Effective Stress Testing in Enterprise Risk Management

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Abstract

Recent developments and the change in the global business environment have brought great urgency to enterprise risk management (ERM) issues, and insurers have been searching for the best ERM solutions for their practice. Stress testing has long been used as an essential risk management tool for insurers. This paper discusses both the theoretical and the application aspects of stress testing in managing enterprise risks. Effective stress testing maximizes the risk adjusted enterprise profit by controlling major risks (financial, strategic, operational and hazard) upon identifying risk metrics and modeling the correlations. A case study is included for demonstration purposes.

1. Introduction

Actuaries rely on statistical models to measure and manage financial risks, ranging from underwriting risks to market risks, credit risks and operational risks. These models provide a coherent framework for identifying, analyzing and communicating enterprise risks. However, models are only simplifications of reality and cannot capture every aspect of these risks. For example, unlikely yet possible events that could cause significant losses are not captured readily by models constructed to monitor typical risk outcomes.

This paper discusses the use of stress testing in ERM practice for calculating economic capital as well as meeting the regulatory capital requirements. These methods can be applied to provide better solutions or alternative effective approaches in the insurance risk management practice.

This paper is organized as follows. Discussion of stress testing concepts and techniques is presented in Section 2. The process of the common stress testing methods is introduced in Section 3. Implementing effective stress testing on both the assets and liabilities is discussed in Section 4. Section 5 concludes the paper.

2. Stress Testing

Stress testing is a process to evaluate the potential impact on company balance sheets of a specific event and/or movement in a set of financial variables. It is a simulation technique used on asset and liability portfolios to determine their reactions to different financial situations.

Stress testing is an effective tool for improving understanding of economic balance sheets. It is an effective risk management tool with its flexibility and the way it explicitly links potential impacts to specific events.

It can also be used in meeting the insurance regulatory and compliance requirements, such as Solvency II in Europe and principle-based valuation in the United States. In addition, it can be used as an effective tool for IAIS/fair value accounting and for public companies (SEC). Because it is used to determining how a portfolio will fare during a period of financial crisis, it is one of the important parts of the ERM process, for financial and capital management as well as the operational/strategic excellence.

Stress-testing techniques fall into two general categories: sensitivity tests and scenario tests. Sensitivity tests assess the impact of large movements in financial variables on portfolio values without specifying the reasons for such movements. A typical example might be a 100 basis point increase across the yield curve or a 10 percent decline in stock market indexes. These tests can be run relatively quickly and are commonly used as a first approximation of the portfolio impact of a financial market move. However, the analysis lacks historical and economic content, which can limit its usefulness for longer term risk management decisions.

2.1 Sensitivity Test

As specified in ASOP #7—Analysis of Life, Health, or Property/Casualty Cash Flows, which applies to actuaries when performing analysis of an insurer's asset, policy or other liability cash flows for life/health insurers (with similar application for P/C actuaries), sensitivity tests should be applied in performing reserve or capital adequacy (e.g., asset adequacy analysis, economic capital calculations) as well as in financial projections or forecasts. ASOP #7 requires that the actuary should consider sensitivity of the model to variations in key assumptions, taking into account the purpose/use of the analysis and test to see whether results reflect a reasonable range of variation in the key assumptions, consistent with intended purpose and use.

ASOP #22—Statements of Opinion Based on Asset Adequacy Analysis by Actuaries for Life or Health Insurers—requires that stress testing should consider moderately adverse conditions—those "that include one or more unfavorable, but not extreme, events that have a reasonable probability of occurring during the testing period."

More specifically, New York DOI requires, for long-term care liability, a sensitivity test assuming voluntary lapses grading down to 1.0 percent by duration 15; and interest rate scenario with pop-down 100 b.p. and then remain level.

Sensitivity testing should recognize benefits such as distribution of business by benefit period; greater build-up of active life reserves; greater exposure to asset-related risk and lower interest rates; need to make appropriate provision in claim reserves; inflation benefits; lower termination rates (mortality, voluntary lapses); and lower interest rates and asset-related risk (lower yield curves, lower margins over Treasuries, higher default rates).

Scenario tests are constructed either within the context of a specific portfolio or in light of historical events common across portfolios. Upon identifying a portfolio's key financial drivers, a set of the economic scenarios is generated in which these drivers are stressed beyond standard risk standards. For the event-driven approach, stress scenarios are based on plausible but unlikely events, and the analysis addresses how these events might affect the risk factors relevant to a portfolio. Commonly used events for historical scenarios are the large U.S. stock market declines in October 1987, the Asian financial crisis of 1997, financial market developments following Sept. 11, 2001 and Hurricane Katrina in 2005.

The Monte Carlo simulation is one of the most widely used methods of stress testing. The choice of portfolio-based or event-based scenarios depends on several factors, including the relevance of historical events to the portfolio and the firm resources available for conducting the exercise. Historical scenarios are developed more fully since they reflect an actual stressed market environment that can be studied in great detail, therefore requiring fewer judgments by risk managers.

3. Stress Testing Process

As part of the ERM process, stress testing steps start with risk identification for risk factors in earnings-at-risk analysis, dynamic capital adequacy testing and tail fitting. It then identifies and models the outlying possibilities and correlated events, models/values the impact of these scenarios and incorporates this analysis into the ERM framework.

In assessing market risks, underwriting risks, operations risks and credit risks, the process includes selection of scenarios for the core risk factors, and stressing scenarios for these have been specified.

Core risk factors for asset risk exposures are listed as the following.

- Credit risk
- Market risk
  - Interest rate curves
  - Credit spread curves
  - Equities and market indices
  - Foreign exchange rates
  - Implied volatility surfaces
  - Macroeconomic factors
- Operational risk
- Liquidity risk
- Group risk
- Systematic risk

As for the liability risk exposures, core risk factors include:

- Underwriting risk
- Catastrophe (influenza pandemic)
- Business continuity
- Claims
- Reserving risk
- Reinsurance
- Liquidity risk
- Group risk
- Interaction/correlation of risk factors

While scenario tests take portfolio-driven and event-driven approaches, sensitivity tests focus on the key assumptions and are projected over a time horizon. In practice, the stress testing more often involves the combinations of Monte Carlo (single and multi-step), historical, stress scenarios, sensitivity shocks and historical replays.

Finally, stress scenarios can be created from the following.

- Scenarios from recent history
  - 1987 equity crash
  - ERM crises of 1992-1993
  - Bond market crash of 1994
  - 1997 east Asian crisis and its aftermath
  - September 11
  - Hurricane Katrina
- Predefined scenarios that have proven to be useful in practice
  - Fall in the stock index of x standard deviations
  - A change in an exchange rate of y%
  - Yield curve shift of so–many basis points
- Mechanical-search stress tests
  - Use automated routines to over prospective changes in risk factors
  - Evaluate P/L under each set of risk-factor changes
  - Report the worst-case results
- Statistical tools (principal component analysis) can be used to determine the scenarios for other factors/multiple risk factor shocks

4. Stress Testing Example

In this case study, we consider a 20-year projection—annual time steps for liability cash flow starting at 2006/12/31 (t=0). Assume there are 2,000 policies, each with initial premium of $100,000. The liability features are listed in the following.

- Equity guarantees: 1,000 with both GMMB (ROP) and GMDB (ROP)
- Interest rate guarantees: 1,000 with GAO
- Strikes on guarantees: 35% OTM, ATM, 30% ITM
- Maturity date for each policy: 1–20 years
- Random annuitization date: 1–20 years
- Random policyholder age: 50–70 years
- Random policyholder gender: M or F
- General account cash flows: fees & annuities
- Risk factors:
  - S&P 500 Index: 1418.3
  - USD-SWAP Curve: ~4%
- Other market factors (e.g., swap or bond spreads)
  - Compute conditional expectations using covariance matrix (and expected changes, if these are nonzero)
  - Covariance matrix could be estimated using only data from periods of past market crises
  - Stress scenario both internally consistent and consistent with the data from past periods of market stress.

The assets back the liability exposure include the following.

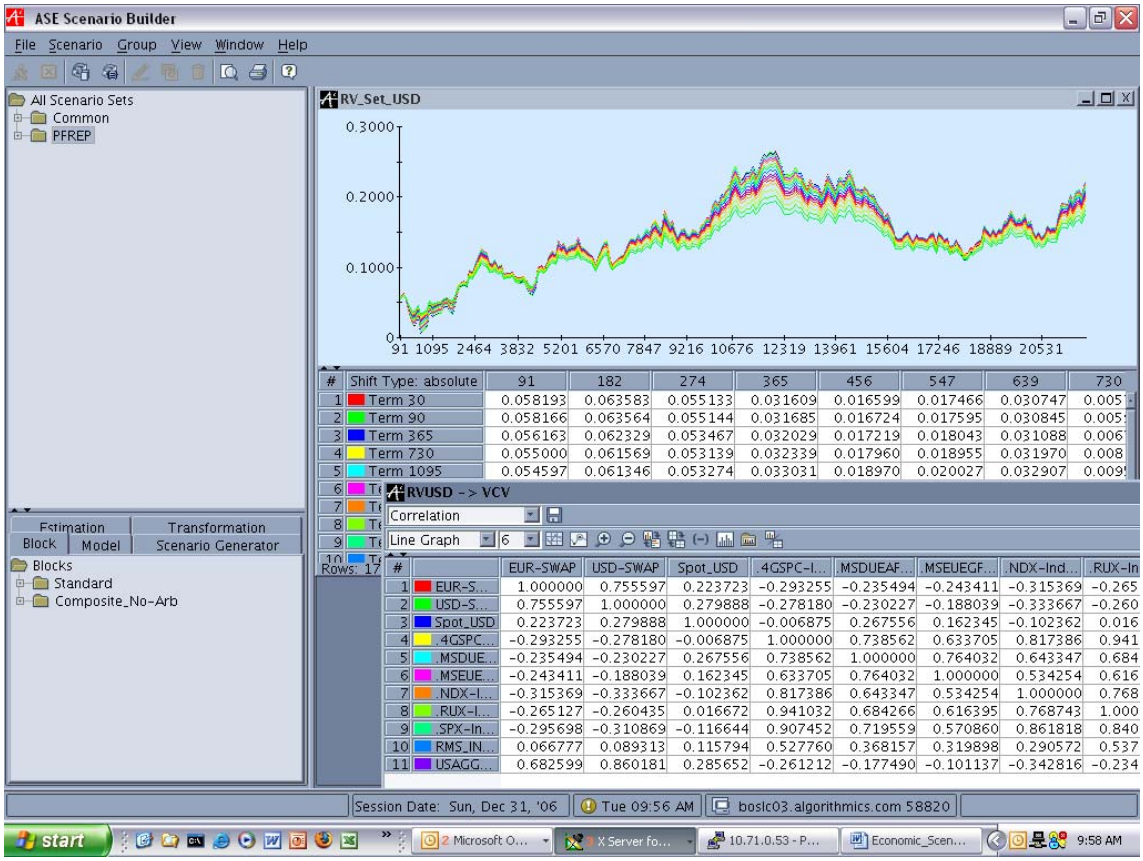
Instruments	Maturity/Effective Date	Strikes
Zero Coupon Bonds	1-20 year	N/A
Equity Forwards	1-20 year	current level of market index
Equity Put Options	1-20 year	ITM 25% ATM OTM 25%
Swap Fixed Leg	5 year, 10 year Effective 1-20 year	2% 4% (current level of ir curve) 6%
Swap Floating Leg	5 year, 10 year Effective 1-20 year	N/A
Swaptions	5 year, 10 year Effective 1-20 year	2% 4% (current level of ir curve) 6%

The value of the liability is $23,018,481 and the value of asset portfolio is $22,848,929.

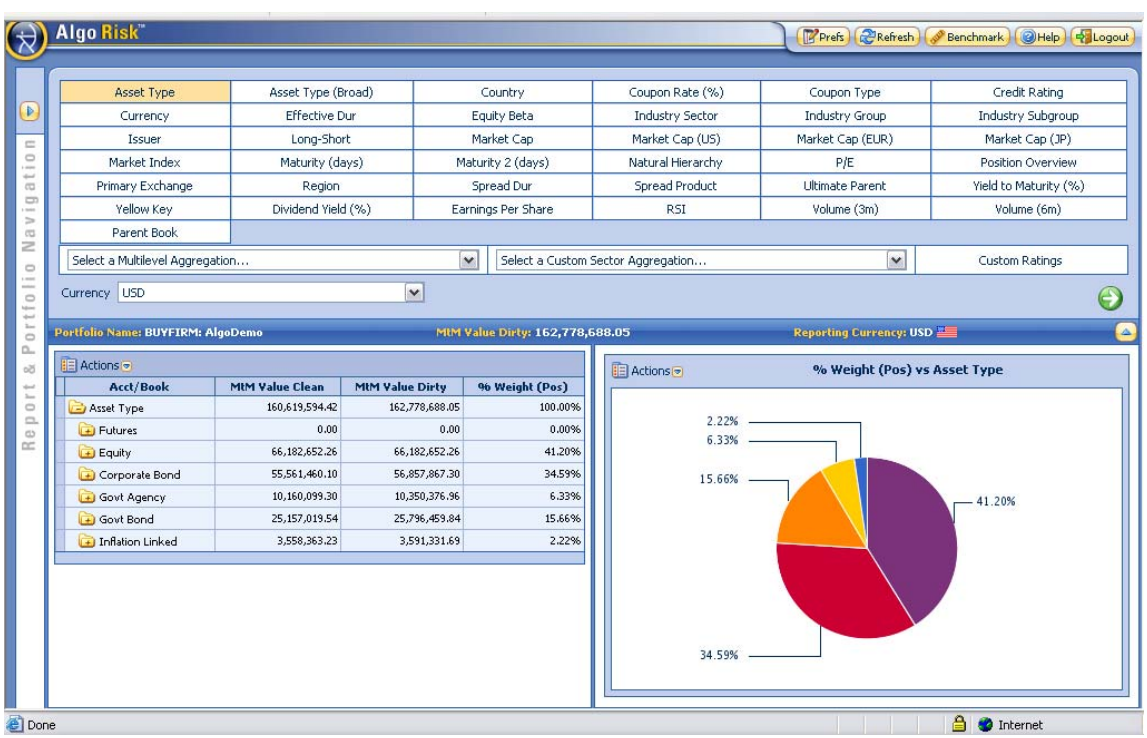
Scenario Sets	Value Liabilities	Value Assets
Base	23,018,481	22,848,929
Volatility Up	24,135,400	23,687,883
IR Up (50bp)	22,622,558	21,232,286
IR Down (50bp)	23,515,014	24,592,528

Remarks: The conditional expectations are computed using covariance matrix (and expected changes, if these are nonzero) while the covariance matrix is estimated using only data from periods of past market crises. Stress scenario both internally consistent and consistent with the data from past periods of market stress.

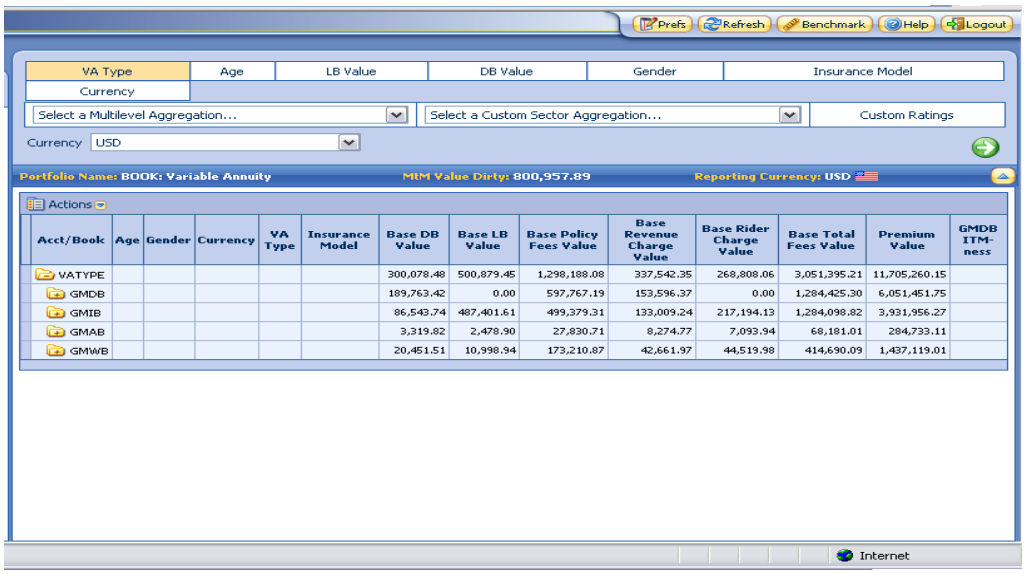
Notice that separate stresses are applied to cover a variety of risks, and the results are aggregated using a correlation matrix approach.



- Four scenario sets by risk types: IR, spread, equity, FX
- Asset and liabilities are stressed with the four scenario sets individually
- VaR calculated based on the P&L strips for each risk type
- Total ERC/VaR calculated based on the sum of the four P&L strips

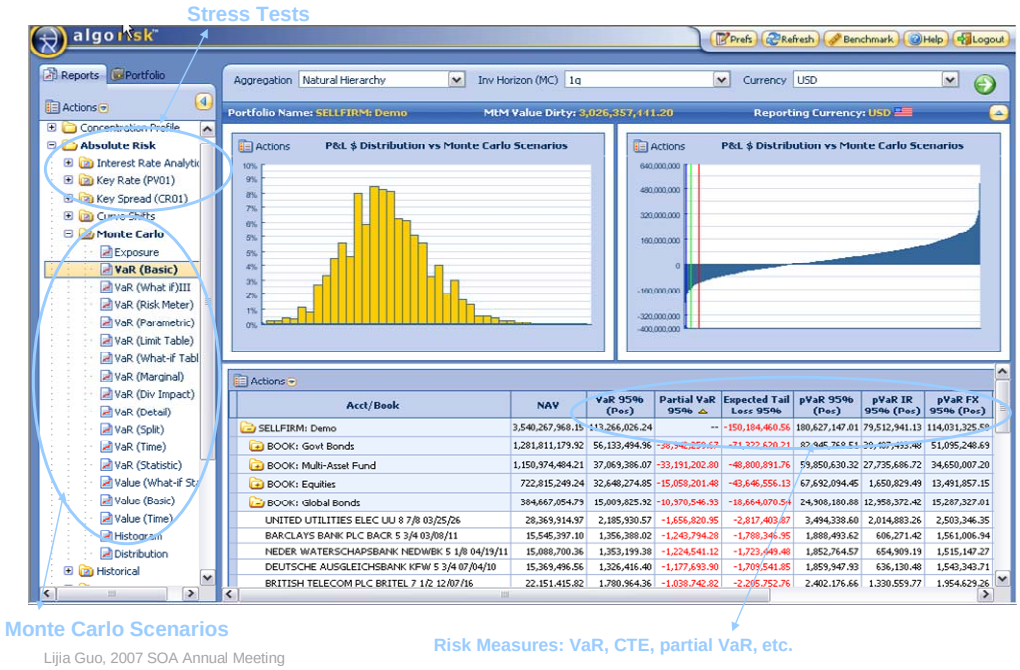


Liability Example - Variable Annuity

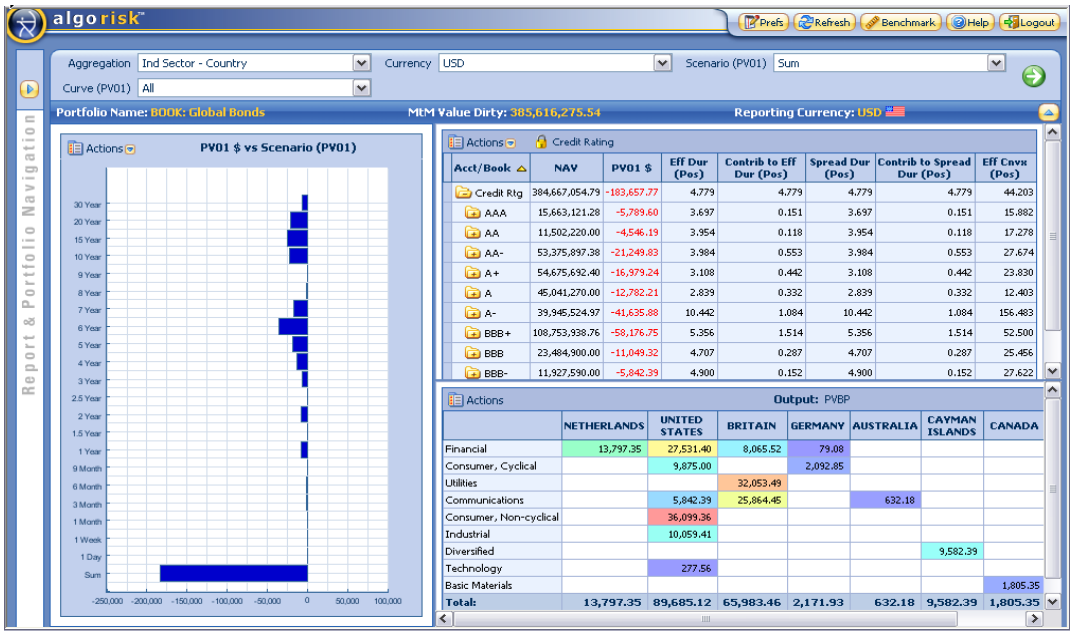


Acct/Book	Age	Gender	Currency	VA Type	Insurance Model	Base DB Value	Base LB Value	Base Policy Fees Value	Base Revenue Charge Value	Base Rider Charge Value	Base Total Fees Value	Premium Value	GMDB ITM-ness
VATYPE						300,078.48	500,879.45	1,298,188.08	337,542.35	268,808.06	3,051,395.21	11,705,260.15	
GMDB						189,763.42	0.00	597,767.19	153,596.37	0.00	1,284,425.30	6,051,451.75	
GMIB						86,543.74	487,401.61	499,379.31	133,009.24	217,194.13	1,284,098.82	3,931,956.27	
GMAB						3,319.82	2,478.90	27,830.71	8,274.77	7,093.94	68,181.01	284,733.11	
GMWB						20,451.51	10,998.94	173,210.87	42,661.97	44,519.98	414,690.09	1,437,119.01	

Effective Stress Testing Example



Acct/Book	NAV	VaR 95% (Pos)	Partial VaR 95%	Expected Tail Loss 95%	pVaR 95% (Pos)	pVaR IR 95% (Pos)	pVaR FX 95% (Pos)
SELLFIRM: Demo	3,540,267,968.15	113,266,026.24	--	-150,184,460.56	180,627,147.01	79,512,941.13	114,031,325.59
BOOK: Govt Bonds	1,281,811,179.92	56,133,494.96	-38,942,259.67	-71,322,620.21	82,945,769.51	30,407,455.48	51,095,248.69
BOOK: Multi-Asset Fund	1,150,974,484.21	37,069,386.07	-33,191,202.80	-48,800,891.76	59,850,630.32	27,735,686.72	34,650,007.20
BOOK: Equities	722,815,249.24	32,648,274.85	-15,058,201.48	-43,646,556.13	67,692,094.45	1,650,829.49	13,491,857.15
BOOK: Global Bonds	384,667,054.79	15,009,825.92	-10,970,546.33	-18,664,070.54	24,908,180.88	12,958,372.42	15,287,327.01
UNITED UTILITIES ELEC UU 8 7/8 03/25/26	28,369,914.97	2,185,930.57	-1,656,820.95	-2,817,403.87	3,494,338.60	2,014,883.26	2,503,346.35
BARCLAYS BANK PLC BACR 5 3/4 03/08/11	15,545,397.10	1,356,388.02	-1,243,794.28	-1,788,346.95	1,888,493.62	606,271.42	1,561,006.94
NEDER WATERSCHAPSBANK NEDWBK 5 1/8 04/19/11	15,088,700.36	1,353,199.38	-1,224,541.12	-1,723,649.48	1,852,764.57	654,909.19	1,515,147.27
DEUTSCHE AUSGLEICHSBANK KFW 5 3/4 07/04/10	15,369,496.56	1,326,416.40	-1,177,693.90	-1,709,541.85	1,859,947.93	636,130.48	1,543,343.71
BRITISH TELECOM PLC BRITEL 7 1/2 12/07/16	22,151,415.82	1,780,964.36	-1,038,742.82	-2,205,752.76	2,402,176.66	1,330,559.77	1,954,629.26



By identifying and modeling the outlying possibilities and correlated events, the economic capital and capital adequacy movement due to exceptional market moves can be assessed. It addresses the impact of exceptional but plausible loss events and their impact on funding liquidity and the impact of operational risks: system failures and terrorist attacks. All the assessments can then be incorporated by this analysis into the ERM framework.

5. Conclusion

Stress testing is an appealing risk-management tool because it provides risk managers with additional information on possible portfolio losses arising from extreme, although plausible, scenarios. In addition, stress scenarios can often be an effective communication tool within the firm and to outside parties, such as supervisors and investors.

Stress tests are modeled as specific directional shocks to market prices and rates, so stress profit and loss (P&L) values are more intuitive than VaR numbers and can provide a more concrete picture of the risks being taken, as well as a basis for more meaningful discussions about the risks in the portfolio. Stress testing brings flexibility to ERM and is used to meet the regulatory requirement and external disclosure. Once implemented in the corporate decision making process, stress testing can effectively increase enterprise economic profit.

A good set of stress tests enables managers to proactively reduce unacceptable risk levels by indicating how to structure hedges for unacceptable risk exposures (i.e., where to take risk-offsetting long or short positions). A consistent set of stress tests that is run on multiple, independently managed portfolios can reveal overall concentrations in risk that might not appear in the aggregate portfolio VaR (i.e., portfolio effects may differ in stressed markets).

When implementing stress testing, challenges remain in modeling the interaction of different risk factors and their impacts; integrating stress testing at different levels; and how to make stress tests workable, realistic and timely.

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