Introduction

Stress testing is a risk management tool for firms to evaluate the potential impact of an event or movement on the firm's asset quality, profitability, capital and other financial variables.

Stress testing aims to primarily identify latent exposures – those that are less obvious, perhaps hidden across a wide variety of instruments, credits and derivatives positions. It focuses on traded market portfolios, which are well suited to stress testing because they can be marked to market on a regular basis. Stress testing of funding liquidity and operational risk is common in financial institutions such as banks (the scope of this paper) although loan book stress testing is less frequent.

Stress tests are a valuable aid in assessing the stability of banking systems. They permit a forward-looking analysis and adopting a uniform approach to identifying potential risks to the banking system as a whole. Unlike Value at Risk (VaR), which reflects price behaviour in everyday markets, stress tests simulate portfolio performance during abnormal market periods. Thus, in general, VaR and stress test exposure estimates are not added to each other.

Stress testing is needed for the following reasons:

- Capturing the impact of exceptional but plausible large-loss events on a portfolio
- Checking if the capital buffer is sufficient under stress conditions
- Introducing forward-looking elements in the capital assessment process
- Reducing reliance on model parameters (e.g. when historical correlation may no longer be valid)
- Ascertaining changes in the business environment, e.g. in liquidity
- Reviewing changed horizons and liquidity of instruments
- Supporting portfolio allocation decisions beyond the range of normal business conditions
- Identifying hidden correlations within portfolios
- Assessing the tail events beyond the level of confidence assumed in a given statistical model because, under stress conditions, the following may occur:
  - Less predictability in the behaviour of stress factors
  - Rapid price movements and contagion may impact other markets
  - Shocks may spread across multiple markets
  - Economic conditions in affected regions may suddenly deteriorate

A stress test measures the xth percentile of the profit and loss distribution of an asset, while VaR measures the mark-to-market gain or loss that an asset would experience, should one or more of the underlying economic factors that determine the asset’s value experience a specific change in value.

Stress tests capture exceptional but plausible events: they provide information about risks falling outside those typically captured by the VaR framework (Figure 1). These risks include those associated with extreme price movements and with...
forward-looking scenarios not reflected in the recent history of the price series used to compute VaR.

The application of stress tests has broadened due to its wide acceptance by firms, from the exploration of exceptional but plausible events to the exploration of the risk profile of firms, the allocation of economic capital, the verification of existing limits and the evaluation of business risks.

Stress testing scenarios have four main undergirding principles:

- **Plausibility.** They must be realistic, i.e. have a reasonable probability of actually occurring.
- **Consistency.** They should be consistent with existing quantitative frameworks.
- **Adaptivity.** Stress scenarios should be specifically designed for a given portfolio.
• **Reportability.** They should provide information that can be translated into concrete action.

Stress tests are of two types: scenario tests and sensitivity tests.

• **Scenario tests** measure the cumulative effect of adverse movement in a number of risk factors, e.g. equity prices, foreign exchange rates and interest rates on a bank’s financial position. A scenario test can be based on historical or hypothetical data, employing shocks that occurred in the past, or on hypothetical scenarios that account for plausible changes in circumstances that have no historical precedent. An important element of scenario development is the assessment and incorporation of the linkages between the various risk factors.

• **Sensitivity tests** assess the impact of changes in one or a select number of inter-related risk factors on a firm’s financial position.

Scenario tests can be formulated using portfolio-driven, event-driven, top-down or bottom-up approaches.

**The Portfolio- and Event-Driven Approaches**

In the portfolio-driven approach, vulnerabilities in the portfolio are identified and plausible scenarios subsequently formulated, under which the vulnerabilities are stressed. In the event-driven approach, however, the scenario is formulated based on plausible events and how the events might affect the relevant risk factors in a bank’s portfolio (Figure 2).

Stress tests can focus on individual risks, such as credit risk or interest rate risk, or can include multiple risks.

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![Figure 3: The Decision Sequence for Formulating Stress Tests](image-url)
Figure 3 below shows a sequence of the portfolio-level decision elements invoked in formulating a stress test.

**The Top-Down and Bottom-up Approaches**

The top-down approach uses aggregated or macro-level data to estimate impact. The scenario is defined first and the individual factors worked out later. Here, macroeconomic scenarios are linked to a bank’s aggregate sectoral losses. The responsiveness of a group of banks to a particular scenario is considered and a common parameter derived to estimate the aggregate impact (e.g., using a regression of aggregated information on macroeconomic variables). In the field of credit risk, when conducting macro-stress tests, heterogeneity in models necessitates a top-down approach.

In the bottom-up approach, the parameters for change in the risk factors are decided and the scenario made up thereafter, based on these. Estimates are based on data for individual portfolios, where the impact of various shocks in a scenario is estimated at the portfolio level. Each bank estimates the increase in credit losses in an entire portfolio. The results are then aggregated or compared to analyze the sensitivity of the entire bank.

The bottom-up approach is suited mainly for assessing market risk, as many banks possess comparable market risk models. The advantage of using the bottom-up approach is that banks can evaluate each portfolio at fine-grained disaggregation levels. The approach also provides information on how a bank itself assesses the likely impact of adverse events on the quality of its loan book.

**Examples of Stress Test Scenarios**

A number of elements are involved in designing stress scenarios including the type of risks to analyze (i.e., whether market, credit, interest rate, liquidity or other); whether single or multiple risk factors are to be shocked; and the parameter(s) to shock (e.g., prices, volatilities, correlations, etc), by how much (depending on whether the scenarios are historical or hypothetical) and over what time horizon.

Figure 4 below shows some typical stress test scenarios.
Financial Soundness Indicators

Financial Soundness Indicators (FSIs) include both aggregated information on financial institutions and indicators that are representative of markets in which financial institutions operate. There are three categories of FSIs, each having a different role: monitoring financial sector vulnerabilities arising from credit, liquidity and market risk; assessing the condition of non-financial sectors; and assessing the capacity of the financial sector to absorb losses, as measured by capital adequacy.

Various FSIs are used to measure the bank’s vulnerability to stress scenarios:

- Capital adequacy
  - Regulatory capital to risk-weighted assets
  - Regulatory Tier I capital to risk-weighted assets

- Asset quality
  - Non-performing loans (NPLs) to total gross loans

NPLs net of provisions to capital
- Sectoral distribution of loans to total loans
- Large exposures to capital

- Earnings and profitability
  - Return on assets
  - Return on equity
  - Interest margin to gross income
  - Non-interest expenses to gross income

- Liquidity
  - Liquid assets to total assets (liquid asset ratio)
  - Liquid assets to short-term liabilities

Stress Tests and Regulatory Expectations

Stress testing techniques were applied widely in international banks in the early 1990s and have now spread to many large financial institutions. As Figure 5 shows, banking supervisors and regulators have
prescribed stress tests as being important components of the internal model-based approach to market risk monitoring.

**Implementing Stress Testing: A Seven-step Approach**

Stress testing can be viewed as a seven-step process (Figure 6) that involves the following:

- Identifying the major risks and exposures in the system and formulating questions about those risks and exposures
- Defining the coverage and identifying the data required and available
- Calibrating the scenarios or shocks to be applied to the data
- Selecting and implementing the methodology
- Interpreting the results

**Step 1: Setting the Stage**

The first step in the stress testing process is setting the stage for the main vulnerabilities of the portfolio or system to be understood.

- The stress program should identify the portfolios to be stressed and be conducted on an institution-wide basis.
- The risk factors/parameters to be stressed should be decided based on the specific vulnerabilities recommended by the regulator and the bank’s own assessment.
- The quarter-end/year-end position on the banking book should be taken as the baseline scenario.
- The bank should ensure the reliability of data, so as to provide input on the identification of vulnerabilities.
- The timeline for the stress condition should then be decided. (For banking books, this is generally 6 months to a year.)
- The impact variables to be measured, e.g. capital requirement, P&L, Net Interest Income (NII), liquidity ratio, etc should be identified.

**Step 2: Identifying the Risk Factors**

The number of risk factors to be stressed should depend on the complexity of the portfolio and the risks the financial institution is exposed to. Senior management is expected to be actively involved in identifying the principal risk factors and justifying their choice of stress tests and risk factors to stress. However, it is unrealistic to attempt to stress every possible risk factor for a portfolio or system. Thus, narrowing one’s focus to identify select risk factors makes for practicable and refined analysis.

Some issues to keep in mind during the identification process (Figure 7) are:
• **The number of risk factors to be stressed.** This depends on the complexity of the bank’s portfolio, the risks characteristics of the bank, correlations between the risk factors, and the material impact on the bank’s financial position.

• **Obligor specificity.** The relevant risk factors can be specific to the obligor (typically, transactions) or a pool of obligors (as in industry segments, sectors, etc).

• **Qualitative and quantitative elements.** Risk identification includes both qualitative and quantitative elements (see Step 4 below).

• **Availability of data.** Inter-linking risk factors, risk parameters and impact variables requires historical data on risk factors and NPL data of the bank and its peers.

• **Multiplicity of impact.** Risk factors likely to have a second round of impact are considered on priority.

**Step 3: Constructing the Stress Test**

Once the institution identifies the vulnerabilities, a scenario needs to be constructed, which will form the basis of the stress test. One approach is to construct scenarios with input from business units and ranking them by relevance and plausibility.

Building a stress test depends on the circumstances of the particular bank, and data availability. To construct a good scenario, one should determine overall impact by adjusting the variables that influence the output and estimating the probability of occurrence.

Ideally, a macroeconomic or simulation model should form the basis of stress testing scenarios. To achieve risk management objectives effectively, scenarios should be realistic, in line with the approach adopted, and sensitive to portfolios of exposures.

For risk factors where good historical data are available, it is better to base the scenarios on the pattern of volatility and covariance observed in past data. Hypothetical scenarios may be created by combining a scenario justified by historical data with sensitivity analysis. It may not always be feasible to generate a scenario using a consistent macroeconomic model.

An alternative to presenting stress tests is to present the largest shocks that leave the system above a certain threshold. For example, one may assume that the largest increase in NPLs that the banking sector can survive without any bank becoming insolvent is at least 8%, as prescribed by the BASEL Committee. The magnitude of shock depends on historical data, subjective judgment or expert opinion; it should neither be fully bound by historical events nor be purely hypothetical; and it should be greater than a conservative estimate of potential losses over the business cycle.

The following are some examples of stress scenarios:

• Domestic economic downturns, which impact macro-variables like GDP growth, unemployment rates, etc.
• Economic downturns of the major economies to which the bank is directly exposed
• Decline in prospects among sectors to which the bank has significant exposure
• Increase in the level of NPLs and provisioning levels
• Increase in the level of rating downgrades
• Failure of major counterparties
• Timing difference in interest rate changes, which influence re-pricing risks
• Adverse changes in the exchange rates of major currencies
• Stock market declines
• Tightening of market liquidity
• System failures or business disruptions

Step 4: Setting the Stage for Stress Measurement

The impact of stress tests is usually evaluated against one or more measures. The specific measures used depend on the purpose of the stress test, the risks and portfolios being analysed and the issue under consideration.

The institution needs first to gauge whether its existing models adequately assess the impact of stress. If they don’t, new models are required to estimate the likely impact of stress on the other risk factors and to link changes in risk factors to risk parameters and impact variables.

The next step is to stress the primary variables and, using the model, assess second-round impact. The stress is applied to the level decided with the bank’s personnel, using deterministic or stochastic means.

If the bank does not possess quantitative models, stress tests may be done using qualitatively, as follows:
• Survey the portfolio and identify the likely stress events
• Estimate the bottom line of each obligor contingent on the stressful event occurring
• Calculate the total stress loss that the bank is likely to incur, given the stress event

Step 5: Measuring the Stress

Different measurement frameworks exist for credit risk, interest rate risk, concentration risk, liquidity risk and other types of risk. The following subsections present an overview of the risk type, followed by a discussion of approaches to stress testing for that risk.

Credit Risk Stress Measurement. Credit risk is the risk that a counterparty or obligor defaults on its contractual obligations. For credit risk, data on the loan-loss provisions held by banks against various categories of assets and exposures are used to understand the credit quality of existing loan books, while new provisions provide an indication of the evolution of credit quality.

Banks following standardized approaches measure stress as follows:
• Model the possible rating movement, based on changes in risk factors. If modelling is not possible, use subjective judgment
• Estimate the impact of increases in NPL levels
• Measure the impact on regulatory capital requirements as per the changed ratings

Banks following the Foundation Internal Ratings Based (FIRB) or Advanced Internal Ratings Based (AIRB) approaches measure stress as follows:
• Use risk factors in the rating model and measure the impact on risk parameters, i.e. choose a bottom-up approach
• If such modelling is not possible, then link the macro-variables to the NPL rates of major banks, using panel data
regression in a jurisdiction, choosing a top-down approach
• Estimate stressed PD and stressed LGD for the given bank
• Apply the required proportions of stressed PD and LGD to the base PD and LGD of the bank, to assess individual exposures

**Interest Rate Stress Measurement.**
Interest rate risk is that risk in which changes in market interest rates adversely affect a bank’s financial condition. Two approaches are used for interest rate risk stress measurements:
• Earnings-based. Here, the immediate impact of changes in interest rates is on the bank’s earnings through changes in its NII.
• Economic value-based, where the long-term impact of changes in interest rates is on the bank’s market value of equity (MVE) or net worth, through changes in the economic value of its assets, liabilities and off-balance sheet positions.

Risk measurement techniques such as gap analysis, duration analysis, income simulation or other interest rate risk modelling may be used to stressing a portfolio. The next step is to specify the shocks—parallel shifts in the yield curve, changes in the slope of yield curves and changes in the spread at different tenors with the same time horizon.

By varying interest rates across maturities by modelling the impact of other risk factors, e.g. GDP, exchange rates, etc on interest rate or applying different yield curve assumptions, the impact on NII may be evaluated. Alternatively, the bank can model the relation between the NII of the top five to 10 banks in its jurisdiction and their risk factors, using panel data regression to determine NII under stress, using this relation.

**Concentration Risk Stress Measurement.**
Concentration risk is the effect of exposures to common systematic risk factors for particular sectors or regions. Stress tests are conducted to identify, monitor and control risk concentrations. In order to adequately address risk concentrations, the following are to be done:
• Identification of plausible events and systematic risk factors that may affect the asset quality
• Conceptualisation of the risk of credit concentrations as the impact of stress in one or more systematic risk factors on the loss distribution of a credit portfolio (for instance, the impact of stress scenarios on sectoral concentration may be conceptualised as loan losses that may spread further due to interdependencies between sectors: a crisis in the automotive industry can spill over to ancillary industries, like mechanical engineering and the chemical industry and also lead to loan losses there)
• Measurement of impact, by setting one or more values of the systematic risk factors to their stressed value and performing a portfolio loss simulation based on the conditional distribution of risk factor changes
• For banks with FIRB and AIRB, a regulatory capital requirement is calculated in stress scenarios by recalculating the BASEL II formula with the stressed PDs

**Liquidity Risk Stress Measurement.**
There are two types of liquidity risks: asset
liquidity risk and funding liquidity risk. Asset liquidity risk refers to a bank's inability to conduct a transaction at current market prices because of the size of the transaction. This type of risk is envisaged when certain assets need to be liquidated at short notice. Funding liquidity risk refers to a bank's inability to access sufficient funds to meet financial obligations when they are due.

Liquidity risk can also be viewed as the risk that a bank will incur unexpected costs or losses in meeting its financial obligations when they are due, because of the mismatch between the maturities of its current and contingent financial assets and liabilities. The impact of liquidity risk on an institution is summarised in Figure 8.

There are two approaches to measuring liquidity risk under stress conditions:
- The Sources and Uses of Funds approach. In this approach, assumptions are made on the behaviour of liabilities, funding cost increases and so on during stress periods. The actual sources and uses of funds and the estimated changes in them must be forecast for a given liquidity planning period.
- The Structure of Funds approach. In this approach, bank deposits and other sources of funds are divided into categories, based on their estimated probability of withdrawal pattern. The bank may also need to identify the sources of funds that can become illiquid under certain situations.

Possible scenarios for liquidity risk include:
- The ratio (in percentage) of retail deposits to total deposits that may be withdrawn in a stress scenario (banks may assume outflows in low double digits)
- Corporate deposits or other uninsured deposits that may be assumed to reduce between 20% and 50%, typically over a month
- Disposal of assets to raise liquidity, which may involve applying haircuts while arriving at their realisable value

Step 6: Reporting the Stress

Banks need to document the underlying assumptions, results and outcomes of each stress scenario. The results need to be integrated with the bank's risk management system.

Stress reports include details like:
- Assessment of vulnerability, identifying the main vulnerable areas and risk factors that affect each of these areas
- A description of the coverage of the stress test
- Conditions prevailing and assumptions used for the stress test time horizon
- The resulting impact on profitability, capital and asset quality at each significant balance sheet date over the stress test time horizon
- Financial data in absolute figures and ratios
- Procedures to monitor stress loss/tolerance limits

Step 7: Defining the Stress Testing Workflow

Banks need to define their ongoing stress testing framework, workflow and responsibilities. The assumptions underlying the stress tests should be reviewed periodically for assessing their validity. Back-testing needs to be conducted as and when a stress scenario materialises. The stress frequency is dictated by the bank's business requirements, relevance and cost.

When stress tolerance levels are breached, banks may need to take remedial action:
- Reducing risk limits
- Amending pricing policies to reflect additional risks
- Augmenting capital levels to absorb shocks
Enhancing sources of funds to meet liquidity requirements
• Reducing risks by enhancing risk mitigation strategies, e.g. additional collateral, securitisation, hedging, etc

Conclusion

Over the years, stress testing has been integrated with risk management frameworks in various institutions. Given the unexpected severity of events, it has gained greater importance and credibility with banks as a complementary risk management tool that provides a different risk perspective.

Stress testing discipline has evolved in a way that meets the demands of top management, business units and investors alike. Stress tests are being used increasingly as a tool for risk managers to communicate with senior management about risk exposure and, in turn senior management uses this to communicate the institution’s risk appetite to other large financial firms.

However, there is no single framework of best practice on stress testing, and industry practices still vary widely. This reflects not only the varying levels of sophistication across institutions but, more importantly, the different risk profiles of the firm and the availability of transparent data. Some technological and data hurdles are being overcome, facilitated by progress in the introduction of common platforms within and across business units and the increased availability of transparent data. However, the cost and availability of data warehousing remain a hurdle, particularly in the area of credit risk management.

Issues and Challenges

The following are some of the issues, challenges and opportunities for future improvement:
• Constant review of existing scenarios and the search for new ones
• Collection of all relevant data
• Examination of new products to identify potential risks
• Linking of scenarios to risk parameters
• Lack of regulatory standards to evaluate stress test
• High model risk/model validity
• Model deployment, maintenance and remedial action

Bibliography


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