White Paper
Stress Testing & VaR Implications in Market Risk Modeling
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Executive Summary

Overview

There are two potential ways to measure the overall risk of a firm's position, the first approach is a statistical based approach called value-at-risk, and the second one is based on economic insight rather than statistics, called stress test analysis. Since VAR is a statistical measure, it can be used to develop a relatively objective comparison of different types of risks by examining the specified probability of loss. Since VAR is expressed as a potential dollar loss amount, it can also be compared to similar measures of other types of risk, such as credit and operational risks. As for stress testing, which relies on economic and financial indicators where from a computational standpoint, is simply another variant of simulation; it uses a different method to generate the scenarios of the underlying market variables.

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Background

Stress testing and VaR Value at Risk share a number of features in that they both assess market risk. They both consider the change in market risk over a fixed horizon due to changes in specific risk factors. Like any tool, VaR has limitations, and those limitations were significant with many of the crude VaR implementations of the day. In light of those limitations, it became customary to recommend stress testing as a supplement to VaR.

Since VaR measures the statistical approach to overall risk measures when it first began to be calculated by financial firms, about 20 years ago, three methods have dominated:

- Direct measurement of P&L distribution.
- Calculation of P&L distribution based on historical statistics representing the variance and covariance of market variables and the current size of position exposures to each of these market variables.
- Simulation of P&L distributions based on a selected set of possible moves of market variables and the current size of the position exposure to each of those market variables.

The use of direct measurement of P&L distribution is still widely used, as can be seen from the frequent use of histograms of daily P&L distributions published in annual reports of financial firms. It has the advantage of simplicity of calculation, not having to make any use of models or statistical assumptions, and ability to capture effects of the trading culture (e.g., does management respond to periods of greater market volatility by reducing position size.) that the competing methods do not. It is also the only method which is available for measuring risk when access to details of trading positions is not available.
On the other hand, Stress testing involves using economic insight rather than strict reliance on statistics to generate scenarios against which to measure risk. From a computational standpoint, it is simply another variant of simulation — it just uses a different method to generate the scenarios of underlying market variables. Following this, the other two steps in simulation analysis, translation to all market variables and calculation of firm P&L can be carried out exactly as per simulation VAR — indeed, the exact same system can be used for both.

Limitations of Stress Testing during the recession

The recession left the financial community with an unanticipated set of failures that were never forecasted into the scenario analysis models. We believe systemic risk was not factored into the equation and little attention was paid to the possibilities of counterparty credit risk default i.e probability of default for Lehman as it filed for bankruptcy and ultimately had to be liquidated. Furthermore, the bailout by the government of AIG and the takeover of Bear Stearns by JP Morgan further exacerbated the economic environment.

Most bank stress tests at the time, were not designed to capture extreme market events they experienced during the crisis. The firms discovered one or several aspects of their stress tests did not even broadly match actual market risk models. In particular, the scenarios tended to reflect mild shocks, assumed shorter durations and underestimated the correlations between different positions, risk types and markets due to system-wide interactions and feedback effects. Prior to the crisis, "severe" stress scenarios typically resulted in estimates of losses that were no more than a quarter's worth of earnings (and typically much less at other times).
A range of techniques have been used to develop scenarios such as Sensitivity tests, which are at the most basic level, shock individual parameters or inputs without relating those shocks to an underlying event or real-world outcomes.

Stress Testing Methodologies

Types of Stress Tests

The essence of stress testing is the creation of user defined scenarios, fed into a calculation engine to produce estimates of the profits or losses that can be expected under these scenarios. Stress tests fall into three main types, which differ in how the scenarios are constructed. Any effective stress testing methodology should consist of "sensitivity analysis" (single and multi-factor analysis) and "scenario analysis" addressing all material risks at various levels of the institution. The combination of approaches as well as the level of detail will depend on the size and complexity of the specific institution. A smaller institution may place greater emphasis on the qualitative elements of its stress testing supported by quantitative outputs of the balance sheet, whereas large banks would be expected to run complex models which would be complemented by appropriate qualitative oversight.

- Sensitivity Analysis
  Sensitivity analysis is the simple stressing of one risk driver to assess the sensitivity of the institution to that risk driver. For example, institutions might choose a simple interest rate shift stress or a straight forward shift in probabilities of defaults (PDs), or the default of their largest counterparties, or a decline in value of liquid assets. Such analyses provide information about key risks and enhance understanding about potential risk concentrations in one or several risk factors.

- Scenario Analysis
  Forward-looking hypothetical scenario analysis is a core part of the suite of stress tests that institutions should include in their stress testing. The development of a hypothetical scenario can start

from historically observed realizations of risk parameters, but relying solely on historical scenarios has proved to be insufficient. Pure historical scenarios can give insights into impact but not into the confluence of events that may occur. Moreover, as historical scenarios are purely backward-looking, they tend to neglect recent developments and current vulnerabilities. Therefore, scenario design should take into account systematic and institution-specific changes in the present and near future and thus be forward-looking.

- Reverse Stress-Testing
  Reverse stress testing consists in identifying a significant negative outcome and then identifying the causes and consequences that could led to such an outcome. In particular, a scenario or combination of scenarios that threaten the viability of the institution's business model is of particular use as a risk management tool in identifying possible combinations of events and risk concentrations within an institution that might not be generally considered in regular stress testing.

The advantage of using stress-testing as a supplement to VAR is that it can pick up possible extreme events which can cause large losses to the firm's positions which may be missed by a purely statistical approach. The disadvantage is that once we leave the realm of statistics, we must substitute a standard of plausibility for one of probability, and plausibility is a very subjective notion. However subjective plausibility, must still be insisted upon.

VaR (Value-at-Risk) Methodologies

The following methodologies below are the most significant approaches to measuring risk such as Variance/Covariance, Monte Carlo Simulation and historical simulation. Generally, it involves using historical data on market prices and rates, the current portfolio positions, and models (e.g., option models, bond models) for pricing those positions. These inputs are then combined in different ways, depending on the method, to derive an estimate of a particular percentile of the loss distribution, typically the 99th percentile loss.

- Variance/Co-variance
  This is a simplified approach to VaR computation. It assumes a particular distribution for both the changes in market prices and rates and the changes in portfolio value. Usually, this is the "normal" distribution. The interesting aspect of the concept for "normal" is that a lot is known about it, including how to readily obtain an estimate of any percentile once you know the variances and co-variances of all changes in position values. These are "normally" estimated directly from historical data. In this method the VaR of the portfolio, is a simple transformation of the estimated variance/covariance matrix. It is simple enough in that it does not address the non-linear positions for instruments.

- Monte Carlo Simulations
  It is a simulation technique that makes assumptions about the distribution of changes in market prices and rates by assuming they are normally distributed, then collecting data to estimate the parameters of the distribution. The Monte Carlo model then uses those assumptions to give consecutive sets of possible future realizations of changes in those rates. For each set, the portfolio is revalued. When completed, we arrive at a set of portfolio revaluations corresponding to the set of possible realizations

of rates. From that distribution of the confidence level is determined at the 99th percentile loss as the VaR.

- Historical Simulations
  It is a simulation technique, but it skips the step of making assumptions about the distribution of changes in market prices and rates. Instead, it assumes that whatever the realizations of those changes in prices and rates were in the past is what they can be applied over the forecast horizon. It takes those actual changes, applies them to the current set of rates, and then use those to revalue the portfolio. When completed, we arrive at a set of portfolio revaluations corresponding to the set of possible realizations of rates. From that distribution, we arrive at confidence level of 99^{th} percentile loss is determined as the VaR.

Practical Comparisons between VaR & Stress Testing

It is highly critical to distinguish between what constitutes a VaR Value at risk simulation using one of the methods to estimate a forward looking exposure as opposed to the main functions of stress testing.

- While VaR models have proven themselves to be very useful risk management tools, the recent financial crisis have also highlighted their limitations—in particular, their excessive dependency on unrealistic statistical assumptions. The natural response to these limitations is for firms to resort to stress tests to complement the results of their VaR analysis. Stress tests are exercises to determine the losses that might occur under unlikely, but realistic real life circumstances which has seen dramatic increase in importance since the recent credit crisis of 2008-2009. Indeed, many firms and regulators now regard stress testing as no less important than VaR for assessing a firm's risk exposure.

- The one significant weakness of VaR as compared to stress testing is sudden changes in historical correlations. If two currencies have been pegged to one another, they will exhibit a high degree of historical correlation. A VaR analysis based on historical correlation will not address the risk that one of the currencies may be devalued relative to the other. If this is a scenario that concerns management, a simple stress test will offer more insights than would, say, a VaR analysis performed with a modified correlation assumption.

- One of the strengths of VaR stems from its broad coverage. In order to measure market risk in a portfolio using VaR, some mechanism must be found for determining the probability of occurrence and distribution of the portfolio's market value. All liquid assets have uncertain market values, which can be characterized with probability distributions. All sources of market risk contribute to those probabilities. Being applicable to all liquid assets and encompassing, at least in theory, all sources of market risk, VaR is an all-encompassing measure of market risk. It is worth distinguishing between three concepts that VaR methodologies rely on:
  - A VaR measure is an algorithm (computational formula with a sequence of steps to arrive at a risk factor) with which to calculate a portfolio's VaR.
  - A VaR model is the financial theory, representing the logic that motivates a VaR measure. It is the intellectual justification for the computations which is the VaR measure.
  - A VaR metric is the output (i.e a numeric risk factor) of the VaR measure.

- Stress testing is a simple form of scenario analysis. It is worth considering the evolution of risk factors over several time steps; stress testing considers changes in risk factors over a single time step. That

horizon is usually a single trading day, but stress testing can be considered over longer horizons—a week, two weeks, a quarter or even a year. However, any scenario analysis that employs a single time step may be referred to as a stress test. A single scenario consists of projected values for applicable risk factors at the end of the horizon. Based on these values, a portfolio is marked-to-market. The result is compared with the portfolio's current market value, and the portfolio loss is calculated as the difference between the two.

- Stress testing can be user defined as scenarios and are entered into a computation engine. A bank may specify certain fixed scenarios (defined in terms of percent changes in applicable risk factors) and then perform periodic stress testing with those scenarios. In this manner, a firm might present stress test results in its daily risk report. Such stress scenarios may be hypothetical, perhaps reflecting contingencies that are a recurring concern of management. They can also be historically based. With that approach, stress scenarios may reflect the percentage changes in risk factors experienced during selected historical periods of market turmoil—stock market crashes, currency devaluations, and downgrades.

- Scenarios can be constructed in an ad-hoc manner. If management is concerned about the effect of an inverted yield curve or a breakdown in a specific correlation, a scenario can be constructed specifically to assess that eventuality. The stress test would re-calculate a VaR on a portfolio where the amended exchange rate amongst the two main currencies to exhibit the following shocks: -10%, +5%, and -15%. Under the scenario analysis argument, it is recommended that studying the historical movements of these two currencies can provide some information to project various scenarios on how the market would behave.

Conclusion

In summary, stress testing can be a nice supplement for VaR analysis, and many firms use for this purpose. This is accomplished in order to assess the risk of a breakdown in historical correlations where stress testing can be valuable. Other than this factor, as a tool for addressing vaguely defined limitations of a VaR measure, stress testing is largely a panacea.

The author of this white paper does not advocate any of the methodologies for stress testing or VaR. Both methodologies appear to have strengths and weaknesses in mitigating risk. While VaR is largely appropriate with easily identifiable market inputs and short durations. On the other hand, stress testing has to build scenarios around realistic shock events not easily identifiable where the definition for plausible and realistic scenarios to shock a portfolio can be convoluted. Frequently, economic downturns occur when they are least expected and catches firms ill-prepared for what follows. By the same token, it is critical to not minimize the impact of total correlation breakdown of markets, assets and portfolios in times of severe market downturn thus making VaR and Stress models obsolete as we witnessed during the credit crisis.