

Integrating Stress Testing with Risk Management

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Extrême market moves, “abnormal” events, and distress conditions have occurred since the beginning of organized markets. Even so, 1998 was distinguished by the number of spectacular market stresses. Many market participants should have learned powerful lessons. But 1998 shows that many of us are still ill prepared.

This article will show why stress testing is a critical component of effective risk management. It will discuss reasons for stress testing, general approaches, and specific stress tests. It examines why many firms that stress test are dissatisfied with their efforts. It identifies the key attributes of effective stress testing and outlines actions to consider, given the results of stress testing. Stress testing, which is very much an art, when integrated with the science of risk management, enables us to sleep better at night.

EXAMPLES OF EXTREME MARKET MOVES (1987-99)

1987 Stock market crash: one day moves. Dow Jones Industrial Average (DJIA) fell 23% to 1738.74, and the S & P500 Index fell 20% to 224.84 on October 19, 1987. Contagion effects included the Nikkei index's 15% drop, the FTSE 100 Index's 12% drop, and the Hang Seng Index closing for four days and falling 33% on October 26 (Exhibit 2).

1990 Nikkei crash, high yield tumbles. Nikkei fell 48% to a low of

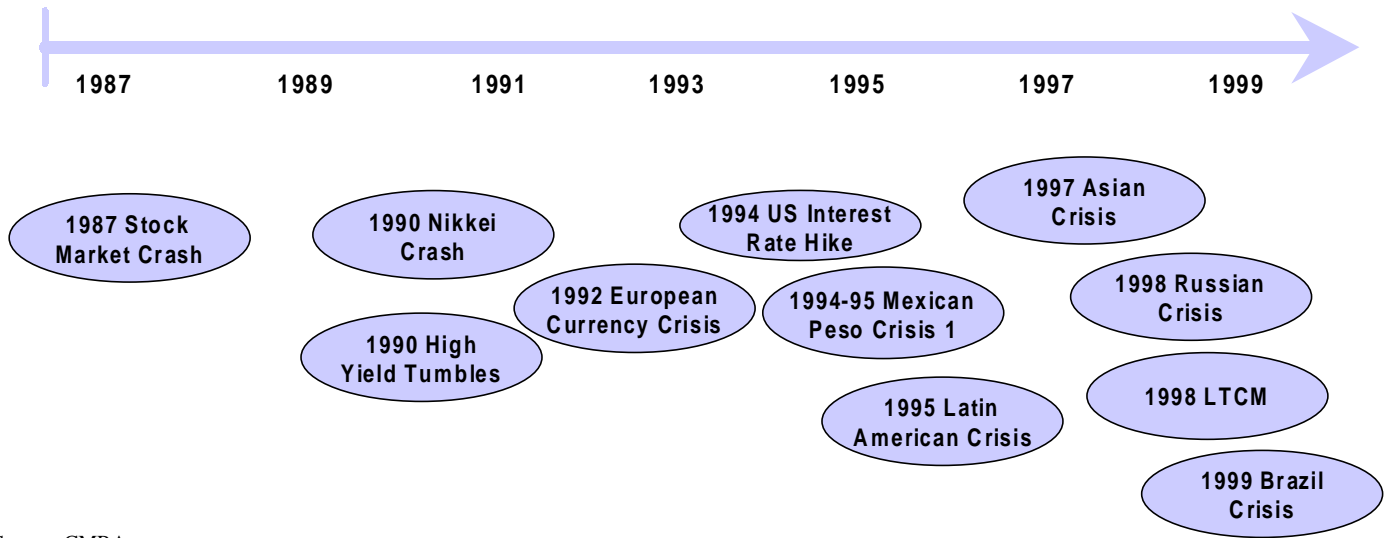
20,221.86 over the year, and the one-week historical volatility exceeded 120% in September/October 1990. The Japan Real Estate Index tumbled 56%. In addition, the Salomon Brothers High Yield composite fell 13% to 158.75 in October. Drexel Burnham Lambert collapsed.

1992 European currency crisis. The European Rate Mechanism, a prescribed set of ranges that the 12-member European community's currencies can trade between, broke down. When the monetary system started to crumble, institutions rushed to protect their investments by selling the weaker currencies and buying the German mark. The UK raised rates to 12% to defend the currency but eventually suspended its participation in the European monetary system and let the pound fall. Italy devalued the lire by 7%, Spain devalued the peseta by 5% (Exhibit 3).

1994 U.S. interest rates. U.S. Federal Funds short-term target rate was raised six times from 3.0% on January 3, 1994, to 5.5% on December 30, 1994, an increase of 83%. Following, the 12-month domestic funds rate increased 110% to 7.75% at year-end. The DJIA fell 10% to 3593.35 on April 4, 1994. The Salomon Treasury Index fell 5% to 446.8 on June 30, 1994, and the Salomon Corporate Bond index fell 6% to 489.8 on June 30, 1994.

1994 and 1995 Mexican peso crisis and Latin America crisis. Mexican peso devalued 15% to 3.975 on December 20,

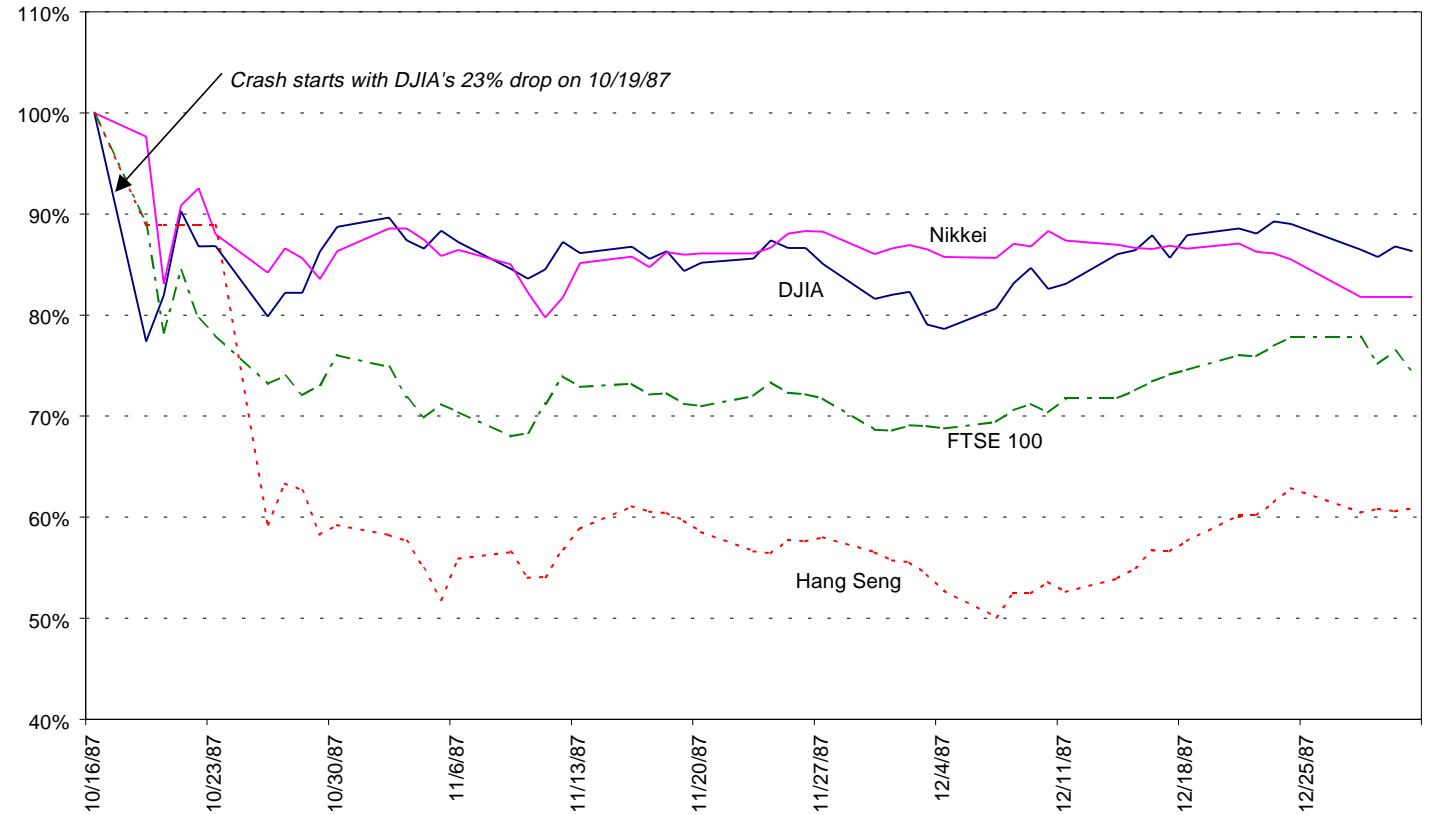
EXHIBIT 1
Unexpected Financial Shocks



Source: CMRA.

EXHIBIT 2
1987 Equity Market Crash

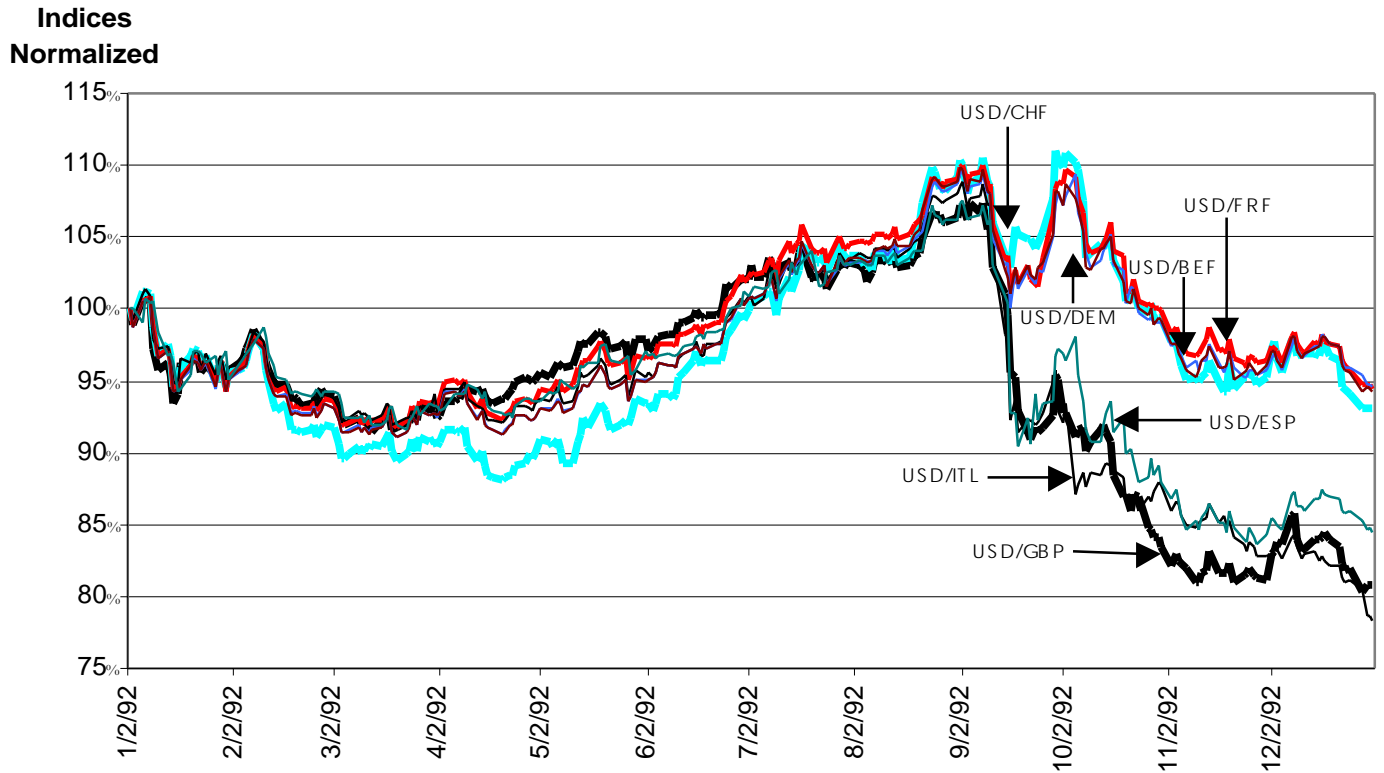
Equity Index*



* All indices are normalized based on 100% at 10/16/87

Source: Bloomberg.

EXHIBIT 3
1992 European Currency Crisis
Currency Band Depegging



Source: Bloomberg

1994, and the one-week historical volatility exceeded 150% in December. From September 1994 to March 1995, the Mexican Bolsa Index dropped 49% to 1447.52, the Brazilian Bovespa Stock Index dropped 61% to 2138.28, and the Argentinian Merval Index dropped 58% to 262.11 (Exhibit 4).

1997 Asian crisis. The Thai baht had a oneday fall of 16% on July 2, 1997. The crisis spread rapidly to the other Asian currencies. The South Korean won dropped 41% between December 4, 1997, and December 23, 1997, and the Korea Composite Index dropped 50% to 350.68. The Indonesian rupiah fell 71% between December 1, 1997, and January 26, 1998, and one-week volatility exceeded 200%. The Jakarta Composite Index dropped 41% to 339.53 from September 10, 1997, to December 15, 1997. The Malaysian ringgit fell 25% in December. The Kuala Lumpur Composite Index dropped 45%

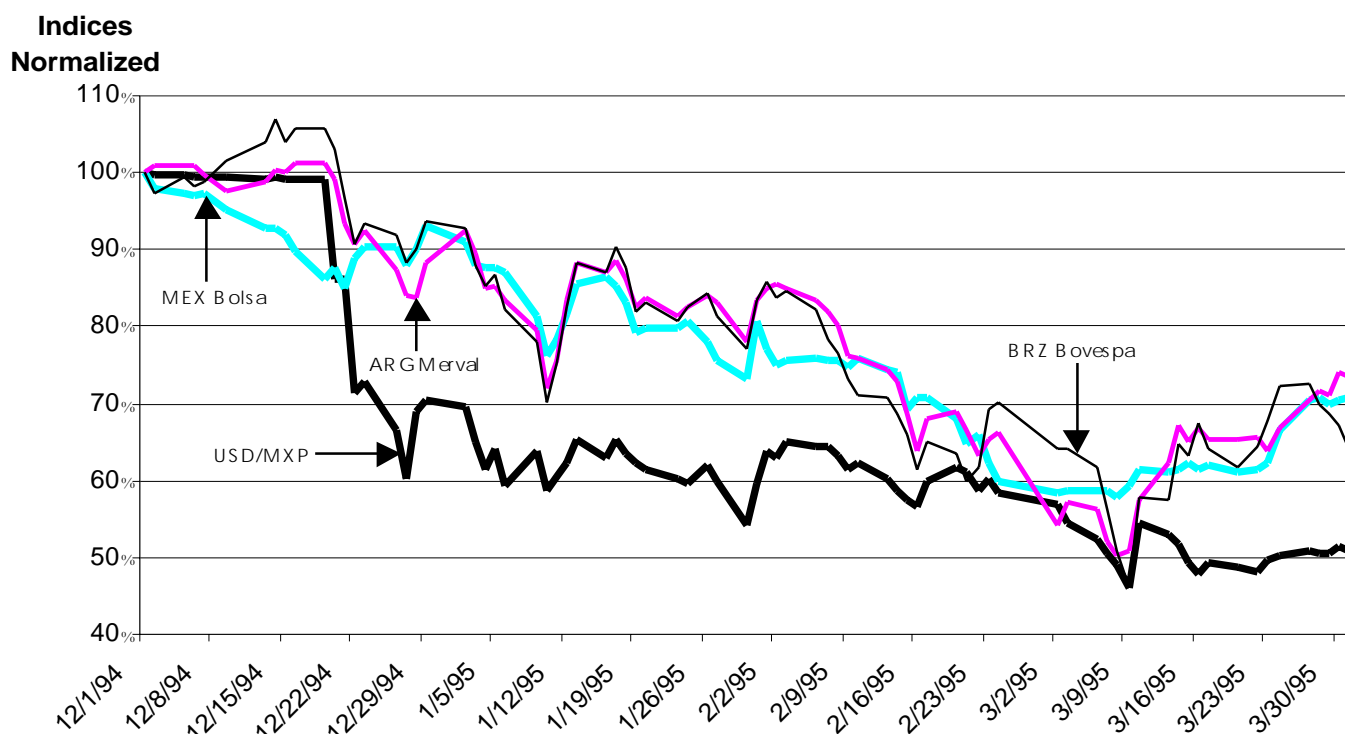
to 477.57 from September 10, 1997, to January 12, 1998 (Exhibit 5).

1998 Russian crisis. The Russian ruble fell 41% from August 25, 1998, to August 27, 1998, with a one-day fall of 29% on August 27, 1998, as Russia defaulted on its internal government debt. Russia's RTS stock index lost 86% for 1998. Also, Russian government bond yields increased from 333% on August 26, 1998, to 578% on August 27, 1998 (24,290 bps).

1998 LTCM. Long Term Capital was a major driver of the depressed equity markets in the third quarter. The DJIA fell 12%, price volatilities exceeded 70% in August, credit spreads increased substantially across the board.

1999 Brazil crisis. Brazil devalued its currency by 8% on January 14, 1999, and the Bovespa stock index fell 10% to a low of 5057.19 the same

EXHIBIT 4
1994/1995 Latin American Crisis



Source: Bloomberg

day. Price volatilities on the Brazilian real exceeded 80% in January.

LESSONS LEARNED

These crises show that it is hazardous to base one’s risk-management process on “normal” or “likely” market moves. Effective risk management must minimize surprises and, hence, must cover less likely but severe events, shocks, or surprises like the following:

- **Linkages/“abnormal” correlations.** In distress conditions different markets can become linked quickly and normal correlations cease to hold. Markets do not stay compartmentalized due to the speed of information and investor-driven financial flows. Hence, correlation assumptions based on history of normality break down, and correlations tend to swing to extremes, including + 100% or - 100%.

- **speed of price shocks.** Markets gap or price moves become discontinuous as information spreads almost instantaneously and market participants rush to act. Hedging assumptions break down and orderly execution becomes difficult.
- **Concentration.** Under normal conditions, one can balance the hazards of concentration against the competitive benefits of scale and market leadership that it allows. But market shocks can turn a concentration into a near-fatal loss. Further, distress market conditions can create new, surprising, and near-fatal concentrations through new and sudden linkages. Each market crisis or major loss reveals surprising new sources of concentration.
- **Sudden decreases in liquidity.** All markets can experience dramatic drops in liquidity and, through new linkages, multiple markets can become illiquid at the same time. Institutions have generally become more vulnerable to liquidity shocks as growth in investor needs and higher-

EXHIBIT 5
1997 Asian Crisis

Currency
Devaluation*



* All currency devaluation values are normalized based on 100% at 7/1/97

margin products are increasingly in newer, smaller markets and more complex and thinly traded products.

- **Credit / macroeconomic bets.** An increasing proportion of many portfolios are bets on creditworthiness, credit spreads, or favorable macroeconomic conditions in a country or region. Hence, structural changes or shocks in macroeconomic, sociopolitical factors leading to crises of confidence; pressures on currency values, interest rates, or capital flows; and sudden worsening of economic conditions in a country or region can cause spectacular losses.
- **Hedging techniques fail.** Severe market turbulence can create excessive costs if not outright difficulties in hedging or rebalancing positions. Key assumptions built into pricing models cease to be valid. Large unexpected losses occur.

WHY STRESS TESTING IS A CRITICAL COMPONENT OF EFFECTIVE RISK MANAGEMENT

Although the lessons from actual market shocks all point to the need for stress testing your portfolio, the inherent nature of risk management makes stress testing imperative:

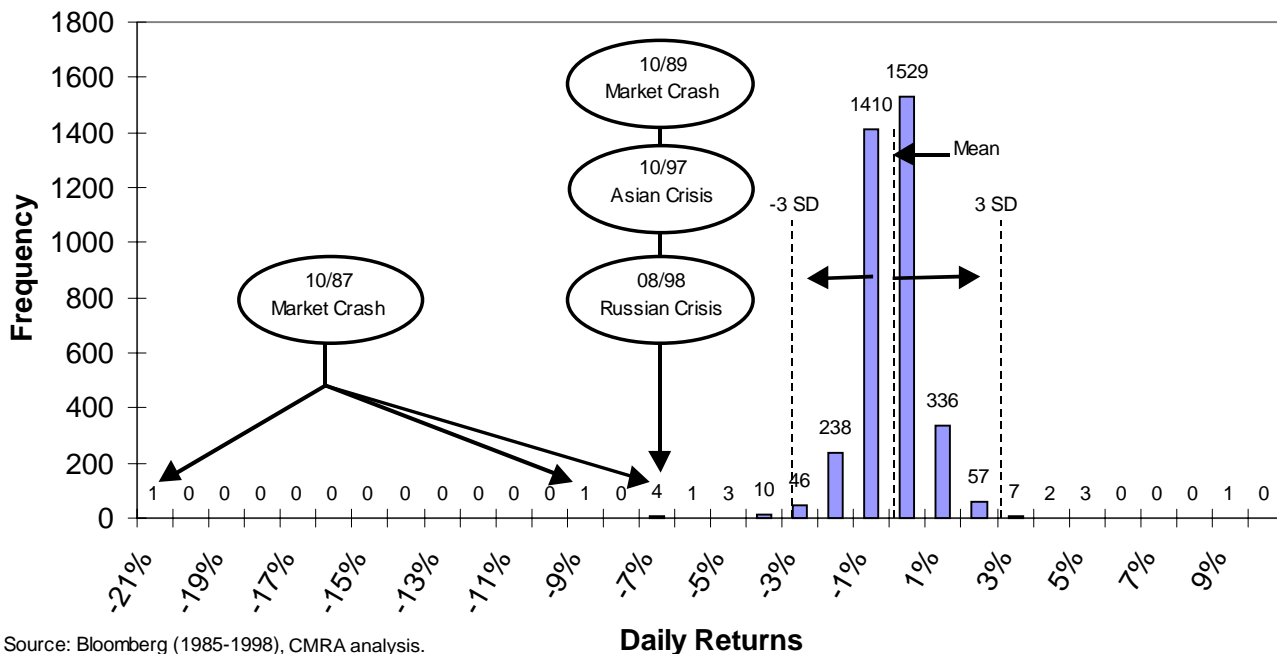
- **Risk measures are based on historical assumptions that include normal distributions of volatilities and correlations, continuous prices, and adequate liquidity.** Such measures are practical and useful under normal market conditions and serve as the base case for daily management dialogue and decisions about risks. However, they fail in extreme market moves or distress conditions. For example, value-at-risk (VAR) calculations for market risks

are typically based on up to three standard deviations. They are also based on limited historical data of usually no more than three years. As we have seen, market shocks far exceeding three standard deviations are not uncommon (Exhibit 6). Hence, the fact that such risk measures are used make it imperative that stress testing be a routine supplementary process. Further, stress testing is needed to counter the almost perverse, unintended effect of the popularity of VAR—the false sense of comfort and overreliance on VAR because of its simplicity, ease of use, the volume of quantitative data, and the sophisticated math involved. Stress testing reminds us that VAR is not a guarantee of the worst-case loss.

- **Risk capital cannot protect against all losses.** VAR and risk-capital models require many of the same assumptions. It can provide a substantial cushion against losses caused by a large range of market moves but will fall under many extreme shocks. Therefore, stress testing is needed to identify the vulnerabilities and to provide contingencies for when capital is insufficient protection.

- **Effective risk management aims to minimize surprises.** Risk measures such as VAR provide useful base-case information. Risk capital serves as a last line of defense. Stress testing, together with daily management dialogue and decision making, provides proactive and dynamic management of risk. No risk management can prevent losses but the best can minimize surprises. Stress testing is a powerful means of anticipating, understanding, and preparing for shocks and the resulting potential losses.
- **Business lines are necessarily biased toward likely events.** They identify opportunities, serve client needs, and make prices and decisions based on expected market moves. Stress testing focuses on what can go wrong, the highly unlikely but severe events. Together, the institution can maximize business opportunities while reducing the likelihood of financial distress. It also helps the institution to be resilient in difficult market conditions.
- **Regulators, ratings agencies, and investors worry about catastrophic losses and restrictions in the abil-**

EXHIBIT 6
Market Shocks Can Exceed Three Standard Deviations
S & P 500 Price Returns



Source: Bloomberg (1985-1998), CMRA analysis.

ity of institutions to do business in distressed market conditions. Their understanding of what effective risk management requires is increasingly sophisticated. They expect to see a disciplined process of stress testing. Liquidity risks, systemic risks, and, ultimately, solvency are top of mind. Merely complying with capital requirements does not provide adequate comfort. When these constituencies are uncertain, they generally overpenalize institutions through ratings or stock valuation multiples.

Stress testing reminds us that
VAR is not a guarantee of the
worst-case loss.

WHAT TO STRESS TEST

Stress Testing Approaches

The following comprise a fairly comprehensive set of approaches for stress testing:

- **Historical event analysis.** What happens if the severe market event happens again? For example, what is the impact on your portfolio if the Dow Jones drops 23% as it did on October 19, 1987?
 - **Scenario analysis based on historical events.** Develop scenarios based on historical events but update them for current conditions.
 - **Institution-specific scenario analysis.** Identify scenarios based on the institution's portfolio, businesses, and structural risks. This seeks to identify the vulnerabilities and the worst-case loss events specific to the firm.
 - **Extreme standard deviation scenarios.** Identify extreme moves and construct the scenarios in which such losses can occur. For example, what can cause a 5-, 6-, 7-, 8-, 9-, 10-standard-deviation loss event?
 - **Extreme incremental market moves and tail risk.** This approach does not identify the scenarios but just quantifies a set of progressively severe market moves and the resultant loss. For example, what is the potential loss if all equity mar-
- kets gap by plus and minus 5%, 10%, 15%, 20%, etc.?
- **Quantitative evaluation of distributions of tail events and extreme value theory.** Based on observed historical market events, quantify the impact of a series of tail events to evaluate the severity of the worst case losses. This approach also evaluates the distribution of tail events to determine if there are any patterns that should be used for scenario analysis.

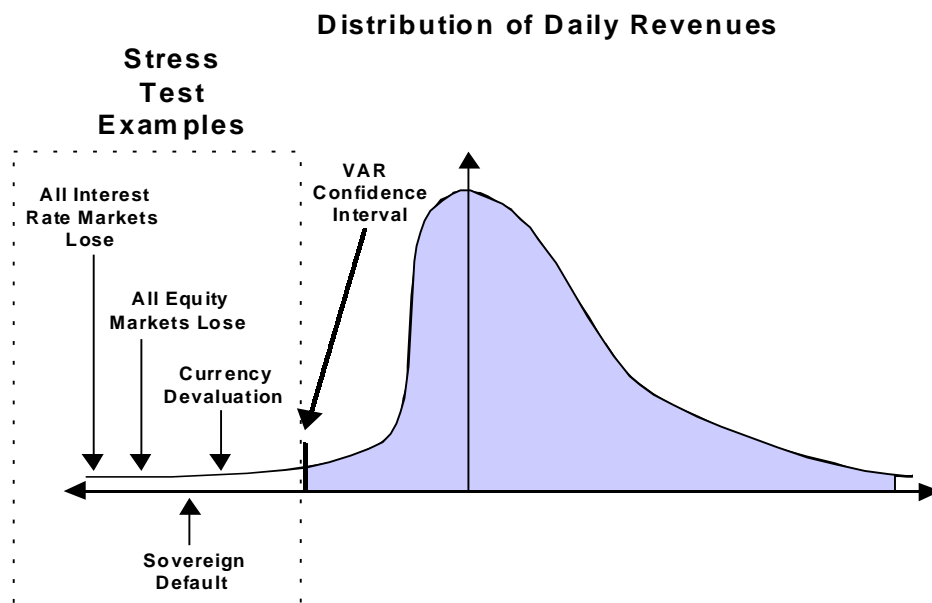
Specific Stress Tests by Category

Stress tests can be categorized by the types of assumptions they challenge, the types of things that can go wrong, the nature of the surprises or market moves, model parameters, product complexity, credit, sea changes.

Market moves. Stress testing for extreme market moves is common. We're all familiar with tests like shocking equity prices by gaps of 10%, 20%, 30%, and 40%. Other important tests, some of which are not as common as should be, include the following:

- **Parallel shifts in the yield curve,** for example, the interest-rate-risk and portfolio impact of a 100-basis-point shift in the yield curve. Identify the number and level of yield curve shifts to test for. These can be designed to take into consideration the individual market's propensity for large movements by evaluating the impact of a large standard deviation move in the market, such as "What's the impact of a 5, 6, or 7 + standard deviation move?"
- **Yield curve twists.** Identify the impact of changes in the shape of the yield curve. What happens when the curve steepens, flattens, or inverts by 25, 50, or 100 basis points? How sensitive is your portfolio to each of these scenarios and by how much?
- **Basis changes.** Understand and test for the relationships assumed in the risk exposures of your portfolio. For example, are you betting that the relationship between two countries' rates or their interest-rate differential holds, narrows, or widens?
- **Swap and other credit spreads.** Test for the impact of changing credit spreads on the portfolio. How

EXHIBIT 7
Stress Tests



Source: CMRA.

hedged is the portfolio? What are the implicit credit spread assumptions within each of your portfolios of swaps, corporate bonds, high-yield securities, converts versus equities, and how would these differ by market or country?

- **Price shifts.** Evaluate the impact of price shifts in equities, commodities, currencies, and other asset classes such as real estate and their impact on the portfolio. For each asset or market, select the size of the price shocks that are stressful enough but still possible based on evidence of a similar event in order to make it meaningful.
- **Currency devaluations.** Estimate the impact to the portfolio of currency devaluations and the effect on related markets and currencies.
- **Volatility changes and twists in the term structure of volatility.** What is the impact of changes in volatilities in the market and changes in the volatility term structure on the options and other portfolios?
- **Liquidity.** Test what happens when market liquidity dries up so that you can no longer hedge your portfolio. Likewise, test for instances where you have to liquidate your hedges if the underlying

ing transaction's hedging is extinguished. Test for the impact of reducing large positions at different levels of market liquidity and estimate how long it takes and the costs of covering the position.

- **Credit tightening.** What is the impact to your portfolio of credit and counterparty lines tightening? Estimate and anticipate alternative funding costs and sources in a difficult market environment. How would this affect the economics of current business and the pricing and competitiveness of future business?
- **Contagion.** Evaluate the portfolio impact of all positions and markets moving in the wrong direction. What is the worst-case loss? Understand how markets are linked and size the impact of a regional and worldwide effect on markets.
- **Speed and time period.** Estimate the speed and duration of the extreme market moves and how well the portfolio can withstand it.

Model assumptions. Whether it is deal valuation, credit estimates or VAR, models are used with assumptions that are not routinely stress tested. It's

critical to understand the limitations of all the models used and understand their sensitivity to inputs, calculations, and methodologies. Modeling assumptions to be stress tested include the following:

- **Yield curve interpolation and creation.** The yield curve used for valuations across many instruments should be tested rigorously. In addition, it is important to stress test more routinely for markets with less liquid or fewer available instruments along the yield curve.
- **Pricing models.** What is the choice of pricing models used? For example, there are differences in option-pricing models used even for instruments in deeply traded markets. In newly developing markets the differences may be very significant as it is in the current state of credit derivatives models used. Differences in pricing models used are also due to the proprietary nature of the models as in the case of mortgage models. Further, are the same models used in different parts of the organization to evaluate the same portfolio?
- **Models used for trading and hedging strategies.** Models used for trading and hedging strategies should be evaluated for critical assumptions such as, “What is a typical market move? What correlation assumptions are assumed in pricing different markets? How dependent is the portfolio’s value on these models?”
- **Risk and economic capital measures.** Identify the portion of the risk and capital measures that is dependent on assumptions of volatilities and correlations. Assess the impact of differences in methods and calculations used.
- **Volatilities.** Evaluate the historical volatilities used in the models. How close are these to the implied volatilities? What is the impact on the portfolio valuations and risk measures if the assumptions are 10%, 20%, 30% + off?
- **Correlations.** What happens when correlations are different from history? Test for extreme moves such as correlations going to 1. Test for all markets moving against the portfolio positions or correlations moving opposite from history to the extremes at 1, 0, and - 1. Create scenarios where markets are linked, such as equity moves affecting interest-rate moves, affecting currency moves, etc.

Product complexity. As products become more complex, what drives their valuation becomes less transparent. The risks are less obvious and difficult to visualize. These products typically have multiple risk elements and linked parameters. For such products, stress testing is imperative for understanding and quantifying the risks.

- **Derivatives.** All derivative portfolios should be stress tested along with the models used. Derivatives models assume continuous markets and the ability to dynamically hedge the portfolio. Often these assumptions are taken for granted, because this is usually the case in the most liquid derivatives markets of USD or other major currencies. However, there is a crucial distinction between the conditions in major markets and conditions for derivatives in the emerging markets.
- **Mortgages.** Complex proprietary pricing models have been developed to manage and assess the risks of mortgages. However, the behavioral aspects of mortgages and the results on the cash flow assumptions leave no choice but to do a battery of scenarios and stress testing of underlying parameters.
- **Structured products with embedded multiple risks.** The more complex the instrument that embodies a structured view on the market and risk types, the more difficult it is to simply view the drivers of the risks. It becomes crucial for these products to have sensitivity analysis done for extreme levels of market moves.
- **Products that have a wide range in acceptable pricing models used.** The pertinent questions are: What is the range of acceptable prices and how wide is it? What happens with hedging accuracy? How much of the portfolio do you feel comfortable to be at risk to this modeling and product assumption?
- **Difficult-to-handle risks and asset types.** Private equity, venture capital, and real estate are examples of non-traditional asset classes that have become larger pieces of portfolios. Products that have wide bid/ask spreads also fall into this category. These assets require stress testing to properly measure and manage.
- **Emerging markets and other difficult-to-handle markets.** Emerging markets have a high propensity for discontinuous market moves as a result of

political and economic changes. They often also have short histories of relevant market information that can be applied in the traditional risk measures such as VAR. As a result, it is crucial to supplement the standard measures by asking “What can go wrong? What happens in a default situation? How exposed is the portfolio to devaluations, currency controls, liquidity crises, client concentrations, etc.?”

Credit. Much attention has been paid to the market-risk side of the equation, but for most financial institutions, the credit-risk portfolio is still the larger portion by far of total risk exposure. Further, a larger part of the traded portfolio is dependent on credit plays in the form of taking basis risks on corporations, sovereign risks in non-G7 countries, and outright credit positions through credit derivatives. Hence, it is crucial to stress test the various facets of credit risk in an institution.

- **Credit or name concentration.** How much outstanding is there to a name or counterparty? How much outstanding risk is there to each credit class, for example, BBB credits? What are the effects on the portfolio of significant downgrades and the rollover effects to like credits?
- **Industry concentration.** How much exposure is there to an industry, and what is the impact if the industry sector is undergoing cyclical changes, economic downturn, etc.?
- **Country or region concentrations.** What is the country mix of the portfolio? How is it exposed to regional concentrations? What is the likely impact of credit downgrades by country and the rollover effects in the region? How linked are countries in that region?
- **Concentration across different client segments.** Identify drivers of client financial flows that are similar across otherwise different client segments. These are hidden potential sources of concentration.
- **Drivers of the ability and willingness to repay, particularly under crises.** Evaluate the impact of significant market crises and the effect it has on entire classes of counterparties or credits. What are potential default rates? What is the range of reasonable recoveries and in what time frame?

- **Contingent credit exposures, particularly of derivatives.** Design stress tests that allow you to estimate the potential exposure of the portfolio to extreme market moves. This is an area where market risk drives the size of the credit risk exposure and linkages across risk types.

Sea changes. The year 1998 was also notable in the number of “firsts” or records in the financial markets, for example:

- the lowest Japanese long-term interest rates in recorded history, 0.25%, which makes borrowing money almost cost-free;
- the lowest U.S. mortgage rates since 1967;
- the largest drop in the Russell 2000 index of small cap stocks (31% from the high);
- record levels of trading losses across all financial institutions.

These market records should warn us of the need to watch for sea changes and to anticipate the potential impact on the portfolios of these changes. Sea changes on the horizon include the following:

- the effects of the European monetary union on trading, on Europe as a common market force, and on the potential winners and losers due to competition, consolidation, and rationalization of resources and assets in the markets;
- the millennium and the impact of Y2K, changes in the political arena the next century will bring, and the changes in the nature of the financial services industry;
- the impact of countries’ political and economic policies on the financial markets, such as capital controls, and the speed to which everyone would need to manage across boundaries that are quickly disappearing.

MANY DO IT BUT FEW ARE SATISFIED

Although many firms have stress-testing programs, few are satisfied with their efforts or the results. Our experience suggests that one or more of the following attributes of effective stress testing are usually missing:

- **Must be stressful enough.** Smaller moves are not relevant for stress testing and are already taken

care of in risk and capital measures. As long as the events are not impossible, no matter how unlikely or draconian it may seem, it is important to include it. Also, it is important to account for the speed and duration of the stress event.

- **Must identify key assumptions.** It must answer “What key assumptions when changed would substantially change my results and comfort level with the portfolio and risks?” Unless explicitly examined, key assumptions tend to remain hidden.
- **Must make risks transparent.** It must describe and measure the difficult-to-visualize, nonlinear, asymmetric risks, such as options and prepayment risks.
- **Must not compartmentalize risks.** It must identify linkages across risks and markets and describe how these can change, for example, the impact of correlations on liquidity, the impact of extreme correlations on prices. Stress tests must also take into account the ripple effect across markets, industries, and institutions, for example, LTCM.
- **Must be updated systematically.** Stress tests must be refreshed and updated systematically to capture new sources of surprises and current portfolio characteristics.
- **Must be aligned to the firm’s culture.** To be effective, methods selected should take into consideration the culture, management style, and processes of the firm. For example, how quantitative or qualitative a stress testing program is will be driven primarily by the firm’s style and comfort.

In addition to missing one or more of the above attributes, some firms are paralyzed by the following concerns:

- If I apply a capital charge based on the results of stress tests, it’ll kill my business. If I don’t what’s the point of stress testing?
- How can I communicate the stress-testing program to senior management without raising undue alarm?
- Ultimately, what can I do with the results of stress testing? If the tests are extreme enough, wouldn’t the results be too scary? If we ignore

the results in order to continue to run our businesses, why go through the exercise?

WHAT TO DO WITH THE RESULTS OF STRESS TESTING

In our experience, the following process works well:

- Senior management must take the lead in designing the stress-testing program and in asking the extreme and difficult questions.
- Scan all markets and extraordinary risk events to learn the lessons from history.
- Identify the key assumptions, common drivers, and other vulnerabilities affecting the portfolio and earnings.
- Run stress tests and scenarios appropriate for the portfolio and risks.
- Systematically refresh the battery of stress tests specific to the portfolio and repeat periodically (some tests weekly, others yearly, others as needed).

Moments of crisis often present unusual but fleeting opportunities to profit from strategic repositioning.

The following is a comprehensive list of actions that should be considered:

- Buy protection or insurance for risks that can be immunized.
- Restructure business, client, or product mix.
- Price differently to include previously unidentified risk.
- Get out of the position, market, or business.
- Don’t change the business but systematically monitor and manage the business through more stress testing, and develop contingency plans for the shocks.
- Evaluate the returns over the life cycle of the business for the total economics.

- Beware of the industry herd mentality and the resulting concentration of risks.
- Be careful of the “greater fool” assumption.
- Prepare for liquidity and funding issues that naturally occur in stressful market environments by increasing credit/counterparty lines/ limits and funding sources, and managing liability structure for adequate short-, medium-, and long-term funding in a crisis.

In general, a capital charge is not a useful tool for dealing with the results of stress tests. One or more of the above solutions should provide the protection more effectively.

Taken together, the above seeks to first ensure that the firm can survive the stress events (which includes the impact on capital adequacy, reported earnings, firm liquidity, credit ratings, and customer and investor confidence). In addition, the actions aim to preserve enough resilience in distressed market conditions and to enable the firm to take the offensive and move quickly, because moments of crisis often present unusual but fleeting opportunities to profit from strategic repositioning.

STRESS TESTING PROVIDES THE JUDGMENT IN RISK MANAGEMENT

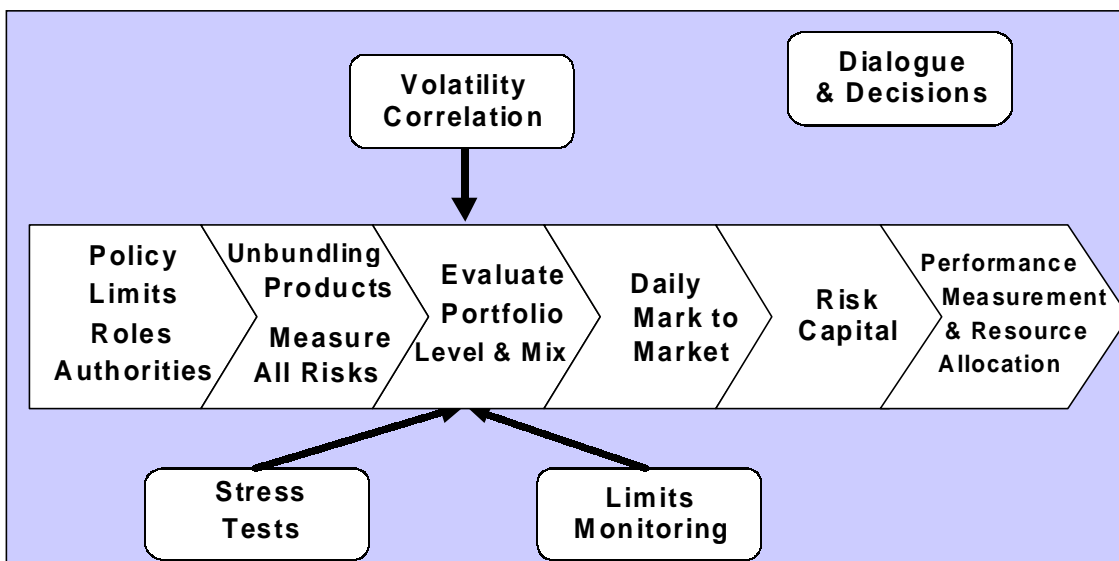
Fundamentally, measuring how much risk one has is driven by the answers to three questions:

- How much exposure?
- How sensitive is the value to a unit change in an underlying variable?
- How big could the change in variable(s) be (for example, price volatility and correlation)?

Sophisticated risk-management methods can take care of the first two questions. They are factual, objective, or scientific. But the third question depends on judgment, on one’s forecasts. We certainly will use as much historical data, analysis, and experience as we can muster, but ultimately answering the third question is an art. This is where stress testing is valuable. It pinpoints the key assumptions and quantifies the risks faced by the firm when things go really wrong, when the highly unlikely moves and events do occur.

Effective risk management requires much sophisticated financial modeling, math, and computer

EXHIBIT 8 Risk Management Framework



processing power. Stress testing is a critical component that uses rigorous analytics but requires management judgment and forecasts. To be effective, the various components provide a rigorous and disciplined manner, timely and complete data for senior management and the business lines to debate about and decide on the level and mix of risks on an ongoing basis (Exhibit 8).

We have seen how volatile and unpredictable financial markets can be. The year 1998 was a powerful reminder that sophisticated risk-management models, while necessary, are insufficient. The disci-

pline of a well-designed and implemented stress testing program is critical. Used with an understanding of the imperative for senior management judgment, of ongoing risk-management dialogue and decision making, stress testing can help everyone sleep better at night.

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