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Understanding Tail Risk: Reverse Stress Testing

Highlights

The evolution of the post-crisis financial regulatory reform agenda has positioned stress testing as a key tool in assessing the system-wide safety and soundness of the global financial sector. However, traditional stress testing frameworks do not identify all the potential risks that institutions may face and are typically based on a set of pre-defined scenarios. Therefore, regulators have advocated for the use of reverse stress testing as a tool to supplement stress testing by exploring tail risks and revealing hidden vulnerabilities and scenarios that are not reflected through traditional stress testing analysis. This paper reviews the implications of reverse stress testing for financial institutions and outlines the steps required to perform such analysis to meet regulatory expectations. Finally, we discuss the advantages of having an integrated enterprise-wide stress testing and reverse stress testing platform at institutions.

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Enhancing Stress Testing Frameworks

Stress testing is a scenario contingent analysis of the risk of an institution: it helps institutions to put in place capital contingency measures, develop a firm's risk appetite, drive strategic business planning, set risk limits, identify portfolios' vulnerabilities and opportunities in terms of risk-return trade-offs and determine the optimal timing of strategic decisions.

In the years preceding the recent financial crisis, stress testing results were primarily used as a component of internal risk reporting and monitoring frameworks. However, stress testing did not feature prevalently in management decisions. The losses suffered by financial institutions during the crisis highlighted the need for enhanced stress testing approaches across all components of the balance sheet and income statement to assess an institution's capital sufficiency to withstand unforeseen market conditions and drive strategic risk management decisions.

Many stress testing frameworks that are currently in place at financial institutions have two major shortcomings that should be addressed within the context of an enterprise risk management framework:

- In order for stress testing to be effective at estimating and measuring risk, an institution's tail risks should be accurately reflected in any stress testing analysis performed. Therefore, scenarios that may render an institution's business model unviable should be identified as well.
- Stress testing is often executed in silos and different business units have different models, scenarios, calibration processes, or approaches to compute stressed risk measures.[1] In order to be effective, a single enterprise-wide risk management platform[2] should be used to integrate, execute, and report all the stress testing calculations across all material business units and asset classes.

Within this context, the global financial regulatory reform agenda has further emphasized the significance of reverse stress testing as a key component of prudent risk management standards by enhancing and supplementing the stress testing function at financial institutions.

Reverse stress testing analysis offers a unique opportunity for financial institutions to better understand their business and focus management's attention on the areas where weakness could turn out to be potentially harmful to the entire organization. Reverse stress test addresses the first shortcoming identified above by explicitly identifying and assessing only the tail risk scenarios most likely to render business models unviable, that can cause the institution to default. This is a core difference when compared with traditional stress testing methodologies, where stress scenarios are chosen based on expert knowledge or historical evidence a priori.

Reverse stress testing was introduced by the Financial Services Authority for the first time in 2008. After that, the Basel Committee of Banking Supervision (BCBS) and the Committee of European Banking Supervisors (CEBS) have issued additional supervisory guidelines on reverse stress testing as well.[3] The core elements of these guidelines are:

- "…We are proposing to introduce a 'reverse-stress test' requirement, which would apply to banks, building societies, CRD investment firms and insurers, and would require firms to consider the scenarios most likely to cause their current business model to become unviable…"
- "…A key objective of the reverse stress testing is to overcome disaster myopia and the possibility that a false sense of security might arise from regular stress testing in which institutions identify manageable impacts…"
- "…Our aim is to ensure that firms more fully explore 'Tail Risks' which, if they were to crystallize, would cause counterparties and investors to lose confidence in them, so that a firm is more aware of its business model vulnerabilities when making strategic business decisions, when contingency planning, and when considering its risk management arrangements…"

[1] The most recent example is JP Morgan. The CIO had a different Value-at-Risk model that the rest of the firm that underestimated the potential losses for the portfolio under an event of stress. Eventually, this has led to a loss of almost $6 bn.

[2] For example, Moody's Analytics ScenarioAnalyzer™ provides a consolidate platform to perform, report, audit, and monitor stress and reverse stress testing at enterprise-wide level.

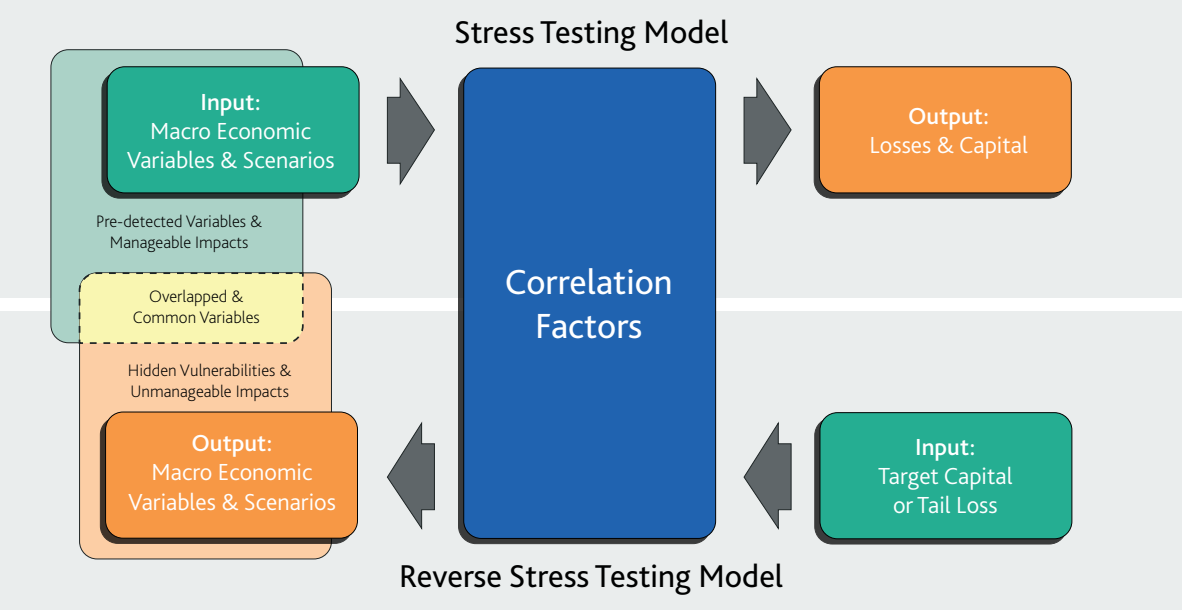
[3] FSA CP08/24, BCBS 155 and CEBS CP 32 documents, respectively.

Processes and Challenges

For a large complex firm, reverse stress testing is a significantly challenging exercise requiring involvement of executive management, all material risk areas across the firm, finance and treasury. A reverse stress test helps firms to discover scenarios beyond normal fundamental, historical, and market considerations, and leads to tail events with contagion and systemic implications.

Reverse stress testing processes range in levels of complexity from purely qualitative discussions of key risk factors conducted by a firm's board and senior management to more sophisticated model-driven quantitative approaches that identify the levels of capital and liquidity insufficiency at which insolvency would begin and work backwards, in a quantitative manner, to identify the range of risk drivers and scenarios that would cause it. Figure 1 illustrates the framework within an enterprise risk management context:

FIGURE 1
An Integrated Enterprise-wide Stress and Reverse Stress Testing Framework



Source: Moody's Analytics

The results of reverse stress testing are particularly useful for lines of business that demonstrate highly optimistic risk-adjusted return metrics, markets that have not yet been subject to severe stress, and supplement capital planning and contingency planning. The process of reverse stress testing explores high-risk vulnerabilities within a firm's business model, considers the interactions across risk types, evaluates the likelihood of such events occurring, and facilitates ongoing risk management oversight at the board level.

Reverse stress testing is not intended to be used for capital allocation: stress testing is the analysis to do it. The goal of reverse stress testing is to provide a fair assessment of when a financial institution should be recapitalized or would default identifying the scenarios and factors causing this. Therefore, a reverse stress testing methodology helps analyzing the risk appetite and should be used as an strategic decision-making tool addressing these questions:

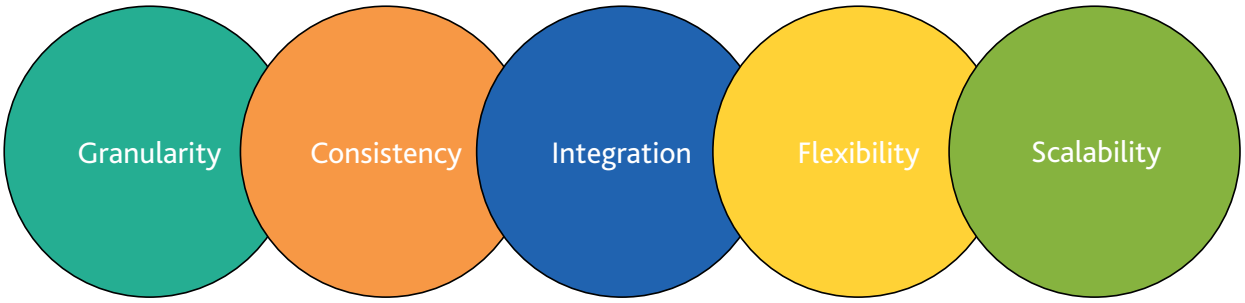
- What losses lead to dropping below a minimum capital ratio X and what events, scenarios, and business lines could cause these losses?
- When a financial institution should be recapitalized under a given (macro) scenario?
- What risk factors drive the losses and their connections with portfolio's performance (e.g. insolvency, bankruptcy…etc.)?
- What are the hidden vulnerabilities of my business model?
- Is there any relationship between the stress testing and the reverse stress testing outcomes? Reconciliation, benchmarking, and supplementation.

Some of the challenges typically faced when conducting a reverse stress test are the comprehensive identification of a firm's business model, scenario development that is sufficiently extreme but at the same time relevant for a firm's activities, identifying non-linear compounding effects of a scenario and embedding the results of such exercises in strategic planning and decision making. From a methodological perspective, a bottom-up enterprise-wide portfolio platform is a necessary condition to perform the analysis. This usually creates modeling challenges as well.

From a business strategy perspective, an assessment of the reverse stress testing outcomes may determine the solvency and financial performance of the institution in the medium term. For example, a wrong risk appetite statement can render the institution business model unviable if this have not been capture during the stress testing analysis. Therefore, the institutions' senior management should analyze the sensitivity of their business model during the strategic planning phase using reverse stress testing in order to identify hidden vulnerabilities as well as opportunities.

Executing Reverse Stress Testing: Modeling Flow

Although an accurate modeling methodology able to characterize the institutions' business model and portfolio compositions is critical to analyze, identify hidden vulnerabilities within an reverse stress testing framework, the regulatory bodies have not provided methodological guidelines. However, the following principles should apply when developing one:



- **Granularity:** The framework should be able to able to drill down to individual factors that may affect to business lines or products.
- **Consistency:** The framework should be consistent with the overall stress testing methodology and regulatory guidelines.
- **Integration:** The framework should be integrated within the enterprise risk management function and architecture.
- **Flexibility:** The framework should be fully customizable to the business model of the institution.
- **Scalability:** The framework should be able to accommodate future requirements in terms of asset coverage, portfolios, geographies, or regulatory guidelines.

From a workflow and data management perspective, institutions should develop centralized enterprise-wide stress testing and reverse stress infrastructures that strive to integrate data, analytics, and reporting. All information critical to calculating, managing, reporting, and monitoring the stress and reverse stress testing results should be easily and cost-effectively available.

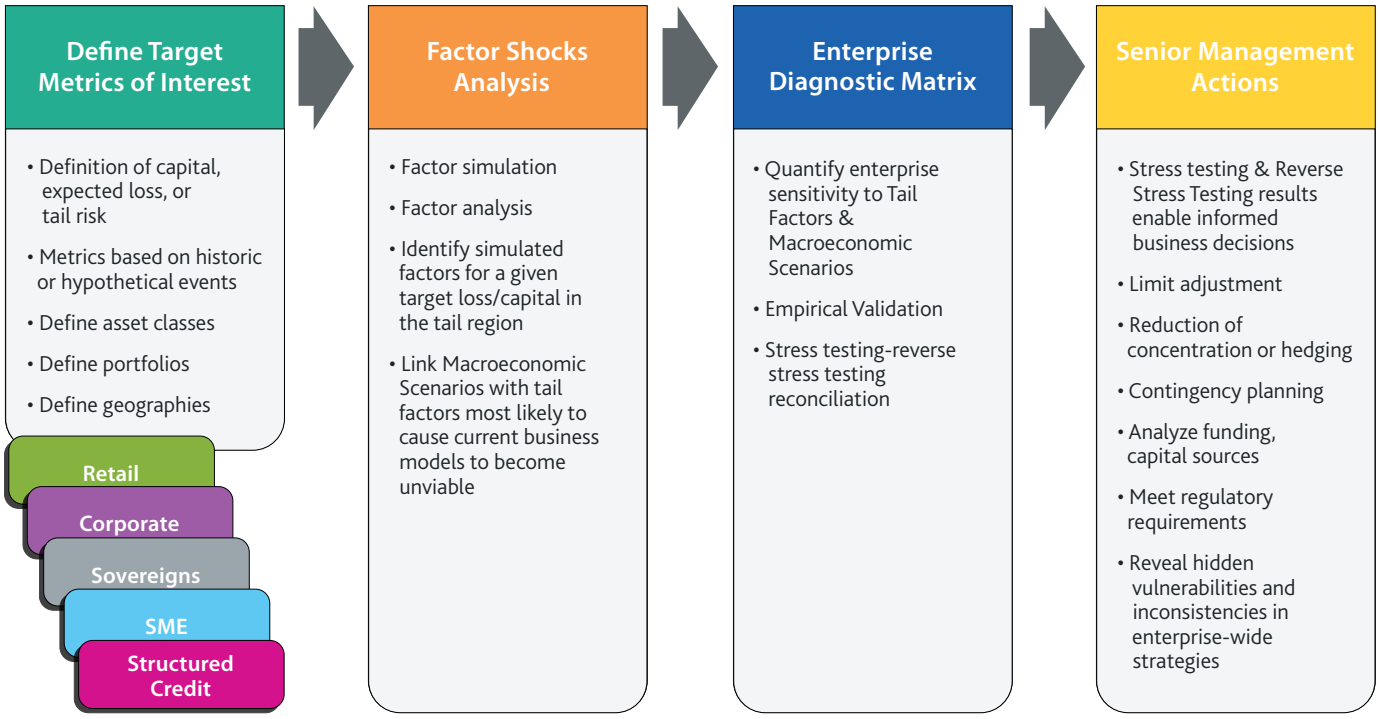
From a regulatory compliance perspective, institutions' enterprise risk management platform should be able to generate pre-configured stress testing and reverse stress testing reports by different regulatory jurisdictions.[4] The institutions should also maintains the analysis history for trend analysis, auditing, and benchmarking across several dimensions and for each legal entity of the institution.

From an operational perspective, the institutions' enterprise risk management platform should allow users to drill down into each scenario to see the detailed underlying factors' composition during the reverse stress testing calculation process. From a reporting perspective, the platform should perform side-by-side comparison analysis between the stress testing and reverse stress testing results across jurisdictions, strategies, or portfolios.

[4] For example, CCAR for the institutions regulated by the Federal Reserve in US.

Figure 2 provides a high-level view of the modelling flow:

FIGURE 2
Reverse Stress Testing Modelling Flow



Source: Moody's Analytics

Finally, to be effective, the reverse stress testing exercise should finalize with an enterprise-wide contingency plan framework to address vulnerabilities before changes hit and ensure the survival of the institution under those events.

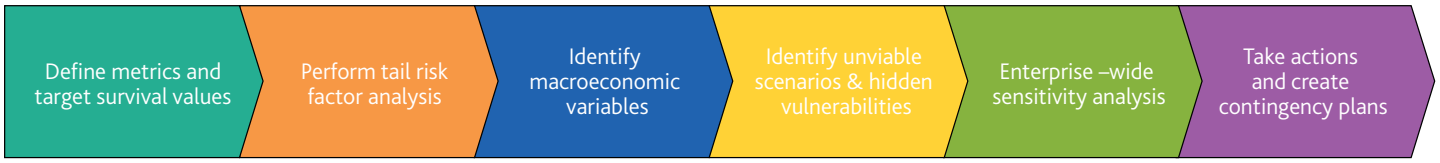
Executing Reverse Stress Testing: A Bottom-up Modeling Approach

Institutions should address the reverse stress testing analysis using a bottom-up modelling approach. This approach has the advantage that avoid solving inversion problems arising from maximization-based models and at the same time accounts for all the risk dependencies during the simulation through the factors' correlation structure and migration dynamics. On the other hand, top-down approaches are usually not suitable for reverse stress testing analysis since the factor realizations are aggregated and cannot be decomposed at individual level.

Once the modelling flow and enterprise risk management architecture has been set at the institution, the reverse stress test analysis should start by specifying a target loss level, business line or sub-portfolio subject to the analysis, and then identifying the macroeconomic shocks, scenarios, and tail risk factors driving those losses.

Subsequently, their connections with portfolio's performance, strategic events (merger, acquisition, new portfolio composition...etc) and business model weaknesses (insolvency, bankruptcy,…etc) should be analyzed as well. Therefore, the analysis would identifies hidden vulnerabilities that may have not been detected during the stress testing analysis.

There are six main stages when performing a bottom-up reverse stress testing analysis at enterprise-wide level:

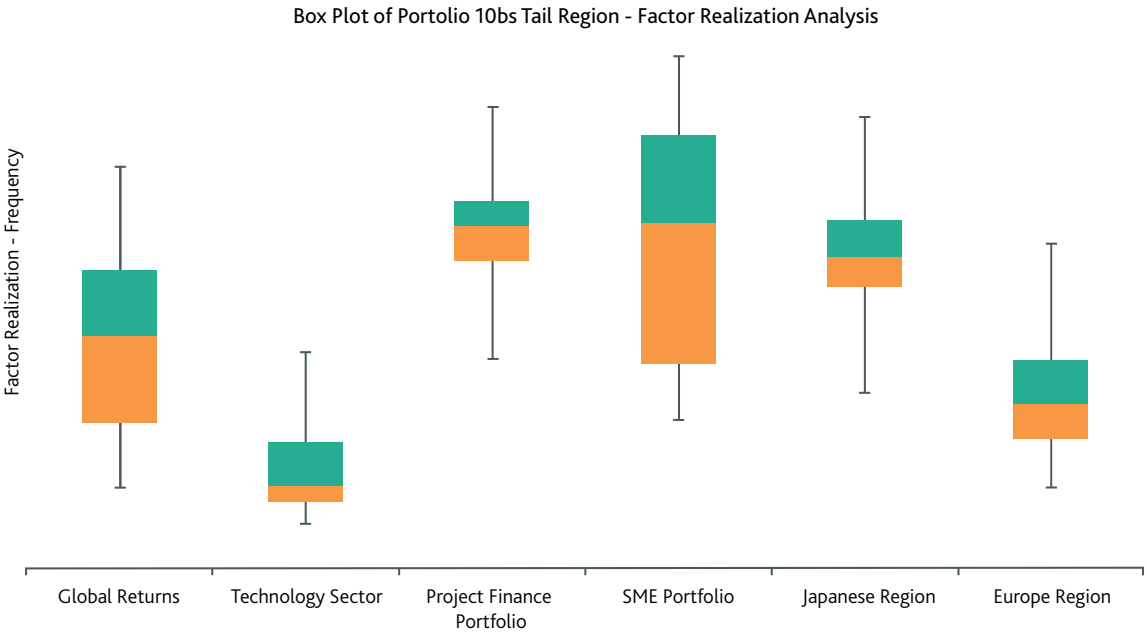


Stage 1: Definition of the appropriate loss level (e.g. confidence level) for the metric of interest for the financial institution (e.g. capital ratio, solvency ratio, …etc.). At this stage, the horizon for the analysis should be consistent with the requirements to fulfil the capital requirements under the corresponding regulatory jurisdiction and guidelines (e.g. one year under Basel III).

Stage 2: Identify the factor draws and their combinations[5] that had the most impact on the portfolio tail region through a quantitative discovery process. The factors and the loss associated with the portfolio in the tail region as well as which instruments, counterparties, countries and industries react most to these states are also known at this step. At this stage, the correlation structure affecting the institution's balance sheet composition should be taken into account in the analysis as well. For example, figure 3 shows the factors[6] that will make the institution unviable for a sample institution's portfolio for a given target tail risk probability of 10 basis points (or equivalent, a target confidence level of 99.9%). In this specific case, SME portfolio is the most reactive factor that causes the institution to default:

[5] In order to assess these iterations a correlation and migration structure is core during the simulation.
[6] Reverse stress testing and factor analysis performed using Moody's Analytics RiskFrontier™ credit portfolio model and ScenarioAnalyzer.™

FIGURE 3
Analyzing Factors' Realizations Across Tail Events for Reverse Stress Testing Purposes



Source: Moody's Analytics

Stage 3: Once the most reactive factors have been identified from step 2 then a sensitivity analysis is performed to measure the impact of these factors in the institution business model thus identifying the severity of the scenarios needed for the financial institution to fail, or losses to exceed the given level of capital in step 1.

Stage 4: Factors from step 3 are ranked and mapped to macro economic variables[7] and scenarios analyzed during the simulation. In detail, for each simulated trial and each analyzed sector a unique vector ϕ determines the relevant macroeconomic variables MV and their weights w at counterparty level:

$$\varphi = \sum_{i=1}^{N} w_i MV_i \text{ where } \sum_{i}^{N} w_i = 1$$

Stage 5: Macro economic variables from step 4 are mapped to macro economic variables from the stress testing analysis, thus identifying hidden vulnerabilities and overlapping effects.

Stage 6: Finally, to be effective, the analysis should finalize first with a enterprise-wide stress testing assessment by identifying how resilient their business model is for different solvency and capitalization rates. An enterprise-wide risk management diagnostic matrix should present the information, sensitivity analysis, and facilitates analyzing the results for regulatory reporting and decision-making initiatives.

[7] Modeling Credit Correlations using Macro Variables", Nihil Patel, Moody's Analytics Research, Risk Practitioner Conference October 2012.

Toward an Enterprise-wide Stress Testing Framework

Having an enterprise-wide stress testing framework that address both traditional stress testing analysis and reverse stress testing is a game changer for financial institutions. Reverse stress testing addresses tail risk analysis by starting from a known stress test outcome and then asking what events could lead to such an outcome for the financial institution, revealing hidden vulnerabilities in the portfolio and in the firm's stress testing framework that may not be detected during the stress testing analysis. Therefore, a robust and consistent portfolio bottom-up modelling approach is core to avoid under or over-estimation of risk for thus assuring flexible risk management policies and increasing the return for the shareholders.

We have introduced a modelling framework that allows financial institutions to understand and identify the enterprise-wide risks under adverse conditions that may have serious implications for their solvency. The framework can be used to provide guidance and perform analysis in order to reveal hidden vulnerabilities and tail risks for several key metrics:

- Capital and losses
- Bail-out costs and likelihood
- RAROC
- Provisions
- Risk appetite and risk limit settings
- Contingency planning
- Strategic business decisions (e.g. mergers or acquisitions)
- Optimal portfolios composition and business lines growth, hedging and exit strategies
- Balance sheet composition
- Enterprise-wide capital and funding structure

Finally, an enterprise-wide reverse stress testing analysis should be a strategic, risk management decision-making tool: setting an appropriate reverse stress testing framework and the correspondent contingency plans can impact the overall business strategy, improve profitability, make more resilient the business model and balance sheet, and allow senior management to be prepared to respond to adverse scenarios and regulatory requests before changes hit. At this stage, institutions should leverage reverse stress testing results to exploit hidden competitive advantages in their business model and reduce future costs in the event of a major unexpected shock.

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