

***LEHMAN BROTHERS***

**Market Risk Management**

**Stress Testing: Policy & Procedures**

Revised: October 2006

***CONFIDENTIAL***

---

## Stress Testing: Policy & Procedures

### Overview

The term “stress testing”, widely used in the risk management profession, covers a number of techniques used as a supplement to other risk measurement methods, such as VaR, to explore the vulnerability of a portfolio of positions to extreme market events. Statistical techniques such as VaR address the question of how much could a portfolio lose over a given time-horizon and with a given degree of confidence, but do not address the question which is often of greatest concern to a firm’s management, shareholders and regulators, namely how much could the firm lose in a plausible, if unlikely, worst-case scenario.

Stress testing may be carried out and may add value at any level of a firm’s hierarchy. This may range from the firm-wide implications of a global macro-economic event, in which many markets exhibit stressed characteristics, such as loss of liquidity, violent price moves and a break-down of no-arbitrage relationships, down to the impact on a trader, book, line of business, region or specific legal entity arising from a localised micro-economic event. Regardless of the scale of the event, to add value to a firm’s portfolio of risk management metrics, useful scenarios need to satisfy three requirements:-

- scenarios need to be plausible and economically coherent, however unlikely
- scenarios need to seek out the vulnerabilities in the portfolio
- there needs to be a means of drilling-down into the results of the scenario to see which positions and market shocks are driving the largest P&Ls, and hence what mitigating courses of action may be taken

Stress testing is a regulatory requirement as a supplement to VaR models under 1996 amendment to the Basel Accord, and in the proposed Basel II framework, although the nature, form and frequency of the analysis is not prescribed. (Certain regulators, such as the UK’s FSA, require that regular stress testing be done weekly, at a minimum; that some should be done daily; and that there should be a capability of performing some stress testing upon demand.) Stress testing should be performed for both Trading Book and Banking Book positions, as appropriate.

Owing to the fact that it is not possible to ascribe meaningful probabilities to these events, since they are so rare, we do not intend at this point to put hard-limits onto the outcomes of scenario analysis, nor to apply the results to our internal capital allocation methodology. However, the results will be used by senior management, Risk Management and the businesses as a regular part of the Firm’s risk management framework to draw attention to particular scenarios in which the firm might suffer substantial losses, and to suggest possible mitigating courses of action which may be taken, should the possible losses highlighted by scenario analysis be in excess of the

Firm's appetite for such risk, or should the probability of the highlighted scenario be deemed sufficiently large that such mitigation would be wise.

The remainder of this document proposes the stress testing framework to be developed during the course of 2005 and subsequently carried out at the Firm.

### **Nature of Stress Testing to be Implemented**

#### **1) Firm-wide Scenario Analysis**

Of greatest concern to senior management and the regulators is the vulnerability of the Firm to exogenous shocks which may give rise to extreme market moves, such as those during the global stock market crash in 1987, or the Russian default and subsequent liquidity crisis surrounding LTCM in 1998. Given the risk of contagion and systemic risk which may ensue from such events it is necessary to stress the Firm's portfolio of both market and credit exposures simultaneously. Included within the portfolio will be scenarios in which the Firm's ability to access liquidity and credit are impaired, such as may be caused by a rating downgrade for the Firm, or an inability to access capital markets for unsecured short-term funding.

To address such concerns we will subject the Firm's overall portfolio to a number of coherent macro-economic scenarios in which pertinent market factors are shocked by extreme, although plausible amounts. The scenarios which are relevant at any particular time will be driven by the nature of our exposures. To determine the plausible shock-factors to apply to our portfolios we will draw upon our experience of historic events. Although stress events, by their nature, are relatively rare, and history is not bound to repeat itself exactly, we use examples of historical events as a means of judging the magnitudes of plausible shock-factors and the extent of plausible correlation changes. Correlation changes during extreme market events may be very significant, which implies that stress test results may not be deduced merely by taking multiples of VaR.

The portfolio of scenarios we apply will, of necessity, need to evolve over time. There are certain exposures we may have which are structural, in the sense that whilst the magnitudes of the exposures may fluctuate, the nature of the exposure may be relatively unchanged over time. However, rather more often it will be the case that the nature of our exposures will be dynamic, changing with market dynamics and our views on markets. As a result, a static portfolio of scenarios will not suffice to perform adequate stress testing, given the requirement that the scenarios must continually seek out the vulnerabilities in our portfolios.

Similarly, applying shock factors derived from historical events to our exposures of today will not be adequate, because it will be the case that the market environment today, in terms of the levels of interest rates, the shapes of yield curves and volatility surfaces, etc. may be very different to those extant at the time of the historical event. Likewise, there may have been paradigm shifts since the historical event occurred, such as the development of new instruments, the lengthening of tenors, the advent of new currencies such as the Euro, or the subsequent breaking of currency pegs long after the event, which

may mean that blindly applying the shocks which occurred during the historical event to the positions today may well result in implausible market effects.

As a consequence of these considerations, the core of our firm-wide scenario analysis will be to build hypothetical scenarios designed to deliberately stress our portfolios, which evolve over time as our portfolios change, using plausible shocks and correlation changes drawn from our experience of historical events.

## **2) Localised Stress Testing**

In addition to macro-economic scenarios as described above, we will also carry out more localised stress testing, designed to explore the specific vulnerabilities of each line of business and region, and of specific legal entities. Such stress testing will include examination of our exposures to idiosyncratic events, such as changes to tax codes, which may give rise to significant valuation changes for our municipals business, or the dividend assumptions used in our equity derivatives valuation models; or changes to the implicit government guarantee backing Agencies positions, etc. Such localised events may not be as financially devastating for the Firm as a whole as are the macro-economic scenarios, but they could nevertheless give rise to significant losses for a particular line of business, or a regulated entity.

A second kind of localised stress scenario which we intend to carry out is what we refer to as a "Dealer-Exit" scenario. A number of our businesses trade highly structured and complex products in which we, along with other competing dealers, tend to warehouse exotic risks which we may not easily trade out of. As a result of these trades the dealer community tends to warehouse one side of these transactions, whilst the end-user clients tend to hold the other side. As a consequence, the forced exit from the market of one of our competitors may give rise to large losses on a mark-to-market basis.

Such a forced exit may be triggered by a change of management, such as occurred when Berkshire Hathaway acquired General Re, or by senior management or regulatory fiat, as a result of losses elsewhere in the portfolio which force exposure reduction. In this latter case, it may be appropriate to combine losses from the Dealer Exit scenario together with losses from a macro-economic scenario where such combination would be economically coherent.

For example, suppose we consider the synthetic CDO book at a time when it is structurally long super-senior risk. Losses in this book arising from a combination of wider credit-spreads, increase in implied correlation and a decrease in implied recovery rates could plausibly be combined with losses in a macro-stress event which saw significant spread-widening (and the exit from the market of a competitor in synthetic CDOs could plausibly be triggered by large losses for that firm arising from large spread-widening in its marked-to-market credit portfolios). On the other hand, losses for the CDO book triggered by a combination of spread widening, a *decrease* in implied correlation and an *increase* in implied recovery rates could not plausibly be combined with a macro-stress event which saw significant spread-widening.

## **Duration of Stress Scenarios**

Historically, stressed market conditions have persisted over periods of duration from as short as a few days to several weeks. A defining feature of stress events is that during them liquidity may be severely diminished for many markets, and except for the most liquid traded instruments, such as spot FX, government bonds and interest rate swaps in the OECD major currencies, it is practically impossible to exit or neutralize the risk of a firm's exposures. Even exchange-traded products, such as equities or futures contracts, may suffer circuit-breaker rules which mean that liquidity is not available without large price-gaps.

For the purposes of calculating the P&L impact of stress shock-factors we will assume that the shock occurs instantaneously, i.e. that traders have no opportunity to re-hedge or adjust their positions, and that we may ignore the impact of declining tenors for, for example, futures and options contracts. Apart from simplifying the calculations, such an assumption is not unreasonable given our practical experience of the actions of traders during historical events, and it is consistent with our approach to the annualization of daily VaR to obtain the market risk element in the calculation of Risk Appetite.

For the purposes of extracting plausible magnitudes and correlations of shock-factors from historic events we will assume a maximum horizon over which positions could not be mitigated of two weeks for global macro-economic scenarios, and for individual product/line of business scenarios we will use such horizons as may be appropriate, given the liquidity of the instruments.

## **Systems Implementation**

Given the large shock-factors which are required in meaningful stress testing, Taylor's series approximations of risk sensitivities are not usually adequate and full-revaluation is necessary. Market Risk Management, working together with the businesses, having determined the appropriate scenarios and their associated shock-factors, will use the front-office valuation systems to calculate the impacts of the scenarios. The results of these calculations will then be fed to LehmanRisk, where they will be aggregated and presented, together with the means to drill-down into the numbers to see what is driving the significant P&L terms.

## **Frequency and Scope of Stress Testing**

Stress scenario analysis of the Firm's current exposures should be carried out regularly with a frequency of at least monthly. The Market Risk Management and Quantitative Risk Management departments will collectively review the portfolio of scenarios used at least quarterly to ensure that they remain plausible and continue to address the vulnerabilities in the Firm's portfolios. Whilst leveraging input from other areas of the Firm, such as the businesses and Research, in determining the appropriate scenarios to

use, Risk Management will retain responsibility for scenario selection, and for the determination of the magnitudes of the respective shock-factors to be employed within them.

Results of scenario analysis for each business will be reported to the respective business heads, and recommendations regarding loss mitigation strategies will be made to them by Market Risk Management on a monthly basis. In addition, the results of the scenario analyses, including possible risk mitigation strategies, will be presented to the Senior Management for the Firm-wide, division, global line of business, regional line of business levels, and for specific legal entities, as required.

The CRO will present scenario analysis results to the board of directors as part of the quarterly board presentation. The results of scenario analysis will be reviewed in the context of the capital position of the Firm, or legal entity, as appropriate.