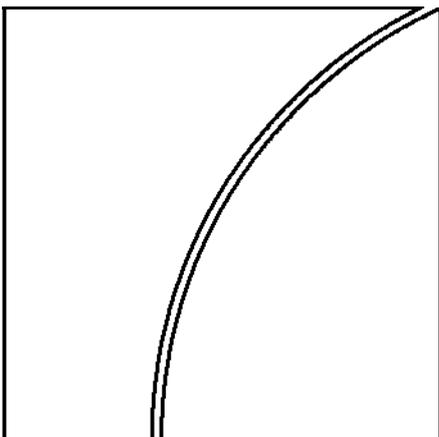


Basel Committee  
on Banking Supervision



Principles for sound stress  
testing practices and  
supervision

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# Principles for sound stress testing practices and supervision

## Introduction

The depth and duration of the financial crisis has led many banks and supervisory authorities to question whether stress testing practices were sufficient prior to the crisis and whether they were adequate to cope with rapidly changing circumstances. In particular, not only was the crisis far more severe in many respects than was indicated by banks' stress testing results, but it was possibly compounded by weaknesses in stress testing practices in reaction to the unfolding events. Even as the crisis is not over yet there are already lessons for banks and supervisors emerging from this episode.

Stress testing is an important risk management tool that is used by banks as part of their internal risk management and, through the Basel II capital adequacy framework, is promoted by supervisors. Stress testing alerts bank management to adverse unexpected outcomes related to a variety of risks and provides an indication of how much capital might be needed to absorb losses should large shocks occur. While stress tests provide an indication of the appropriate level of capital necessary to endure deteriorating economic conditions, a bank alternatively may employ other actions in order to help mitigate increasing levels of risk. Stress testing is a tool that supplements other risk management approaches and measures. It plays a particularly important role in:

- providing forward-looking assessments of risk;
- overcoming limitations of models and historical data;
- supporting internal and external communication;
- feeding into capital and liquidity planning procedures;
- informing the setting of a banks' risk tolerance; and
- facilitating the development of risk mitigation or contingency plans across a range of stressed conditions.

Stress testing is especially important after long periods of benign economic and financial conditions, when fading memory of negative conditions can lead to complacency and the underpricing of risk. It is also a key risk management tool during periods of expansion, when innovation leads to new products that grow rapidly and for which limited or no loss data is available.

Pillar 1 (minimum capital requirements) of the Basel II framework requires banks using the Internal Models Approach to determine market risk capital to have in place a rigorous programme of stress testing. Similarly, banks using the advanced and foundation internal ratings-based (IRB) approaches for credit risk are required to conduct credit risk stress tests to assess the robustness of their internal capital assessments and the capital cushions above the regulatory minimum. Basel II also requires that, at a minimum, banks subject their credit portfolios in the banking book to stress tests. Recent analysis has concluded that banks' stress tests did not produce large loss numbers in relation to their capital buffers going into the crisis or their actual loss experience. Further, banks' firm-wide stress tests should have included more severe scenarios than the ones used in order to produce results more in line with the actual stresses that were observed.

The Basel Committee has engaged with the industry in examining stress testing practices over this period and this paper is the result of that examination. Notwithstanding the ongoing evolution of the crisis and future lessons that may emerge, this paper assesses stress testing

practices during the crisis. Based on that assessment and in an effort to improve practices, it develops sound principles for banks and supervisors. The principles cover the overall objectives, governance, design and implementation of stress testing programmes as well as issues related to stress testing of individual risks and products.

The recommendations are aimed at deepening and strengthening banks' stress testing practices and supervisory assessment of these practices. By itself, stress testing cannot address all risk management weaknesses, but as part of a comprehensive approach, it has a leading role to play in strengthening bank corporate governance and the resilience of individual banks and the financial system.

A stress test is commonly described as the evaluation of a bank's financial position under a severe but plausible scenario to assist in decision making within the bank. The term "stress testing" is also used to refer not only to the mechanics of applying specific individual tests, but also to the wider environment within which the tests are developed, evaluated and used within the decision-making process. In this paper, we use the term "stress testing" in this wider sense.

## **Performance of stress testing during the crisis<sup>1</sup>**

The financial crisis has highlighted weaknesses in stress testing practices employed prior to the start of the crisis in four broad areas: (i) use of stress testing and integration in risk governance; (ii) stress testing methodologies; (iii) scenario selection; and (iv) stress testing of specific risks and products.

### **Use of stress testing and integration in risk governance**

Board and senior management involvement is critical in ensuring the appropriate use of stress testing in banks' risk governance and capital planning. This includes setting stress testing objectives, defining scenarios, discussing the results of stress tests, assessing potential actions and decision making. At banks that were highly exposed to the financial crisis and fared comparatively well, senior management as a whole took an active interest in the development and operation of stress testing, with the results of stress tests serving as an input into strategic decision making which benefited the bank. Stress testing practices at most banks, however, did not foster internal debate nor challenge prior assumptions such as the cost, risk and speed with which new capital could be raised or that positions could be hedged or sold.

The financial crisis has also revealed weaknesses in organisational aspects of stress testing programmes. Prior to the crisis, stress testing at some banks was performed mainly as an isolated exercise by the risk function with little interaction with business areas. This meant that, amongst other things, business areas often believed that the analysis was not credible. Moreover, at some banks, the stress testing programme was a mechanical exercise. While there is room for routinely operated stress tests within a comprehensive stress testing

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<sup>1</sup> The discussion of the market crisis is based on information provided to the Basel Committee through discussions with industry representatives; the work of the Senior Supervisors Group (SSG); industry reports such as that produced by the Institute of International Finance (IIF); questionnaires and industry workshops; and from the knowledge obtained by individual agencies through their own supervisory and information gathering activities.

programme (eg for background monitoring), they do not provide a complete picture because mechanical approaches can neither fully take account of changing business conditions nor incorporate qualitative judgments from across the different areas of a bank. Furthermore, in many banks, stress tests were carried out by separate units focusing on particular business lines or risk types. This led to organisational barriers when aiming to integrate quantitative and qualitative stress testing results across a bank.

Prior to the crisis, many banks did not have an overarching stress testing programme in place but ran separate stress tests for particular risks or portfolios with limited firm-level integration. Risk-specific stress testing was usually conducted within business lines. While stress testing for market and interest rate risk had been practiced for several years, stress testing for credit risk in the banking book has only emerged more recently. Other types of stress tests are still in their infancy. As a result, there was insufficient ability to identify correlated tail exposures and risk concentrations across the bank.

Stress testing frameworks were usually not flexible enough to respond quickly as the crisis evolved (eg inability to aggregate exposures quickly, apply new scenarios or modify models). Further investments in IT infrastructure may be necessary to enhance the availability and granularity of risk information that will enable timely analysis and assessment of the impact of new stress scenarios designed to address a rapidly changing environment. For example, investing in liquidity risk management information systems would enhance a bank's ability to automate end-of-day information, obtain more granularity as to unencumbered assets and forecast balance sheet needs of business units.

### **Stress testing methodologies**

Stress tests cover a range of methodologies. Complexity can vary, ranging from simple sensitivity tests to complex stress tests, which aim to assess the impact of a severe macroeconomic stress event on measures like earnings and economic capital.<sup>2</sup> Stress tests may be performed at varying degrees of aggregation, from the level of an individual instrument up to the institutional level. Stress tests are performed for different risk types including market, credit, operational and liquidity risk. Notwithstanding this wide range of methodologies, the crisis has highlighted several methodological weaknesses.

At the most fundamental level, weaknesses in infrastructure limited the ability of banks to identify and aggregate exposures across the bank. This weakness limits the effectiveness of risk management tools – including stress testing.

Most risk management models, including stress tests, use historical statistical relationships to assess risk. They assume that risk is driven by a known and constant statistical process, ie they assume that historical relationships constitute a good basis for forecasting the development of future risks. The crisis has revealed serious flaws with relying solely on such an approach.

First, given a long period of stability, backward-looking historical information indicated benign conditions so that these models did not pick up the possibility of severe shocks nor the build

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<sup>2</sup> For an overview of different stress testing objectives and how these relate to modelling see Drehmann (2008), "Stress Tests: Objectives, Challenges and Modelling Choices", *Riksbank Economic Review*, June. For a discussion of economic capital, see *Range of practices and issues in economic capital frameworks*, Basel Committee on Banking Supervision, March 2009.

up of vulnerabilities within the system. Historical statistical relationships, such as correlations, proved to be unreliable once actual events started to unfold.

Second, the financial crisis has again shown that, especially in stressed conditions, risk characteristics can change rapidly as reactions by market participants within the system can induce feedback effects and lead to system-wide interactions. These effects can dramatically amplify initial shocks as recent events have illustrated.<sup>3</sup>

Extreme reactions (by definition) occur rarely and may carry little weight in models that rely on historical data. It also means that they are hard to model quantitatively. The management of most banks did not sufficiently question these limitations of more traditional risk management models used to derive stress testing outcomes nor did they sufficiently take account of qualitative expert judgment to develop innovative ad-hoc stress scenarios. Therefore, banks generally underestimated the strong interlinkages between, for example, the lack of market liquidity and funding liquidity pressures. The reliance on historical relationships and ignoring reactions within the system implied that firms underestimated the interaction between risks and the firm-wide impact of severe stress scenarios.

Prior to the crisis, most banks did not perform stress tests that took a comprehensive firm-wide perspective across risks and different books. Even if they did, the stress tests were insufficient in identifying and aggregating risks. As a result, banks did not have a comprehensive view across credit, market and liquidity risks of their various businesses. An appropriately conducted firm-wide stress test would have beneficially drawn together experts from across the organisation. For example, the expertise of retail lenders, who in some cases were reducing exposure to US subprime mortgages, should have counteracted the overly optimistic outlook of traders in securities backed by the same subprime loans.

## Scenario selection

Most bank stress tests were not designed to capture the extreme market events that were experienced. Most firms discovered that one or several aspects of their stress tests did not even broadly match actual developments. In particular, scenarios tended to reflect mild shocks, assume shorter durations and underestimate 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).

A range of techniques has been used to develop scenarios. Sensitivity tests, which are at the most basic level, generally shock individual parameters or inputs without relating those shocks to an underlying event or real-world outcomes. Given that these scenarios ignore

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<sup>3</sup> At the outset of the crisis, mortgage default shocks played a part in the deterioration of market prices of collateralised debt obligations (CDOs). Simultaneously, these shocks revealed deficiencies in the models used to manage and price these products. The complexity and resulting lack of transparency led to uncertainty about the value of the underlying investment. Market participants then drastically scaled down their activity in the origination and distribution markets and liquidity disappeared. The standstill in the securitisation markets forced banks to warehouse loans that were intended to be sold in the secondary markets. Given a lack of transparency of the ultimate ownership of troubled investments, funding liquidity concerns were triggered within the banking sector as banks refused to provide sufficient funds to each other. This in turn led to the hoarding of liquidity, exacerbating further the funding pressures within the banking sector. The initial difficulties in subprime mortgages also fed through to a broader range of market instruments since the drying up of market and funding liquidity forced market participants to liquidate those positions which they could trade in order to scale back risk. An increase in risk aversion also led to a general flight to quality, an example of which was the high withdrawals by households from money market funds.

multiple risk factors or feedback effects, their main benefit is that they can provide a fast initial assessment of portfolio sensitivity to a given risk factor and identify certain risk concentrations.

More sophisticated approaches apply shocks to many parameters simultaneously. Approaches are typically either historically based or hypothetical.

Historical scenarios were frequently implemented based on a significant market event experienced in the past. Such stress tests were not able to capture risks in new products that have been at the centre of the crisis. Furthermore, the severity levels and duration of stress indicated by previous episodes proved to be inadequate. The length of the stress period was viewed as unprecedented and so historically based stress tests underestimated the level of risk and interaction between risks.

Banks also implemented hypothetical stress tests, aiming to capture events that had not yet been experienced. Prior to the crisis, however, banks generally applied only moderate scenarios, either in terms of severity or the degree of interaction across portfolios or risk types. At many banks, it was difficult for risk managers to obtain senior management buy-in for more severe scenarios. Scenarios that were considered extreme or innovative were often regarded as implausible by the board and senior management.

### **Stress testing of specific risks and products**

Particular risks that were not covered in sufficient detail in most stress tests include:

- the behaviour of complex structured products under stressed liquidity conditions;
- pipeline or securitisation risk;
- basis risk in relation to hedging strategies;
- counterparty credit risk;
- contingent risks; and
- funding liquidity risk.

Scenarios were not sufficiently severe when stress testing structured products and leveraged lending prior to the crisis. This may, to some degree, be attributed to reliance on historical data. In general, stress tests of structured products suffered from the same problems as other risk management models in this area in that they failed to recognise that risk dynamics for structured instruments are different from those of similarly-rated cash instruments such as bonds. These differences were particularly pronounced during the crisis, further degrading the performance of the stress tests. In particular, stress tests should specifically consider the credit quality of the underlying exposures, as well as the unique characteristics of structured products. Furthermore, stress tests also assumed that markets in structured products would remain liquid or, if market liquidity would be impaired, that this would not be the case for a prolonged period. This also meant that banks underestimated the pipeline risk related to issuing new structured products.

In many cases stress tests dealt only with directional risk and did not capture basis risk, thereby reducing the effectiveness of hedges. Another feature of the crisis was wrong-way risk, for example related to the credit protection purchased from monoline insurers.<sup>4</sup>

In addition, stress tests for counterparty credit risk typically only stressed a single risk factor for a counterparty, were insufficiently severe and usually omitted the interaction between credit risk and market risk (specific wrong way risk). Stress testing for counterparty credit risk should be improved by utilising stresses applied across counterparties and to multiple risk factors, as well as those that incorporate current valuation adjustments.

Another weakness of the models was that they did not adequately capture contingent risks that arose either from legally binding credit and liquidity lines or from reputational concerns related, for example, to off-balance sheet vehicles. Had stress tests adequately captured contractual and reputational risk associated with off-balance sheet exposures, concentrations in such exposures may have been avoided.

With regard to funding liquidity, stress tests did not capture the systemic nature of the crisis or the magnitude and duration of the disruption to interbank markets. For a more in-depth discussion of the shortcomings of liquidity stress tests, see the Basel Committee's *Principles for Sound Liquidity Risk Management and Supervision* (September 2008).

### **Changes in stress testing practices since the outbreak of the crisis**

Given the unexpected severity of events, stress testing has gained greater prominence and credibility within banks as a complementary risk management and capital planning tool to provide a different risk perspective. It is important that this process continues so that stress testing programmes become embedded in banks' governance structures. Moreover, this process needs to be led by the board and senior management.

Banks recognise that current stress testing frameworks must be enhanced both in terms of granularity of risk representation and the range of risks considered. Some banks have started to address these issues and other weaknesses of stress tests for the specific risks identified above. More general areas in which banks are considering future improvement include:

- constantly reviewing scenarios and looking for new ones;
- examining new products to identify potential risks;
- improving the identification and aggregation of correlated risks across books as well as the interactions between market, credit and liquidity risk; and
- evaluating appropriate time horizons and feedback effects.

Generally, firm-wide stress testing is an area that many banks recognise they will need to improve to ensure appropriate risk capture and to aggregate risk more effectively across business lines. The principles set forth in this paper are intended to support and reinforce efforts made by banks to improve their practices, but banks should not restrict themselves to a checklist approach to improvement.

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<sup>4</sup> Some credits on which banks and dealers had purchased protection from monolines to help manage risk on their structured credit origination activities became impaired at the same time that the creditworthiness of the monolines deteriorated.

After the onset of the crisis, ad hoc “hot-spot” stress testing has been used by some banks as an important tool to inform senior management’s crisis management decisions. The ability to conduct stress tests at very short notice has proven to be valuable during a period of rapidly changing market conditions.

The need for improvement in stress testing has also been recognised by the financial industry. In July 2008 the Institute of International Finance published its *Final Report of the IIF Committee on Market Best Practices: Principles of Conduct and Best Practice Recommendations*. The report among other things reviewed stress testing practices and set out two principles and five specific recommendations in this area. The principles include the need for stress testing to be carried out comprehensively and integrated with the overall risk management infrastructure. They also identified the need for stress testing to have a meaningful impact on business decisions, with the board and senior management having an important role in evaluating stress test results and impact on a bank’s risk profile. Recommendations by the Counterparty Risk Management Policy Group (CRMPG III) in its August 2008 report (*Containing Systemic Risk: The Road to Reform – The Report of the CRMPG III*) include the need for firms to think creatively about how the value of stress tests can be maximised, including a so-called reverse stress test to explore the events that could cause a significant impact on the firm.

## Principles for sound stress testing practices and supervision

The following recommendations are formulated with a view towards application to large, complex banks. The extent of application should be commensurate with the size and complexity of a bank's business and the overall level of risk that it accepts. These recommendations should therefore be applied to banks on a proportionate basis.

### Principles for banks

#### Use of stress testing and integration in risk governance

- 1. Stress testing should form an integral part of the overall governance and risk management culture of the bank. Stress testing should be actionable, with the results from stress testing analyses impacting decision making at the appropriate management level, including strategic business decisions of the board and senior management. Board and senior management involvement in the stress testing programme is essential for its effective operation.**

The board has ultimate responsibility for the overall stress testing programme, whereas senior management is accountable for the programme's implementation, management and oversight. Recognising that many practical aspects of a stress testing programme will be delegated, the involvement of the board in the overall stress testing programme and of senior management in the programme's design are essential. This will help ensure the board's and senior management's buy-in to the process. It will also help maximise the effective use of stress tests, especially with respect to firm-wide stress testing. The rationale for particular choices, as well as their principal implications, should be explained and documented so that the board and senior management are aware of the limitations of the stress tests performed (eg key underlying assumptions, the extent of judgment in evaluating the impact of the stress test or the likelihood of the event occurring). Stress testing should promote candid discussion on modelling assumptions between the board and risk managers.

Senior management should be able to identify and clearly articulate the bank's risk appetite and understand the impact of stress events on the risk profile of the bank. Senior management must participate in the review and identification of potential stress scenarios, as well as contribute to risk mitigation strategies. In addition, senior management should consider an appropriate number of well-understood, documented, utilised and sufficiently severe scenarios that are relevant to their bank. Senior management's endorsement of stress testing as a guide in decision-making is particularly valuable when the tests reveal vulnerabilities that the bank finds costly to address.

A stress testing programme as a whole should be actionable and feed into the decision making process at the appropriate management level, including strategic business decisions of the board or senior management. Stress tests should be used to support a range of decisions. In particular but not exclusively, stress tests should be used as an input for setting the risk appetite of the firm or setting exposure limits. Stress tests should also be used to support the evaluation of strategic choices when undertaking and discussing longer term business planning. Importantly, stress tests should feed into the capital and liquidity planning process.

**2. A bank should operate a stress testing programme that promotes risk identification and control; provides a complementary risk perspective to other risk management tools; improves capital and liquidity management; and enhances internal and external communication.**

A stress testing programme is an integrated strategy for meeting a range of purposes (described below) by means of the origination, development, execution and application of a suitable range of stress tests. The range of purposes requires the use of a range of techniques since stress testing is not a one-size-fits-all approach.

To promote risk identification and control, stress testing should be included in risk management activities at various levels. This includes the use of stress testing for the risk management of individual or groups of borrowers and transactions, for portfolio risk management, as well as for adjusting a bank's business strategy. In particular, it should be used to address existing or potential firm-wide risk concentrations.

Stress testing should provide a complementary and independent risk perspective to other risk management tools such as value-at-risk (VaR) and economic capital. Stress tests should complement risk management approaches that are based on complex, quantitative models using backward looking data and estimated statistical relationships. In particular, stress testing outcomes for a particular portfolio can provide insights about the validity of statistical models at high confidence intervals, for example those used to determine VaR.

Importantly, as stress testing allows for the simulation of shocks which have not previously occurred, it should be used to assess the robustness of models to possible changes in the economic and financial environment. In particular, appropriate stress tests should challenge the projected risk characteristics of new products where limited historical data are available and which have not been subject to periods of stress. Users should also simulate stress scenarios in which the model-embedded statistical relationships break down as has been observed during the recent market crisis. Use of these various stress tests should help to detect vulnerabilities such as unidentified risk concentrations or potential interactions between types of risk that could threaten the viability of the bank, but may be concealed when relying purely on statistical risk management tools based on historical data.

Stress testing should form an integral part of the internal capital adequacy assessment process (ICAAP), which requires banks to undertake rigorous, forward-looking stress testing that identifies severe events or changes in market conditions that could adversely impact the bank. Stress testing should also be a central tool in identifying, measuring and controlling funding liquidity risks, in particular for assessing the bank's liquidity profile and the adequacy of liquidity buffers in case of both bank-specific and market-wide stress events.<sup>5</sup>

Stress tests should play an important role in the communication of risk within the bank. In contrast to purely statistical models, plausible forward-looking scenarios are more easily grasped and thereby assist in the assessment of vulnerabilities and evaluation of the feasibility and effectiveness of potential counter actions. Stress tests should also play an important role in external communication with supervisors to provide support for internal and regulatory capital adequacy assessments. A bank may also want to voluntarily disclose its stress test results more broadly to enable the market to better understand its risk profile and management. If a bank does voluntarily disclose its stress test results, it may also wish to provide relevant supporting information in order to ensure that informed judgements of the

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<sup>5</sup> See also *Principles for Sound Liquidity Risk Management and Supervision*, Basel Committee on Banking Supervision, September 2008.

results can be made by third-parties. This supporting information could include any major stress test limitations, underlying assumptions, the methodologies used and an evaluation of the impact of the stress test.

### **3. Stress testing programmes should take account of views from across the organisation and should cover a range of perspectives and techniques.**

The identification of relevant stress events, the application of sound modelling approaches and the appropriate use of stress testing results each require the collaboration of different senior experts within a bank such as risk controllers, economists, business managers and traders. A stress testing programme should ensure that opinions of all relevant experts are taken into account, in particular for firm-wide stress tests. The unit with responsibility for implementing the stress testing programme should organise appropriate dialogue among these experts, challenge their opinions, check them for consistency (eg with other relevant stress tests) and decide on the design and the implementation of the stress tests, ensuring an adequate balance between usefulness, accuracy, comprehensiveness and tractability.

Banks should use multiple perspectives and a range of techniques in order to achieve comprehensive coverage in their stress testing programme. These include quantitative and qualitative techniques to support and complement the use of models and to extend stress testing to areas where effective risk management requires greater use of judgement. Stress tests should range from simple sensitivity analysis based on changes in a particular risk factor to more complex stress tests that revalue portfolios taking account of the interactions among risk drivers conditional on the stress event. Some stress tests should be run at regular intervals whilst the stress testing programme should also allow for the possibility of ad hoc stress testing.

Sensitivity analysis is generally intended to assess the output from quantitative approaches when certain inputs and parameters are stressed or shocked.<sup>6</sup> In most cases, sensitivity analysis involves changing inputs or parameters without relating those changes to an underlying event or real-world outcomes. For example, a sensitivity test might explore the impact of varying declines in equity prices (such as by 10%, 20%, 30%) or a range of increases in interest rates (such as by 100, 200, 300 basis points). While it is helpful to draw on extreme values from historical periods of stress, sensitivity analysis should also include hypothetical extreme values to ensure that a wide range of possibilities is included. In some cases, it can be helpful to conduct a scenario analysis of several factors at the same time, because simply testing factors individually may not reveal their potential interaction (particularly if that interaction is complex and not intuitively clear). For example, scenarios can evaluate the combined impact on credit risk capital needs from sudden spikes in probabilities of default and concurrent changes in the dependence parameters of a credit capital model.

Sensitivity and scenario analysis has additional benefits in helping to reveal whether quantitative approaches are working as originally intended.<sup>7</sup> For example, one can check the assumption that a relationship continues to be linear when extreme inputs are used. If the analysis results show that a certain model is unstable or does not work as originally intended with extreme inputs, then management should consider rethinking the model, modifying certain parameters, or at least putting less weight on the accuracy of model output. Finally, sensitivity and scenario analysis should be conducted regularly (not just during model

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<sup>6</sup> Note that using less extreme values of parameters and inputs can also be useful in sensitivity analysis.

<sup>7</sup> In this manner, sensitivity analysis can also play an important role in validation.

development), since models can deteriorate and relationships among variables can change over time.

**4. A bank should have written policies and procedures governing the stress testing programme. The operation of the programme should be appropriately documented.**

The stress testing programme should be governed by internal policies and procedures. These should be appropriately documented.

The programme should be documented particularly in relation to firm-wide stress tests. The following aspects should be detailed: (i) the type of stress testing and the main purpose of each component of the programme; (ii) frequency of stress testing exercises which is likely to vary depending on type and purpose; (iii) the methodological details of each component, including the methodologies for the definition of relevant scenarios and the role of expert judgement; and (iv) the range of remedial actions envisaged, based on the purpose, type and result of the stress testing, including an assessment of the feasibility of corrective actions in stress situations. Documentation requirements should not, however, impede the bank from being able to perform flexible ad-hoc stress testing, which by their nature need to be completed quickly and often to respond to emerging risk issues.

A bank should document the assumptions and fundamental elements for each stress testing exercise. These include the reasoning and judgements underlying the chosen scenarios and the sensitivity of stress testing results to the range and severity of the scenarios. An evaluation of such fundamental assumptions should be performed regularly or in light of changing external conditions. Furthermore, a bank should document the outcome of such assessments.

**5. A bank should have a suitably robust infrastructure in place, which is sufficiently flexible to accommodate different and possibly changing stress tests at an appropriate level of granularity.**

Commensurate with the principle of proportionality, a bank should have suitably flexible infrastructure as well as data of appropriate quality and granularity. The infrastructure should enable the bank on a timely basis to aggregate its exposures to a given risk factor, product or counterparty, and modify methodologies to apply new scenarios as needed.

The infrastructure should also be sufficiently flexible to allow for targeted or ad-hoc stress tests at the business line or firm-wide level to assess specific risks in times of stress. System flexibility is crucial to handle customised and changing stress tests and to aggregate comparable risks and exposures across a bank.

**6. A bank should regularly maintain and update its stress testing framework. The effectiveness of the stress testing programme, as well as the robustness of major individual components, should be assessed regularly and independently.**

The effectiveness and robustness of stress tests should be assessed qualitatively as well as quantitatively, given the importance of judgments and the severity of shocks considered. Areas for assessment should include:

- the effectiveness of the programme in meeting its intended purposes;
- documentation;

- development work;
- system implementation;
- management oversight;
- data quality; and
- assumptions used.

The quantitative processes should include benchmarking with other stress tests within and outside the bank.

Since the stress test development and maintenance processes often imply judgmental and expert decisions (eg assumptions to be tested, calibration of the stress, etc.), the independent control functions such as risk management and internal audit should also play a key role in the process.

### **Stress testing methodology and scenario selection**

- 7. Stress tests should cover a range of risks and business areas, including at the firm-wide level. A bank should be able to integrate effectively, in a meaningful fashion, across the range of its stress testing activities to deliver a complete picture of firm-wide risk.**

A stress testing programme should consistently and comprehensively cover product-, business- and entity-specific views. Using a level of granularity appropriate to the purpose of the stress test, stress testing programmes should examine the effect of shocks across all relevant risk factors, taking into account interrelations among them.

A bank should also use stress tests to identify, monitor and control risk concentrations.<sup>8</sup> In order to adequately address risk concentrations, the scenario should be firm-wide and comprehensive, covering balance sheet and off-balance sheet assets, contingent and non-contingent risks, independent of their contractual nature. Further, stress tests should identify and address potential changes in market conditions that could adversely impact a bank's exposure to risk concentrations.

The impact of stress tests is usually evaluated against one or more measures. The particular measures used will depend on the specific purpose of the stress test, the risks and portfolios being analysed and the particular issue under examination. A range of measures may need to be considered to convey an adequate impression of the impact. Typical measures used are:

- asset values;
- accounting profit and loss;
- economic profit and loss;
- regulatory capital or risk weighted assets;

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<sup>8</sup> These may arise along different dimensions: single name concentrations; concentrations in regions or industries; concentrations in single risk factors; concentrations that are based on correlated risk factors that reflect subtler or more situation-specific factors, such as previously undetected correlations between market and credit risks, as well as between those risks and liquidity risk; concentrations in indirect exposures via posted collateral or hedge positions; concentrations in off-balance sheet exposure, contingent exposure, non-contractual obligations due to reputational reasons.

- economic capital requirements; and
- liquidity and funding gaps.

Developing coherent stress testing scenarios on a firm-wide basis is a difficult task as risk factors for different portfolios differ widely and horizons vary.<sup>9</sup> For example, deriving a coherent scenario for market and credit risk is not straightforward as market risk materialises quickly whereas credit risk will need a longer time horizon to feed through the system. However, in order to effectively challenge the business model and support the decision-making process, the scenarios have to assess the nature of linked risks across portfolios and across time. A relevant aspect in this regard is the role played by liquidity conditions for determining the ultimate impact of a stress test.

**8. Stress testing programmes should cover a range of scenarios, including forward-looking scenarios, and aim to take into account system-wide interactions and feedback effects.**

An effective stress testing programme should comprise scenarios along a spectrum of events and severity levels. Doing so will help deepen management’s understanding of vulnerabilities and the effect of non-linear loss profiles. Stress testing should be conducted flexibly and imaginatively, in order to better identify hidden vulnerabilities. A “failure of imagination” could lead to an underestimation of the likelihood and severity of extreme events and to a false sense of security about a bank’s resilience.

The stress testing programme should cover forward-looking scenarios to incorporate changes in portfolio composition, new information and emerging risk possibilities which are not covered by relying on historical risk management or replicating previous stress episodes. The compilation of forward-looking scenarios requires combining the knowledge and judgment of experts across the organisation. The scenarios should be based on senior management dialogue and judgements. The challenge is to stimulate discussion and to use the information at different levels of the bank in a productive way.

An appropriate stress testing framework should comprise a broad range of scenarios covering risks at different levels of granularity, including firm-wide stress tests, as well as product-, business- and entity-specific stress tests. Some stress scenarios should provide insight into the firm-wide impact of severe stress events on a bank’s financial strength and allow for an assessment of the bank’s ability to react to events. In general, stress scenarios should reflect the materiality of particular business areas and their vulnerability to changes in economic and financial conditions.

The financial crisis has shown that estimating *ex ante* the probabilities of stress events is problematic. The statistical relationships used to derive the probability tend to break down in stressed conditions. In this respect, the crisis has underscored the importance of giving appropriate weight to expert judgment in defining relevant scenarios with a forward looking perspective.

Stress testing should include various time horizons depending on the risk characteristics of the analysed exposures and whether the particular test is intended for tactical or strategic use. A natural starting point for stress tests conducted for risk management purposes is the relevant risk management horizon of the target portfolio and the liquidity of the underlying exposures. However, there is need to cover substantially longer periods than this as liquidity

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<sup>9</sup> As suggested in principle 21, supervisors should engage in cross-border efforts with other public bodies, as well as with the industry, to discuss stress testing practices.

conditions can change rapidly in stressed conditions. The bank should also assess the impact of recession-type scenarios, including its ability to react over a medium to long time horizon. The bank should note the increased importance of assumptions as the time horizon of a stress test is lengthened. A bank should also consider incorporating feed-back effects and firm-specific and market-wide reactions into such stress tests.

When analysing the potential impact of a set of macroeconomic and financial shocks, a bank should aim to take into account system-wide interactions and feedback effects. Recent events have demonstrated that these effects have the capacity to transform isolated stress events into global crisis threatening even large, well capitalised banks, as well as systemic stability. As they occur rarely, they are generally not contained in historical data series used for daily risk management. A stress test supplemented with expert judgement can help to address these deficiencies in an iterative process and thereby improve risk identification.

**9. Stress tests should feature a range of severities, including events capable of generating the most damage whether through size of loss or through loss of reputation. A stress testing programme should also determine what scenarios could challenge the viability of the bank (reverse stress tests) and thereby uncover hidden risks and interactions among risks.**

Commensurate with the principle of proportionality, stress tests should feature the most material business areas and events that might be particularly damaging for the firm. This could include not only events that inflict large losses but which subsequently cause damage to the bank's reputation.

Reverse stress tests start from a known stress test outcome (such as breaching regulatory capital ratios, illiquidity or insolvency) and then asking what events could lead to such an outcome for the bank. As part of the overall stress testing programme, it is important to include some extreme scenarios which would cause the firm to be insolvent (ie stress events which threaten the viability of the whole firm). For a large complex firm, this is a challenging exercise requiring involvement of senior management and all material risk areas across the firm.<sup>10</sup>

A reverse stress test induces firms to consider scenarios beyond normal business settings and leads to events with contagion and systemic implications. Hence, reverse stress testing has important quantitative and qualitative uses, such as informing senior management's assessment of vulnerabilities. For example, a bank with a large exposure to complex structured credit products could have asked what kind of scenario would have led to widespread losses such as those observed in the financial crisis. Given this scenario, the bank would have then analysed its hedging strategy and assessed whether this strategy would be robust in the stressed market environment characterised by a lack of market liquidity and increased counterparty credit risk. Given the appropriate judgments, this type of stress test can reveal hidden vulnerabilities and inconsistencies in hedging strategies or other behavioural reactions.

Before the financial market crisis, such an analysis was considered of little value by most senior management since the event had only a remote chance of happening. However, banks now express the need for examining tail events and assessing the actions to deal with them. Some banks have expressed successes in using this kind of stress test to identify risk

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<sup>10</sup> See also *The Report of the CRMPG III* (August 2008).

concentrations and vulnerabilities. A good reverse stress test also includes enough diagnostic support to investigate the reasons for potential failure.

Areas which benefit in particular from the use of reverse stress testing are business lines where traditional risk management models indicate an exceptionally good risk/return trade-off; new products and new markets which have not experienced severe strains; and exposures where there are no liquid two-way markets.

**10. As part of an overall stress testing programme, a bank should aim to take account of simultaneous pressures in funding and asset markets, and the impact of a reduction in market liquidity on exposure valuation.**

Funding and asset markets may be strongly interrelated, particularly during periods of stress. The recent crisis has demonstrated this fact in several circumstances, impacting severely on the financial condition of individual banks and affecting systemic stability. Banks did not address in their risk management approaches significant linkages between asset and funding liquidity.

A bank should enhance its stress testing practices by considering important interrelations between various factors, including:

- price shocks for specific asset categories;
- the drying-up of corresponding asset liquidity;
- the possibility of significant losses damaging the bank's financial strength;
- growth of liquidity needs as a consequence of liquidity commitments;
- taking on board affected assets; and
- diminished access to secured or unsecured funding markets.<sup>11</sup>

**Specific areas of focus**

The following recommendations to banks focus on the specific areas of risk mitigation and risk transfer that have been highlighted by the financial crisis.

**11. The effectiveness of risk mitigation techniques should be systematically challenged.**

Stress testing should facilitate the development of risk mitigation or contingency plans across a range of stressed conditions. The performance of risk mitigating techniques, like hedging, netting and the use of collateral, should be challenged and assessed systematically under stressed conditions when markets may not be fully functioning and multiple institutions simultaneously could be pursuing similar risk mitigating strategies.

**12. The stress testing programme should explicitly cover complex and bespoke products such as securitised exposures. Stress tests for securitised assets should consider the underlying assets, their exposure to systematic market factors, relevant contractual arrangements and embedded triggers, and the**

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<sup>11</sup> See also *Principles for Sound Liquidity Risk Management and Supervision*, Basel Committee on Banking Supervision (September 2008).

**impact of leverage, particularly as it relates to the subordination level in the issue structure.**

Banks have mistakenly assessed the risk of some products (eg CDOs of ABS) by relying on external credit ratings or historically observed credit spreads related to (seemingly) similar products like corporate bonds with the same external rating. Such approaches can not capture relevant risk characteristics of complex, structured products under severely stressed conditions. A bank, therefore, should include in its stress tests all relevant information related to the underlying asset pools, their dependence on market conditions, complicated contractual arrangements as well as effects related to the subordination level of the specific tranches.

**13. The stress testing programme should cover pipeline and warehousing risks. A bank should include such exposures in its stress tests regardless of their probability of being securitised.**

Stress testing is particularly important in the management of warehouse and pipeline risk associated with underwriting and securitisation activities. Many of the risks associated with pipeline and warehoused exposures emerge when a bank is unable to access the securitisation market due to either bank specific or market stresses. A bank should therefore include such exposures in its regular stress tests regardless of the probability of the pipeline exposures being securitised.

**14. A bank should enhance its stress testing methodologies to capture the effect of reputational risk. The bank should integrate risks arising from off-balance sheet vehicles and other related entities in its stress testing programme.**

To mitigate reputational spill-over effects and maintain market confidence, a bank should develop methodologies to measure the effect of reputational risk on other risk types, with a particular focus on credit, liquidity and market risks. For instance, a bank should include non-contractual off-balance sheet exposures in its stress tests to determine the effect on its credit, liquidity and market risk profiles.

A bank should carefully assess the risks associated with commitments to off-balance sheet vehicles related to structured credit securities and the possibility that assets will need to be taken on balance sheet for reputational reasons. Therefore, in its stress testing programme, a bank should include scenarios assessing the size and soundness of such vehicles relative to its own financial, liquidity and regulatory capital positions. This analysis should include structural, solvency, liquidity and other risk issues, including the effects of covenants and triggers.

**15. A bank should enhance its stress testing approaches for highly leveraged counterparties in considering its vulnerability to specific asset categories or market movements and in assessing potential wrong-way risk related to risk mitigating techniques.**

A bank may have large gross exposures to leveraged counterparties including hedge funds, financial guarantors, investment banks and derivatives counterparties that may be particularly exposed to specific asset types and market movements. Under normal conditions, these exposures are typically completely secured by posted collateral and continuous re-margining agreements yielding zero or very small net exposures. In case of severe market shocks, however, these exposures may increase abruptly and potential cross-correlation of the creditworthiness of such counterparties with the risks of assets being hedged may emerge (ie wrong-way risk). A bank should enhance its stress testing

approaches related to these counterparties in order to capture adequately such correlated tail risks.

## Principles for supervisors

### **16. Supervisors should make regular and comprehensive assessments of a bank's stress testing programme.**

Supervisors should assess banks' compliance with sound stress testing practices, including the aspects listed under *Principles for banks*.

Supervisors should verify the active involvement of senior management in the stress testing programme and require a bank to submit at regular intervals the results of its firm-wide stress testing programme. Supervisors should evaluate how the stress testing analysis impacts the bank's decision making at different management levels, including strategic business decisions of the board and senior management.

Supervisors should verify that stress testing forms an integral part of the ICAAP and of the bank's liquidity risk management framework. Supervisors should also verify that a bank devotes sufficient resources and develops explicit procedures to undertake rigorous, forward looking stress testing in order to identify possible adverse events that could significantly impact the bank and threaten its viability. Supervisors should engage senior management in regular communication to discuss its view on major macroeconomic and financial market vulnerabilities as well as threats specific to the bank's operations and business model.

### **17. Supervisors should require management to take corrective action if material deficiencies in the stress testing programme are identified or if the results of stress tests are not adequately taken into consideration in the decision-making process.**

In making their assessments of a bank's stress testing programme, supervisors should assess the effectiveness of the programme in identifying relevant vulnerabilities. Supervisors should review the key assumptions driving stress testing results and challenge their continuing relevance in view of existing and potentially changing market conditions. Supervisors should challenge banks on how stress testing is used and the way it impacts upon decision-making. Where this assessment reveals material shortcomings, supervisors should require the bank to detail a plan of corrective action.

The range of remedial action should take into consideration the magnitude and likelihood of potential stress events and be proportionate to the severity of the impact of the stress test, the overall risk management framework and to other limiting or risk mitigating policies. The measures undertaken by supervisors may involve:

- the review of limits;
- the recourse to risk mitigation techniques;
- the reduction of exposures to specific sectors, countries, regions or portfolios;
- the revision of bank policies, such as those that relate to funding or capital adequacy; and
- the implementation of contingency plans.

**18. Supervisors should assess and if necessary challenge the scope and severity of firm-wide scenarios. Supervisors may ask banks to perform sensitivity analysis with respect to specific portfolios or parameters, use specific scenarios or to evaluate scenarios under which their viability is threatened (reverse stress testing scenarios).**

Supervisors should question a bank's methodology when the impact of stress tests seems unrealistically low or when mitigating actions are unrealistic.

Supervisors should ensure that a bank conducts appropriate sensitivity analysis at multiple levels of the organisation. They should ensure that a bank's sensitivity analysis is rigorous, includes different types of tests, and incorporates a range of extreme values (from mild to extreme) for inputs and parameters. In their evaluations, supervisors should review whether the bank uses output from sensitivity tests appropriately, shares sensitivity analysis results within the organisation (such as with risk managers and senior management) and properly acts upon the results (eg by taking remedial actions if sensitivity tests show large adverse outcomes or reveal model weaknesses).

Supervisors should evaluate whether the scenarios are consistent with the risk appetite the bank has set for itself. Supervisors should ensure that the scenarios chosen by the bank are appropriate to its risk profile and business mix and that they include a severe and sustained downturn. The scenarios chosen should also include, where relevant, an episode of financial market turbulence or a shock to market liquidity.

Supervisors may ask a bank to evaluate scenarios under which the bank's viability is compromised and may ask the bank to test scenarios for specific lines of business, or to assess the plausibility of events that could lead to significant strategic or reputational risk, in particular for significant business lines.

**19. Under Pillar 2 (supervisory review process) of the Basel II framework, supervisors should examine a bank's stress testing results as part of a supervisory review of both the bank's internal capital assessment and its liquidity risk management. In particular, supervisors should consider the results of forward-looking stress testing for assessing the adequacy of capital and liquidity.**

Supervisors should examine the future capital resources and capital needs of a bank under adverse scenarios. In particular, supervisors should examine the results of forward-looking stress testing as part of a supervisory evaluation of the adequacy of capital buffers. Supervisors should assess capital adequacy under stressed conditions against a variety of capital ratios, including regulatory ratios, as well as ratios based on a bank's internal definition of capital resources.

Supervisors should take account of the extent to which capital might not be freely transferable within banking groups in periods of severe downturn or extended market disruption. Supervisors should also consider the possibility that a crisis impairs the ability of even very healthy banks to raise funds at reasonable cost.

Supervisors should review the range of remedial actions envisaged by a bank in response to the results of the stress testing programme and be able to understand the rationale for management decisions to take or not to take remedial actions. Supervisors should challenge whether such actions will be feasible in a period of stress and whether the institution will realistically be willing to carry them out.

Supervisors may wish to take actions in the light of this review. These actions might entail requiring a bank to raise the level of capital above the minimum Pillar 1 requirement to

ensure that it continues to meet its minimum capital requirements over the capital planning horizon during a stress period.

Supervisors should also examine the liquidity needs of a bank under adverse scenarios and consider the adequacy of liquidity buffers under conditions of severe stress. Supervisors should review the use of stress test results to ensure that the potential impact on a bank's liquidity is fully considered and discussed at senior management level. Where deficiencies are noted, supervisors should ensure that management takes appropriate action, such as increasing the liquidity buffer of the bank, decreasing its liquidity risk, and strengthening its contingency funding plans. More detailed information on stress testing for liquidity risk is outlined in the Basel Committee's *Principles for Sound Liquidity Risk Management and Supervision*.

**20. Supervisors should consider implementing stress test exercises based on common scenarios.**

Supervisors should consider complementary supervisory stress test exercises, based on common scenarios for banks in their jurisdiction. They should ensure that banks have a common understanding as to the scope of such tests and the manner in which the tests complement individual bank stress testing programmes. These may be used to assess risk across banks at a range of levels (from the portfolio level to aggregate firm-wide exposures).

Supervisory determined stress scenarios can enhance the ability of supervisors and banks to assess the impact of specific stress events. Such stress tests could complement a bank's own stress testing programme, and should not be problematic to execute for a bank that has an adequate stress testing programme in place. However, supervisory stress tests should on their own not be considered as sufficient by a bank. In considering such stress test exercises, supervisors should make clear that these are not a substitute for stress tests designed by bank management, given that a common supervisory scenario is not tailored to the unique characteristics of individual banks.

**21. Supervisors should engage in a constructive dialogue with other public authorities and the industry to identify systemic vulnerabilities. Supervisors should also ensure that they have the capacity and skills to assess a bank's stress testing programme.**

Supervisors should engage with other public bodies and the industry to discuss stress testing practices. Discussion could include ways in which scenarios could unfold and systemic interactions could crystallise. A constructive, systematic dialogue with the industry should help the financial community to understand how the behaviour of banks and other market participants may contribute to the build up of financial imbalances and the crystallisation of systemic vulnerabilities.

Supervisors should possess expertise in quantitative modelling that is sufficient to be able to meaningfully review a bank's internal stress testing programmes. Supervisors should have adequate skill and ability to assess the scope and severity of stress scenarios and to form judgements on behavioural reactions, systemic interactions and feedback effects.

## **List of members of the Risk Management and Modelling Group**

|                                     |   |
|-------------------------------------|---|
| Chairman:                           | Mr Klaas Knot   |
| Belgium:                            | Ms Claire Renoirte  |
| Canada:                             | Mr Richard Gresser  |
| France:                             | Mr Nicolas Péligny<br>Mr Olivier Prato  |
| Germany:                            | Mr Jochen Flach<br>Mr Martin Bourbeck   |
| Italy:                              | Mr Pierpaolo Grippa<br>Ms Simonetta Iannotti  |
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| Netherlands:                        | Mr Marc Pröpper   |
| Singapore:                          | Mr Shaji Chandrasenan   |
| Spain:                              | Mr Luis Gonzalez-Mosquera<br>Mr Jesus Ibanez  |
| Sweden                              | Ms Camilla Ferenius   |
| Switzerland:                        | Mr Roland Goetschmann   |
| United Kingdom:                     | Mr Alan Cathcart<br>Mr Kevin Ryan   |
| United States:                      | Mr Kapo Yuen<br>Mr Miguel Browne<br>Mr Mike Carhill<br>Mr Jonathan Jones<br>Mr Marius Rodriguez |
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| European Commission                 | Mr Martin Spolc   |
| Financial Stability Institute:      | Mr Juan Carlos Crisanto   |
| BCBS Secretariat:                   | Mr Neil Esho<br>Mr Tom Boemio   |