bankruptcy events. Shocks to solvency can increase banks' funding costs, putting additional pressure on solvency conditions, and liquidity stress can amplify shocks. In addition, indirect contagion due to incomplete selling and information asymmetry has been observed as a source of systemic crises. Existing concurrent stress tests typically include some degree of market dislocation and liquidity stress, but integrating the additional risk of severe and widespread fund outflows, with a focus on solvency stress, remains a challenge for supervisors' internal modelling across jurisdictions. However, it should be noted that regulatory reforms since the crisis have significantly increased banks' resilience to severe liquidity shocks.

The modelling of potential feedback effects between banks' lending decisions and the real economy has mainly been addressed outside the scope of regulatory stress tests. The modelling of the feedback between bank lending and the real economy in stress scenarios has taken the form of macroprudential stress test models designed and run by financial authorities.

④ Integration of Stress Testing into Banks' Risk Management Frameworks and Capital and Liquidity Planning

As noted above, stress testing faced difficulties due to "internal incentive issues" prior to the global financial crisis. Recently, the HSBC Group Board set out a vision for stress testing, stating that "stress testing serves as a core component of sound capital planning and risk management, helping authorities to assess the resilience of banks and the system". This reflects a shift in the

positive attitude of financial firms towards stress testing. Conducting concurrent stress tests and stress tests as part of banks' internal capital adequacy assessment processes can add momentum to banks' liquidity and capital planning. However, because incentive issues are inherently difficult to monitor and prevent, financial authorities have invested considerable time and effort in examining the adequacy and quality of banks' stress testing processes.

Supervisors aim to prevent disaster myopia and to reflect new risks at the macroeconomic level through the next generation of advanced stress tests, and banks' internal stress tests can be used as a means to identify and address new risks in their business models. In sum, supervisory and individual bank stress tests should not only inform banks' capital and liquidity planning, but also provide a robust combination for policy and supervisory actions to support resilience to different potential crises.

⑤ Public Disclosure of the Coherence between Stress Testing Frameworks, Results, and Regulatory Actions

Transparency in the stress testing process has several potential benefits. Providing market participants with more information about banks' tail risk exposures through credible stress tests can enhance confidence in the banking system and strengthen market discipline (Goldstein and Sapra, 2013). The appropriate level of transparency is needed, maximising the "signal" while minimising the "noise". Over the past decade, there has been significant progress in transparency on stress testing, with various supervisors disclosing detailed stress scenarios applied and hurdle rates for banks. Many authorities also publish information on the results of stress tests for individual banks and the policy actions taken as a result. Full disclosure of the models and analytical tools used to generate stress test results can facilitate participation and improvement by academics and market participants. However, full model disclosure can potentially lead banks to adjust their portfolios to appear less risky in line with the model ("gaming"), with no guarantee that they are actually less risky, and can also

exacerbate noise and uncertainty. Disclosure of models can lead to dispersion of interest in key judgements and uncertainty in stress test results. Accuracy of communication is important. In cases where bad news is delivered, supervisors should promptly disclose corrective actions, and these corrective actions need to be credible. As stress testing becomes more routine and supervisory modelling and analysis tools mature, transparency is likely to increase further.

2. Introduction Strategy for Macroeconomic Stress Testing in Nepal

In order to introduce macroeconomic stress testing, a concrete strategy needs to be formulated. First, it needs to be decided whether macroeconomic stress testing will be designed on the basis of microprudential stress testing. In addition, decisions need to be made on the implementation of top-down and bottom-up stress testing. Herring and Schuermann (2022) identified seven key issues that need to be addressed when conducting stress testing, including (1) designing stress scenarios; (2) selecting risk factors; (3) considering stress scenarios to mitigate procyclicality of banks; (4) setting pass/fail criteria for stress testing; (5) determining the scope, duration, and frequency of stress testing; (6) selecting models; and (7) communication strategies. In the context of Nepal's stress testing implementation strategy, we will focus on the distinction between macroprudential and microprudential stress testing, the choice between top-down and bottom-up stress testing, and the seven decision-making challenges identified by Herring and Schuermann (20-22).

A. Microprudential and Macroprudential Stress Testing

Microprudential and macroprudential stress tests differ in the nature of their assessment (Adrian et al., 2020).

Microprudential stress testing assesses whether an individual bank's capital (or liquidity) is adequate under specified conditions. It is forward-looking and

primarily for supervisory purposes, focusing on whether a bank 'passes' or 'fails' the test. If a bank fails the test, supervisory action is taken.

Macroprudential stress testing, on the other hand, focuses on financial vulnerabilities that could lead to systemic risk. Financial vulnerabilities refer to the amplification of adverse shocks due to imbalances in the financial environment and other financial characteristics (such as high leverage, pricing errors, risk concentration, lack of liquidity management, etc.). The objective of macroprudential stress testing is to identify financial vulnerabilities that could undermine financial stability in the economy as a whole. While it also assesses the soundness of individual financial institutions under crisis scenarios, it differs in that it can lead to macroprudential supervisory measures, such as debt-to-income (DTI) and loan-to-value (LTV) ratios and countercyclical capital buffers.

Meanwhile, macroprudential stress tests aimed at reducing systemic risks need to be based on microprudential stress tests for systemically important banks. This is necessary because, through maturity and liquidity transformations and credit risk transmission channels, banks may engage in behaviours that can lead to systemic risks. In this context, Bassett and Rapporport (2022) explain approaches to implementing macroprudential stress tests.

Since the global financial crisis, many countries have conducted regular microprudential stress tests. In advanced economies, the use of these stress tests for macroprudential policy purposes has increased over time. If we define the objective of macroprudential policy as reducing systemic risks, such as widespread disruptions in the supply of financial services that could have adverse effects on the real economy, the implementation of macroprudential policy objectives in stress tests would involve pursuing three intermediate objectives: (1) enhancing the resilience of the financial system to shocks,)2) addressing the build-up of systemic vulnerabilities over financial cycles (leaning against), and (3) limiting structural vulnerabilities arising from the interconnectedness of financial intermediaries or the critical role of individual financial intermediaries.

Achieving these objectives in stress tests that embody macroprudential policy objectives may involve developing a new stress testing framework, adding macroprudential elements to existing microprudential stress tests, incorporating them as part of scenario variables, or using structural models.

On the other hand, the regulatory stress tests that are widely used by supervisors around the world are not easily categorised as macroprudential stress tests. While these regulatory stress tests are comprehensive, they primarily use microprudential stress testing techniques to assess the impact of large adverse tail events on individual banks. For example, the stress tests conducted jointly by the US Federal Reserve (CCAR) and the European Banking Authority across member countries apply a wide range of large adverse shocks to all financial risks faced by banks, such as market, credit, counterparty and funding risks. These regulatory stress tests do not directly take into account market interconnectedness, endogenous risk (and leverage) within the system as a whole, or the impact of the financial sector on the real economy.

The stress tests conducted by the Financial Supervisory Service (FSS) in Korea encompass both microprudential and macroprudential supervision. The FSS's stress test model is primarily designed to measure the solvency of individual banks in stress situations, as it is microprudential in nature. Therefore, in response to the COVID-19 shock, the FSS instructed individual banks to limit dividends based on stress tests in order to preserve the banks' fund intermediation functions. In addition, the FSS actively uses stress tests for macroprudential supervisory purposes, such as pushing for the addition of liquidity and transmission effect models.

Given that Nepal is currently in the early stages of conducting microprudential stress tests for individual banks, it may be prudent to initially introduce an advanced form of microprudential stress testing with a focus on solvency. Subsequently, a phased approach could be considered to add macroprudential elements, including transmission effects.

B. Top-Down and Bottom-Up Stress Testing

Stress testing can be categorised into top-down and bottom-up approaches. In a top-down approach, supervisors take the lead in conducting stress tests and apply identical scenarios to all banks at the same time. In a bottom-up approach, individual banks calculate the impact of stress using their own models and report the results to supervisors, who may use their models to validate the results. There are differences between these two approaches. Supervisors conducting top-down regulatory stress tests directly estimate the impact of stress on banks based on data provided by the banks. For example, the US Federal Reserve's Supervisory Capital Assessment Program (SCAP) is a prominent example of a top-down stress test. The Federal Reserve calculates the impact of stress on individual banks using data provided by the banks. In contrast, the stress tests conducted by the European Banking Authority (EBA) follow a bottom-up approach. Under this approach, banks individually calculate the impact of stress using their own models, report the results to supervisors, and supervisors use their models to verify the banks' results.

Both top-down and bottom-up approaches have their advantages and disadvantages. Top-down stress testing offers the advantage of comparability across banks, as the same methodology is applied to all banks, ensuring rigour and fairness in supervisory actions, such as capital increases and dividend restrictions, based on stress test results. In addition, in the United States, specific details of the calculation models are not publicly disclosed. This prevents banks from exploiting the calculation method to avoid unfavourable stress test results, while effectively addressing excessive risk-taking (gaming). However, a drawback of top-down stress testing is that it does not effectively integrate banks' risk management and stress testing. To address these issues, the US Comprehensive Capital Analysis and Review (CCAR) takes into account both the capital plans submitted by banks and the results of the Federal Reserve's internal models. This dual approach combines a quantitative assessment with a qualitative evaluation of

banks' risk management.

Bottom-up stress testing encourages banks to integrate stress testing into their internal risk management systems. Since the global financial crisis, there has been a growing emphasis on integrating stress testing into the core of a bank's overall risk management system, going beyond mere compliance with minimum regulatory requirements. The bottom-up approach allows banks to conduct stress testing directly and provides supervisors with an opportunity to review and guide improvements in banks' stress testing practices. However, bottom-up stress testing poses challenges in terms of comparability and consistency of results across banks, as each bank uses its own models. This can lead to debates about the imposition of formal supervisory actions based on stress test results. For example, in the European Union (EU) stress tests, banks calculate the impact of stress using their own models in a bottom-up process, which is then verified using the European Central Bank's (ECB) top-down model. However, the results are primarily used as key assessment criteria in the Pillar 2 supervisory review, rather than directly informing formal supervisory measures such as dividend restrictions.

Moreover, the implementation of a bottom-up stress test requires banks to have sufficient risk management capabilities to develop their stress test models. In Korea, the Financial Supervisory Service (FSS) conducts both bottom-up and top-down stress tests based on scenarios developed jointly with the Bank of Korea, and allows banks to conduct their own stress tests based on their models. The Bank of Korea also conducts its own top-down stress tests. While the FSS stress tests were used as the basis for the dividend restriction system during the COVID-19 pandemic in 2021, they were not operationally linked to supervisory actions related to capital adequacy. As a result, there was no rigorous comparison and validation of the results of the bank-specific bottom-up stress tests with the FSS top-down stress tests.

The Financial Supervisory Service (FSS) in South Korea is currently pushing for the introduction of a stress buffer capital system for banks based on the

results of stress tests, similar to the approach in the European Union (EU). This system aims to impose different capital requirements on banks according to the results of stress tests. As reported on 21 September 2023, the FSS has initiated an analysis of banks' crisis response and loss-absorption capacity. It is considering a stress test that would impose an obligation to hold buffer capital, similar to the EU's bottom-up stress test methodology. A common set of stress testing criteria is being developed to ensure comparability and consistency across banks.

In Nepal, stress testing is not common for most banks, except for a few foreign banks such as Standard Chartered. The stress tests conducted by the financial authorities in Nepal involve assigning stress scenarios directly to risk factors, which may not be as comprehensive as EU-style stress tests. While these tests ensure comparability across banks, they may lack integration with banks' risk management and have limitations in terms of scenario stringency and methodology. Therefore, in Nepal, it is considered necessary to first develop a top-down stress testing model that takes into account available data and then establish minimum standards for stress testing methodologies through discussions with banks. Banks can then conduct bottom-up stress tests using their own models and the results can be used for validation by the NRB.

A. Other Selected Tasks for the Establishment of the Stress Testing System

(1) Design of Stress Scenarios

Scenario design is the most critical aspect of stress testing. It is well known that scenario design can be challenging, mainly due to the tendency towards disaster myopia, where it is difficult to design scenarios correctly in times of crisis compared to times of financial stability. Financial systems appear strongest when they are most vulnerable. Moreover, frequent shocks can be statistically identified and managed without undermining financial stability. However, rare and irregular shocks, which do not provide a comparable statistical record, can make

it difficult to predict tail events that pose a threat to financial stability.

Stress tests are designed to help banks prepare for these difficult-to-predict virtual shocks. Nevertheless, there can be conflicts between supervisors and banks over how severe the scenarios should be. Scenarios based on statistical techniques such as Growth at Risk (GaR) are essential to maintain confidence in stress tests. However, in cases where historical data on crisis situations is limited, there may be limitations in properly reflecting tail events or introducing new shocks such as the COVID-19 pandemic. Supervisors may therefore consider the following issues in turn when setting up stress scenarios:

(1) The conventional approach to scenario design for stress testing is based on historical empirical data related to actual banking crises or the distribution of risk factors. However, the risk inherent in this approach is that history rarely repeats itself.

(2) An alternative approach to scenario design relies more on expert judgement than on historical cases. However, relying on expert judgement may lead to more room for debate about the validity of scenarios.

(3) Another alternative to adjust the severity of stress scenarios is to use the reverse stress testing technique, which aims to identify the types and magnitudes of shocks that could seriously threaten a bank's solvency.

In the case of South Korea, stress scenarios were previously developed on the basis of expert opinion. However, they are now derived statistically using the GaR method to generate plausible severe crisis scenarios. South Korea has experienced several financial crises, such as the foreign exchange crisis in 1999, the credit card crisis in 2003, the global financial crisis in 2008 and the savings bank crisis in 2010. Therefore, statistical scenario design has proved useful to some extent.

In Nepal, there is no known instance of financial crises with available statistical data in the past. Consequently, there may be limitations to scenario design based on statistical techniques. Nonetheless, despite these challenges, a statistical approach serves as a crucial starting point for scenario analysis.

Initially, attempts can be made to design scenarios based on GaR within the possible scope. Second, expert opinions on significant risk factors, such as the linkage with the Indian economy, fixed exchange rates, and remittances from overseas workers, can be considered to complement scenarios. Finally, if these methods prove to be infeasible, the option of scenario design through reverse stress testing may be explored.

(2) Selection of Risk Factors

Stress tests can be categorised into solvency stress tests, which mainly analyse credit, market and interest rate risks affecting solvency, liquidity stress tests, which model funding liquidity risk and market liquidity risk, and add-on models specific to macroprudential concerns, which address the amplification of transmission effects and feedback loops. While liquidity stress tests are typically conducted separately from solvency stress tests, recent efforts have been made to integrate liquidity risk into solvency stress tests. The Liquidity Coverage Ratio (LCR) regime introduced by Basel III can be seen as a form of stand-alone liquidity stress testing, assuming a one-month stress scenario. Historically, most banking crises have been caused primarily by loan defaults, leading to loan loss provisions. It is therefore crucial to develop appropriate credit risk models. It is also desirable to include models for market risk, interest rate risk and operational risk.

Typically, scenarios are based on shocks to macroeconomic indicators such as unemployment rates or GDP growth rates. However, these real macroeconomic variables tend to lag behind financial crises. Therefore, Borio et al. (2012) emphasised the need to focus more on financial cycle indicators in financial stability scenarios, such as credit growth rates, which move in tandem with changes in real estate prices. Adrian et al. (2020) also argued that it is essential to take into account cyclical vulnerabilities during boom periods. They highlighted the following risk factors that should be considered: (1) Leverage

measures such as sectoral credit growth rates and the credit to GDP gap are widely used as indicators of cyclical vulnerabilities. (2) Risk premia, deviations from long-term trends in house prices and other risk pricing indicators are valuable in assessing cyclical vulnerabilities. (3) Structural vulnerabilities, such as changes in international capital flows in emerging markets, increased dollar-denominated financial intermediation and high interconnectedness among financial firms in advanced economies, can amplify shocks. (4) Finally, institutional vulnerabilities, such as weaknesses in anti-money laundering systems, are also factors to consider.

In South Korea, the Bank of Korea's SAMP model classifies macroeconomic risk factors into (1) real variables, (2) financial variables, and (3) overseas variables. Real variables include economic growth rates, unemployment rates, inflation rates, and fluctuations in housing prices. Financial variables include exchange rate movements, stock price volatility, corporate bond credit spreads and government bond yields. Overseas variables include world economic growth rates, changes in world trade volumes, US Treasury yields and international oil prices.

In Nepal, the primary focus should be on developing solvency stress tests, with an emphasis on credit risk. Market risk and interest rate risk should also be included, with consideration given to adopting the Basel III interest rate risk in the banking book (IRRBB) standard methodology, an upgrade from current business reporting for monitoring interest rate risk. On liquidity risk, Nepal has established a system to monitor detailed risk profiles through call reporting. However, there is a need to consider implementing the Basel III Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR) regulations to align with international standards. In addition, consideration could be given to phasing in the macroprudential add-on after the solvency stress test model is refined. The Korean Financial Supervisory Service is still in the experimental phase of implementing a macro-prudential add-on model.

In Nepal, while a considerable amount of time series data is available for

macroeconomic indicators that are essential for building solvency stress test models, there is insufficient time series data for financial variables. Therefore, it is necessary to include significant risk factors such as financial sector leverage, risk pricing and variables related to the Indian economy, Indian currency, fixed exchange rate regime, foreign exchange reserves and remittances from overseas workers, along with variables related to the real economy that affect banks' provisioning costs. Statistical significance is to be confirmed.

(3) Consideration of Stress Scenarios to Mitigate Bank Pro-Cyclicality

Risk-based capital rules are inherently pro-cyclical. As measured risks increase, so does the required capital, creating incentives for banks to reduce lending during economic contractions and to increase lending during economic expansions. Stress tests are designed to account for potential future shocks, which means that they can partially offset the incentives to increase lending even during economic expansions. For example, the Federal Reserve has increased the countercyclical nature of its stress scenarios by allowing them to automatically worsen as unemployment rates decline, although the effectiveness of this measure is considered limited. In Nepal, to mitigate procyclicality, it is important to consider incorporating into the prudential requirement that banks should be dealt with if they fail to meet the hurdle rates in the stress tests, as discussed below.

(4) Design of Stress Scenarios

The US Federal Reserve explicitly specifies five hurdle rates for stress tests, including the Common Equity Tier 1 capital ratio, while the EBA has refrained from providing pass criteria since 2016, instead using Pillar 2 assessment factors. The EBA's approach may lead to less clear stress test results and difficulties in market assessment. Moreover, banks that do not pass the stress test hurdle rates may be incentivised to shrink their assets to meet the standards, potentially

exacerbating pro-cyclicality in times of crisis. Therefore, it is necessary not to allow banks that fall short of the hurdle rates to meet the standards by reducing assets. In South Korea, stress tests were conducted during the global financial crisis using a simple model. For banks that did not meet the hurdle ratio, the Financial Supervisory Service did not require them to meet the capital adequacy ratio, but instead calculated the amount of capital needed to meet the capital adequacy ratio for each bank and advised them to raise capital individually.

In Nepal, it is crucial that the future application of stress test pass criteria emphasises capital enhancement rather than capital ratio compliance to avoid pro-cyclicality issues.

(5) Scope, Period, and Frequency of Stress Tests

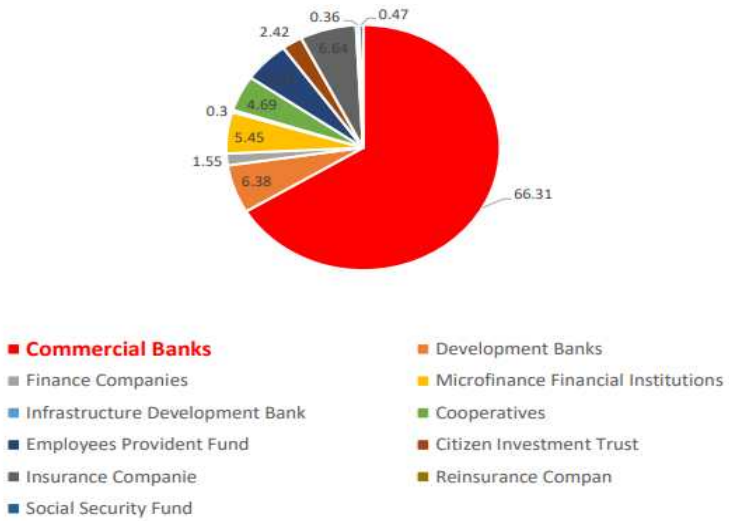
Currently, stress tests in most countries focus on the banking system, and major countries even conduct stress tests for the largest banks, which account for 70-80% of banking assets. This is mainly because the main objective of stress testing is to address systemic risk issues, and banks, especially systemically important large banks, are considered to be at the core of the financial system. In addition, supervisors, such as central banks, typically have clear supervisory and data access powers over banks, but not necessarily over non-bank financial companies. The scope of financial institutions subject to stress tests may expand or contract over time, depending on the purpose of the stress tests. In particular, as the share of bank assets in the financial system declines in many countries, consideration should be given to expanding the scope of stress testing to non-bank financial institutions. In South Korea, stress tests were initially developed and applied to banks and later extended to non-bank financial institutions.

The impact of stress scenarios takes a considerable time to manifest itself in banks' balance sheets and income statements. As a result, the time horizons for stress scenarios and impact calculations are typically set at years. The typical stress testing period in many countries is 2-3 years. In South Korea, the stress

testing period is 2 years.

In Nepal, given that 26 commercial banks account for 66.31% of total financial system assets in 2021, or about two-thirds, it is reasonable to conduct stress tests for commercial banks first and then consider expanding the scope to non-bank financial institutions in later stages. A stress test period of 2 years should be considered, taking into account cases in other countries.

<Figure 4-1> The composition of total assets in Nepal's financial sector (%, 2021)



Source: Nepal Rastra Bank (2023)

(6) Model Selection

The US Federal Reserve uses only its own model to determine whether banks have passed stress tests, while many supervisors, including the EBA, consider the estimates based on banks' internal models to be the primary determinants of final losses, with supervisors' models serving as complementary tools to validate banks' results.

In general, stress testing models aim to measure the impact of scenarios on a bank's income statement and balance sheet, which ultimately affect its capital adequacy ratio. However, as these models primarily deal with accounting

changes, they may not adequately reflect the sharp decline in the value of bank assets during financial crises. In light of these considerations, some academics have proposed stress-testing models that rely more on market data, such as bank share prices, rather than accounting data. However, regulators have been reluctant to adopt market data-based stress tests due to concerns about excessive stock price volatility and exacerbation of pro-cyclicality issues. South Korea, for example, uses an accounting data-based stress testing model.

In Nepal, it is considered preferable to adopt an accounting data-based stress test model, which is widely used by many supervisors, rather than a market data-based stress test model. However, if an accounting data-based stress test is conducted, it is important to ensure the accuracy of accounting in reflecting credit risks and to consider the implementation of IFRS9 for the recognition of expected losses in the future. In addition, the amendments to the asset classification regulations prepared by the NRB in 2022 and the IMF's joint initiative with Nepal to review the asset portfolio of the ten largest banks in 2024 (IMF, 2023) will play an important role in facilitating rigorous accounting-based stress testing.

(7) Communication Challenges

One of the key objectives of stress testing is to restore or maintain confidence in the banking system and banking supervision. Therefore, it is necessary to disclose the results of stress tests to the public. However, if there is a suspicion that the scenarios do not adequately reflect severe situations, public disclosure of the stress test results may not be very helpful.

On the other hand, the disclosure of stress test results for individual banks has its advantages and disadvantages. In principle, providing more information about individual banks can reduce uncertainty about the condition of the bank and increase confidence in the financial system. It is also expected to strengthen market discipline and improve regulatory accountability, while preventing

regulatory forbearance. However, disclosing the capital shortfalls of individual banks can exacerbate market fears and weaken the financial system. Therefore, disclosure of capital shortfalls of individual banks should be accompanied by a credible plan to increase capital within a relatively short period of time. Major countries such as the United States and the EU disclose stress test results for individual banks, but Korea has not yet disclosed stress test results for individual banks. The Financial Supervisory Service (FSS) of Korea is considering the possibility of public disclosure as it introduces stress capital buffer requirements in the near future.

In Nepal, the objective is to disclose individual bank stress test results. However, it is prudent to refrain from premature disclosure at a stage when the reliability of the stress test model and capital build-up plans for undercapitalised banks are not in place. However, if the lack of confidence in the soundness of the banking sector escalates during an actual financial crisis, it may be feasible to consider the strategy of disclosing individual bank stress test results in order to reduce uncertainty and restore market confidence.

3. Construction Approach of Macroeconomic Stress Test Model in Nepal

A. Scenario Setting

Scenario design, the starting point and most important step in stress testing, is covered separately in “Chapter 5: Macro Stress Test Scenario Design and Estimation Methodology”.

B. Solvency Stress Test

(1) Concept of Solvency Stress Test

Solvency stress tests are used by financial institutions, such as banks, to measure resilience under stress scenarios and to identify vulnerabilities. Resilience is assessed through the adequacy of bank capital under stress, where adequacy is determined by comparing "actual capital" at the time of the stress test, adjusted for expected net losses under stress scenarios, and "required capital". Required capital is calculated to meet the minimum capital adequacy ratio for risk-weighted assets, taking into account changes in asset size and credit risk parameters under stress conditions (Adrian et al., 2020).

To conduct stress tests, it is necessary to estimate changes in income statements and balance sheets under stress scenarios, going beyond the simple measurement of losses by risk source. P&L projections are essential to reflect changes in bank capital. Stress tests focus primarily on credit risk-related provisions, taking into account changes in market risk, net interest income (NII) and various operating costs. Balance sheet projections are necessary to measure changes in risk-weighted assets. However, for banks using standardised approach, as opposed to IRB models, it is difficult to reflect changes in risk weights due to rating downgrades, which reduces the importance of balance sheet estimation.

(2) Historical Development of Solvency Stress Test Methodology

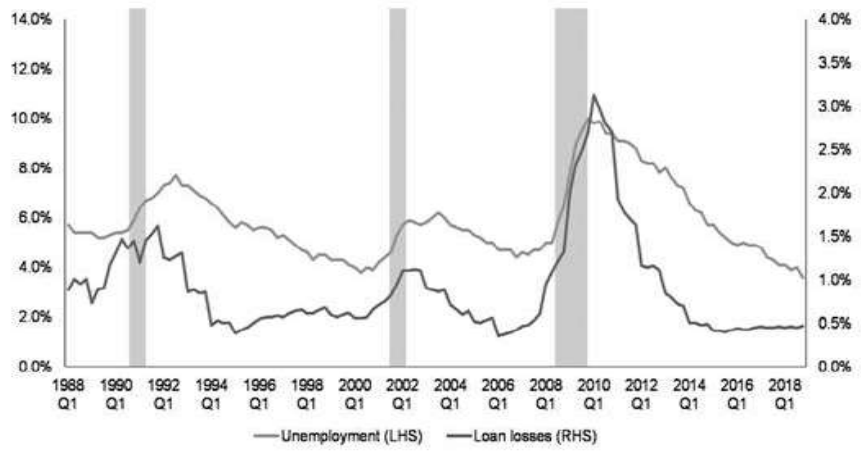
In the early days of stress testing, aggregate variables were used to assess the impact of macroeconomic variables, such as GDP growth rates, on banks' credit risk. For example, Pesola (2007) conducted stress tests using aggregate variables to assess the impact of fluctuations in macroeconomic variables, such as interest rates, inflation rates and GDP, on the non-performing loan ratio of the banking sector as a whole. Pesola argued that credit losses could be significantly affected by unexpected shocks, especially in cases of high financial fragility as measured by leverage and other indicators. The use of aggregate variables in stress tests has the disadvantage of assuming that all banks in the system have the same quality of credit exposures. However, banks may pursue riskier strategies or have

more robust risk management systems, leading to uneven portfolio and market losses across banks. As a result, different credit risk models that incorporate both common macroeconomic factors and individual risk factors have been used in stress testing (Drehmann, 2009).

The most widely used approach to incorporate portfolio and market losses that may differ across banks under common stress scenarios is the Basel Framework approach based on probability of default (PD), loss given default (LGD) and exposure at default (EAD). The Basel Framework provides the basis for estimating expected and unexpected losses under stress. The Basel Committee's minimum capital requirement is equal to the difference between the expected loss and the loss that could occur at the 99.9th percentile of the adjusted loss distribution under the Asymptotic Single Risk Factor (ASRF) model.

A brief explanation of the ASRF model according to BCBS (2005) is that when a portfolio consists of many loans, the idiosyncratic risks associated with individual loans tend to cancel each other out and do not significantly affect the credit risk of individual loans. Instead, it is the systemic risk (or system-wide risk) affecting multiple loans that significantly affects portfolio losses. The ASRF model represents systemic (or system-wide) risks, such as industry or regional risks that affect all borrowers, as a single systemic risk factor.

<Figure 4-2> The trend of the unemployment rate and the bank's loan loss provision ratio in the United States

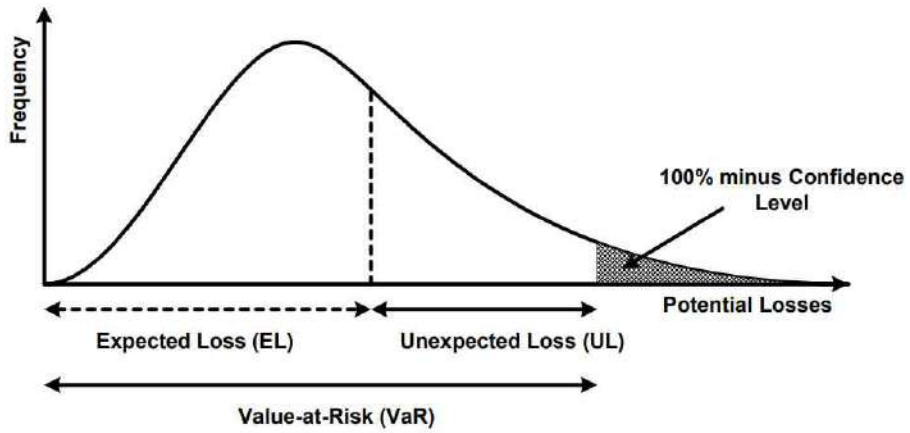


Data: Cope et al.(2022)

<Figure 4-2> shows the unemployment rate in the United States and the cost of credit losses to banks. In the case of the United States, the unemployment rate is a good indicator of systemic risk factors that effectively explain changes in bank credit risk. Therefore, a key aspect of solvency stress testing is to accurately identify the systemic risk factors that affect banks' credit risk.

Next, the loss that can occur at the 99.9th percentile refers to the estimation of conditional expected losses. Applying Merton's (1974) single-asset model to credit portfolios, it can be interpreted that if the value of assets, which varies according to a probability distribution over a period of time, falls below the amount of liabilities, this leads to default. Vasicek (2002) showed that, under certain conditions, Merton's model can be extended to specific ASRF loan portfolios.

<Figure 4-3> The calculation principles for the required capital for credit risk by the Basel Committee



Data: BCBS(2005)

In <Figure 4-3>, the shaded area to the right of the curve represents the probability that losses will exceed the sum of expected losses (EL) and unexpected losses (UL). Subtracting this probability, i.e. the likelihood that a bank will be unable to cover its liabilities with loan loss provisions and capital, from 100% is the confidence level. The corresponding threshold at this

confidence level is called the value-at-risk (VaR). Capital requirements are set as the difference between EL and VaR. If EL is covered by loan loss provisions, the probability that a bank can remain solvent for one year is equal to the confidence level. The Basel Committee has conservatively set the conditional expected losses required for capital calculation within a fixed 99.9% confidence level. In theory, this corresponds to stress scenarios that could occur once every 1,000 years. Despite this conservative approach to the calculation of capital requirements, the historical development of the stress test mentioned above shows that even more severe stress scenarios are needed.

For banks using the internal ratings-based (IRB) approach, the expected credit losses for a bank's loan portfolio are the product of the probability of default (PD), the loss given default (LGD) and the exposure at default (EAD) for each sector of the bank's loans. The same formula, using estimated stress parameters, can be applied for stress testing purposes. The core of solvency stress testing for credit risk is therefore the derivation of PD, LGD and EAD values under stress conditions. Stress tests assess whether a bank's capital meets a predetermined hurdle rate, taking into account conditional expected losses.

From an accounting perspective, the introduction of the Expected Credit Loss (ECL) model based on IFRS 9 in 2014 has been replacing the previous Incurred Loss model since 2018. Five G20 countries, including China, Indonesia, India, Japan and the United States, have not adopted IFRS. However, Japan recognises IFRS as an accounting standard that companies can choose to adopt. The United States adopted the Current Expected Credit Loss (CECL) model, which is equivalent to IFRS 9, in 2016 and became effective in 2019. In this context, the International Monetary Fund (IMF) developed an accounting loss model based on systemic risk factors and estimated transition matrices (TR12, TR13, TR23) between stages 1, 2 and 3 to incorporate accounting losses into stress tests for major countries, including South Korea (Gross et al., 2020). To achieve this, the estimation of transition rates (TR) such as TR12 (Stage 1 to Stage 2), TR13 (Stage 1 to Stage 3), and TR23 (Stage 2 to Stage 3) is crucial, and in practice

these are estimated using a simple regression model that relates these rates to the probability of default (PD). In addition to PD data, a time series of transition rates (TR), even for shorter periods, is required to make such estimates. As Nepal is in the process of adopting IFRS 9, it is likely that it will be able to use transition rates between Stages 1, 2 and 3 to further improve stress testing in the future.

(3) Calculation of Credit Losses in Nepal

① Utilization of PD and LGD Data

The Probability of Default (PD) model is a critical factor in determining the level of credit losses and has the greatest impact on the overall stress test results. Therefore, it is essential to develop this model in a sophisticated manner. The first step in developing a PD model is to secure historical default rate data. While it is highly desirable to use observed default rate data, in cases where this data is not readily available, alternative estimates based on NPL ratios or similar metrics can be used. In the case of Nepal, banks predominantly use the standardised approach rather than the internal ratings-based (IRB) approach to calculate the capital adequacy ratio. As a result, there may be a lack of time series data for PD, LGD and EAD statistics for each bank. In cases where it is difficult to obtain observed PD time series data for each bank, alternative measures such as the new NPL ratio or the NPL ratio differential may be used, as shown in <Table 4-3>. The new NPL ratio provides the closest approximation to PD when strictly adhering to the principles of the asset classification criteria, where accounts overdue more than 90 days are classified as substandard. However, this method requires additional data on write-off rates (WROt) and cured rates (CUREt). On the other hand, the use of the NPL ratio differential is more accessible, but ignores the impact of write-offs or recoveries, leading to lower accuracy.

<Table 4-3> Available Probability of Default (PD) Data and Substitutes

	Concepts	Features
Observed default data	The proportion of amounts (or borrowings) that will become delinquent within one year, as a proportion of amounts (or borrowings) that are healthy at baseline.	Borrower-specific and account-specific default data must go back far enough in time. Data is mainly available by year
New NPL ratio	$NPL_t=NPL_{t-1}-NPL_{t-1}*WRO_t-CURE_t+D_t$ ➧ $DR_t = \frac{NPL_t - NPL_{t-1}(1-WRO_t) + CURE_t}{PL_{t-1}}$	In addition to the NPL ratio, additional data on charge-offs and cure rates are required. Quarterly data available.
NPL ratio differential	$D_t = NPL_t - NPL_{t-1}$	Less accurate as it is affected by charge-offs, recoveries, etc. Quarterly data available

Data: Kim Jung-il(2023)

In the case of Nepal, it is considered desirable at this stage to use the new NPL ratios as a proxy for default ratios. In addition, given that a bank's credit losses during the period are ultimately reflected in the profit and loss account as provisions for credit losses, the banks' credit costs have been directly extracted as follows:

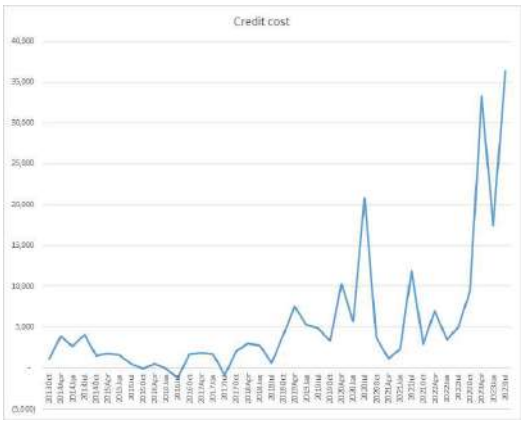
Credit costs = provisions for credit losses + write-offs of provisions - write-backs of provisions for credit losses - recoveries on written-off loans.

These loan loss provisions are primarily reflected in the half-year and annual financial statements, resulting in a seasonal pattern as shown in <Figure 4-4>. Taking into account both the seasonal effect and the increase in the Bank's lending activity, the ratio of the four-quarter moving average of credit costs to total loans is shown in <Figure 4-5>. The ratio of credit costs to total loans fluctuates considerably, ranging from -0.01% to 0.56%. In particular, it has increased almost fourfold over the past year, from 0.15% in October 2022 to 0.56% in July 2023.

Regarding the direct use of provisions for credit losses in stress tests, the IMF

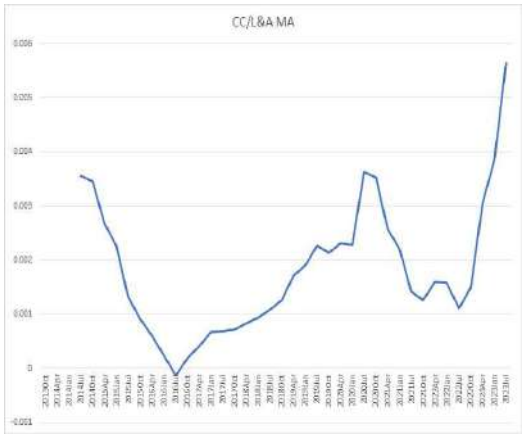
has indicated that banks that calculate credit risk under the standardised approach generally use provisions for credit losses, typically defined for non-performing loans (NPLs) that are more than 90 days past due, as a proxy for expected losses (Adrian et al., 2022). In addition, there is a case where the IMF conducted stress tests as part of the Financial Sector Assessment Program (FSAP) in Israel in 2012, directly modelling provisions for the household sector (IMF, 2012).

<Figure 4-4>
Trend of Credit Costs Amount in Nepal Commercial Bank (2013.10~2023.7)



Sources: NRB

<Figure 4-5>
Trend of Credit Costs (4Q Moving Average) to Total Loan Amount Ratio in Nepal Commercial Bank (2013.10~2023.7)



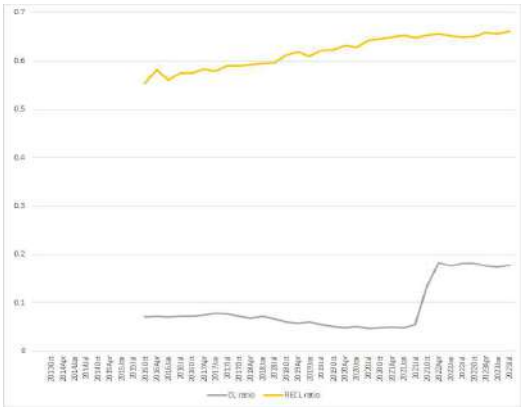
Sources: NRB

To better explain the variability in the magnitude of credit costs, it is desirable to disaggregate a bank's exposure and estimate default rates separately. In this regard, the Bank of Korea's SAMP model and the Financial Supervisory Service's STARS model disaggregate exposure under Basel III standards into five borrower characteristics: large corporates, small and medium enterprises (SMEs), residential mortgages, retail (household), and credit cards, and estimate default rates for each.

In Nepal, the situation is such that exposure is not broken down into these

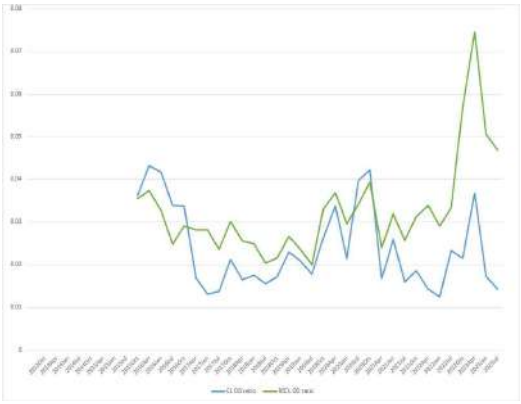
categories in the banks' call reports. However, in order to examine whether the variability in the magnitude of loan losses can be explained, it is suggested that the data available through call reports should first be used to distinguish consumer (household) loans and mortgage loans separately from total loans. This may involve distinguishing between the delinquency rate on total loans, the delinquency rate on consumer loans and the delinquency rate on real estate mortgage loans and assessing whether these distinctions help to explain the variation in the magnitude of credit costs.

<Figure 4-6>
Trend of Real Estate Mortgage Loans and Consumer Loans Ratio in Nepal Commercial Bank
(2015.10~2023.7)



Notes : CL ratio : Share of consumer loans (%) RECL ratio : Share of real estate mortgage loans (%) Sources : NRB

<Figure 4-7>
Delinquency Rate of Real Estate Mortgage Loans and Consumer Loans in Nepal Commercial Bank
(2015.10~2023.7)



Notes : CL OD ratio : Delinquency rate of consumer loans (%) RECL OD ratio : Delinquency rate of real estate mortgage loans (%) Sources : NRB

<Figure 4-6> shows the trend in the proportion of real estate mortgage loans and consumer loans of commercial banks in Nepal since October 2015. The proportion of real estate mortgage loans has continuously increased from 55.4 per cent in October 2015 to 66.1 per cent in July 2023. On the other hand, the proportion of consumer loans has increased significantly from 7.0% in October 2015 to 17.8% in July 2023, with a noticeable spike from October 2021. In addition, <Figure 4-7> shows the evolution of the delinquency rates for real

estate mortgage loans and consumer loans. These rates remained relatively stable in 2021, but started to increase significantly after October 2022, reaching a peak in April 2023, with a delinquency rate of 7.5% for real estate mortgage loans and a delinquency rate of 3.7% for consumer loans. Therefore, possible explanations for the sharp increase in credit loss ratios from October 2022 onwards could include: 1) The continued increase in the share of real estate mortgage loans, exacerbating financial vulnerability. 2) An increase in household loans during the COVID-19 period, exacerbating potential financial vulnerability. 3) A direct relationship between the significant increase in delinquency rates on real estate mortgage loans after October 2022 and the subsequent increase in credit costs.

In addition, values for LGD (loss given default) and EAD (exposure at default) are also required to estimate credit loss models. While EAD is less critical when a bank's credit exposure consists mainly of simple forms such as general loans, LGD should be estimated separately as it tends to increase in stress situations. In the case of South Korea, the Financial Supervisory Service has constructed LGD estimation models by distinguishing between collateral status and borrower characteristics. The credit LGD estimation models are based on time series data of realised credit LGDs and realised credit conversion rates for large corporates, other retail and self-employed individuals from systemically important banks since 2003, with the models explained by default rates, debt-to-income ratios and short- and long-term interest rate spreads. Collateral LGD estimation models distinguish between residential real estate, commercial real estate and other real estate, using time series information on net recovery rates (market price-to-auction ratio) from court auctions from 1996 to 2016. In addition, in the case of the Bank of Korea's SAMP model, LGD was estimated by appropriately modifying the Altman et al. (2003) and S&P (2010) models to fit the Korean situation, using default rates as explanatory variables, as follows (Bank of Korea, 2012).

$$LGD_S = LGD_C + 2.1535 \times (PD_S - PD_C)$$

LGD_S and LGD_C are the scenario and actual values of LGD, while PD_S and PD_C are the scenario and actual values of PD. The value of 2.1535 is the LGD sensitivity coefficient of PD from the S&P (2010) model.

For Nepal, given that the proportion of real estate mortgage loans is currently as high as 66.1% as of July 2023 and considering the fluctuation in real estate prices, it is essential to establish an LGD model for real estate mortgage loans. However, Nepal does not yet have comprehensive statistics on real estate prices, and there are no adequate controls in place for evaluating real estate prices by third parties when banks use real estate as collateral. Therefore, at this stage, it may be necessary to explore methods like the one adopted by the Bank of Korea's SAMP model, which estimates LGD using PD as an explanatory variable. Additionally, with the adoption of IFRS 9, the LGD values derived by individual banks can be considered.

② Overview of Credit Loss Models

The core of a credit loss model is to explain variations in credit losses using macroeconomic and financial variables. Factors affecting bank credit losses can generally be categorised into macro variables, such as economic growth rates and unemployment rates, and financial variables, which represent accumulated financial vulnerabilities. It is known that the easing of financial conditions has a short-term effect of mitigating economic downturns, but tends to increase risks in the medium term (Adrian et al., 2018).

Moreover, the credit loss model is mainly centred on the PD (probability of default) model, with the LGD (loss given default) model also being an important component. The PD model is the most critical factor in determining the magnitude of credit losses and has the greatest impact on the overall stress test results. It should therefore be developed with great care. There are various methods for constructing PD models, including those based on the Merton

model, linear regression models and logistic regression models. Each of these models has its own advantages and disadvantages, and the choice of model type should be based on practicality and usefulness in practice.

<Table 4-4> Classification of PD Models

	Merton Model-based	Linear Regression Model	Logistic Regression Model
Dependent Variable	Systematic Risk Derived through PD(X_t)	PD_t	PD_t
Functional Form	Linear $X_t = a + b_1*GDP_t+...$, $PD_t = f(X_t,,R_t)$	Linear $PD_t = a + b1*GDPt+..$	Nonlinear $PD_t = \frac{1}{1+\exp(a+b_1*GDP_t+....)}$
Characteristics	Highly versatile, as it takes into account the intraday correlation of asset classes to further reflect changes in correlation under stress	Simple and intuitive.	Reflects the characteristic of the dependent variable that takes values between 0 and 1. The most common form of PD estimation model.
Application Examples	Financial Supervisory Service (STARS-1), CreditMetrics™, Basel k-fuction	Bank of England, Bank of Japan, ECB	Austrian Central Bank, Bank of Korea (SAMP), Credit Portfolio View™

Sources: Kim Jung-il (2023)

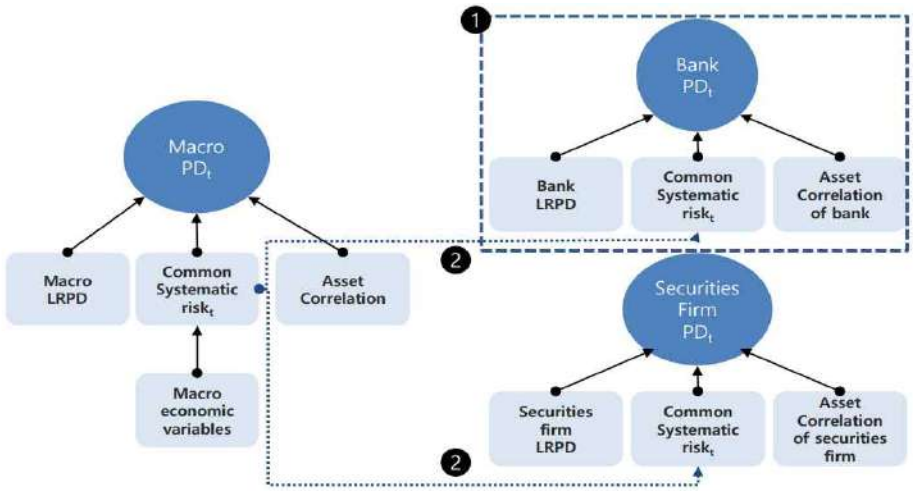
The concept of the Financial Supervisory Service's (FSS) STARS PD model is illustrated below. The STARS PD model is based on the theoretical foundation of the Basel regulatory capital formula, utilizing the single Merton model (1974). The Basel model assumes that the asset value of a bank is influenced by common factors (systematic risk, Xt), which impact all borrowers, and individual factors specific to each borrower (εit). It further assumes that if the total asset value of a bank falls below a fixed threshold, defaults occur.[8)]

By modelling the PD under these assumptions, it becomes possible to eliminate the part of the correlation due to the correlation coefficient and focus on the part influenced by macroeconomic variables (systematic risk) as explanatory

8) If we formalize this, it can be expressed as follows

variables. This approach allows for extending the model differentially for non-bnak financial institutions, where sufficient time series data may not be available, by sharing the bank's systematic risk and differentiating only based on long-term average PD and asset correlations.

<Figure 4-8> Sharing and extension of bank systemic risk by non-banks in PD models based on the Merton model



Sources: Kim Jung-il(2023)

In the FSS's STARS model, the PD model involves fitting a model using macroeconomic and financial variables provided as variables in the scenario setting. It consists of two steps:

1) Estimation of systematic risk (Xt) for five different portfolios: large

$$p_t(x) = \Pr(X_t\sqrt{\rho} + \epsilon_t^i\sqrt{1-\rho} < v)$$
$$= \Pr(\epsilon_t^i < \frac{v - X_t\sqrt{\rho}}{\sqrt{1-\rho}})$$
$$= \Phi(\frac{v - X_t\sqrt{\rho}}{\sqrt{1-\rho}})$$

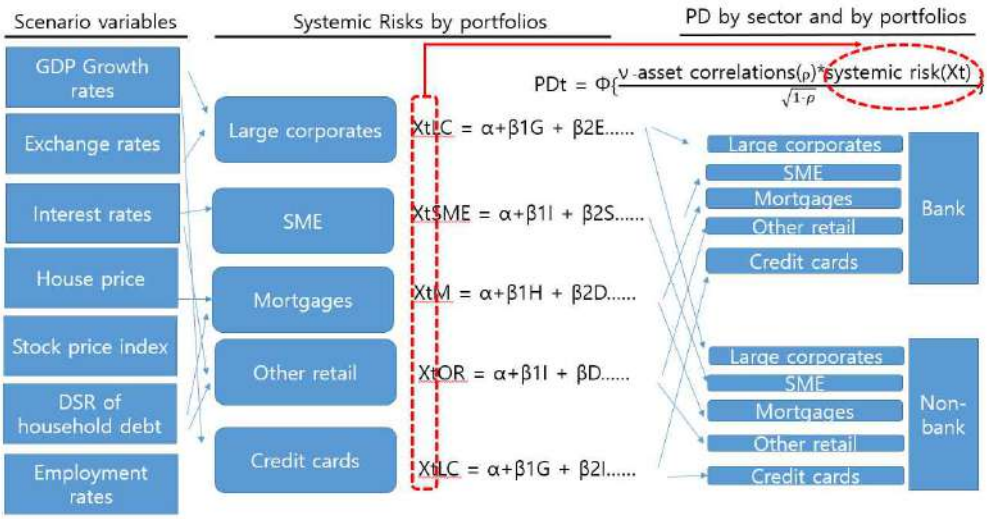
Here, Xt(Systematic Risk) = f(domestic and international financial markets, macroeconomic variables, etc) + ut

v = Φ(Long-term average default rate of the portfolio(LRPD))

ρ represents the inter-asset correlation coefficient within the portfolio

corporates, small and medium enterprises, real estate mortgages, other retail and credit cards. 2) Estimation of default rates (PDt) by financial sector and portfolio based on the estimated systemic risk.

<Figure 4-9> Structure of the Financial Supervisory Service (FSS) STARS PD model



Data: Kim Jung-il(2023)

Nepal currently plans to conduct stress tests only on commercial banks, so there is no significant need to construct a Merton model-based PD model like the Financial Supervisory Service (FSS) of Korea. However, if stress testing is extended to non-bank financial institutions with limited time series data in the future, it may be necessary to consider building a Merton model-based PD model.

In the PD model, the choice of macroeconomic and financial variables as explanatory variables for model construction is crucial. Examples from major countries are as follows:

The Bank of England used variables such as real GDP, commercial property prices, loan-to-GDP ratios and effective interest rates to construct PD models for corporate loans.

In addition, for household mortgage loans, variables such as interest burden as

a share of income, unused credit limits and unemployment rates were used to construct the model as follows:.

$$PD_t^{corp} = 0.07 - 14.7\Delta \ln RGDP_{t-4} - 18.6\Delta \ln RGDP_{t-8} - 5.34\Delta \ln P_{t-8}^{comm.pr} - 6.77\Delta \ln\left(\frac{M4L}{NGDP}\right)_{t-4} - 0.194 r_t^{corp}$$

$$PD_t^{h.sec} = 7.97 + 0.26IG_{t-4} - 14.6UEQ_{t-2} + 0.19UNEMP_{t-2}$$

The IMF's 2019 Financial Sector Assessment Programme (FSAP) for Singapore did not use a PD model, but instead used the log-transformed non-performing loan ratios of Singapore and five other closely related large countries: China, Malaysia, etc. They used these ratios as dependent variables and included explanatory variables such as real GDP growth rate, real GDP growth rate squared, short-term interest rates, house prices, stock prices, exchange rates, and more in their credit loss model.

In the IMF FSAP for Romania conducted in 2018, they used a linear regression model after log-transforming the default rates for four portfolios: residential mortgage loans, real estate-backed small business loans, other small business loans, and consumer loans. For corporate PD, variables such as past GDP growth rate, interest rates and stock prices were used as explanatory variables, while for retail PD variables such as GDP growth rate, unemployment rate and interest rates were chosen.

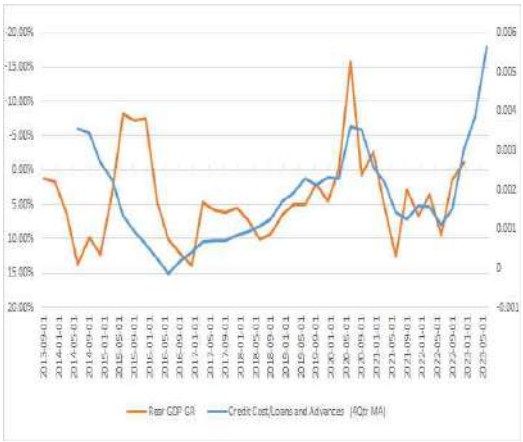
In Austria, they first conducted a univariate analysis to select effective variables, using default rates as the dependent variable and macroeconomic variables, including cyclical indicators (such as GDP, industrial production excluding the energy sector), price stability indicators (such as inflation rate, monetary aggregates M1 and M3), household indicators (such as household consumption, disposable income, unemployment rate, new car registrations) and others as explanatory variables. They then carried out a multivariate regression analysis using the selected macroeconomic variables as explanatory variables, with default rates as the dependent variable.

③ Factors Explaining Credit Loss Changes in Nepal

In the case of Nepal, it is first necessary to examine the pre-identified vulnerabilities in the financial sector in order to select explanatory variables for the credit loss model. According to the IMF's Staff Report on Nepal (IMF, 2023), factors that significantly affect Nepal's real economy include remittances from overseas workers and tourism receipts. In addition, external factors such as Nepal's pegged exchange rate with India make fluctuations in the trade balance and foreign exchange reserves important sources of uncertainty. Financial vulnerabilities include concerns about the rapid growth of private sector credit, which could lead to a build-up of latent defaults, and the subsequent rise in interest rates, which could significantly increase defaults in the financial sector. Furthermore, in discussions with the IMF office and bank management, concerns have been raised about the increase in mortgage-backed loans and the rapid rise in property prices. To the extent possible, we will explore these variables as explanatory variables for credit losses in the form of graphs.

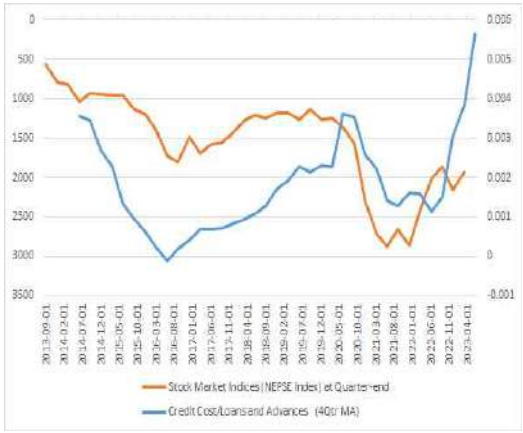
First, <Figure 4-10> shows the inverse relationship between the real GDP growth rate and the credit cost ratio, with the credit cost ratio rising sharply when the GDP growth rate falls. <Figure 4-11> shows the inverse relationship between the stock market index and the credit cost ratio, with a decline in the stock market index preceding an increase in the credit cost ratio. These observations are consistent with general economic theory, which predicts an increase in loan defaults during economic downturns.

<Figure 4-10> Real GDP growth rate of Nepal (inverse) and the commercial bank's credit cost ratio (2013.10~2023.7)



Data: NRB

<Figure 4-11> Inverse of the Nepal stock market index and the trend of the commercial bank's credit cost ratio (2013.10~2023.7)



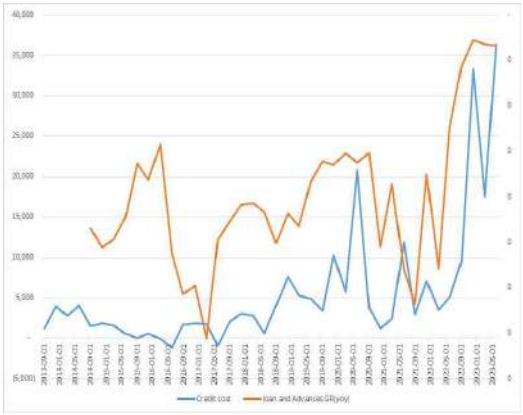
Data : NRB

<Figure 4-12> shows the evolution of the loan growth rate and the credit cost ratio of a commercial bank, and generally shows that after the loan growth rate declines, the credit cost ratio rises rapidly. This suggests the typical behaviour of financial vulnerability, where a rapid increase in loans expands the potential for defaults, and then defaults materialise as loan growth slows. It should be noted, however, that the credit cost ratio is calculated using loans as the denominator, so the increased amount of loans may have the effect of lowering the credit cost ratio, making the interpretation somewhat imprecise. <Figure 4-13> shows the evolution of the loan growth rate and the amount of credit costs for a commercial bank. In this case, the cost of credit shows a somewhat similar trend to the loan growth rate, with the cost of credit increasing rapidly with a lag after an increase in the loan growth rate.

<Figure 4-12> Inverse of the commercial bank's loan growth rate in Nepal and the credit cost ratio (2013.10~2023.7)

Data: NRB

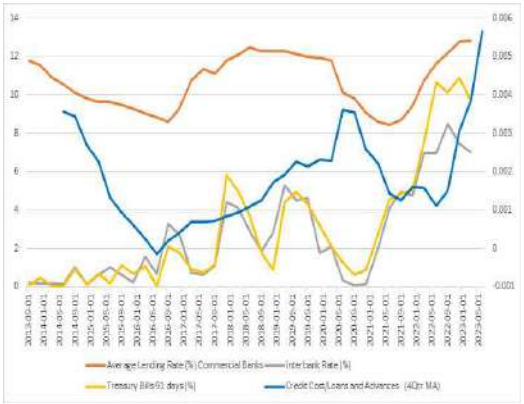
<Figure 4-13> Inverse of the loan growth rate of commercial banks in Nepal and credit cost (2013.10~2023.7)



Data : NRB

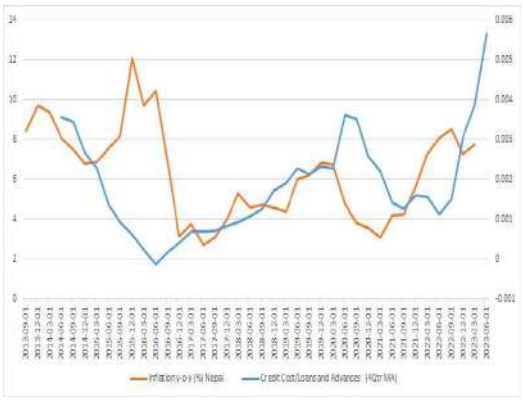
The reason for the unsustainable trajectory of excessive bank lending is the risk of excessive liquidity leading to significant inflation and the formation of bubbles in assets such as real estate, requiring a response of monetary tightening. <Figure 4-14> shows the evolution of interest rates and the credit cost ratio. While market interest rates are somewhat more volatile than lending rates, it can generally be observed that when interest rates rise, the credit cost rises rapidly. <Figure 4-15> illustrates the inflationary trends that serve as the underlying cause for such a tightening of monetary policy, ultimately leading to a high level of inflation before the increase in the credit cost ratio.

<Figure 4-14> Commercial bank loan interest rates, market interest rates, and the trend of the commercial bank's credit cost ratio in Nepal (2013.10~2023.7)



Data : NRB

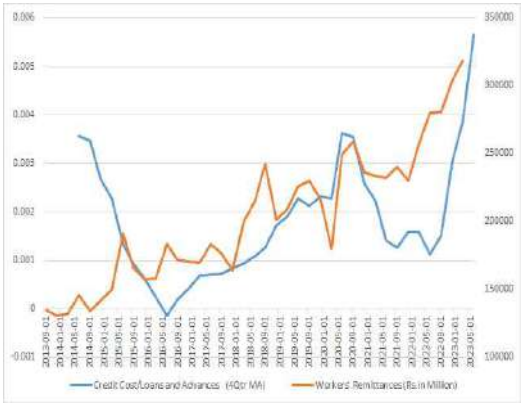
<Figure 4-15> Nepal's inflation rate and the trend of the commercial bank's credit cost ratio (2013.10~2023.7)



Data: NRB

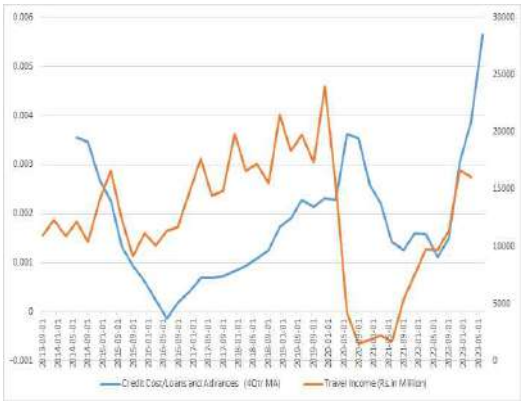
Given the characteristics of the Nepalese economy, it is necessary to examine remittances from overseas workers and government revenue imports. <Figure 4-16> shows the trend of remittances from overseas workers and the credit cost ratio. Between 2013 and 2015, remittances increased, which led to a decline in the credit cost ratio. After remittances stabilised, the credit cost ratio started to increase. Since 2019, however, remittances and the credit cost ratio have shown a trend of moving together. <Figure 4-17> shows the trend of tourist income and the credit cost ratio. After a sharp decline in tourist income in 2019, the credit cost ratio surprisingly declined. Then, when tourist income started to recover, the credit cost ratio increased sharply. This could be interpreted as a lag between the decline in remittances and tourist income, leading to economic deterioration and an increase in defaults. However, given the earlier discussion of the rapid increase in credit during the period of declining credit cost ratios, it would be reasonable to attribute the decline in the credit cost ratio to a proactive credit easing policy aimed at minimising the negative impact of COVID-19.

<Figure 4-16> Nepal's overseas remittance inflows and the trend of the commercial bank's credit cost ratio (2013.10~2023.7)



Data: NRB

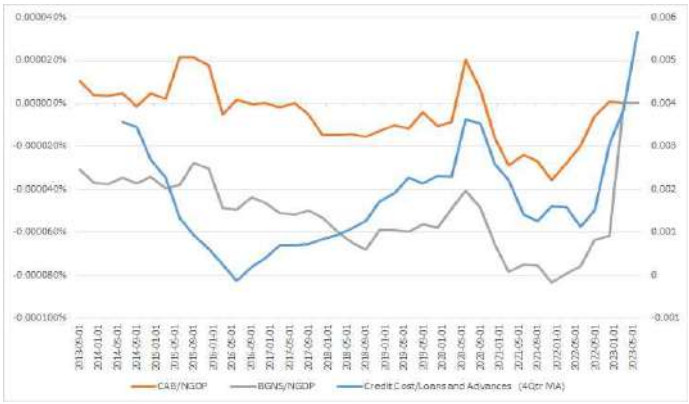
<Figure 4-17> Nepal's overseas remittance inflows and the trend of the commercial bank's credit cost ratio (2013.10~2023.7)



Data : NRB

Nepal consistently runs trade and current account deficits, supplemented by remittances from overseas workers and foreign aid. <Figure 4-18> shows the ratio of the trade and services balance to nominal GDP and the credit cost ratio of commercial banks. The deficit in the trade and services balance is significantly larger than the deficit in the current account. Since 2018, when the trade and service balance improved due to lower import demand and import restrictions, the credit cost ratio has increased. In this case, similar to the increase in loans, an improvement in the trade and services balance due to increased import demand could initially reduce credit losses. However, it could also lead to an accumulation of potential financial instability, such as reduced foreign exchange reserves, import restrictions and related issues.

<Figure 4-18>
Nepal's current account balance(CAB)/nominal GDP, goods and services balance(BGNS)/nominal GDP, and the trend of the commercial bank's credit cost ratio (2013.10~2023.7)



Data: NRB

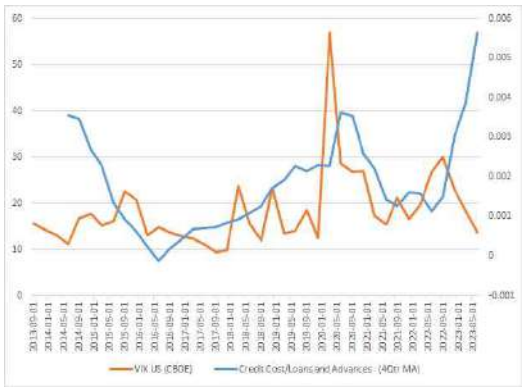
Finally, let's look at the impact of exchange rates and overseas financial instability. <Figure 4-19> shows the evolution of the Nepalese exchange rate against the US dollar and the credit cost ratio. It shows that, in general, when the Nepalese currency appreciates, the credit cost ratio decreases, especially after 2019. However, it's important to note that the Nepalese currency is pegged to the Indian currency, which means that the Nepalese exchange rate is heavily influenced by the Indian exchange rate, limiting the interpretation of its relationship with credit losses.

Figure 4-20 shows the relationship between the volatility of overseas financial markets, represented by the VIX, and Nepal's credit cost ratio. In general, when the volatility of overseas financial markets is high, the credit cost ratio of Nepalese commercial banks increases. However, it's worth noting that even though the volatility of overseas financial markets has decreased since 2022, Nepal's credit cost ratio has continued to increase, indicating a somewhat counterintuitive trend.

<Figure 4-19>
Nepal's average exchange rate against the US dollar and the trend of the commercial bank's credit cost ratio (2013.10~2023.7)

Data: NRB

<Figure 4-20>
The US VIX (Volatility Index) and the trend of the commercial bank's credit cost ratio (2013.10~2023.7)



Data : NRB

④ Construction of a Credit Loss Model in Nepal (Provisional)

The objective is to construct a credit loss model that explains variations in the credit cost ratio, centred on the variables mentioned above. The dependent variable is the credit cost ratio, which is the ratio of the four-quarter moving average of credit costs to outstanding loans of 20 commercial banks. The explanatory variables are divided into real, financial and foreign indicators to estimate a panel data model.

The panel data model can be generalised as follows:

$$Y_{it} = \alpha + X_{it}' \beta_{it} + \delta_i + \gamma_t + \varepsilon_{it}$$

Y_{it} is the dependent variable, representing the cost of credit ratio for each bank and each period. X_{it} is a k-vector of explanatory variables composed of real, financial and foreign indicators, while ε_{it} represents the error term for data from i = 1, 2, ..., 20 banks and quarterly data from t = Q3 2013, ..., Q2 2023. Meanwhile, α is the constant term of the model. δ_i and γ_t represent the

cross-sectional and period-specific effects, respectively, where the β_{it} to be estimated may vary depending on whether a common coefficient is estimated for each bank and each period, or a different coefficient is estimated for each bank. Fixed effects and random effects methods are available as approaches to estimating δ_i and γ_t.

Fixed effects represent effects that are unique to specific units. For example, applying fixed effects to each bank includes a unique constant term for each bank in the model that represents the characteristics of the bank and remains consistent across all periods. This can be used if it is assumed that each bank has different characteristics due to size and different management styles. Conversely, random effects assume that the effects between entities follow a probability distribution, thereby modelling the variability of the effects. For example, it effectively reflects the possibility that the effect of a particular bank may vary over time, while accounting for differences between banks.

In this paper, using panel data for 20 banks, the common slopes model for the credit cost ratio was estimated, applying the same coefficient to all banks, while reflecting bank-specific differences through fixed effects and incorporating random effects for the period. This approach aimed to take into account the common effects that apply to all banks, while accounting for potential changes in the credit cost ratio over time through random effects. The estimated results are shown below:

CCRMA = - 0.00434 - 0.00537*RGDPGR + 0.00168*LAGR - 0.00446*PCRGR - 0.00016*INFR - 0.00285*CLR + 0.00298*RECLR + 4.814e-05*AEXR + 1.343e-05*VIX + [δ_i = Fixed, γ_t = Random]

RGDPGR is the GDP growth rate (yoy), LAGR is the bank loan growth rate (yoy), PCRGR is the domestic credit growth rate (yoy), INFR is the inflation rate (yoy), CLR is the consumer loan ratio of each bank, RECLR is the real estate collateral loan ratio of each bank, AEXR is the average exchange rate

against the US dollar and VIX is the US VIX volatility index. All estimated coefficients were significant at the 5% level of significance.

Notable aspects of the Nepal credit cost ratio model are as follows:

1) As expected, a higher real economic growth rate indicates a decline in the credit cost ratio.
2) A higher inflation rate leads to a lower credit cost ratio, which is likely to reflect already eased financial conditions due to measures such as interest rate cuts. On the other hand, the interest rate indicator ultimately did not have a significant impact.
3) While an increase in domestic credit lowers the credit cost ratio, each individual bank may experience an increase in the credit cost ratio as its loan growth rate increases.
4) The consumer loan ratio (CLR) and the real estate collateral loan ratio (RECLR) are indicators that, in addition to the growth rate of bank loans, may reflect differences in each bank's portfolio. They were statistically significant. An increase in the RECLR correlated with an increase in the cost of credit ratio, while an increase in the CLR was associated with a decrease in the cost of credit ratio.
5) With regard to external indicators, the average exchange rate against the US dollar (AEXR) and the VIX showed significant effects.

<Table 4-5> Estimation Results for the Credit Cost Ratio

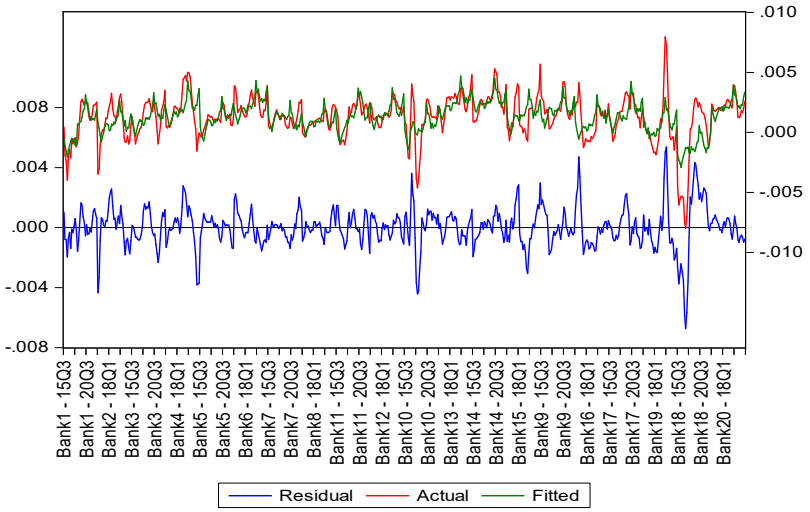
Explanatory var.		Model 1		Model 2		Model 3	
		Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
	Intercept	-0.003464	0.0471	-0.003763	0.0027	**-0.004344**	**0.0001**
Real Economy Indicators	Real GDP Growth Rate	**-0.006102**	**0.0000**	**-0.005957**	**0.0000**	**-0.005368**	**0.0000**
	Stock Price Index Growth Rate	2.29E-05	0.8543				
	Growth Rate of Tourism Income	-2.49E-05	0.4552				

	Growth Rate of Worker Remittances	**-0.000130**	**0.1961**	-0.000127	0.1949		
Financial Indicators	Individual Loan Growth Rate	**0.001787**	**0.0008**	**0.001785**	**0.0007**	**0.001684**	**0.0013**
	Private Credit Growth Rate	**-0.006927**	**0.0015**	**-0.006802**	**0.0002**	**-0.004464**	**0.0011**
	Inflation Rate	**-0.000156**	**0.0000**	**-0.000155**	**0.0000**	**-0.000160**	**0.0000**
	Average Bank Loan Interest Rate	-1.02E-05	0.8523				
	Interbank Interest Rate	**0.000208**	**0.0579**	0.000153	0.0919		
	T-bill Rate	**-0.000197**	**0.0308**	-0.000159	0.0512		
	Individual Consumer Loan Ratio	**-0.002300**	**0.1130**	**-0.002210**	**0.1256**	**-0.002853**	**0.0237**
	Individual Real Estate Collateral Loan Ratio	**0.002869**	**0.0000**	**0.002874**	**0.0000**	**0.002981**	**0.0000**
Foreign Indicator	Average Exchange Rate Against the US Dollar	**3.11E-05**	**0.0550**	**4.18E-05**	**0.0006**	**4.81E-05**	**0.0000**
	Current Account Balance/Nominal GDP	1801.814	0.3077				
	Goods and Services Balance/Nominal GDP	**-2957.427**	**0.1422**	-1039.150	0.1778		
	VIX	**2.00E-05**	**0.0184**	**1.61E-05**	**0.0260**	**1.34E-05**	**0.0479**
R-squared		46.9%		46.8%		46.2%	

Estimated model : Panel EGLS (Period random effects)

<Figure 4-21> compares the credit cost ratio of Nepal's commercial banks, as estimated by the above model, with the actual credit cost ratio.

<Figure 4-21> Comparison of Credit Cost Ratio Model Estimates and Actual Values



<Table 4-6> shows the estimated bank-specific fixed effects for Nepalese commercial banks, according to the aforementioned model.

<Table 4-6> Estimated Fixed Effects by Bank

Bank	FE	Bank	FE	Bank	FE	Bank	FE
Bank1	-0.000300	Bank6	0.000417	Bank10	-0.001609	Bank16	0.000327
Bank2	-0.000896	Bank7	-0.000130	Bank13	0.001046	Bank17	-5.54E-05
Bank3	0.000419	Bank8	0.000407	Bank14	0.001932	Bank19	-0.001227
Bank4	0.000423	Bank11	-7.37E-06	Bank15	-0.000866	Bank18	-0.002625
Bank5	6.08E-05	Bank12	0.001157	Bank9	0.000973	Bank20	0.000554

(4) Estimating interest income for banks in Nepal

① How to estimate the change in interest income for stress testing

In general, interest income is the largest component of a bank's income. As shown in <Table 4-7>, for commercial banks in Nepal, net interest income accounted for the majority of total operating income during the three-year period from 2018-19 to 2020-21, ranging from 75.7 per cent to 90.7 per cent. As a percentage of net profit after tax, it ranges from 201.9 per cent to 251.9 per

cent. In 2020-21, net interest income accounted for 75.7 per cent of total operating income, compared with 14.2 per cent for commission income, 10.7 per cent for net trading income and only 6.8 per cent for other operating income.

<Table 4-7> shows that credit costs ("impairment charge/(reversal) for loans and other losses") account for only 7.1 per cent to 13.5 per cent of operating income over the three-year period from 2018-19 to 2020-21, but they increase sharply during a crisis. Therefore, estimating the evolution of net interest income during a crisis is considered the second most important task after estimating the cost of credit when stress testing the solvency of a typical bank.

<Table 4-7> Consolidated P&L of Commercial Banks in Nepal

(Million Rs.)

	2018-19		2019-20		2020-21	
Interest Income	294,095.98		321,768.16		315,506.97	
Interest Expenses	183,196.58		207,682.34		200,860.94	
Net Interest Income	**125,468.58**	**(80.7)**	**131,520.68**	**(81.1)**	**131,999.92**	**(75.7)**
Fee and commission income	30,093.15		31,166.88		34,196.24	
Fee and commission expense	3,388.11		3,337.15		4,055.64	
Net Fee and commission income	**21,600.23**	**(13.9)**	**23,045.21**	**(14.2)**	**24,741.28**	**(14.2)**
Net Interest, Fee and commission income	**143,831.27**		**149,360.30**		**152,093.56**	
Net trading income	**16,571.27**	**(10.7)**	**15,853.09**	**(9.8)**	**18,707.67**	**(10.7)**
Other operating income	**3,298.46**	**(2.1)**	**4,048.68**	**(2.5)**	**11,880.55**	**(6.8)**
Total operating income	**155,391.08**	**(100.0)**	**162,132.03**	**(100.0)**	**174,456.90**	**(100.0)**
Impairment charge/(reversal) for loans and other losses	11,028.20	(7.1)	21,903.12	(13.5)	18,994.67	(10.9)
Net operating income	**149,618.31**	**(96.3)**	**143,891.82**	**(88.7)**	**162,840.24**	**(93.3)**
Personnel expenses	46,846.07		49,367.74		57,687.83	
Other operating expenses	21,185.30		23,678.08		24,012.23	
Depreciation &Amortization	4,526.49		5,212.56		6,132.20	
Operating Profit	**86,592.49**	**(55.7)**	**74,090.37**	**(45.7)**	**85,545.45**	**(49.0)**
Non operating income	6,466.14		4,231.04		5,351.97	
Non operating expense	1,185.48		1,058.78		1,244.70	
Profit before income tax	**80,254.31**	**(51.6)**	**74,191.16**	**(45.8)**	**85,352.64**	**(48.9)**
Income Tax Expense	4,611.66		4,643.28		6,107.23	
Current Tax	25,334.07		21,850.61		25,670.42	
Deferred Tax	2,225.74		1,375.55		1,361.49	
Profit/Loss for the period	**62,138.03**	**(40.0)**	**52,207.28**	**(32.2)**	**59,931.9**	**(34.4)**

Notes : ( ) represents Composition as a % of Total Operating Income
Source : “Bank Supervision Report 2020/2021”, NRB, July 2022

There are two main ways of estimating the change in net interest income through the income statement in a stress test. The first is to measure net interest income (NII) risk based on the interest rate risk in the banking book (IRRBB) management standard, and the second is to estimate the model that best explains the variation in net interest income of individual banks through regression analysis using economic and financial variables. First, we discuss how to measure NII interest rate risk based on Choi (2023), and then we explain the net interest income estimation model.

In general, a bank's interest rate risk from changes in interest rates is divided into trading and banking books. The interest rate risk of bonds traded for trading purposes is managed as market risk, with mark-to-market gains and losses directly reflected in the bank's financial statements. The interest rate risk of trading accounts is directly reflected in risk-weighted assets in the calculation of the Basel Committee on Banking Supervision's (BCBS) regulatory capital ratios (the so-called BIS capital ratios), i.e. the greater the interest rate risk of trading accounts due to changes in interest rates, the lower the bank's capital ratio. This is known as Pillar 1 capital requirements. On the other hand, interest rate risk arising from deposits, loans, etc. that are not held for trading but are inherent in the bank's business is not directly reflected in the financial statements as mark-to-market gains and losses and is called interest rate risk in the banking book (IRRBB). Instead of being subject to Pillar 1, IRRBB is subject to Pillar 2 capital requirements, which are reflected in the economic capital ratio when banks conduct Internal Capital Adequacy Assessment Process (ICAAP).

In April 2016, the Basel Committee on Banking Supervision (BCBS) published the "Standards, Interest rate risk in the banking book (IRRBB)" (BCBS, 2016), a major revision of the existing "Principles for the management and supervision of interest rate risk (July 2004)" to enhance banks' ability to manage interest rate risk. At that time, the Basel Committee considered a Pillar 1 approach (minimum capital requirements), but decided against it in favour of an enhanced Pillar 2 approach (as part of ICAAP), which includes the enhanced market

discipline requirements of Pillar 3. According to the BCBS (2016), interest rate risk in the banking book (IRRBB) is split into the impact on the economic value of equity (EVE) and the impact on net interest income (NII) under a scenario that considers interest rate shocks of ±200 bp to 400 bp per currency, as proposed by the Basel Committee. EVE interest rate risk refers to changes in the economic value of equity that may arise as a result of changes in interest rates affecting the value of assets, liabilities and off-balance sheet items, and the impact on the bank's medium to long-term soundness. NII interest rate risk represents the impact on a bank's short-term profitability of changes in net interest income that may occur over a period of time (e.g. one year) due to changes in interest rates. The failure of the US SVB in early 2023 was triggered by a large decline in asset values due to rising interest rates, as it had invested mainly in long-term government bonds funded by deposits, and poor management of EVE interest rate risk can be seen as a fundamental cause. However, supervisors in major countries do not yet rely on market data such as bank share prices or conduct stress tests based on economic values, but follow models based on accounting data presented in financial statements. In South Korea, the Financial Supervisory Service supervises interest rate risk management for EVE together with NII under a separate interest rate risk management standard, but the stress test only reflects changes in net interest income (NII) as reflected in the income statement.

The Basel Committee's IRRBB Management Standard (BCBS, 2016) provides that the measurement of interest rate risk may be derived from an internal measurement system (IMS) or measured using standardised methods as specified by the Basel Committee. An important aspect of measuring interest rate risk is the treatment of non-maturity deposits (NMDs). Non-maturity deposits, such as demand deposits, are statistically stable over time and the assumptions made about them can be an important determinant of IRRBB. The BCBS (2016) standards require that the key assumptions and behaviours for non-maturity deposits (NMDs) used in the internal measurement system (IMS) are

documented, monitored and regularly updated. The standard methodology applies a core deposit ratio cap of 50-70% for non-maturity deposits, depending on retail/wholesale and trading/non-trading requirements, as shown in <Table 4-8>, and limits the average maturity of the recognised portion of these core deposits to 4-5 years.

<Table 4-8> Caps on core deposits and average maturity by category

	Cap on proportion of core deposits (%)	Cap on average maturity of core deposits (years)
Retail/transactional	90	5
Retail/non-transactional	70	4.5
Wholesale	50	4

Sources : BCBS(2016)

In supervisory stress tests, the IRRBB NII measure of interest rate risk is used to estimate the change in net interest income at the interest rate level in the stress scenario using the bank's reported distribution of interest-bearing assets and liabilities by maturity. The difference with the IRRBB measure of interest rate risk would be the adjustment of the interest rate change scenario and the size of the assets and liabilities. It is common for interest-bearing assets and liabilities to increase during the stress period, so it is desirable to reflect this, but if necessary it is also useful to consider the size of interest-bearing assets and liabilities at the baseline as fixed and measure the change in net interest income due to interest rate changes. However, when using the level of assets and liabilities at baseline, the interest income on the increase in non-performing loans under a stress scenario should be excluded, i.e. calculated by subtracting the increase in non-performing loans from the interest-bearing assets at baseline. More importantly, the estimate of net interest income is highly sensitive to assumptions about non-maturity deposits (NMDs). Banks may assume, on the basis of historical customer behaviour, that low- or no-interest demand deposits

will be held for a long time, even under stressful conditions. The problem with this optimistic assumption is that net interest income appears to be overly stable in stress scenarios. The results of the stress tests are also subject to considerable variation due to differences in the assumptions about non-maturity deposits across banks. The more optimistic the assumptions, the smaller the decline in capital ratios in the stress tests. It is therefore important to establish an objective and conservative standard for banks' treatment of non-maturity deposits.

The second method is to use a model to estimate net interest income. There are two ways of estimating net interest: the first is to estimate net interest income itself using the net interest margin (NIM) model, and the second is to split interest income and interest expense using the interest income rate (IIR) and interest expense rate (IER) models.

Net interest margin (NIM) is defined as (interest income/interest earning assets - interest expense/interest earning liabilities)/(amount of interest earning assets). Therefore, finding the net interest margin and the size of interest-earning assets gives net interest income. Here is an example of a model for estimating NIM.

$$NIM_{i,t} = \beta_0 + \beta_{i,t-1} NIM + \beta_2 Call\,rate + \beta_3 \log\left(\frac{GDP_t}{GDP_{t-1}}\right) + \beta_4 \left(\frac{Household\,Debt_t}{Housegold\,Debt_{t-1}}\right) + \ldots + e_{i,t}$$

An example of a model that separately estimates the interest income rate (IIR) and the interest expense rate (IER) is the following.

$$IER_{i,t} = \beta_0 + \beta_1 IER_{i.t-1} + \beta_2 Call\,rate + \beta_3 Gov.Bond\,rate + \beta_4 (Capital\,ratio_{i,t-1} - Capital\,ratio_{i,t-2}) + Bank\,fixed\,effect + \ldots + e_{i,t}$$

$$IIR_{i,t} = \beta_0 + \beta_1 IIR_{i.t-1} + \beta_{2_1} IER_{i.t} + \beta_3 \log(GDP_t) + \beta_4 \log(GDP_{t-1}) + \beta_5 \log(GDP_{t-2}) + Bank\,fixed\,effect + \ldots + e_{i,t}$$

Using the interest income rate (IIR) and interest expense rate (IER) models,

net interest income is calculated as follows.

Net interest income = IIR*Future interest-earning assets (average) - IER*Future interest-earning liabilities (average)

Assets at the future date are derived from assets at the base date, reflecting the scenario-derived growth rate of credit assets, but excluding non-performing assets. Future liabilities are calculated by adding the asset growth and subtracting the equity growth (= net income) from the liabilities at the base date. The average balance is usually the average of the opening and closing balances.

Most major economies use models to estimate changes in net interest income in stress tests. For example, the Bank of Japan's Financial Macroeconomic Model (FMM) in early 2012 used a model that directly estimated the year-on-year change in interest income as follows (Ishikawa et al., 2012).

Year-on-year change in net interest income
= 0.003 × year-on-year change in lending volume
+ 205.1 × year-on-year change in (lending interest rate − call rate)
+ 58.2 × twelve-quarters mean of year-on-year change in corporate profit margin

Meanwhile, the lending interest rate in the above equation is estimated by the following model.

Year-on-year change in lending interest rate
= 0.6 × year-on-year change in call rate(- 1)
+ 0.01 × four-quarters mean of year-on-year change in lending volume gap
− 0.02 × capital adequacy ratio gap

However, in later stress tests, the Bank of Japan has begun to distinguish between interest income and interest expense in estimating net interest income.

For example, according to the Explanatory Notes to the 2022 version of the Financial Macroeconomic Model (FMM) released by the Bank of Japan in March 2023, net interest income is divided into four items: interest income on loans, interest and dividends on securities, other interest income, and interest expense, of which domestic and foreign borrowing rates for interest income on loans and domestic and foreign borrowing cost rates for interest expense are estimated using an endogenous variable model (see Abe et al. (2023)). The model used to estimate net interest income is detailed below.

Net interest income = A + B + C - D
(A) Loan interest income
- Domestic : Domestic lending interest rate★ × Domestic loans
- Foreign : Foreign lending interest rate★ × Foreign loans
(B) Interest and dividends on securities : Yields on securities × Securities holdings
(C) The others : Yields on other assets × Other assets holdings
(D) Interest expenses
- Domestic : Domestic funding rate★ × Domestic fundings
- Foreign : Foreign funding rate★ × Foreign fundings

In the construction of the net interest income model, the superscript ★ indicates that there is a model with separate endogenous variables. For example, in the 2022 edition of the Bank of Japan's Financial Macro-economic model (FMM), the model for the domestic lending interest rate is as follows.

Domestic lending interest rate$i$
= $\alpha 1$ × Domestic funding rate$i$ + $\alpha 2$ × Term spread [5-year − 3-month]
+ $\alpha 3$ × Non-performing loan ratio$i$ + $\alpha 4$ × Loan demand index$i$
+ Fixed effect$i$ + Constant

Where Loan demand index$i$ is defined as (The number of borrowing firms in the prefecture where i ′s head office is located)/(The number of branches in the

prefecture where i ′s head office is located).

On the other hand, when the IMF conducted a stress test for Korea as part of the FSAP in 2020, the methodology used to estimate net interest income was to estimate the interest income ratio (IIR) and interest expense ratio (IER) separately by bank (IMF, 2020). For this purpose, the time series of IIR and IER were first derived as follows.

$$IIR = 4 * \frac{II}{SEC + loans\,gross\,of\,LLA * (1 - SBL\,ratio)}$$

$$IER = 4 * \frac{IE}{TA\,net\,of\,LLA - E}$$

The abbreviations used are explained below.

- II: Quarterly flows of nominal interest income.
- IE: Quarterly flows of total interest expense.
- SEC: Securities, as total financial assets of banks minus their loan stock.
- LLA: Loan loss allowance stock.
- Loans gross of LLA: Total loans without deduction of loan loss allowances.
- SBL ratio: Substandard and below.
- TA: Total assets
- TA net of LLA: Total assets less loan loss allowances.
- E: Equity

The results of the models estimated in the same way for the IIR and IER time series for 19 banks for the period 2000Q4 to 2018Q4, divided into Nation-wide Banks, Regional Banks and Specialised Banks, are shown in <Table 4-9> and <Table 4-10>.

<Table 4-9> IIR model for Korean banks

	Nation-wide Banks		Regional Banks		Specialized Banks	
	coef.	p-val.	coef.	p-val.	coef.	p-val.
IIR (-1)	0.725	0.000	0.501	0.000	0.618	0.000
IER	0.352	0.000	0.691	0.000	0.348	0.000
D(LOG(RGDP))*100	-0.089	0.000	-0.034	0.099	0.015	0.657
D(LOG(RGDP(-1)))*100	0.141	0.000	0.106	0.000	0.048	0.153
D(LOG(RGDP(-2)))*100	0.043	0.038	0.027	0.186	0.007	0.820
D(LOG(RGDP(-3)))*100	-0.019	0.368	-0.013	0.514	0.036	0.243
Obs. combined T and N	320		414		177	
R2	0.96		0.95		0.95	
SE of residuals	0.28		0.32		0.28	
SE of data	1.41		1.34		1.22	
Mean of data	5.09		5.81		4.25	

Sources: IMF(2020)
RGDP = real GDP

<Table 4-10> IER model for Korean banks

	Nation-wide Banks		Regional Banks		Specialized Banks	
	coef.	p-val.	coef.	p-val.	coef.	p-val.
STN	0.326	0.000	0.241	0.000	0.364	0.000
LTN	0.356	0.000	0.430	0.000	0.338	0.000
E/TA(-1)	-0.181	0.000	-0.300	0.002	-0.229	0.026
(E/TA(-1))^2	0.005	0.001	0.023	0.004	0.007	0.119
Obs. combined T and N	353		432		218	
R2	0.92		0.87		0.88	
SE of residuals	0.31		0.38		0.37	
SE of data	1.07		1.03		1.07	
Mean of data	2.46		2.73		2.64	

Sources : IMF(2020)
STN = short-term interest rate, LTN = long-term interest rate.

The interest income rate (IIR) model is simply composed of the interest expense ratio(IER), the previous year's IIR and real GDP growth. The interest expense rate (IER) model shows a statistically significant effect of the bank's simple capital ratio, together with short and long-term market interest rates. This reflects the phenomenon that the cost of funding increases when the bank's capital ratio is low. It is worth noting that an increase in NPLs under stress not only reduces interest income by the amount of NPLs, even if the interest income

rate (IIR) is the same, but also increases interest expense due to the increase in NPLs, which leads to a deterioration in external credit as equity decreases due to the increase in NPLs, thus doubly worsening net interest income. On the other hand, as the capital ratio rises above a certain level, the effect of improving funding costs gradually diminishes, so they have accounted for the non-linear effect by adding the equity ratio squared term to the IER model.

In Korea, the Financial Supervisory Service initially used a method similar to the IRRBB interest rate risk measure. This method estimates the change in net interest income given the interest rates under a stress scenario by reporting the interest rate maturity status of interest rate assets and interest rate liabilities of banks. In this case, there were two practical problems. The first is that banks often make optimistic assumptions about the maturity of non-maturity deposits (NMDs), leading to an underestimation of interest rate risk, and the second is that it does not adequately reflect the deterioration in funding costs due to a decline in capital ratios under stress.

As a result, in recent years the IRRBB interest rate risk measure has been used in the bottom-up (BU) stress tests conducted by banks, but the FSS uses a separate net interest income estimation model. The FSS net interest income estimation model estimates the interest income rate (IIR) and the interest expense rate (IER) separately. Given that the interest expense rate changes during a crisis, the economic situation is divided into normal (S1) and crisis (S2) and the coefficients of the model vary by state, and the IIR and IER are modelled using a hidden Markov model as shown in <Table 4-11>.

<Table 4-11> FSS's hidden Markov model for IIR and IER

	Model Design (fixed effects)	Explanatory variables
IRR	$IR^1_{it} = X_{it}\beta^1 + \alpha^1_{it} + u_{it}$ (S1) $IIR^2_{it} = X_{it}\beta^2 + \alpha^2_{it} + u_{it}$ (S2)	Macro variables such as GDP, Financial firm-specific variables such as maturity structure
IER	$IER^1_{it} = X_{it}\beta^1 + \alpha^1_{it} + u_{it}$ (S1) $IER^2_{it} = X_{it}\beta^2 + \alpha^2_{it} + u_{it}$ (S2)	Macro variables such as interest rates and volatility, and Financial firm-specific variables such as capital ratios

Sources : Kim Jung-il(2023)

② Status of bank interest rate risk supervisory reporting in Nepal

Currently, there are two main ways in which banks in Nepal estimate changes in interest income: bottom-up (BU) stress testing and reporting through call reports.

Banks in Nepal report the measurement of interest rate risk through the BU stress test. Banks estimate the impact on profit and loss under seven different interest rate shock scenarios: a 1%, 1.5% and 2% change in deposit and lending rates respectively, and a 1% increase in deposit rates combined with a 1% decrease in lending rates. The change in profit or loss is calculated by multiplying total deposits and loans excluding fixed-term instruments (i.e. deposits excluding fixed-term and current deposits and loans excluding fixed-term loans) by the 1% to 2% interest rate change and dividing by 12, which estimates the change in short-term interest income over a one-month period. This measure has a number of limitations. First, it considers only deposits and loans and does not take into account the interest rate risk of other interest-bearing assets and liabilities. Second, by considering only floating rate deposits and loans without sufficient consideration of maturity, it can only measure the effect of changes in interest income in the short term. In addition, like the IRRBB method of measuring interest rate risk, it does not take into account the effect of a decrease in interest income due to an increase in NPLs and the effect of an

increase in funding costs due to a decrease in the capital ratio.

<Table 4-12> shows the estimated impact of interest rate shocks using the current bottom-up (BU) stress test for banks in Nepal. The impact of changes in net interest income on banks' capital ratios is estimated to be quite small, ranging from -0.02 to -0.10 percentage points of the capital ratio on average for a 1 to 2 per cent interest rate shock.

<Table 4-12> Estimating the impact of interest rate shocks in the current NRB BU stress test

Scenario	Impact on bank capital ratios (%p, average)	Distribution of impact by bank (%p)
(IR-1a) Deposits interest rate change by +1.0% on an average	-0.02	-0.01 ~ -0.04
(IR-1b) Deposits interest rate change by +1.5% on an average	-0.04	-0.02 ~ -0.06
(IR-1c) Deposits interest rate change by +1.5% on an average	-0.05	-0.03 ~ -0.08
(IR-2a) Loan interest rate change by -1.0% on an average	-0.04	-0.04 ~ -0.06
(IR-2b) Loan interest rate change by -1.5% on an average	-0.07	-0.06 ~ -0.09
(IR-1c) Loan interest rate change by -2.0% on an average	-0.10	-0.08 ~ -0.12
(IR-3) Deposits interest rate change by +1.0% and Loan interest rate change by -1.0% on an average	-0.07	-0.06 ~ -0.10

Sources : NRB(2023)

On the other hand, the Nepalese bank call report provides a more sophisticated measure of the changes in profit and loss due to interest rate movements by reporting the total of the bank's interest rate sensitive assets and interest rate sensitive liabilities by maturity. <Table 4-13> shows an example of a bank's form of interest rate risk measurement. Measuring changes in net interest income through a bank's call report is considered to be more advanced than stress testing. First, it includes all interest-sensitive assets and liabilities, not just deposits and loans, and second, it divides interest rate maturities into five

periods rather than into floating and fixed rates, allowing for a longer time horizon for the impact of interest rate changes on interest income. However, this approach has drawbacks compared to using the net interest income estimation model, as it does not take into account the effect of an increase in NPLs, which reduces interest income, and the effect of a decrease in the capital ratio, which increases funding costs, and may be somewhat problematic compared to the Basel Committee's IRRBB interest rate risk measure. For example, in the case of non-maturity deposits (NMDs), when market interest rates rise, only part of the increase in interest rates is reflected in the increase in deposit rates (this is known as beta), which has the effect of effectively lengthening the maturity of the NMD. However, Nepal Bank's reporting does not fully reflect this effect.

<Table 4-13> Quarterly interest rate risk report form for Nepalese banks (example)

Particulars	1 - 90 days	91 - 180 days	181 - 270 days	271 - 365 days	Over 1 year	Total
Interest Sensitive Assets (1)	43,589.00	29,607.09	20,499.44	23,715.03	63,892.60	181,303.16
Interest Sensitive Liabilities (2)	34,282.11	12,436.53	11,962.76	8,552.39	74,423.61	141,657.40
Gap (1 - 2)	9,306.89	17,170.56	8,536.68	15,162.64	(10,531.01)	39,645.76
Cumulative Gap	9,306.89	26,477.45	35,014.13	50,176.77	39,645.76	
Adjusted Interest Rate Change (IRC)	0.25%	0.25%	0.25%	0.26%	1.00%	
Impact on Quarterly Earnings (Cumulative Gap x IRC)	22.95	65.29	86.34	130.60	396.46	701.63
Accumulated Earnings Impact to date	22.95	88.24	174.57	305.17	701.63	

Sources: NRB bank call report
"5.2 Interest Rate Related Risk Monitoring Table"

To fully address these issues, it is necessary to implement the Basel Committee's IRRBB standard (BCBS, 2016) in Nepal. Adoption of the IRRBB

standardised approach for measuring interest rate risk will provide a more reasonable estimate of the magnitude of changes in net interest income, in line with international standards and practices. In addition, a net interest income estimation model needs to be developed in the top-down (TD) stress test to overcome the limitations of the IRRBB interest rate risk measurement methodology. It would be desirable to validate the changes in interest income under stress measured by the supervisor's net interest income model against the impact of changes in interest income calculated from each bank's interest rate maturity structure.

③ Design of net interest income model for Nepalese banks

To estimate net interest income in Nepal, we first examine the evolution of the interest income rate (IIR) and the interest expense rate (IER). The interest income rate and interest expense rate were calculated in three ways.

First, we defined II/ISA and IE/ISL as the bank's interest income and interest expense divided by interest sensitive assets (ISA) and interest sensitive liabilities (ISL), respectively, in "5-2 Interest Rate Related Risk Monitoring Table (Quarterly)" in the bank's call report.

Second, we define IIR_Loan and IER_Dep as the interest rates on the average balance of loans and deposits as reported in "15-2 Statement of Interest Rate Spread of Loans & Advances and Deposits" in the call reports.

Third, the approximate estimation method used by the IMF to estimate Korea's net interest income is calculated as follows.

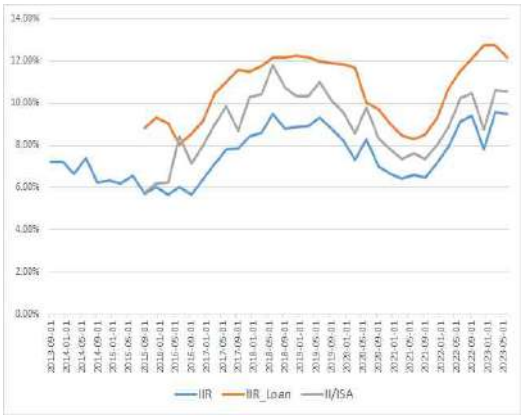
$$IIR = \frac{\text{Interest income}}{\text{Total assets - Fixed assets - NPL}}$$

$$IER = \frac{\text{Interest expense}}{\text{Total assets - Loan loss allowance (LLA) - Equity}}$$

Although the first two, II/ISA and IE/ISL, are theoretically correct concepts,

they move in much the same way as their approximate estimates, IIR and IER, as shown in <Figure 4-22> and <Figure 4-23>. In contrast, IIR_Loan and IER_Dep show a more gradual trend of change than II/ISA and IE/ISL, and in contrast to IIR and IER. Given the short time series of II/ISA and IE/ISL and the difficulty of estimating the value of interest rate sensitive assets and liabilities separately, we use the approximate estimates of IIR and IER to estimate net interest income under stress.

<Figure 4-22> Nepal Commercial Bank IIR trend (2013.10~2023.7)



Sources : NRB
Note: Interest income is calculated as quarterly income*4

<Figure 4-23> Nepal Commercial Bank IER trend (2013.10~2023.7)

Sources : NRB
Note: Interest expense is calculated as quarterly expense*4

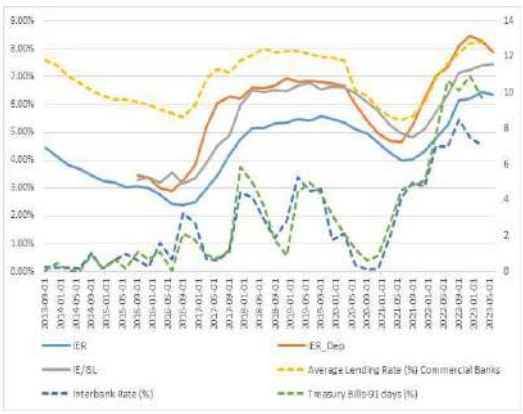
In <Figure 4-22> and <Figure 4-23>, interest income and interest expense rates are calculated by annualising (i.e. quadrupling) quarterly income and expenses. In this case, if interest income and expenses are properly recorded, there should in principle be no seasonal effect, but overall interest income and expenses show a sawtooth shape on an annual basis, and some banks have a significant seasonal effect on their financial statements, such that interest income in the fourth quarter (annual - cumulative interest income in the first three quarters) appears as a loss. To adjust for this seasonality, we use the cumulative interest income and expense for the year up to each quarter. <Figure 4-24> and <Figure 4-25>

show the trend of the interest income rate and the interest expense rate calculated on the basis of the annual cumulative income and expense rate together with market interest rates. The short-term market interest rates, the interbank rate and the Treasury bill - 91 days rate, have shown relatively large fluctuations and have increased rapidly since 2021, while the average lending rate of commercial banks has shown a moderate increase with some delay. Movements in the IIR and IER have generally been more in line with commercial bank lending rates than with short-term market rates.

<Figure 4-24> Trend of market interest rates and IIR of Nepal Commercial Bank (2013.10~2023.7)

Sources : NRB
Note: Interest income is cumulative for a full year up to the quarter (hereafter referred to as same).

<Figure 4-25> Trend of market interest rates and IER of Nepal Commercial Bank (2013.10~2023.7)

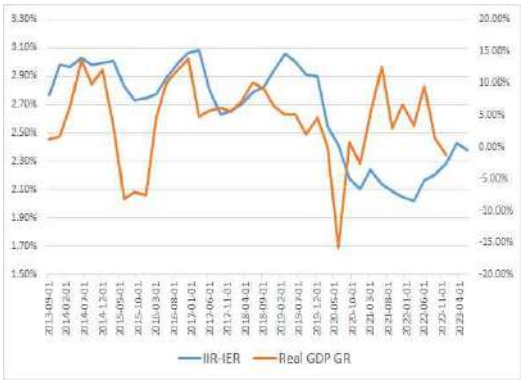


Sources : NRB
Note: Interest expense is cumulative for a full year up to the quarter (hereafter referred to as same).

<Figure 4-26> and <Figure 4-27> show the evolution of the net interest margin (IIR-IER), the difference between the interest income rate (IIR) and the interest expense rate (IER), together with the evolution of GDP growth and market interest rates. First, we can see that the net interest margin moves in a similar way to GDP growth. This suggests that banks can set their lending rate higher than their funding rate when the economy is expanding. Second, the relationship between the net interest margin and market interest rates is less clear. As market interest rates continue to rise until 2019, net interest margins

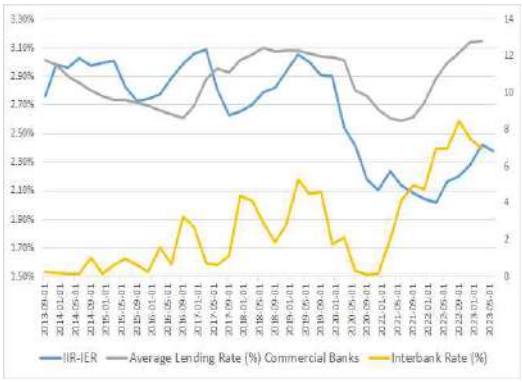
fall, but from 2021 onwards, net interest margins improve as T-bill rates and average lending rates rise rapidly.

<Figure 4-26> Trends in GDP growth and net interest margin of commercial banks in Nepal (2013.10-2023.7)



자료: NRB

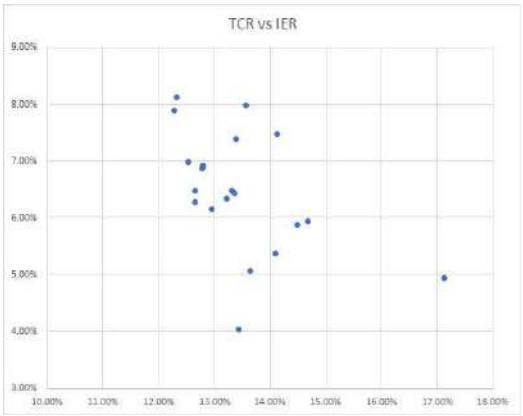
<Figure 4-27> Trends in market rate and net interest margin of commercial banks in Nepal (2013.10-2023.7)



자료 : NRB

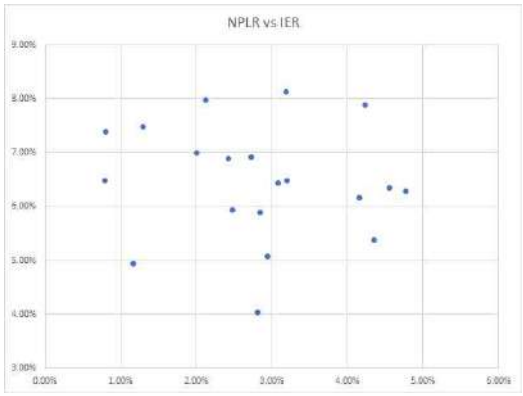
Next, we examine whether lower capital ratios or higher nonperforming loans are associated with higher funding costs for each bank. <Figure 4-28> shows the correlation between the core capital ratio and the interest rate for 20 commercial banks as of July 2023. The correlation is generally right-skewed and negative, with the exception of the outlier at the bottom, which is a bank with a loss in its fourth quarter interest income. This shows that the lower the capital ratio, the higher the interest expense, i.e. the cost of funding. However, the non-performing loan ratio does not seem to have a direct impact on the cost of funding. <Figure 4-29> shows the correlation distribution of the core capital ratio and the interest expense ratio of 20 commercial banks as of July 2023, and it is difficult to find a specific correlation.

<Figure 4-28> Distribution of Tier 1 capital ratio and interest expense ratio of commercial banks in Nepal (as of 2023.7)



Sources: NRB

<Figure 4-29> Distribution of NPL ratio and interest expense ratio of commercial banks in Nepal (as of 2023.7)



Sources : NRB

Based on the above discussion, we construct an interest income rate (IIR) and interest expense rate (IER) model. The dependent variables are the quarterly interest income rate (IIR) and interest expense rate (IER) of 20 commercial banks, calculated using the following equation. Interest income and interest expense are cumulated for a past full year up to the quarter to account for seasonality.

$$IIR = \frac{\text{Cumulative Interest income for a full year up to the quarter}}{\text{Total assets - Fixed assets - NPL}}$$

$$IER = \frac{\text{Cumulative Interest expnese for a full year up to the quarter}}{\text{Total assets - Loan loss allowance (LLA) - Equity}}$$

The panel data model is estimated using the previous quarter's capital ratio and the 91-day T-bill rate as explanatory variables for the IER, and the real economic growth rate over the past year for the IIR. Both models also use the previous quarter's IIR and IER as explanatory variables, as the volatility of market interest rates such as the 91-day T-bill rate is high, while the volatility

of deposit and lending rates is low. As with the credit cost ratio, we estimate a common slope model with the same coefficients for all banks, while including the difference between banks (δi) as a fixed effect and the time period (ɣt) as a random effect. The estimation results are as follows.

IIR = 0.010589 + 0.540858*IIR(-1) + 0.452508*IER + 0.015257*RGDPGR + 0.008684*RGDPGR(-1) + 0.005777*RGDPGR(-2) + 0.004774*RGDPGR(-3) + 0.017539*RGDPGR(-4) + [δ_i = Fixed, γ_t = Random]

IER = 0.006062 + 0.845788*IER(-1) + 0.084295*TBR - 0.011139*TCR(-1) + [δ_i = Fixed, γ_t = Random]

Where RGDPGR is GDP growth (yoy), TBR is the 91-day T-bill rate and TCR is the bank-specific total capital ratio. In the above equation, all estimated coefficients are significant at the 5% significance level, except for the coefficients on RGDPGR(-2) and RGDPGR(-3). The peculiarities of these interest income rate (IIR) and interest expense rate (IER) models of Nepalese commercial banks are as follows:

1) As expected, the interest expense rate increases with higher market interest rates and lower Tier 1 capital ratio of the banks. However, most of the variation in the interest expense rate is explained by the level of the previous quarter, which can be attributed to the lower volatility of deposit rates relative to short-term market rates.
2) As expected, the interest income rate increases with higher real economic growth. However, most of the variation in the interest income rate is explained by the interest cost rate and the previous interest income rate. This is probably due to the practice of determining the lending rate by adding a certain margin to the deposit rate and to the lower volatility of the lending rate compared with the short-term market rate.

<Table 4-14> Model estimates for interest income rate (IIR) and interest expense rate (IER)

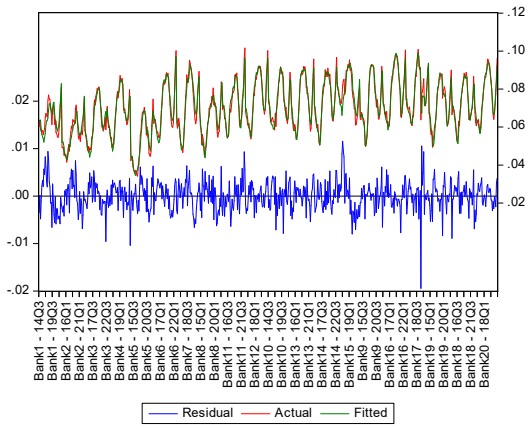
Explanatory variables	IIR model		IER model	
	Coeff.	Prob.	Coeff.	Prob.
Intercept	0.010589	0.0000	0.006062	0.0000
IER	0.452508	0.0000		
IER(-1)			0.845788	0.0000
IIR(-1)	0.540858	0.0000		
91-day T-Bill rate			0.084295	0.0000
Bank total capital ratio(-1)			-0.011139	0.0445
Real GDP growth(yoy)	0.015257	0.0107		
Real GDP growth(-1)(yoy)	0.008684	0.1392		
Real GDP growth(-2)(yoy)	0.005777	0.3267		
Real GDP growth(-3)(yoy)	0.004774	0.4283		
Real GDP growth(-4)(yoy)	0.017539	0.0039		
R-squared	94.7%		94.9%	

Estimation method : Panel EGLS (Period random effects)

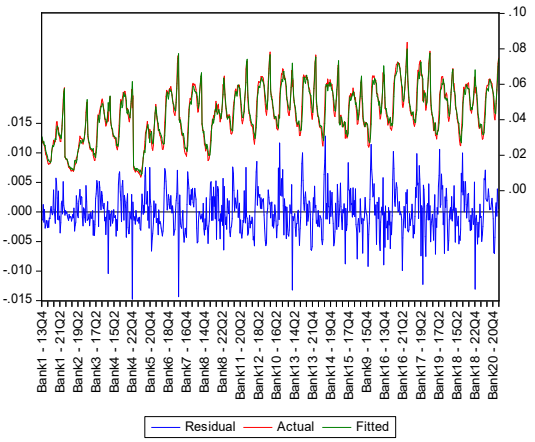
In general, it is desirable to include the interest rate maturity of assets and liabilities as an explanatory variable to properly reflect the change in net interest income due to interest rate changes, i.e., interest rate risk,. However, given that the current bottom-up (BU) stress test for each bank shows negligible interest rate risk, we omit the maturity of each bank from the explanatory variables in this model to simplify the model. The estimates of changes in net interest income due to changes in interest rates from the bottom-up (BU) stress test for each bank can be used to validate the net interest income model results from the top-down (TD) stress test.

<Figure 4-30> and <Figure 4-31> show the comparison of the estimated and actual interest income rate (IIIR) and interest expense rate (IER) of commercial banks in Nepal.

<Figure 4-30> Comparison of IIR Model Estimates and Actual Values



<Figure 4-31> Comparison of IER Model Estimates and Actual Values



<Table 4-15> shows the estimated bank-specific fixed effects for Nepalese commercial banks, according to the aforementioned models.

<Table 4-15> Estimated Fixed Effects by Bank

Bank	IIR model	IER model
Bank1	0.004499	-0.00223
Bank2	0.003521	-0.00329
Bank3	7.44E-05	-0.00136
Bank4	-0.00061	-0.0005
Bank5	0.00063	-0.00241
Bank6	-1.46E-05	0.000215
Bank7	0.000346	0.000241
Bank8	-0.00013	-0.00085
Bank11	-0.00096	0.000654
Bank12	-0.00016	0.001015
Bank10	-0.00245	0.000798
Bank13	-0.00168	0.001092
Bank14	-0.00077	0.000683
Bank15	0.003277	0.000684
Bank9	-0.0005	0.000387
Bank16	-0.00114	0.002051
Bank17	-0.00134	0.001486
Bank19	-0.00133	0.00047
Bank18	-0.00157	0.000102
Bank20	0.000301	0.000748

(5) Estimation of market risk gains and losses for Nepalese banks

① How to estimate market risk profit and loss for stress test

Market risk refers to the variation in profit and loss due to changes in market variables such as foreign exchange rates, interest rates and equity prices, and its impact on the bank's capital ratio. As mentioned above, interest rate risk other than market risk is not directly reflected in risk-weighted assets in the Basel Committee's (BCBS) capital ratio calculation and is regulated under Pillar 2, but market risk is regulated under Pillar 1 together with credit risk and is included in the calculation of risk-weighted assets. In order to strictly implement the stress test, it is necessary to take into account changes in risk-weighted assets due to market risk. However, just as it is common practice not to reflect changes in credit risk-weighted assets due to changes in credit ratings in the event of a deterioration in financial market conditions when using the standardised approach without using an IRB model to calculate the capital ratio, there is less need to reflect changes in market risk-weighted assets due to changes in market volatility when using the standardised approach. As a result, market risk in the stress test can focus on changes in the profit and loss account, as can credit risk.

In general, changes in profit and loss due to market risk are reflected in trading profit and loss, and trading profit and loss is mainly divided into profit and loss from trading activities and mark-to-market profit and loss. Mark-to-market gains and losses are generated by changes in market prices, so it is relatively easy to calculate gains and losses if the market risk exposure remains the same, given market prices such as stock prices, exchange rates, and interest rates in a stress scenario. In the Bank of Korea's SAMP model, market risk gains and losses are measured according to the following simple formula by applying the mark-to-market method to the market losses of trading accounts due to changes in market prices such as interest rates, stock prices, and exchange

rates (Bank of Korea, 2012). This does not reflect gains and losses from trading activities, but only mark-to-market gains and losses.

Trading P&L = trading position x △price

In the NRB's bottom-up (BU) stress test, market risk losses do not reflect gains and losses from trading activities, but only valuation gains and losses. <Table 4-16> shows the profit and loss in the event of a 20% appreciation of the Nepalese currency and a 50% fall in the price of Investment in Shares & Debentures as a result of the bottom-up (BU) stress test as at January 2023. The P&L impact is calculated by multiplying the exposure by the market price change, similar to the BOK SAMP model, and the impact on the capital ratio is calculated by assuming that capital would have changed by the amount of the P&L change. For example, the impact of an exchange rate shock on banks' capital ratios is relatively small, +0.02 per cent on average, ranging from +0.04 to +0.26 per cent for each bank, but a 50 per cent fall in equity prices has a relatively large impact on capital ratios, +0.64 per cent on average, ranging from +0.12 to +1.39 per cent for each bank.

<Table-16> Nepal bottom-up stress test market risk estimates (as of January 2023)

(Millioin Rs, %p)

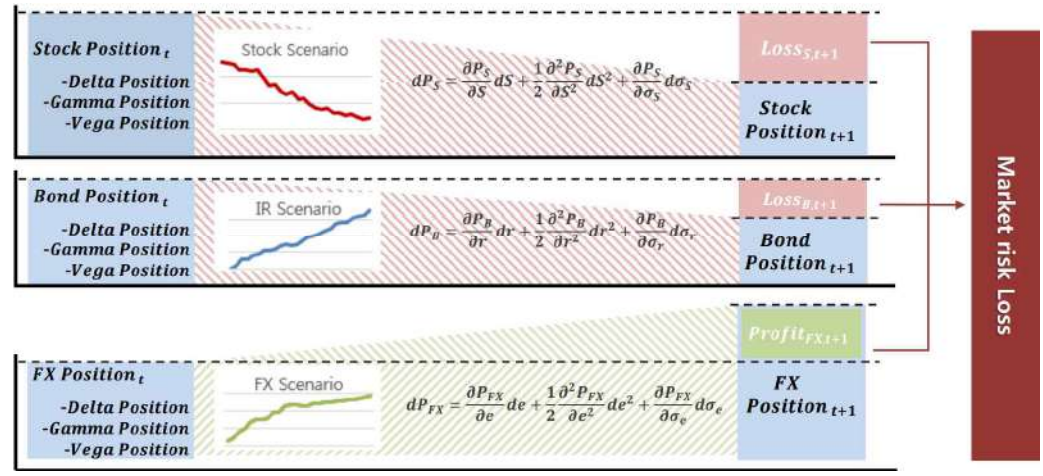
Bank	Exchange rate shock(20%↓)			Stock price shock(50%↓)		
	Net open foreign exchange position	Impact on profits	Impact on CAR	Investment in Shares & Debentures	Impact on profits	Impact on CAR
Bank1	47	-9	(0.00)	4225	-2,113	(0.88)
Bank2	594	-119	(0.04)	8543	-4,271	(1.39)
Bank3	152	-30	(0.01)	4079	-2,040	(0.42)
Bank4	194	-39	(0.01)	6599	-3,299	(0.66)
Bank5	-84	17	0.01	1587	-793	(0.55)
Bank6	-712	142	0.04	1502	-751	(0.22)
Bank7	-42	8	0.00	503	-251	(0.14)
Bank8	196	-39	(0.02)	3146	-1,573	(0.71)
Bank11	27	-5	(0.00)	4953	-2,477	(0.82)
Bank12	30	-6	(0.00)	451	-226	(0.12)
Bank10	34	-7	(0.00)	5591	-2,795	(0.53)
Bank13	24	-5	(0.00)	6610	-3,305	(0.89)
Bank14	139	-28	(0.01)	4760	-2,380	(0.96)
Bank15	78	-16	(0.01)	1427	-714	(0.26)
Bank9	34	-7	(0.00)	5591	-2,795	(0.53)
Bank16	-78	16	0.01	2067	-1,033	(0.50)
Bank17	3155	-631	(0.26)	5277	-2,639	(1.09)
Bank19	92	-18	(0.01)	4061	-2,031	(0.75)
Bank18	1392	-278	(0.08)	6104	-3,052	(0.87)
Bank20	-27	5	(0.00)	2035	-1,017	(0.53)
계	5244	-1,049	(0.02)	79112	-39,556	(0.64)

Sources : NRB

In order to accurately reflect the risk caused by changes in general market risk and individual risk in the calculation of the capital ratio, together with market risk losses, the delta-plus method is sometimes used. This method estimates the gain or loss by dividing the marketable assets held by a financial firm into positions by risk factors such as equity, interest rate and redemption, and then decomposing the changes in the value of the portfolio into (1) positions, (2) changes in the price and volatility of the risk factors, and (3) sensitivity to the price and volatility of the risk factors. This is the same principle as the Greek letters of options, which decompose the profit and loss of a portfolio into delta,

gamma and vega positions, and can be illustrated as shown in <Figure 4-32>. The Financial Services Authority's STARS once used the delta-plus method to estimate market risk gains and losses.

<Figure 4-32> Estimating market risk losses using the Delta-Plus Method (example)



Sources : Kim Jung-il (2023)

Relying solely on market risk positions may not be accurate as it does not reflect the gains and losses from trading activities. However, as the realisation of profits and losses from trading activities during the period is subject to uncertainty, it is difficult to reflect profits and losses accurately, so regression models are used to estimate trading profits and losses, including equity prices, interest rates, exchange rates and, where appropriate, other financial variables as dependent variables. For example, the ECB has published a methodology to estimate changes in the P&L of trading positions under crisis scenarios using a regression model with relevant macroeconomic variables as explanatory variables by risk factor (Giglio et al., 2011). The use of quantile regressions is intended to improve the explanatory power of market losses in response to macroeconomic developments, given the increased asymmetry in the distribution of trading profits and losses during a crisis. The Financial Supervisory Service's

STARS also started to estimate market risk gains and losses using the ECB's methodology in 2023.

② Estimating market risk gains and losses in Nepal

In principle, it is desirable to estimate the market risk component of the stress test by estimating trading gains and losses from both mark-to-market and trading activities, and reflecting the change in market risk assets under the scenario. Despite the technical difficulties of directly estimating trading gains and losses, it is considered necessary to use an estimation model for market risk gains and losses such as the one proposed by the ECB. In Korea, however, both the Financial Supervisory Service and the Bank of Korea initially estimated market risk on the basis of valuation gains and losses only. In particular, the Bank of Korea's SAMP, like Nepal's bottom-up (BU) stress test, reflects a type of simplified sensitivity analysis that reflects price changes in market risk positions. This is because, first, the estimation of changes in trading positions and trading activity during the stress test period depends entirely on the detailed data provided by banks and, second, a simple model reflecting the mark-to-market value of current exposures is sufficient to provide reasonably useful stress test results.

In the case of Nepal, the bank's call report calculates and reports trading gains and losses by separating trading gains and losses from valuation gains and losses only for foreign exchange risk, and does not clearly report trading gains and losses for bonds and equities. In addition, the bottom-up stress test in Nepal only covers changes in net interest income in response to interest rate shocks, not changes in mark-to-market gains and losses. The existence of market risk in interest-bearing assets such as bonds, which are marked to market for trading purposes, requires further verification. Under these conditions, rather than building a separate panel regression model for market risk gains and losses, it seems inevitable to first use the exposure sensitivity analysis of the current bottom-up stress test to reflect equity and foreign exchange risk under stress

scenarios.

However, if the bank's market risk positions in equities and other securities are highly volatile and trading activities are considered to be active, it will be necessary to improve a call report on trading gains and losses and develop an estimation model for trading gains and losses.

In addition, if commercial banks in Nepal currently record and manage only net interest income (NII) for interest rate risk and do not consider market risk, they should consider the change in economic value due to mismatched interest rates in a hypothetical mark-to-market valuation. To this end, we suggest adopting the BCBS (2016) standard to measure the change in the economic value of equity (EVE) under a scenario that takes into account currency-specific interest rate shocks.

(6) Preliminary results of solvency stress tests

① How to estimate financial statements for the stress test

As mentioned above, the purpose of the solvency stress test is to estimate the future financial statements under a stress scenario and to assess capital adequacy by calculating the capital ratio. To do this, we need to estimate the profit and loss account and the balance sheet.

In terms of income statement estimation, we have discussed how to estimate credit losses, net interest income and market risk gains and losses, in order of importance, as these are the most relevant income statement items under stress. Other income statement items are generally assumed to remain at the same level or rate as in the base year to estimate the stressed income statement. For example, commission gains and losses are assumed to be the same in the future as they were in the base year, SG&A expenses are assumed to increase at the rate of expected inflation, and other gains and losses may assume that there are no one-off transactions during the period.

For the balance sheet estimates, you will use the scenario and P&L estimates.

First, assets reflect the base year asset growth rate given in the scenario, and non-performing loans (NPLs) are determined using the NPL ratio derived from the scenario. Equity is calculated by adding the net profit from the estimated profit and loss account to the base year equity, and liabilities are calculated by subtracting the estimated equity from the estimated assets.

However, there is a problem in that the estimates in the financial statements may vary depending on the self-help efforts of individual banks during the period. For example, if non-performing loans increase, banks may reduce their risk-weighted assets by intensifying credit screening and loan recovery efforts, improve net interest income by raising loan interest rates in response to deteriorating earnings, or reduce labour costs by reorganising staff and reducing wages. On the other hand, it is also possible that a credit crunch could occur as banks tighten their credit standards in unison, leading to a further increase in non-performing loans. As a result, the models used to estimate the balance sheets need to be refined to include more variables. However, there are concerns that the rigour of the stress test may be compromised in the process. This is because individual banks may tend to argue that they can prevent their capital ratios from deteriorating by improving their management under stress.

On the other hand, the most rudimentary way of extrapolating financial statements for stress testing is to use the base year financial statements as they are, with only the profit and loss deducted from equity. This is also the method currently used by the NRB for bottom-up (BU) stress testing. This method has the disadvantage that the pro forma accounts are likely to differ significantly from the actual accounts if the bank's asset growth rate is very high and volatile, as is the case in Nepal, but it has the advantage that the results are intuitive and the rigour is not compromised by the bank's self-help efforts.

Currently, there is a lack of data on the time series of trading profits and losses of commercial banks in Nepal and the composition of capital adequacy ratios. Therefore, in this paper, we first calculate the stressed capital ratios based on the base year financial statements. This is believed to be useful for

comparing and verifying the results after calculating the capital ratio by extrapolating the income statement and balance sheet under stress with the necessary assumptions when the relevant data becomes available in the future.

② Stress test provisional results of Nepalese commercial banks

The results of the stress test for Nepal are presented below. The results vary depending on how the scenario is applied, so we have presented a hypothetical scenario with arbitrary economic variables with reference to the discussions in "Chapter 5: Macro Stress Test Scenario Design and Estimation Methodology". The preliminary scenario has the following economic variables

- o Real economic growth rate: -6%. This is assumed to continue until the target year.
- o Stock price: -50%. Reflects market valuation and is therefore only taken into account at the time of the target year.
- o Exchange rate: +50%. Only reflected at the time of the target year estimate.
- o Inflation rate: +10%. Reflected only at the time of the target year estimate.
- o Growth of domestic private credit: 0%. Reflected only at the time of the target year estimation.
- o T-bill rate: 20%. Assumed to continue throughout the projection period.
- o VIX: 50. International financial instability assumed only at the time of the target year.

A conservative estimate of the stress test results under this scenario is as follows. The stress test uses risk-weighted assets as at July 2023, but the capital ratio is calculated by applying the changes in profit and loss during the period to equity as at July 2023. We have used Excel for the estimation and you can refer to the Excel file provided separately for the detailed estimation methodology.

First, assuming that the stress shock lasts for one year, the results of the stress

test are shown in <Table 4-17>. On average, banks' capital ratios fall by 2.75 percentage points, with three banks exceeding 11 per cent and two banks falling to 8-9 per cent.

<Table 4-17> Nepal Stress Test Provisional Results (1)

bank	Assuming the shock lasts for one year					
	CAR (t0)	Impact	Credit Cost	Net Interest Income	Market Risk	CAR^ (t1)
Bank1	14.49%	-2.15%	-0.51%	-0.61%	-1.03%	12.34%
Bank2	13.65%	-3.79%	-1.18%	-1.03%	-1.58%	9.86%
Bank3	12.65%	-1.86%	-0.82%	-0.57%	-0.46%	10.79%
Bank4	14.10%	-2.58%	-1.65%	-0.22%	-0.72%	11.52%
Bank5	17.12%	-4.44%	-2.75%	-1.02%	-0.66%	12.68%
Bank6	13.23%	-1.97%	-0.72%	-0.89%	-0.37%	11.25%
Bank7	12.78%	-2.03%	-0.94%	-0.92%	-0.17%	10.75%
Bank8	13.32%	-3.00%	-1.40%	-0.80%	-0.80%	10.32%
Bank11	13.39%	-4.60%	-2.04%	-1.63%	-0.93%	8.79%
Bank12	13.57%	-2.90%	-1.64%	-1.13%	-0.13%	10.66%
Bank10	12.65%	-2.20%	-0.98%	-0.47%	-0.75%	10.45%
Bank13	13.43%	-4.00%	-2.01%	-0.97%	-1.01%	9.44%
Bank14	12.53%	-3.97%	-1.44%	-1.47%	-1.06%	8.56%
Bank15	14.68%	-0.54%	0.10%	-0.36%	-0.29%	14.13%
Bank9	13.37%	-2.80%	-1.51%	-0.69%	-0.60%	10.56%
Bank16	12.32%	-2.99%	-1.33%	-1.08%	-0.58%	9.33%
Bank17	12.28%	-1.56%	-0.43%	-0.63%	-0.50%	10.72%
Bank19	12.80%	-2.53%	-0.59%	-1.06%	-0.87%	10.27%
Bank18	12.95%	-2.53%	-1.32%	-0.45%	-0.76%	10.42%
Bank20	14.13%	-4.26%	-2.57%	-1.07%	-0.62%	9.87%
total	13.37%	-2.75%	-1.25%	-0.79%	-0.71%	10.62%

Second, the results of the stress test for the case where the shock lasts for two years are shown in <Table 4-18>. As the model is estimated by the ratio of the credit cost ratio, the interest income ratio and the interest expense ratio, the reduction in credit cost and interest income is about twice as large when the shock lasts for two years as when it lasts for one year. Banks' capital ratios fell

by an average of 5.45 percentage points, with all but one bank's capital ratio falling below 11 per cent, and 10 banks falling below 8 per cent.

<Table 4-18> Nepal Stress Test Provisional Results (2)

Bank	Assuming the shock lasts for two years					
	CAR (t0)	Impact	Credit Cost	Net Interest Income	Market Risk	CAR^ (t2)
Bank1	14.49%	-4.95%	-1.96%	-1.96%	-1.03%	9.54%
Bank2	13.65%	-7.19%	-2.76%	-2.85%	-1.58%	6.46%
Bank3	12.65%	-4.30%	-2.11%	-1.73%	-0.46%	8.35%
Bank4	14.10%	-4.42%	-2.81%	-0.89%	-0.72%	9.68%
Bank5	17.12%	-7.25%	-3.96%	-2.63%	-0.66%	9.87%
Bank6	13.23%	-4.68%	-1.99%	-2.32%	-0.37%	8.55%
Bank7	12.78%	-4.80%	-2.18%	-2.44%	-0.17%	7.98%
Bank8	13.32%	-5.90%	-2.88%	-2.23%	-0.80%	7.42%
Bank11	13.39%	-8.62%	-3.74%	-3.94%	-0.93%	4.77%
Bank12	13.57%	-5.90%	-2.91%	-2.86%	-0.13%	7.67%
Bank10	12.65%	-4.42%	-2.27%	-1.39%	-0.75%	8.23%
Bank13	13.43%	-6.80%	-3.28%	-2.50%	-1.01%	6.63%
Bank14	12.53%	-7.57%	-2.87%	-3.64%	-1.06%	4.96%
Bank15	14.68%	-2.82%	-1.15%	-1.38%	-0.29%	11.86%
Bank9	13.37%	-5.29%	-2.79%	-1.90%	-0.60%	8.08%
Bank16	12.32%	-6.02%	-2.72%	-2.72%	-0.58%	6.30%
Bank17	12.28%	-3.98%	-1.69%	-1.79%	-0.50%	8.30%
Bank19	12.80%	-5.62%	-2.00%	-2.75%	-0.87%	7.18%
Bank18	12.95%	-4.65%	-2.53%	-1.36%	-0.76%	8.30%
Bank20	14.13%	-7.49%	-4.04%	-2.83%	-0.62%	6.64%
Total	13.37%	-5.45%	-2.58%	-2.16%	-0.71%	7.92%

C. Assessment of the solvency stress testing model and future improvements

Although the methodology presented in this report for Nepal's stress test is based on the best practices of stress tests currently conducted by major national financial authorities around the world, it has a number of limitations, including the limited availability of relevant statistical data and the fact that the research was conducted in Korea rather than in Nepal, which prevented us from fully collaborating with the staff of the NRB. Below, we highlight the problems with the stress test and suggest ways to improve it in the future.

① Limitations of short time series data that do not reflect the crisis situation

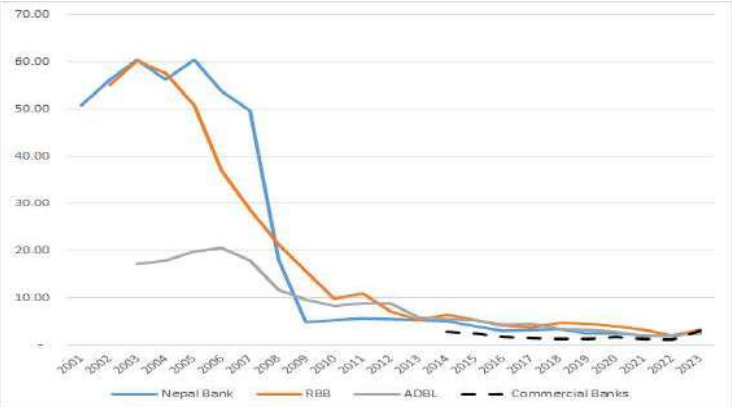
First, the stress test results show that credit costs are not as sensitive to economic shocks as expected. The impact of economic growth shocks was smaller than expected, while the impact of exchange rate and international financial market turbulence was relatively large. This is mainly due to the fact that the time series used in the model are only available from 2013 onwards, which does not include the actual financial crisis.

When introducing the stress test model, the Korean Financial Supervisory Service compared a model that included the 2003 credit card crisis with one that did not. Using data from 2004 to 2016, the model predicted a long-term average default rate of 3.36 percent, but when the model was applied to economic and financial variables during the 2003 crisis, the estimated default rate for self-employed individuals was 7.29 percent, while the actual default rate reached 14.46 percent, indicating an underestimation error of 7.16 percentage points during the crisis. On the other hand, when we estimate a model of the default rate of self-employed workers using data from 2000 to 2016, including the 2003 crisis, we find that the estimated default rate in 2003 was 12.11 percent, reducing the underestimation error to 2.27 percentage points (Shin and Hwang, 2018). This suggests that models of the cost of credit in stress tests that do not include crisis events can lead to significant underestimation of the magnitude of

losses.

In the case of Nepal, the NPL ratio of state-owned banks was very severe during the Asian financial crisis and the global financial crisis in the late 1990s to 2010. <Figure 4-33> shows the contrast with the period 2013-2023. In particular, in 2003 and 2005, the NPL ratio of state-owned banks was as high as 60%. Therefore, the results of the model estimation of the credit cost are likely to significantly underestimate the impact of the crisis. Therefore, efforts should be made in the future to use statistical techniques to reflect past crises with insufficient data..

<Figure 4-33> Changes in NPL ratios of three Nepalese state-owned and 20 commercial banks



Sources : NRB

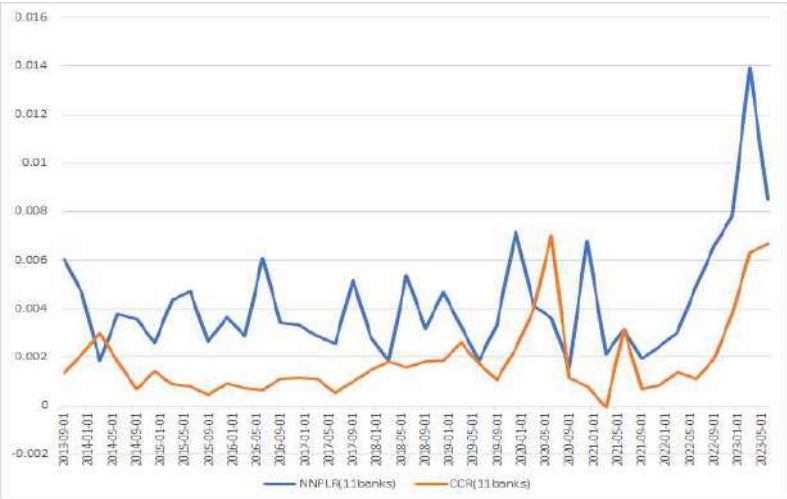
② Lack of statistics on default rates and segmentation of exposures by sector

In order to build a credit loss model, it is generally necessary to segment a bank's exposures into five borrower characteristics, namely large corporates, SMEs, residential mortgages, retail (household) and credit cards, according to the Basel 3 standards to obtain the respective probability of default (PD) and loss given default (LGD). However, in the case of Nepal, the call reports do not disaggregate exposures into large, medium and small enterprises, mortgages, retail (households) and credit cards, and the standardised method for calculating bank

capital ratios is used, so statistics on PD and LGD are not available.

The data used in this paper as a proxy for PD and LGD is the credit cost ratio. As for the new NPL ratio, which was considered as a proxy for PD, only 11 of the 20 commercial banks had time series for the period 2013-2023. <Figure 4-34> shows the evolution of the New NPL ratio and the credit cost ratio for these 11 banks. It can be seen that the New NPL ratio moves ahead of the credit cost ratio, that is, the credit cost increases after a period of time following the increase in the New NPL ratio. Before the Covid-19 outbreak, the credit cost ratio remained relatively low despite the fluctuations in the new NPL ratio, but after the Covid-19 outbreak, the new NPL ratio first spiked and then the credit cost ratio rose. This shows the greater timeliness of the new NPL ratio.

<Figure 4-34> Comparing the evolution of the credit cost ratio and New NPL ratio for 11 banks



Sources : NRB
NNPLR : New NPL ratio
CCR : Credit cost ratio

Therefore, in the future, if banks' exposures are segmented into large, medium and small corporates, residential mortgages, retail (households) and credit cards, and stress tests are conducted based on PD or new NPL data and LGD based on statistical recovery rates depending on the presence and type of collateral, it

will be possible to estimate the more objective level of credit losses in a stress situation.

③ Unavailability of trading P&L statistics and omission of financial statement estimation procedures

We were not able to estimate the financial statements for each period of the stress scenario. The core of the stress test is the estimation of the income statement, which requires the estimation of credit losses, changes in net interest income and trading gains and losses. However, during the period under review, it was not possible to obtain data on the income statement items of the bank's call report, which distinguish between trading and valuation gains and losses on foreign exchange, bonds and equities that are recognised in the income statement or directly in equity. As a result, only valuation gains and losses related to market risk could be obtained on the basis of the exposures identified in the current bottom-up stress test. In addition, as it was difficult to estimate the income statement under stress, the capital ratio under stress was estimated by dividing the baseline capital by the baseline risk-weighted assets after reflecting changes in credit losses, changes in interest income and valuation gains and losses on market risk.

The lack of financial statement estimates and the lack of data on the composition of the bank's capital ratio calculation limited the ability to understand the impact of the stress test. In the Basel Committee's capital ratio calculation, capital is divided into Tier 1 and Tier 2, and Tier 1 is further divided into common equity and other Tier 1 capital. In general, the impact of a stress test directly affects common equity, resulting in a decrease in the common equity ratio that is at least as large as the decrease in the total capital ratio. In general, the common equity ratio has a separate and more stringent minimum standard, so data on the composition of equity is required to determine the results of the stress test.

Therefore, in the future, it will be necessary to obtain a time series of trading

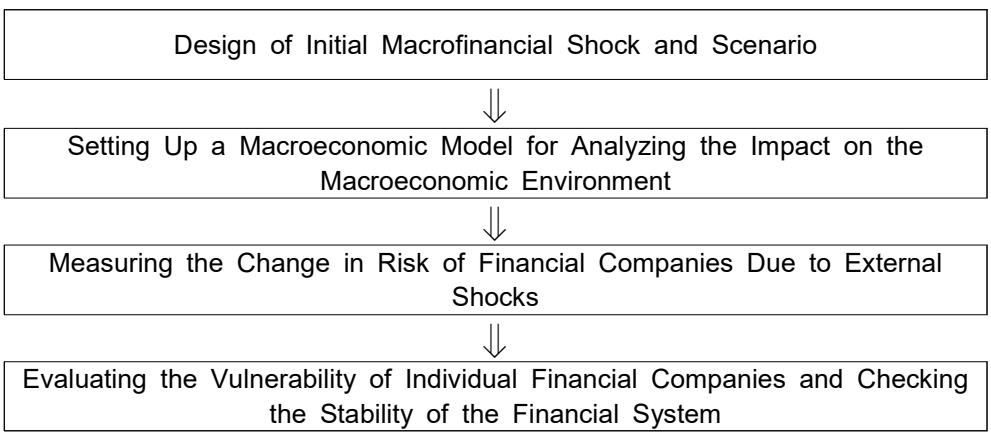
profits and losses separately and estimate financial statements such as income statements for each scenario period and assess the impact separately according to the level of the common equity ratio, tier 1 capital ratio and total capital ratio.

Ⅴ. Macro Stress Test Scenario Design and Estimation Methodology

A macro stress test represents a method to evaluate the stability of financial institutions or the entire financial system under 'plausible, yet severely adverse' macroeconomic conditions. It statistically assesses whether financial companies possess sufficient capital and liquidity to absorb crisis shocks. Through this, financial supervisory authorities can significantly reduce policy uncertainty by securing a benchmark to judge the viability of financial companies against external shocks.

The general procedure of a macro stress test is as follows. The first step involves designing the initial shock through the creation of macroeconomic scenarios. The second step establishes a macroeconomic model to illustrate the impact that the initial shock has on the macroeconomic environment. The third step measures the change in the risk of financial companies due to external shocks in each scenario. The final step involves analyzing the results of the stress test to assess the vulnerability and capital soundness of individual financial companies and, when combined with other information, to check the stability of the financial system.

<Figure 5-1> General Process for Macro Stress Test



This section discusses the methodology related to scenario creation, the first step in stress testing, and applies it to an analysis of the Nepalese economy.

1. Scenario Methods and Setting Initial Shocks

The inception of macro stress tests necessitates the creation of scenarios that embody 'severe yet plausibly exceptional' exogenous shocks. Paramount considerations in crafting a scenario involve determining the magnitude of 'severe yet plausible' shocks that influence the financial sector, and setting the analysis period. Identifying macro-financial variables that underpin these initial shocks is essential, as is designing a macroeconomic model that elucidates the impact of these shocks on the macroeconomic environment. Initial shocks can be examined one by one or simultaneously, considering more than two shocks in a compound manner.

There are four main forms for setting the magnitude of initial shocks, contingent on the scenario method employed. First is the historical method, which faithfully reproduces specific historical stress events involving serious economic crises, utilizing actual data from occurrences like the 1987 stock market crash, the 1998 emerging market crisis, and the 2008 global financial crisis. The second method is the hypothetical method, where scenarios are arbitrarily set by scenario designers to avert the risk of over-reliance on past events, defining fictitious yet severe scenarios capable of inducing considerable shocks to the financial sector. The third method is the probabilistic method, based on the empirical distribution of the relevant risk variables and utilizing values corresponding to the extreme percentiles of this distribution. The fourth and final method is the reverse engineering method, determining retroactively the magnitude of macroeconomic shocks that could lead to pre-set financial soundness situations like BIS ratio reductions or NPL levels.

While the way scenarios are designed varies widely from country to country, the historical and hypothetical methods are commonly used because they are

relatively intuitive to construct and simple to interpret. In particular, some countries tend to use more hypothetical scenarios due to data limitations. Short time series and insufficient coverage of available data often preclude the use of the historical method altogether. In addition, structural breaks in a country's economic continuity or rapidly changing economic environments further limit the extent to which lessons can be learned from past episodes of macrofinancial stress.

This is why the IMF (2019), which has been assessing and monitoring macro-financial stability in fragile economies in recent years, recommends the use of probabilistic methods such as Growth at Risk (GaR). Regardless of the type of scenario adopted, for an initial shock to be meaningful, it must have a low probability of occurrence but a high enough impact intensity that extreme values of the underlying risk factor can be realized, and it must be highly relevant to the financial system. When the overall health of the economy is very good, an extreme shock will not cause the entire financial system to go into stress, so what is important in stress testing is the realization of an extreme shock of sufficient intensity to push the financial system into crisis.

2. GaR Framework

A. Overview

To model initial shocks for Nepal's macro stress test, this study employs the GaR (Growth at Risk) framework, a probabilistic scenario model first proposed by the IMF (2017a). GaR, conceived as a tool to gauge and monitor the possibility and severity of abrupt economic downturns by predicting the future GDP growth rate distribution, takes inspiration from the VaR (Value at Risk) concept, a popular risk management tool used in financial companies.

The concept was first introduced in the Global Financial Stability Report (IMF,

2017a), with its analytical foundation detailed in IMF (2017b) and Prasad et al. (2019). Prasad et al. (2019) offers pragmatic guidelines on the GaR framework methodology and showcase applications of GaR in macro-financial analyses for Canada, Peru, Portugal, and Singapore, serving as a reference for the execution of macro-prudential policies in various countries.

As shown in the IMF's first application of GaR, the use of GaR was focused on analyzing how domestic and international macrofinancial conditionscould affect downside risks to future economic growth..

To conduct this analysis, a quantile regression model, which utilizes specific macro-financial variables as explanatory variables and estimates the future GDP growth rate distribution, is set up according to the method proposed by Adrian, Boyarchenko, Giannone (2018). Therefore, in a GaR model, the choice of macrofinancial variables to explain their relationship with future economic growth becomes very important.

In the case of IMF (2017a, 2017b), the selection of impact variables focused on financial conditions to assess the financial stability risks of individual countries using the GaR framework. Specifically, these two IMF papers grouped relevant variables into three groups: domestic price of risk group, consisting of credit spreads, term spreads, short- and long-term interest rates, asset price returns, and volatility indicators; leverage group, consisting of credit growth and the change in the credit-to-GDP ratio; and external conditions group, consisting of commodity prices and global risk sentiment, and constructed a financial condition index (FCI) with these three grouping variables as subcomponents.

Another important use of the GaR framework is that it allows for scenario analysis. It is possible to assess how shocks to key macrofinancial conditions would change the shape of the probability distribution of future economic growth, and to determine probabilistically how severe an economic downturn would be caused by such a macrofinancial shock. When financial conditions tighten or external economic conditions deteriorate, these changes may primarily affect the mean of the future growth distribution, but in some cases they may

have a much greater impact on the shape and size of the left tail of the distribution, which corresponds to the downside risk. In this case, the GaR model provides a very flexible and concise tool to quantify and understand the impact of macrofinancial shocks.

B. Statistical Methodology

Prasad et al. (2019) proposed the following three stages for estimating the GaR model:

Step 1: Utilizing dimension reduction techniques like Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), or Orthogonal Projection to Latent Structures Discriminant Analysis (OPLS-DA) to partition a broad array of macro-financial variables into several groups. These groups, comprising factors with shared time-series characteristics, are established by grouping them based on their commonalities.

Step 2: Employing the factor variables derived from Step 1 as regression variables to estimate a quantile regression model, predicting the quantiles of the future GDP growth rate distribution based on the current macro-financial conditions.

Step 3: Utilizing density function estimation techniques to forecast parametric asymmetric t-distributions, based on the conditional quantiles estimated in Step 2, and derive economic growth rates at the given confidence level.

The final step involves scenario analysis, where we re-estimate the conditional quantiles with the new partitioning under various scenarios that allow us to derive probability distributions of GDP growth under diverse macroeconomic

conditions.

Partitioning and Dimension Reduction of Macro-financial Variables

The first step is to use dimension reduction techniques to categorize a large number of individual macrofinancial variables by splitting them into a few groups (e.g., risk prices, leverage, external economic conditions, etc.) and condense the related variables in each group into a single factor. These grouped factors are employed as regression variables in estimating the quantile regression model in Step 2. Dimension reduction methods commonly use statistical techniques such as principal component analysis (PCA), linear discriminant analysis (LDA), and orthogonal projection to latent structures discriminant analysis (OPLS-DA).

However, employing such dimension reduction techniques is not mandatory for estimating GaR. The raw data of macro-financial variables can be used as variables for the quantile regression model without extracting factors for each group. Especially when macro-financial data series, typically possessing quarterly frequency, offer limited observations, dimension reduction techniques can be considerably helpful by reducing the number of parameters to be estimated. Moreover, utilizing factor variables extracted by group enables the identification of common trends among group variables, filtering essential information from the intrinsic noise individual macro-financial variables may possess, and potentially enhancing the predictive capacity of GaR.

Estimation of Quantile Regression Model

The quantile regression model, initially developed by Koenker and Bassett (1978), uses the regressor variable $X_{k,t}$ to analyze the determining factors of the quantiles in the conditional distribution of a dependent variable Y_{t+h}. The quantile regression model is expressed as follows:

$$Y_{t+h} = X_t'\beta^\tau + u_t = \sum_{k=1}^{q} X_{k,t}\beta_k^\tau + u_t$$

$$Y_{t+h}^\tau \equiv Q^\tau(Y_{t+h} \mid X_{k,t}) = \sum_{k=1}^{q} X_{k,t}\beta_k^\tau \qquad (1)$$

where Y_{t+h} is the dependent variable at a future h point(h step ahead), $X_{k,t}$ is k-th independent variable, $X_t = (X_{1,t}, X_{2,t}, \cdots, X_{q,t})$ is a matrix consisting of q independent variables($X_{k,t}$), u_t is the error term, and $\beta^\tau = (\beta_1^\tau, \beta_2^\tau, \cdots, \beta_q^\tau)$ denetoes τ-th quantile regression coefficient vector. Y_{t+h}^τ ($= Q^\tau(Y_{t+h} \mid X_{k,t})$) represents the conditional τ-quantile of the dependent variable Y_{t+h} given the independent variables $X_{k,t}$.

The estimator of the regression coefficient β^τ in the quantile regression model can be obtained by minimizing the following quantile loss function:

$$\hat{\beta}^\tau = \arg\min_{\beta} \left(\sum_{Y_{t+h} > X_t'\beta} \tau(Y_{t+h} - X_t'\beta) + \sum_{Y_{t+h} < X_t'\beta} (1-\tau)(Y_{t+h} - X_t'\beta) \right)$$

where $\hat{\beta}^\tau$ represents the vector of estimated coefficients associated with the τ-th quantile in the regression model.

In the GaR (Growth at Risk) framework for scenario analysis, the independent variables $X_{k,t}$ are composed of factor variables obtained through dimension reduction techniques such as PCA (Principal Component Analysis) in the first step. Here, In Equation (1), Y_{t+h}^τ represents the τ-quantile of the future GDP growth rate distribution over the $t+h$-period, and β_k^τ denotes the contribution of the factor variable K in predicting the τ-quantile of the GDP growth rate distribution.

Prediction of the Conditional Probability Density Function (Density Forecasting)

Utilizing the estimation results of the quantile regression model from step 2, The τ-quantile prediction of the dependent variable Y_{t+h} conditional on the macrofinancial variables ($X_{k,t}$) at time *t+h*, $\widehat{Y}^{\tau}_{t+h}$, is given by the following equation based on the point estimates of the quantile regression coefficients, $\widehat{\beta^{\tau}}$.

$$\widehat{Y}^{\tau}_{t+h} \equiv Q^{\tau}\left(Y_{t+h} \mid X_{k,t}, \widehat{\beta}^{\tau}_{k} \right) = \sum_{k=1}^{q} X_{k,t} \widehat{\beta}^{\tau}_{k}$$

The conditional distribution of future GDP growth is now predicted parametrically using each quantile estimate, $\widehat{Y}^{\tau}_{t+h}$, derived from the estimated quantile regression model. The IMF (Prasad et al.: 2019) suggests utilizing the Skewed Student-t distribution introduced by Giot and Laurent (2002) for estimating the parametric probability density of GDP growth. The quantile function of the non-standardized Skewed Student-t distribution is given as follows:

$$F^{-1}(\tau \mid df, \zeta) = \begin{cases} \frac{1}{\zeta} st_{\tau,df}\left[\frac{\tau}{2}(1+\zeta^2) \right] & \text{if } \tau < \frac{1}{1+\zeta^2} \\ -\zeta\, st_{\tau,df}\left[\frac{1-\tau}{2}(1+\zeta^{-2}) \right] & \text{if } \tau \geq \frac{1}{1+\zeta^2} \end{cases}$$

where τ represents the quantile, *df* is the degrees of freedom, ζ is the skewness parameter[9], and $st_{\tau,df}$ denotes the quantile function of a Student-t distribution with unit variance.

The quantile regression model proves to be robust against outliers, which are commonly observed in countries with poor data availability, and offers the best linear unbiased estimator (BLUE) for conditional quantile estimation. Therefore, the utilization of the quantile regression model holds an advantage in estimating

9) This value is always positive; when it is less than 1, it implies left-skewed asymmetry, and when it is greater than 1, it indicates right-skewed asymmetry.

the conditional distribution function.

Scenario Analysis (Counterfactual Scenarios Analysis)

To utilize the GaR framework for scenario analysis, the initial shock to macro-financial variables must be introduced into the GaR model to analyze its impact on the future distribution of economic growth rates. The scenario analysis used in the GaR framework is a comparative static analysis, assuming that when shocks to specific macro-financial variables occur, the states of other variables remain constant. Therefore, to perform scenario analysis that considers the impact of initial shocks on other variables, consideration of multivariate time series models, such as vector autoregression, is required.

In the GaR model, shocks can be applied to one or more of the raw variables or grouped factor variables. Since quantile regression models are estimated on dimensionally reduced factor variables rather than raw variables, for a shock to a raw variable, we must first consider how much the shock will change the factor variables in the group to which the shock variable belongs.

Given a shock to the grouped factor variable itself, a new conditional quantile value and an altered distribution of future economic growth are obtained using the following equation based on the shock-reflecting value, $\widetilde{X_{k,t}} = X_{k,t} \times (1 + shock)$,

$$\widetilde{Q}\left(Y_{t+h}^{\tau} \mid \left\{ \widetilde{X}_{k,\ t} \right\}_{k \in P}, \right) = \sum_{k \in P} \hat{\beta}_k^{\tau} \widetilde{X}_{k,t}$$

3. GaR Scenario Analysis for the Nepalese Economy

We use the IMF's Growth at Risk (GaR) framework to assess the effect of macrofinancial variables in the Nepalese economy on future GDP growth and to analyze scenarios of how the Nepalese economy would be adversely affected if certain shocks occur. Using the three steps of the GaR framework introduced

earlier, links between current macro-financial conditions and future GDP growth rates are identified, and these are used to derive the conditional distribution of future GDP growth.

For the GaR scenario analysis, macro-financial time series data from the first quarter of 2011 (mid-October of 2011) to the 2022 quarter (mid-January of 2022) are used. The total number of observations in the time series data is 46. Given the limited data, the partition domains of the macro-financial variables to be included in the quantile regression model were restricted to five.

Five factor variables are obtained through principal component analysis (PCA): domestic macroeconomic conditions, domestic financial conditions, leverage, macroeconomic conditions of major trading partners, and foreign financial conditions. The list of macro-financial variables included in the five partitioning areas and used in the GaR scenario analysis is summarized in <Table 5-1>.

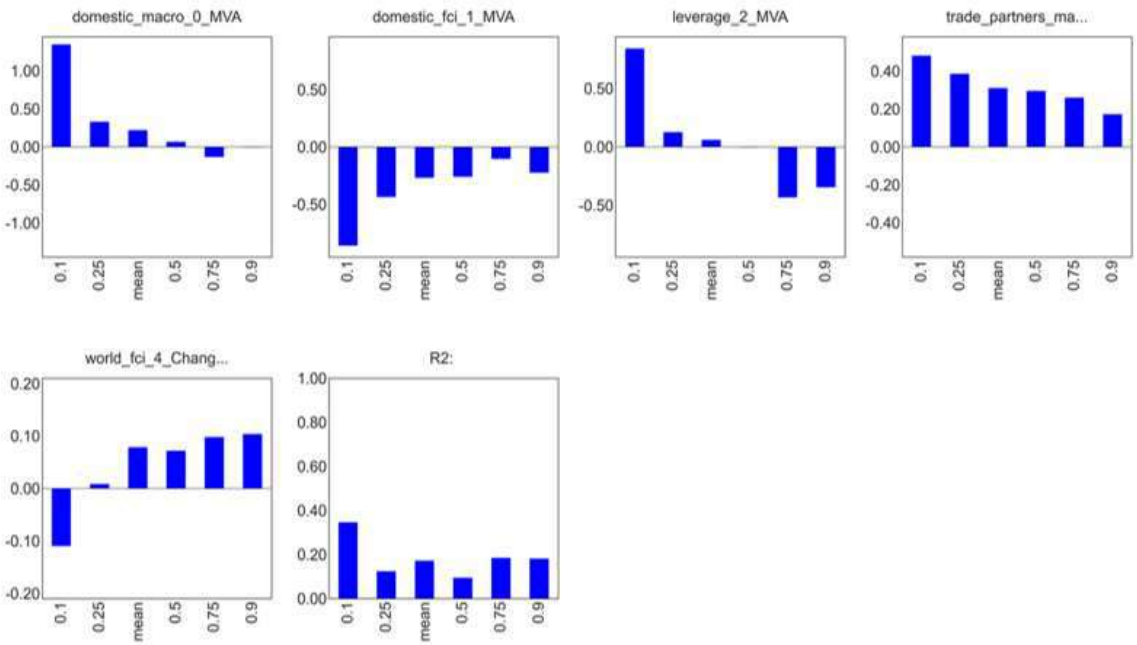
For domestic macroeconomic conditions, variables such as the rate of change in remittances from overseas migrant workers, tourism revenue growth, and current economic growth rate have been considered. In the domain of domestic financial conditions, the 91-day treasury bill rate and the average loan interest rate are considered, while in the leverage domain, the credit/GDP ratio and the bank sector's total loans/total deposits ratio are considered. The macroeconomic conditions of major trading partners include economic growth variables for China and India, and in the overseas financial conditions category the United States' VIX index and international oil prices are included

<Table 5-1> Partition Domain for Macro-financial Variables for Factor Extraction

Common Factors	Domestic Macro)	Domestic Financial Condition	Leverage	Trade Partners Macro	Global Financial Condition
Macro Financial Factors	- current output growth rate - remittance growth rate - travel income growth rate	- treasury bill rate - average lending rate	- credit to gdp ratio - loan to deposit ratio	- India output growth rate - China output growth rate	- VIX - oil price

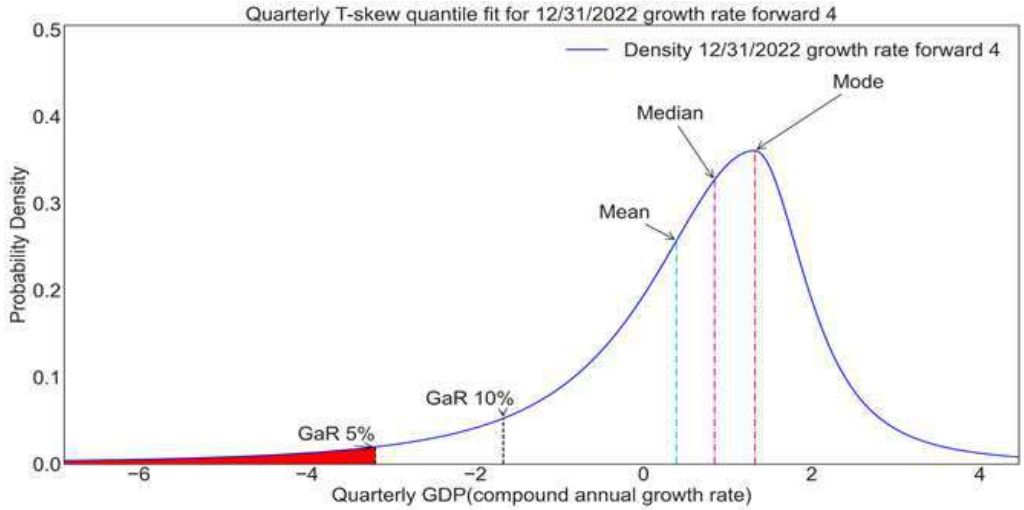
<Figure 5-2> shows the estimation results of a quantile regression model in second step using the factor variables obtained according to the classification in <Table 5-1>. Most of the estimated results are in line with theoretical expectations, but for the leverage partition, the estimation results are unexpectedly positive in the tails. Such outcomes greatly vary depending on the model setting and are presumed to stem from the model's lack of robustness to outliers, due to insufficient data being secured.

<Figure 5-2> Quantile Regressions Coefficients



Using the quantile regression model estimation results from <Figure 5-2>, the conditional distribution of Nepal's GDP growth rate for the fourth quarter ahead can be obtained, resulting in an asymmetric distribution with a long left tail, as shown in <Figure 5-3>. The summary statistics for the distribution are compiled in <Table 5-2>, wherein the 5% GaR (Growth at Risk) can be identified as -3.18%.

<Figure 5-3> Estimation of the Conditional Distribution and 5% GaR of Nepal's GDP Growth Rate

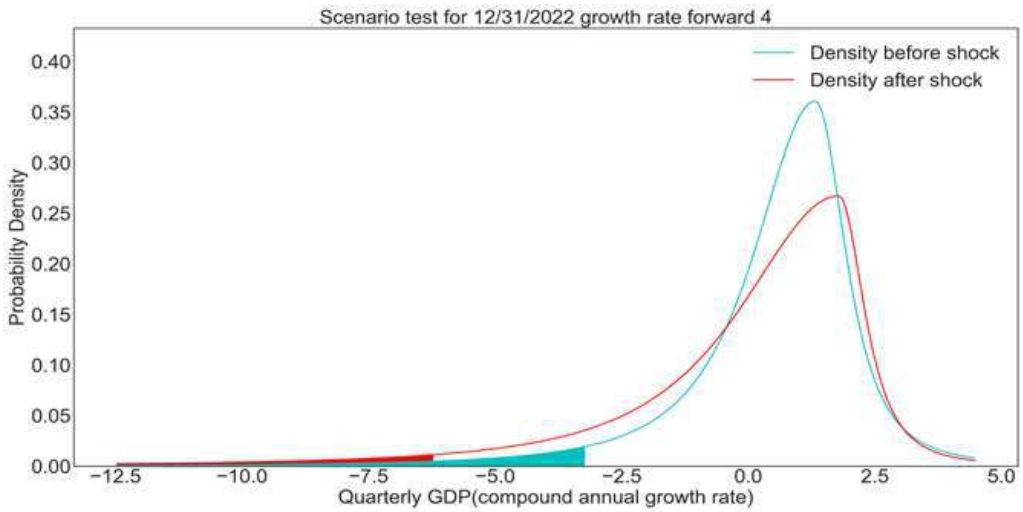


<Table 5-2> Summary Statistics for the Conditional Distribution of Nepal's GDP Growth Rate

Statistics	Estimated Values
Horizon Forward	4
Conditional Mode	1.3258
GaR 5%	-3.18
Skewness	0.7051

For scenario analysis, it is assumed that a severe negative shock has occurred to the remittances from overseas migrant workers and the 91-day treasury interest rate variables. For the remittances of overseas migrant workers, a negative shock of -2 standard deviations is assumed. According to <Figure 5-4>, the result of that shock can be confirmed to have a negative impact on Nepal's economic growth rate. The 5% GaR falls even further from −3.18% to -6.22%, indicating an economic downturn brought about by the remittance shock.

<Figure 5-4> Scenario Analysis: Shock to Overseas Workers' Remittances

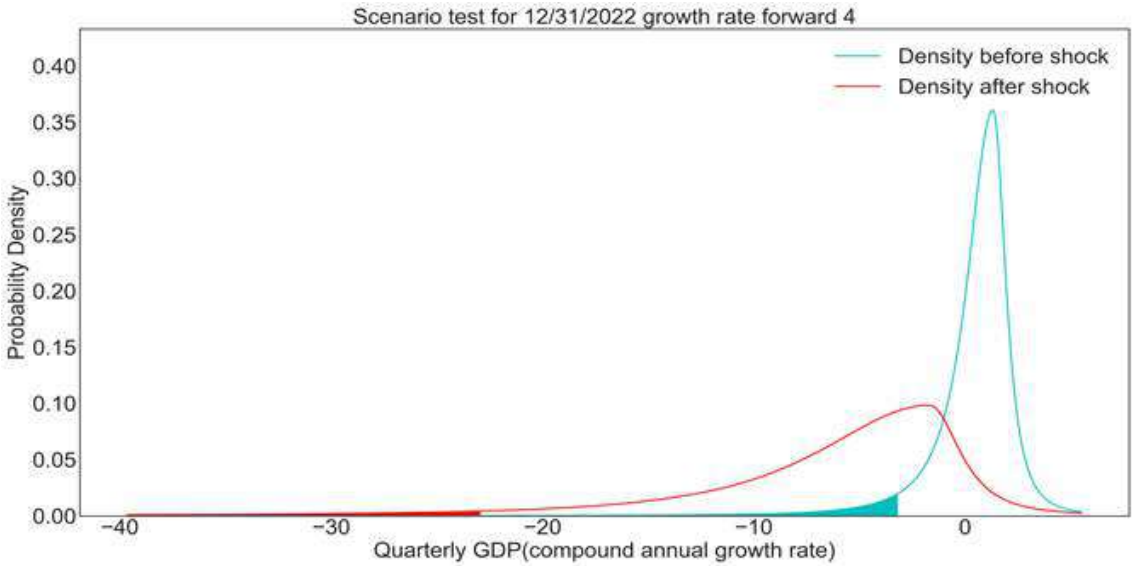


<Table 5-3> Impact of the Shock to Overseas Migrant Workers' Remittances

Statistics	Before Shock	After Shock
Horizon Forward	4	4
Conditional Mode	1.3258	1.7899
GaR 5%	-3.18	-6.22
Skewness	0.7051	0.5084

For the 91-day treasury interest rate variable, it is assumed that there was an increase by 1 standard deviation in the interest rate, and the impact of the treasury interest rate shock was investigated. From <Figure 5-5>, it is evident that the rise in interest rates exerts a profoundly negative impact on the Nepalese economy. However, such results might be attributable to the lack of sufficient data, thereby necessitating caution in interpretation.

<Figure 5-5> Scenario Analysis: Shock to Treasury Interest rate



4. Bayesian VAR Scenario Analysis for the Nepalese Economy

After identifying the initial shock to GDP using the Growth at Risk (GaR) framework for scenario analysis, a multivariate time series model of the macro variables of the Nepalese economy needs to be constructed to determine the behavior of other macro variables in response to the initial shock. The most commonly used models for this purpose are Structural Vector Autoregression (SVAR) and Dynamic Stochastic General Equilibrium (DSGE). The former is a multivariate statistical model that focuses on the interaction and prediction of variables rather than economic theory, while the latter is an economic model that predicts the behavior of macroeconomic variables based on microeconomic theory.

The vector autoregression model, comprised of numerous economic variables, includes lagged variables of all the variables in the model as explanatory variables, and identifies the dynamic effects of certain variables on other variables through impulse response analysis. It analyzes the real economy solely based on the information provided by the actual observed time series, without

establishing a model based on economic theory. The VAR models are useful for exploring dynamic relationships between variables, but they have limitations in that they lack an economic theoretical foundation and the economic interpretation of the estimated coefficients in the model can be difficult. In particular, VAR models require the estimation of a very large number of regression coefficients because they include past lags of all variables in the model. Therefore, in situations where there is insufficient time series data for statistical analysis, the number of regressors to be estimated may exceed the number of available data, making estimation of VARs impossible or inefficient.

In such cases, the Bayesian Vector Autoregression (Bayesian VAR) model can be used as an alternative method. This model has the advantage of enabling efficient estimation even under the insufficient data or the nonstationarity of time series

In general, a VAR model is represented by a multivariate model with r-dimensional multiple time series $\{z_t\}$ given by

$$z_t = \Pi_1 z_{t-1} + \cdots + \Pi_p z_{t-p} + \epsilon_t$$

where the disturbance term, $\{\varepsilon_t\}$, is a white noise process and $\{\varepsilon_t\} \sim \mathbf{WN}(0, \Sigma)$. Both z_t and ε_t are multivariate time series denoted as $z_t = (z_{1t}, z_{2t}, \cdots, z_{rt})'$ and $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, \cdots, \varepsilon_{rt})'$, respectively. The above equation, having p lagged values of time series $\{z_t\}$ as explanatory variables, is called a p-dimentional Vector Autoregression (VAR) model, and is denoted as VAR(p). When we represent above expression in matrix form, it can be written as follows;

$$
\begin{aligned}
Z_t' &= Z_{t-1}\Pi_1' + Z_{t-2}\Pi_2' + \cdots + Z_{t-p}\Pi_p' + \varepsilon_t' \\
&= (Z_{t-1}', Z_{t-2}', \cdots, Z_{t-p}') \begin{pmatrix} \Pi_1' \\ \Pi_2' \\ \vdots \\ \Pi_p' \end{pmatrix} + \varepsilon_t'
\end{aligned} \tag{2}
$$

$$
Y = \begin{pmatrix} Z_{p+1}' \\ Z_{p+2}' \\ \vdots \\ Z_n' \end{pmatrix}, X = \begin{pmatrix} Z_p' & Z_{p-1}' & \cdots & Z_1' \\ Z_{p+1}' & Z_p' & \cdots & Z_2' \\ & \vdots & & \\ Z_{n-1}' & Z_{n-2}' & \cdots & Z_{n-p}' \end{pmatrix}, \beta = \begin{pmatrix} \Pi_1' \\ \Pi_2' \\ \vdots \\ \Pi_p' \end{pmatrix}, E = \begin{pmatrix} \epsilon_{p+1}' \\ \epsilon_{p+2}' \\ \vdots \\ \epsilon_n' \end{pmatrix}
$$

The expression (2) can be expressed in the form of a mutivariate linear regression equation by

$$
Y = X\beta + E \tag{3}
$$

The Bayesian VAR model uses the Bayes Rule to find the conditional posterior density of the parameters in Eq. (3) from the prior information about the parameters and the likelihood function of the data. The posterior distribution of the Bayesian VAR model, which is obtained based on prior information about the variance-covariance of the regression coefficients and error terms, is given as follows:

$$
P(\beta, \Sigma \mid Y) \propto P(Y \mid \beta, \Sigma) \cdot P(\beta) \cdot P(\Sigma)
$$

For the prior distributions used as prior information for the parameters, $P(\beta)$, the Minnesota Prior distribution, as proposed by Litterman (1986), is commonly used for the regression parameters, while the Invert-Wishart distribution is frequently employed as the prior distribution for the variance-covariance matrix, represented as $P(\Sigma)$.

The Bank of Korea and the Financial Supervisory Service of Korea use Bayesian VAR analysis for scenario analysis in macro stress testing, and the European Central Bank distributes the "BEARS toolbox" (Dieppe, Legrand, and Van Roye: 2016) for free, a graphical user interface (GUI) Bayesian VAR

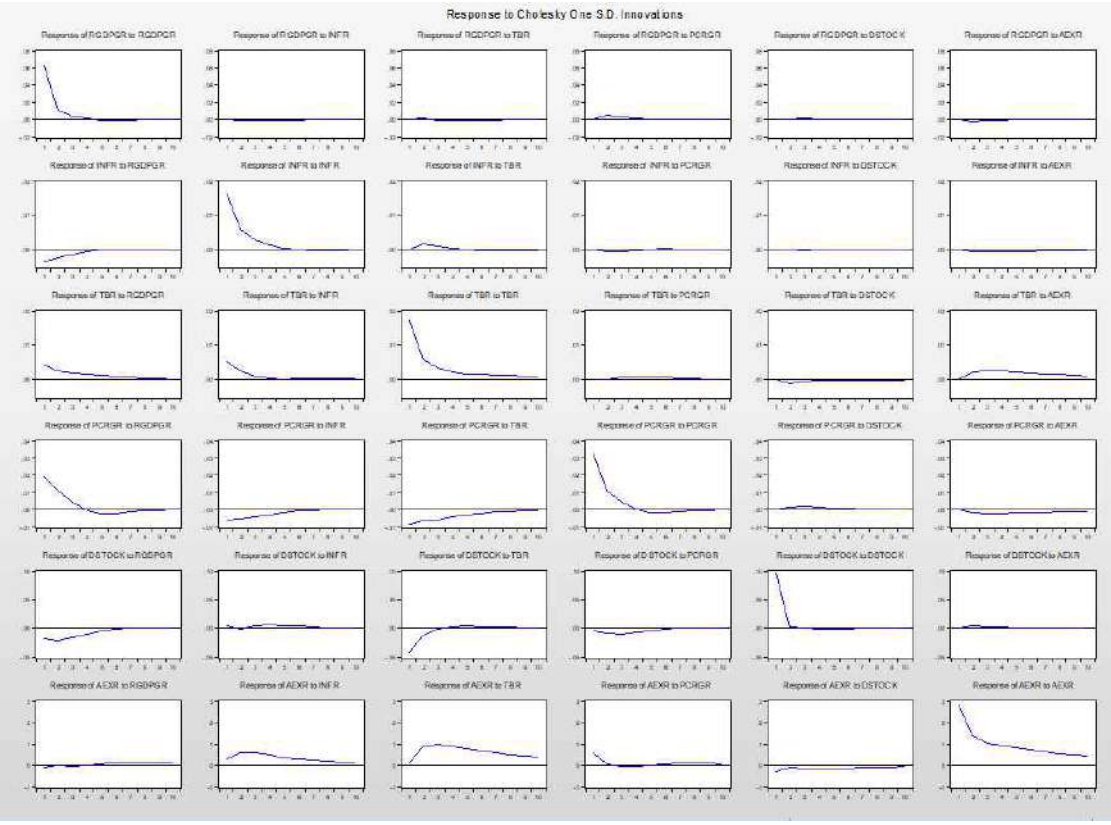
analysis tool developed in Matlab for macro stress testing.

In this study, to conduct a scenario analysis for the macro stress test of the Nepalese economy, it was decided to consider the Bayesian VAR model. The model was estimated using quarterly macroeconomic data of Nepal spanning approximately 10 years, from the third quarter of 2013 to the fourth quarter of 2022

The endogenous variables included in the Bayesian model are real GDP growth (RGDPGR), inflation rate (INFR), 91-day T-Bill rate (TBR), domestic credit growth (PCRGR), stock price differential (dstock), and average exchange rate change (AEXR). As an exogenous variable, the VIX, which is the volatility index of the United States, was considered.

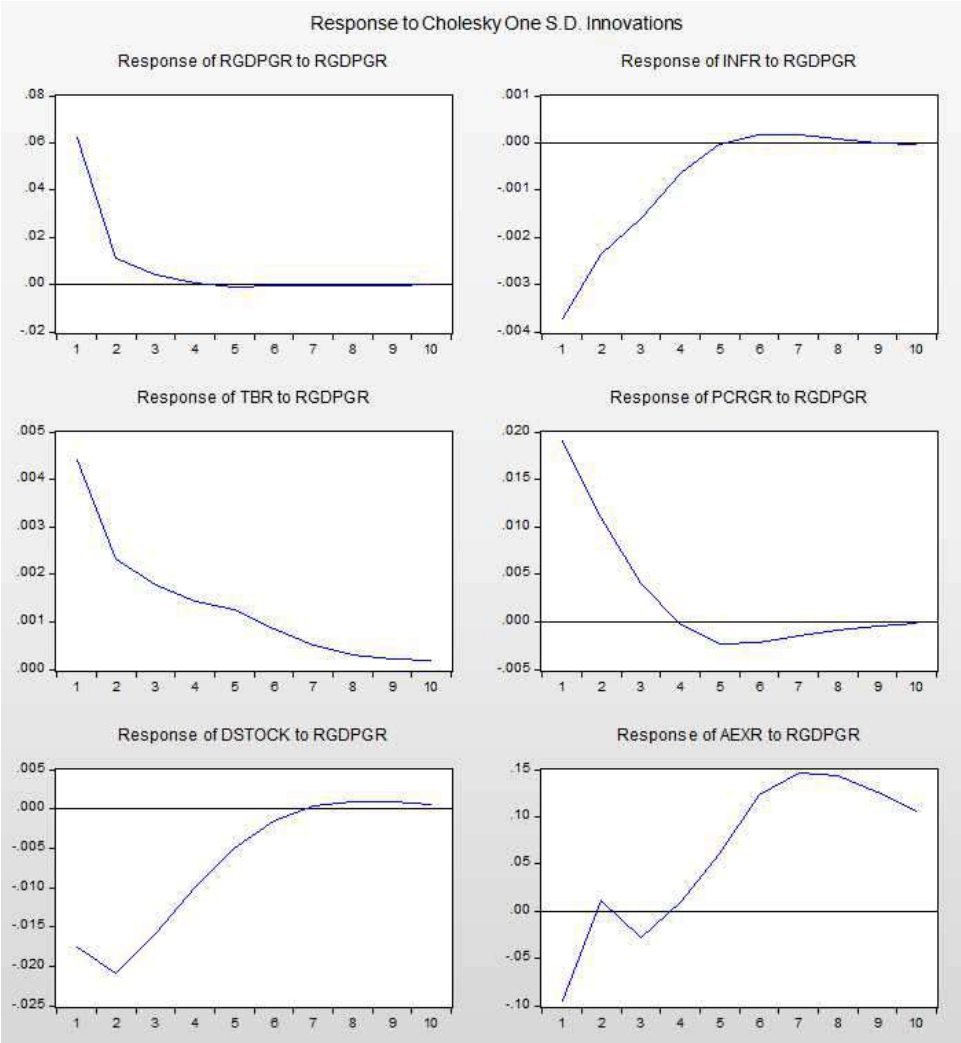
Given that the size of the time series data is only 38, a maximum lag of 4 quarters was used. For the prior information of the parameter vector, the Minnesota distribution as proposed by Litterman (1986) was assumed

<Figure 5-6> Impulse Response Functions in Bayesian VAR Models



<Figures 5-6> shows the impulse response functions of all macro variables included in the model after estimating the Bayesian VAR model. It can be seen from the figures that the magnitude of the response of the other macro variables to each shock is not very large, except for the response to the own shock, and even in cases where there appears to be some shock response, it is not statistically different from zero. We also find that the response of certain variables to shocks to economic growth is not in the direction expected by economic theory. To examine this in more detail, the response functions of other macro variables to shocks to economic growth are plotted in <Figures 5-7>.

<Figure 5-7> Impulse Response Functions to Economic Growth in a Bayesian VAR Model



<Figures 4-6> shows the response functions of the inflation rate (INFR), the 91-day T-Bill rate (TBR), the domestic credit growth rate (PCRGR), the stock index difference (dstock), the exchange rate change (AEXR), and the economic growth rate itself to the shock of the economic growth, respectively. Since the above figure is for a positive growth shock, the inflation rate is expected to respond in a positive direction, but it is found to respond in a negative direction. The stock index is also estimated to respond in the opposite direction to a positive growth shock. In particular, when the macroeconomy is under stress due to a negative growth shock, interest rates and domestic credit are expected to increase, but <Figures 4-6> shows the opposite result.

The reasons for the unexpected results of the Bayesian VAR model estimation for the Nepalese macroeconomy can be considered in two main aspects. One is that the number of time series used in the model estimation is too small, which not only makes the estimation bias large, but also makes the estimation efficiency too low. Therefore, due to data issues, it becomes difficult to trust the results of the estimation. The other reason is that the period used for estimation does not include the economic crisis, so the dynamic relationship between economic variables during the economic crisis cannot be identified. Therefore, for the Bayesian VAR analysis using Nepalese macro variables to be meaningful, it is necessary to secure macro time series data that includes periods of economic crisis.

Based on these results, this study, instead of using the Bayesian VAR estimation results, constructs scenarios for other macro variables besides the economic growth rate for scenario analysis, referencing the case of Korea, which experienced a severe foreign exchange crisis at the end of 1997, in conjunction with the GaR estimation results of Nepalease economy.

During the crisis, the Korean exchange rate more than doubled from 800 Korean Won to 1,962 Korean Won, interest rates rose sharply from 11% to 31% based on 3-year government bond yields, and the KOSPI stock index dropped by one-third from 792 points to 280 points.

To conduct stress tests for credit risk and market risk of Nepalese banks, the scenarios for Nepalese macro variables are performed in an ad-hoc manner, taking into account the actual volatility of Korean macro variables experienced during the Korean economic crisis.

VI. Conclusion

Macro stress testing, as a methodology of macroprudential analysis for assessing system risk, is widely used to evaluate financial stability in the event of exogenous shocks. This report not only introduces Korea's experience in establishing and developing a macro stress test system, but also reviews Nepal's macro stress test introduction strategy and specific model construction plans. In addition, a macro stress test model is constructed based on data provided by the Central Bank of Nepal, and estimation results using actual data are also introduced.

This output, which is based on Korea's experiences and the skills and data of the Nepal Rastra Bank, seems to be a result of desirable collaboration. However, it has a number of limitations, including the limited availability of relevant statistical data and the fact that the research was conducted in Korea rather than in Nepal, which prevented us from fully collaborating with the staff of the NRB.

First, the stress test results show that credit costs are not as sensitive to economic shocks as expected. The impact of economic growth shocks was smaller than expected, while the impact of exchange rate and international financial market turbulence was relatively large. This is mainly due to the fact that the time series used in the model are only available from 2013 onwards, which does not include the actual financial crisis. In the case of Nepal, the NPL ratio of state-owned banks was very serious during the Asian financial crisis and the global financial crisis in the late 1990s to 2010. In the future, efforts should be made to use statistical techniques to reflect past crises with insufficient data.

Second, in order to build a credit loss model, it is generally necessary to segment a bank's exposures into five borrower characteristics, namely, large corporates, SMEs, residential mortgages, retail (households), and credit cards, according to Basel 3 standards, to obtain the respective probability of default (PD) and loss given default (LGD). However, in the case of Nepal, the call reports do not disaggregate exposures into large, medium and small enterprises,

mortgages, retail (household), and credit cards, and the standardised method for calculating bank capital ratios is applied, so statistics on PD and LGD are not available. In the future, if banks' exposures are segmented into large, medium and small corporates, residential mortgages, retail (households) and credit cards, and stress tests are conducted based on PD or new NPL data and LGD based on statistical recovery rates depending on the presence and type of collateral, it will be possible to estimate the more objective level of credit losses in a stress situation.

In addition, this report could not estimate the financial statements for each period of the stress scenario. The core of the stress test is the estimation of the income statement, which requires the estimation of credit losses, changes in net interest income, and trading gains and losses. However, during the research period, it was not possible to obtain data on the income statement line items of the bank's call report, which distinguish between trading and valuation gains and losses on foreign exchange, bonds, and stocks, which are reflected in the income statement or and directly reflected in equity. Therefore, in the future, it is necessary to obtain a time series of trading profits and losses separately and estimate financial statements such as income statements for each scenario period, and evaluate the impact separately according to the level of common equity capital ratio, tier 1 capital ratio, and total capital ratio.

The last thing to point out is that there is a need to secure manpower to develop and operate stress testing models and to continue education and training for them. The economic and financial environment is constantly changing, and new problems always appear. The macro stress test model should also be modified and enhanced in accordance with changes in economic conditions. It is natural that education and training for the personnel in charge is essential in this process. In Korea, institutions that conduct macro stress tests, such as the Bank of Korea, the Financial Supervisory Service, and the Korea Deposit Insurance Corporation, conduct stress tests based on the joint scenarios and engage in various cooperative researches. This is expected to help not only promote

cooperation between the three organizations but also enhance the expertise of the personnel in charge. In the case of Nepal, the Nepal Rastra Bank can cooperate with commercial banks on the development of stress test models and is also expected to continue to cooperate with central banks in Korea and other countries.

References

[References in English]

Adrian, Tobias, Federico Grinberg, Nellie Liang, and Sheheryar Malik (2018), "The Term Structure of Growth-at-Risk." IMF Working Paper 18/180, International Monetary Fund, Washington, DC.

Adrian, Tobias, James Morsink, and Liliana Schumacher (2020), "Stress Testing at the IMF", IMF.

Adrian, Tobias, James Morsink, and Liliana Schumacher (2022), "Stress Testing at the International Monetary Fund", *Handbook of Financial Stress Testing,* Cambridge University.

Adrian, Tobias, Nina Boyarchenko, and Domenico Giannone, (2018), "Vulnerable Growth." *American Economic Review*, 09(4):1263-1289.

Anderson, Nicola, Alex Brazier, Andrew Haldane, Paul Nahai-Williamson, and Amar Radia (2022), "Why Banks Failed the Stress Test: A Progress Report on Stress Testing 10 Years On", *Handbook of Financial Stress Testing,* Cambridge University.

Bank of England (2013), "A framework for stress testing the UK banking system－discussion paper."

Bank of England (2015), "The Bank of England's approach to stress testing the UK banking system."

Basel Committee on Banking Supervision (1996), "Amendment to the capital accord to incorporate market risks," January.

Basel Committee on Banking Supervision (2004), "Basel II: International convergence of capital measurement and capital standards: A revised framework," June.

Basel Committee on Banking Supervision (2005), "An explanatory note on the Basel II IRB risk weight functions".

Basel Committee on Banking Supervision (2009), "Principles for sound stress testing practices and supervision," May.

Basel Committee on Banking Supervision (2018), “Stress testing principles,” October.

Bassett, William F. and David E. Rappoport (2022), “Enhancing Stress Tests by Adding Macroprudential Elements”, *Handbook of Financial Stress Testing,* Cambridge University.

Borio, C. E. V., M. Drehmann, and K. Tsatsoronis (2012), “Stress-testing macro stress testing: Does it live up to expectations?” *Journal of Financial Stability*, 12(1), 3–15.

Committee of European Banking Supervisors (2009), “CEBS’s press release on the results of the EU-wide stress testing exercise,” available at https://eba.europa.eu/cebs-press-release-on-the-results-of-the-eu-wide-stress-testing-exercise.

Committee on the Global Financial System (2000), “Stress testing by large financial institutions: Current practice and aggregation issues,” CGFS Paper No. 14.

Committee on the Global Financial System (2001), “A survey of stress tests and current practice at major financial institutions,” April 2001.

Committee on the Global Financial System (2005), “Stress testing at major financial institutions: Survey results and practice,” CGFS Paper No. 24.

Cope, Daniel, Carey Hsu, Clinton Lively, James Morgan, Til Schuermann, and Evan Sekeris (2022), “Stress Testing for Commercial, Investment, and Custody Banks”, *Handbook of Financial Stress Testing,* Cambridge University.

Das, Udaibir, Kieran Dent, and Miguel Segoviano (2022), “Fit for Purpose? The Evolving Role of Stress Testing for Financial Systems”, *Handbook of Financial Stress Testing,* Cambridge University.

Dieppe, Alistair, Romain Legrand, and Björn Van Roye. (2016), “The BEAR Toolbox”, European Central Bank.

Drehmann, Mathias (2009), “Macroeconomic stress-testing banks: a survey of methodologies”, *Stress-testing the Banking System - Methodologies and Applications,* Cambridge University.

European Banking Authority (2023), “2023 EU-Wide Stress Test – Methodological Note”

General Accounting Office (2012), *Bank Regulation: Modified Prompt Corrective Action Framework Would Improve Effectiveness.*

Giglio, C., F. Shaw, N. Syrichas, G. Cappelletti (2021), "Stress-testing net trading income: the case of European banks", ECB Working Paper Series No 2525.

Giot, Pierre and Sébastien Laurent, (2003), "Value-at-Risk for Long and Short Trading Positions." *Journal of Applied Econometrics*, 18 (6): 641–664.

Goldstein, I., and H. Sapra (2013), "Should banks' stress test results be disclosed? An analysis of the costs and benefits," available at https://papers.ssrn.com/sol3/papers.cfm?abstract id=2367536.

Gross, Marco, Dimitrios Laliotis, Mindaugas Leika, Pavel Lukyantsau (2020), "Expected Credit Loss Modeling from a Top-Down Stress Testing Perspective", IMF Working Paper.

Haldane, A. G. (2009), "Why banks failed the stress test," Speech at the Marcus Evans Conference on Stress Testing.

Herring, Richard J., and Til Schuermann (2022), "Objectives and Challenges of Stress Testing", *Handbook of Financial Stress Testing,* Cambridge University.

International Monetary Fund (2012), "Israel: Technical Note on Stress Test of the Banking, Insurance and Pension Sector", IMF Country Report No. 12/88.

International Monetary Fund (2017), "Financial conditions and growth at risk," in Global Financial Stability Report, October.

International Monetary Fund, (2017), "Global Financial Stability Report, April 2017: Getting the Policy Mix Right", International Monetary Fund, Washington, DC.

International Monetary Fund, (2017), "Chapter 1: Is Growth at Risk?" in Global Financial Stability Report, October 2017, International Monetary Fund, Washington, DC.

International Monetary Fund, (2020), "Republic of Korea Financial sector assessment program, Technical note— Systemic risk analysis, Financial sector stress testing, and an assessment of demographic shift in Korea"

International Monetary Fund (2023), "Nepal: Staff Report for the 2023 Article IV Consultation", IMF Country Report No. 23/158.

Ishikawa, A., K. Kamada, Y. Kurachi, K. Nasu, and Y. Teranishi (2012), “Introduction to the Financial Macro-econometric Model”, Bank of Japan Working Paper Series No.12-E-1.

Koenker, Roger, (2005), Quantile Regression. Cambridge University Press.

Koenker, Roger, and Gilbert Basset, (1978), "Regression Quantiles", Econometrica, vol. 46, no. 1, pp. 33-50.

Litterman, R. B. (1986), “Forecasting with Bayesian Vector Autoregressions: Five Years of Experience”, Journal of Business and Economic Statistics, 4(1), 25-38.

Nehru, Vikram (2015), "Developing Myanmar's Financial Sector", *ADB Economics Working Paper Series*, No. 430.

Nepal Rastra Bank (2023), “Financial Stability Report FY 2021/22”.

Merton, R. C. (1974) “On the pricing of corporate debt: The risk structure of interest rates”, *Journal of Finance* 29, 449 – 470.

Pesola, J. (2007), ‘Financial Fragility, Macroeconomic Shocks and Banks’ Loan Losses: Evidence from Europe’, Bank of Finland Working Paper, 15.

Prasad, M.A., Elekdag, S., Jeasakul, M.P., Lafarguette, R., Alter, M.A., Feng, A.X. and Wang, C., (2019), “Growth at Risk: Concept and Application in IMF Country Surveillance”, IMF Working Paper ,No. 2019/036, International Monetary Fund, Washington, DC.

Vasicek, O. (2002) “Loan portfolio value”, *RISK,* December 2002, 160 – 162.

[References in Korean]

윤성훈・최성일(2023), “SVB 및 CS 정리와 동태적 비일관성”, 『Kiri 리포트 포커스』, 보험연구원.

신원·황태식(2018), “거시건전성 스트레스 테스트 모형(STARS-I) 소개”(비공개 세미나 자료)

김정일(2023), “한국의 스트레스테스트 방법 및 사례, 감독목적 하향식 스트레스테스트 모형”(비공개 세미나 자료)

최성일(2023). “금리상승에 따른 주요국 은행 금리리스크 관련현황 및 시사점”, 『Credit Insight』, NICE 평가정보 NICE 리서치센터

한국은행 (2012), “1. 시스템적 리스크 평가모형(SAMP)”, 금융안정보고서 2012.10.

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Contents	Authors
I. Introduction	Kang, Kyeong-Hoon
II. Economic Trends and Financial Environment in Nepal	NRB Research Team Jeon, Jin Q
III. Korean and Nepali Macro Stress Test Systems and Development Experiences	NRB Research Team Jeon, Jin Q
IV. Proposed Macro Stress-Test Framework for Nepal	Choi, Seong IL
V. Macro Stress Test Scenario Design and Estimation Methodology	Hahn, Sang Buhm
VI. Conclusion	Kang, Kyeong-Hoon