LEHMAN BROTHERS

Risk Management Division

Stress Scenario Analysis

September 2007

CONFIDENTIAL

Stress Scenario Analysis

Overview

The term "scenario analysis" covers a number of techniques used as a supplement to other risk measurement methods, such as VaR and MPE, 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.

Scenario analysis 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 and simultaneously explore exposures to market, credit and operational risks
- 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 determine what mitigating courses of action may be taken

Scenario analysis of operational, market and credit exposures (including counterparty credit exposures) is a regulatory requirement as a supplement to statistical models used to calculate a firm's regulatory capital requirement under Pillar I of Basel II, and a firm is also required to perform a comprehensive program of scenarios analysis to ensure that it has sufficient capital under Pillar II as part of its own internal capital assessment. Scenario analysis needs to embrace both Trading Book and Banking Book positions, as appropriate.

At Lehman Brothers, the results of Firm-wide stress scenario analysis are presented to the Board of Directors periodically, and scenario analysis of the pertinent portfolios is presented to the governing bodies of particular legal entities, as appropriate. Results are also made available to the Firm's senior management and to business management, to draw attention to particular scenarios in which the Firm or a line of business 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 portfolio of scenarios we apply, of necessity, evolves 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 is the case that the nature of our exposures is 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 is not adequate by itself, because 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 scenario analysis is to build hypothetical scenarios designed to deliberately stress our portfolios, and which evolve over time as our portfolios and markets change, using plausible shocks and correlation changes drawn from our experience of historical events. The Risk Management division reviews the portfolio of scenarios used periodically to ensure that they remain plausible and continue to address the vulnerabilities in the Firm's portfolios. Risk Management leverages input from other areas of the Firm, such as the businesses and Economic Research, in determining the appropriate scenarios to use, but is ultimately responsible for scenario selection, and for the determination of the magnitudes of the respective shock-factors and embedded factor correlations to be employed within them. Periodically, the Firm's Stress Scenario Analysis framework, including the suite of scenarios used, are reviewed by the Firm's senior management and governing bodies.

In addition to performing stress scenario analysis at the Firm-wide level, Risk Management also carries out analysis at the regional level and for specific legal entities, where this is appropriate. Scenario analysis of the Firm's current exposures is carried out regularly with a frequency of at least monthly.

Given the large shock-factors which are required in meaningful stress testing, Taylor's series approximations of risk sensitivities are usually inadequate and full-revaluation is necessary. Having determined the appropriate scenarios and their associated shock-factors, Risk Management uses the front-office valuation systems to calculate the impacts of the scenarios, the results of which are then fed to LehmanRisk for the calculation of P&L impact to principal market exposure, and to CWS and the MPE engine for calculation of the impact on CCE and MPE. The results of the principal market risk and counterparty credit risk stress losses are then aggregated to obtain the consolidated view of the Firm's stress exposures.

Nature of Stress Scenarios

Of greatest concern to senior management 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. The fundamental question which scenario analysis attempts to answer is: "How much capital do I need to absorb unexpected losses on my portfolio during a stress event?" Given the risk of contagion and systemic risk which may ensue from such events, to answer the question it is necessary to stress the Firm's portfolio of both market and credit exposures simultaneously, and to consider the potential compounding of losses through default of, for example, a major market participant and the subsequent impact of that default on market levels, as the market fears possible contagion, or that the default will result in liquidation of the participant's portfolio, pressuring markets in which the dealer community tends to warehouse significant one-way exposures.

To address such concerns we subject the Firm's overall portfolio of trading exposures and principal investments, and those of particular legal entities, to a number of coherent macro-economic scenarios in which all pertinent market factors are shocked by extreme, although plausible, amounts at the same time as we shock our counterparty exposures, both in terms of our counterparty ratings (thus stressing our counterparty default probabilities) and the counterparty exposures-at-default, through stressing the inputs to our MPE calculation engine. At the current time we are not additionally stressing loss-given-default assumptions, since we are using the fixed LGD levels as prescribed by the Basel Committee for the F-IRB regulatory capital calculation, however as we move to adopt an A-IRB approach then we will additionally stress LGDs.

The scenarios which are relevant to the Firm at any particular time are driven by the nature of our exposures and then-extant market conditions. To determine the appropriate 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 to assume when devising scenarios. 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 or of MPE.

Likewise, market liquidity often proves to be an illusory concept, being plentiful in normal market times when it is not needed, but rarely being available when it is. The magnitudes of shock-factors we use in our scenarios are based on the cumulative moves observed empirically during stressed market environments over a time period which is commensurate with the risk liquidation (or risk mitigation) horizon of our material economic exposures *during such a stressed market environment*. Once determined, the shock-factors are assumed to occur instantaneously, which is equivalent to saying that for the duration of the shock the traders are unable to liquidate or mitigate the risk. However, for very illiquid exposures, for which the risk mitigation horizon is accordingly very long-dated, it is correct to consider the carry (i.e. net interest income) of the position over

that horizon as part of the net P&L, if it is material. Because different positions will have different risk liquidation horizons, even during a stressed market period, we construct individual scenarios which have many different risk liquidation horizons embedded within them. Since the shocks are assumed to act instantaneously, the differing risk liquidation horizons manifest themselves as shock-factors of varying magnitudes, the longer the liquidation horizon, the larger the shock. The shocks correspond to the cumulative moves we may expect to occur over various time-scales, each one commensurate with the appropriate risk liquidation horizon for that position.

Suppose the portfolio consists of a variety of positions ranging from the very liquid, such as FX exposures, G7 government bonds, G7 I/R swaps and options; through positions of intermediate liquidity such as emerging market bonds/bond options and corporate bonds; to relatively illiquid investments such as loans, private equity, real estate and counterparty credit exposures through OTC derivatives transactions with a tenor out to 10-years. To determine how much capital we require to absorb unexpected losses during a stress event we would aggregate the P&L resulting from applying shock-factors derived from, say two-week cumulative moves in liquid FX and I/R products, with results from shock-factors derived from, say, one-month moves applied to corporate bonds and emerging markets, and with results from applying, say, a two-year property market recession applied to real estate, with results from calculating the MPE of the portfolio of counterparty credit exposures and the potential credit ratings migrations (i.e. P.D. migrations) which might occur commensurately over the lives of the trades, and so on.

“One-in-25-Year Recession Scenario”

A specific requirement of the UK’s FSA, as stated in their BIPRU rules, is that firms should conduct stress tests of their capital requirements during a recessionary period such as might be experienced “once in 25 years”, during which time we might expect to see counterparty ratings downgrades and weakening of real estate, private equity and loan portfolios. The capital requirement is equivalent to the mark-to-market loss observed during such an event, aggregated over all of the Firm’s exposures. The loss arising from our counterparty credit exposures is equal to the product of the stressed EAD, the stressed PD and the stressed LGD resulting in the scenario. Likewise, the capital required to absorb unexpected losses on the portfolio of principal exposures is equal to the losses occurring during this recessionary event, which is calculated by applying shock-factors equal to the cumulative moves which may occur over the respective risk-mitigation horizons of the exposures (which may be less than the full duration of the recessionary event itself) to the respective exposures.

We believe that it is appropriate to calculate the capital loss for this scenario assuming that the recessionary period begins today (as opposed to attempting to pinpoint where we are in the current economic cycle, and then forecasting when in the future the recessionary period may begin), and that it is caused by some exogenous trigger event, which might, for example, be a large terrorist event, or the occurrence of some disease pandemic. The actual causal event is not relevant in itself, it merely serves to be the trigger for the subsequent onset of recession, with the concomitant weakening of the economic environment, weakening of credit quality and equity prices, widening of credit

spreads, decline of short rates and inflation, etc. The detailed scenario specification then determines the impacts on market levels, PDs and LGDs which are then fed into the risk calculation engines to calculate the capital impact.

We assume that the event begins today rather than at some point in the future for three principal reasons. Firstly, under this assumption, the length of time over which the EAD from our counterparty credit exposures may evolve is greater, and thus the resulting stressed EAD will be larger and result in a more-conservative capital requirement, which is obviously the most prudent assumption to make. Secondly, attempting to pinpoint where one is in the economic cycle is fraught with difficulty and is something that becomes clear only with the benefit of hindsight. Empirically, economic cycles are highly variable, being of varying duration and periodicity, and with little evidence of stable correlation between the economic cycles of different countries. Attempting to estimate the current point in the cycle using historical observations of cycle-length would thus be highly dubious. Furthermore, to cast the start of the recessionary period into the future allows the possibility that we could raise further capital between now and the time when the recession hits. Clearly, having the recession begin now obviates this possibility and is therefore necessarily the most prudent treatment for us to adopt.

Following our general principle of drawing upon historical experience to deduce what may happen in future scenarios, we have based our shock-factors for this scenario on cumulative moves observed during US recessionary periods over the last 25 years. Although the Firm has significant non-US counterparty exposures, we believe that increasing globalisation of markets, and the fact that non-US markets have experienced many significant developments since the last major recessions occurred in those countries, means that historical US market experience is a better proxy for future scenarios in all the major economies in which we have material counterparty exposures than would be the actual historical experiences of those economies themselves.

Empirically, we have determined the periods of the most significant US recessions of the last 25 years to have been those occurring between July 1990 and March 1991, and between March 2001 and November 2001. We have then taken the largest cumulative moves in I/R, FX, credit spreads, equities, implied volatilities, etc., in the markets to which we have the greatest exposures occurring during these two eight-month periods (which, in fact, corresponds to the March 2001 to November 2001 recession) and applied these shocks to our counterparty credit exposures to produce stressed CCEs for input into our MPE model. By running the MPE model using these stressed CCEs we have calculated stressed values of EAD for input into the calculation of stressed counterparty exposure capital requirement.

To calculate the stressed default rates to accompany the stressed EAD and LGD rates, we have again turned to empirical observation of (almost) the last 25 years. We have used Moody's default statistics from 1983 to 2005 and compared the worst-case one-year PDs (which correspond to the US recession years 1990 and 2001) with the average one-year PDs over the entire 23-year period. By inspection of the data, the recessionary-year PDs for any particular rating correspond to the average PDs over the whole period for an

entity rated two notches lower (see Appendix A). To estimate the stressed PDs for the "one-in-25-year recession event" we therefore apply a 2-notch downgrade simultaneously to all counterparties, which we believe to be a conservative treatment.

At the current time we are not additionally stressing LGD assumptions, since we use the fixed LGD levels prescribed by the Basel Committee for F-IRB regulatory capital calculations, however as we move to adopt an A-IRB approach then we will additionally stress LGDs.

Major Market Counterparty Default

A second scenario specifically prescribed by the FSA is that of the default of a major market counterparty. Our exposure to such an event results both from our direct and indirect exposures. Direct exposure arises through holdings of the counterparty's securities, loans, or CDS with the counterparty as underlying reference entity, financing transactions (i.e. repos, stock loan/borrows, etc.), and receivables on OTC derivatives transactions with the counterparty. Indirect exposure arises through the impact which default of such a major market participant may have on the broader marketplace.

Furthermore, in a number of our businesses we 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. These exposures are actively risk-managed, however, during a condition of dislocated markets, the ability to dynamically hedge them may be severely impaired. 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 default of a major market participant may cause the forced closure of his portfolios of exotic and one-way warehoused risks, potentially giving rise to large losses on a mark-to-market basis of similar portfolios held by ourselves and other competing dealers.

We anticipate that the impact of such a default would be to cause central banks to inject liquidity in an attempt to avert a liquidity crisis and possible contagion effects. We thus model such a default by assuming a decline in short-rates of major currencies and an accompanying steepening of yield curves; an increase in swap spreads and credit spreads more broadly as the market fears a possible liquidity and credit squeeze, and a general weakening of equity prices. Equity prices and credit spreads of banks and broker/dealers will most likely be particularly severely impacted. The high-level scenario specification is shown in Appendix A.

We model the potential losses on our exotics and one-way risk portfolios by considering the likely mark-to-market impact on our portfolio of the forced unwinding of what we perceive to be the similar portfolio holdings of the largest market participants in these products. We then consider whether the stresses which would give rise to our worst-case losses for these portfolios could occur coherently with the likely impact on the broader markets of the dealer default. 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 macroeconomic-stress event which saw significant spread-widening, such as we believe might happen as a result of the dealer default. 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.

The direct exposures to the defaulted market participant are modeled by calculating the EAD to the counterparty post the impact on market levels per our specification of this scenario, setting the counterparty PD to unity, and (at the present time) using the regulatory-prescribed LGD.