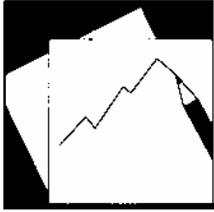


# Working Paper

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# IMF Working Paper

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## Stress Testing Financial Systems: What to Do When the Governor Calls

*Matthew T. Jones, Paul Hilbers,  
and Graham Slack*

## IMF Working Paper

Monetary and Financial Systems and Statistics Departments

### Stress Testing Financial Systems: What to Do When the Governor Calls

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#### Abstract

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Stress testing is becoming a widely used tool to assess potential vulnerabilities in a financial system. This paper is intended to answer some of the basic questions that may arise as part of the process of stress testing. The paper begins with a discussion of stress testing in a financial system context, highlighting some of the differences between stress tests of systems and of individual portfolios. The paper provides an overview of the process itself, from identifying vulnerabilities, to constructing scenarios, to interpreting the results. The experience of the IMF in conducting stress testing as part of the Financial Sector Assessment Program (FSAP) is also discussed.

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## I. INTRODUCTION

Imagine you are an official at a central bank or supervisory agency with responsibility for monitoring financial stability, when you get a call from your Governor or from the head of your agency informing you that you have to “stress test the financial system.” What does this mean? What is involved? Where does one begin? This paper is intended to provide guidance on what to do “when the Governor calls” and answer some of the basic questions that may arise as part of the process of stress testing a financial system. The paper does not focus on the technical aspects of stress testing but is intended as a reference for officials who find themselves in search of guidance at the beginning of the process.<sup>2</sup>

This paper is structured as follows. Section II begins with a discussion of stress testing in a financial system context, highlighting some of the differences between stress testing designed to identify systemic weaknesses and stress testing of individual portfolios. Section III provides an overview of the process itself, from identifying vulnerabilities, to constructing scenarios, to interpreting the results. Section IV draws on the experience of the IMF in conducting stress testing as part of the Financial Sector Assessment Programs (FSAPs), and Section V concludes.

## II. A BRIEF OVERVIEW OF STRESS TESTING

### A. Why Do A Stress Test?

Stress testing a financial system can be a resource intensive process, so it is reasonable to ask the question: *Why should a country undertake such an exercise?* Countries that have completed the process often cite numerous benefits. Financial system stress tests provide information on the behavior of the system under exceptional but plausible shocks, helping policymakers to assess the significance of the system’s vulnerabilities. As noted in IMF and World Bank (2003), the value added from system stress tests derives from a consultative process that integrates a forward-looking macroeconomic perspective, a focus on the financial system as a whole, and a uniform approach to the assessment of risk exposures across institutions. System stress tests can complement stress tests conducted by individual institutions, and act as a cross-check for other types of analysis. The information provided by system stress tests can also help to identify weaknesses in data collection, reporting systems, and risk management. The process itself can help to increase expertise in risk assessment by supervisors and the institutions involved, and promote cooperation and a broader understanding of risks by different regulatory institutions. In turn, this can contribute to a better understanding of the links between the financial sector and the macroeconomy.

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<sup>2</sup>For a broad overview of stress testing, see Blaschke and others (2001). See Laubsch (1999, Ch. 2) for a general discussion of the motivation and design of stress tests.

## B. What Is a Stress Test?

“Stress testing” is a term that comes with much mystique. In individual financial institutions, the term describes a range of techniques that attempt to measure the sensitivity of a portfolio to a set of extreme but plausible shocks (see Box 1). Put more simply, a stress test is a *rough* estimate of how the value of a portfolio changes when you make large changes to some of its risk factors (such as asset prices). We use the term *rough estimate* to avoid the perception that stress testing is a precise tool that can be used with scientific accuracy. Stress tests are simply an analytical technique that can be used to produce a numerical estimate of a particular sensitivity.<sup>3</sup> The stress testing process, however, is more than just applying a set of formulas to spreadsheets of numbers, but involves a series of judgments and assumptions that can be as critical to producing meaningful results as the actual calculations themselves. Each assumption, aggregation, or analytical approximation made in the process can introduce wide margins of error to the results, and so much care should be taken in their estimation and interpretation.

Stress tests were originally developed for use at the portfolio level, to understand the latent risks to a trading book from extreme movements in market prices. They have now become widely used as a risk management tool by financial institutions. Gradually, the techniques have been applied in a broader context,<sup>4</sup> with the aim of measuring the sensitivity of a group of institutions (such as commercial banks) or even an entire financial system to common shocks. The concept of a system stress test is quite an abstract notion, since it is not always clear what is meant by “the system,” nor is it clear that the dynamics or properties of a financial system can be described adequately by a single model or balance sheet. The concept of a firm-wide measure of risks is still not well developed, let alone a measure of risk for an entire financial system. Most stress tests applied at the “system level” are really only performed on a subset of institutions (typically banks), and often ignore the complex institutional links that are inherent in any financial system. Thus it may be more appropriate to describe stress tests of a financial system as “system-focused” stress tests, to acknowledge the limitations inherent in undertaking such an exercise.

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<sup>3</sup>As noted by the Committee on the Global Financial System (2000), stress tests estimate the exposure to a specific event, but not the probability of the event occurring. Thus they can provide information on how much could be lost under a given scenario, but not how much is likely to be lost.

<sup>4</sup>See IMF and World Bank (2003) for details of how stress tests have been used to analyze vulnerabilities at the level of the financial system, and Box 8 of this paper on the use of stress tests at the IMF.

### Box 1. Stress Tests: A Primer

At its simplest, a stress test is a way of revaluing a portfolio using a different set of assumptions. The object of a stress test is to understand the sensitivity of the portfolio to changes in various risk factors. The assumed changes in risk factors are usually made large enough to impose some “stress” on the portfolio.<sup>1</sup>

Stress tests can be applied to both the asset and liability sides of a portfolio. They can be used to assess a variety of risks, including market risk (the possibility of losses from changes in prices or yields), credit risk (potential for losses from borrower defaults or nonperformance on a contract), and liquidity risk (the possibility of depositor runs or losses from assets becoming illiquid). For example, instead of valuing a portfolio using current market values for interest rates, foreign exchange rates, and equity prices, a stress test could involve valuing the same balance sheet using a different set of market prices. More complex stress tests involving multiple risk scenarios or changes in the macroeconomic environment still amount to the same thing: revaluing a portfolio under a different set of assumptions.

Stress tests can involve changes in almost any aspect of a portfolio, including the prices used to calculate market values; as well as the duration, liquidity, default rates, and recovery rates assumed for the portfolio. Stress tests can also be used to examine the impact of changes in the operating environment beyond changes in these parameters. For example, stress tests can be employed to assess the impact of changes in prudential regulations, stricter enforcement of provisioning rules, or a different accounting treatment of allowable capital.

Stress tests usually produce a numerical estimate of the change in value of the portfolio. This change in value is often expressed in terms of the impact on some measure of capital, to understand the sensitivity of the net worth of the institution to the risk being considered.

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<sup>1</sup>/ See Illing and Liu (2003) for a discussion of how to measure stress.

System-focused stress tests, as the name implies, have several important differences with portfolio-level stress tests. The ultimate intent of system-focused approaches is different, as they aim to identify common vulnerabilities across institutions that could undermine the overall stability of the financial system. The focus is also more macroeconomic in nature, as the investigator is often interested in understanding how major changes in the economic environment may affect the financial system. A second difference between system-focused and portfolio-level stress tests lies in the complexity and degree of aggregation. System-focused stress tests may involve aggregation or comparison of more heterogeneous portfolios, often based on different assumptions and methods of calculation. This requires adding or comparing “apples” and “oranges” to a much greater extent than is the case for a single institution’s portfolio.

System focused stress tests are not intended to replace the regular stress testing done by individual financial institutions. Instead, they are designed to complement them with a broader understanding of the sensitivity of the overall system to a variety of shocks, and to leverage the existing expertise found in different institutions. System-focused stress tests can be classified according to two types: simultaneous stress tests of multiple portfolios using a

common scenario, or a single scenario applied to an aggregated portfolio or model of the entire system.<sup>5</sup> Constructing an aggregated portfolio or model with sufficient detail is often an arduous and complex task, and so typically most system-focused stress tests have adopted the first approach of applying a common scenario to a variety of institutions.<sup>6</sup> This approach has the advantage that it provides information on the overall impact of shocks as well as their distribution throughout the system, which can be useful for understanding the potential for contagion and confidence effects on stability. If data availability allows, conducting both types of tests—on an aggregated portfolio as well as on individual portfolios—will provide the maximum information on a system’s vulnerabilities.

### **III. THE PROCESS**

As discussed above, system-focused stress testing is best seen as a process: part investigative, part diagnostic, part numerical, and part interpretive. Ideally, this process begins with the identification of specific vulnerabilities or areas of concern, followed by the construction of a scenario in the context of a consistent macroeconomic framework. The next step is to map the outputs of the scenario into a form that is usable for an analysis of financial institutions’ balance sheets and income statements, then performing the numerical analysis, considering any second round effects, and finally summarizing and interpreting the results. Each stage of the process is important to understanding the sensitivity of a financial system to a particular shock or vulnerability. These stages are not necessarily sequential, as some modification or review of each component of the process may be desirable as work progresses.

The following subsections describe these key stages of the stress testing process in more detail, with the intent of providing better understanding of what is involved and how one goes about implementing them. It also discusses the required skill mix and organizational structure to conduct a stress testing exercise.

#### **A. Identifying Vulnerabilities**

The first stage in the stress-testing process is the identification stage, where the analyst identifies the main vulnerabilities s/he is interested in understanding. Narrowing the focus of the exercise permits a more refined analysis, since it is unrealistic to attempt to stress every possible risk factor for a portfolio or system. Focusing on the weak points in a financial system enables the researcher to tailor the stress testing exercise more effectively, and thus permits a richer understanding of inherent vulnerabilities, and a more effective use of time and resources.

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<sup>5</sup>System-focused stress tests can also take the form of sensitivity tests, where only a single risk factor is shocked. In this paper we focus on scenarios, but sensitivity tests can be considered in the same framework as a one-dimensional scenario.

<sup>6</sup>A notable example of the aggregate approach is Elsinger et al (2002), who develop a network model of interbank exposures to take into account feedback between individual banks and potential domino effects from bank defaults.

Isolating the key vulnerabilities to stress test is an iterative process involving both qualitative and quantitative elements. System-focused stress tests can make use of a range of numerical indicators to help isolate potential weaknesses, including the “big picture” or macro-level indicators, broad structural indicators, and institution-focused or micro-level indicators. These measures should be seen as providing complementary information on potential vulnerabilities. This process may be facilitated by drawing on a range of expertise in the context of a dedicated working group (see Box 2). Annex I also provides further details on data requirements.

### Box 2. Using a Working Group to Coordinate the Process

The process of stress testing a financial system involves many complex interactions between a variety of different specialists. To facilitate and coordinate the overall process, it is often helpful to establish an interdisciplinary team or working group across the range of relevant institutions and departments involved. The working group can act as a forum for discussion of the numerous issues that may arise, and coordinate the collection of necessary inputs. While the exact composition of a working group will vary with the institutional structure and location of relevant skills, some general guidance can be provided on the types of expertise that could prove helpful.

On the supervisory side, it is often useful to include supervisors with expertise in some of the following areas:

- Data collection and analysis, to provide input on the identification of vulnerabilities (e.g., an analyst from the early warning systems team or off-site supervision);
- Internal risk models, to assist in the numerical calculations or their interpretation (e.g., if financial institutions provide estimates for their own portfolios);
- On-site supervision, to help identify weaknesses and to provide counterparty contacts at financial institutions;
- Conglomerate supervision, if financial conglomerates have a large presence in the financial system;
- Nonbank supervision, if nonbank institutions (e.g., insurance companies) play a significant role in the financial system or represent a significant vulnerability;
- Accounting and balance sheet analysis.

On the macroeconomic side, it may be helpful to include representatives from the macroeconomic modeling or forecasting team, to assist in the preparation of scenarios and the macroeconomic framework. If a macro-econometric model will be used, then someone with in-depth knowledge of the workings of the model could be helpful.

Once a working group is established, it can meet periodically to provide input on the design and execution of the stress tests, while various sub-groups can meet at a more technical level on a more frequent basis. It is important to note that cross-disciplinary and cross-institutional involvement is crucial to ensuring that the stress testing process is well understood, is appropriately implemented, and provides useful insights. In particular, contacts and discussions with banks on stress testing can be helpful.

### Macro-level indicators

Knowledge of the broader macroeconomic environment will provide an overall context for the performance of the financial system and indicate potential sources of shocks.

Understanding the macroeconomic picture aids the understanding of what is “normal” for an economy, with respect to its own history and in comparison with other countries. This

information provides a useful metric for understanding potential sources of shocks, since key macro and financial variables that are the most volatile, misaligned, or out of equilibrium are often the most susceptible to major shocks or realignments. This analysis can also inform the macro simulations described later. Such an analysis can make use of data on the following sectors of the economy:

- *The real sector*, such as the growth performance of the economy relative to potential, growth rates for consumption, investment, and incomes; unemployment rates; inflationary pressures on consumer, wholesale, and asset prices. For the household and corporate sectors: measures of indebtedness, leverage, income growth, and debt servicing ability.
- *The government sector*, using indicators of the relative magnitude of the government deficit, debt stock, and associated debt sustainability; the size of the present fiscal impulse; and how the government budget is financed.
- *The external sector*, using indicators of the magnitude of the current account deficit, official reserves, and how the deficit is financed; the relative size, maturity structure, and currency composition of external debt; the extent of exchange rate misalignment and whether there are any pressures on the exchange rate.

### **Structural indicators**

A variety of indicators of the structure of the financial system can provide important insights into the location of risks in the financial system:

- *Ownership and market shares*, by institution and by type of institution identifies linkages between different components of the financial system, and helps identify systemically important institutions and sectors. This data could include total assets or profits, broken down by bank or other institution, as well as by sector.
- *Balance sheet structures*, derived from aggregate financial statements can indicate significant exposures to particular classes of assets and liabilities or income sources. This information can be analyzed by type of financial institutions (e.g., for the banking system, for insurance companies, for other nonbanks) as well as over time to indicate areas of concentration or accumulation of risks. Such aggregated information can be used to analyze growth rates of credit by various types of institutions and to different sectors, in conjunction with a variety of financial soundness indicators.
- *Flow-of-funds accounts* can provide insights into major changes in the patterns of intermediation in the economy, and trends in fund raising by different sectors and instruments, which can help identify key sectoral vulnerabilities.

Qualitative information on the institutional and regulatory frameworks that govern financial activities can help to interpret developments in a range of indicators. Discussions with

supervisors and regulators, private-sector analysts, and market participants can also be quite revealing as to the likely sources of vulnerability in a financial system. This type of information is often anecdotal in nature, which may make interpretation difficult, but it can provide important context to an assessment of potential financial sector vulnerabilities and form the starting point for more quantitative assessments of vulnerabilities.

### **Financial soundness indicators**

In addition to using the broad macroeconomic context and structural indicators, we can use a range of financial soundness indicators (FSIs) to narrow the focus and understand the financial system's vulnerability to shocks and its capacity to absorb the resulting losses. The analysis of FSIs can be informed by the information gathered from the macroeconomic and structural indicators discussed above. These indicators are more "micro-level" because they are typically derived from data on individual institutions or sectors. The health of the financial sector can be analyzed by looking at levels and trends in FSIs—typically of capital adequacy, asset quality, profitability, liquidity, and exposure to market risks. The IMF (2003a) has developed a *core set of FSIs* covering the banking sector, reflecting the central role of the banking sector in many financial systems (Table 1). These FSIs are considered essential for surveillance in most financial systems, and thus serve as a small common set of FSIs across countries. Also, the data to compile these FSIs are generally available. An *encouraged set of FSIs* covers additional FSIs for the banking system as well as FSIs for key nonfinancial sectors, as weaknesses in these sectors are a source of credit risk for banks and, thus, help to detect banking sector vulnerabilities at an earlier stage (Table 2).

Interpreting developments in FSIs presents particular challenges, because they are a new body of statistics in which compilation and analytical experience is often limited. In using FSIs to identify financial vulnerabilities, the following considerations should be kept in mind:<sup>7</sup>

- FSIs for specific peer groups and associated measures of dispersion should be monitored to identify common vulnerabilities and concentration of risks.
- Ideally, FSI data series should extend back to cover at least one business cycle to facilitate interpretation of current FSIs.
- Data underlying the FSI ratios (both numerators and denominators) should be reviewed to gauge the source of inter-temporal movements in the ratios.
- Close attention should be paid to definitions and treatment of accounting and consolidation issues (across borders and within business groups). The general reliability of the data used to construct FSIs should also be assessed.

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<sup>7</sup>IMF (2003a) provides detailed guidance on these issues.

Table 1. Core Set of Financial Soundness Indicators

Indicator	Indicates	Comment
<i>Deposit-taking institutions 1/</i>		
Regulatory capital to risk-weighted assets	Capital adequacy	Broad measure of capital including items giving less protection against losses, such as subordinated debt, tax credits, unrealized capital gains
Regulatory Tier I capital to risk-weighted assets	Capital adequacy	Highest quality capital such as shareholder equity/retained earnings, relative to risk weighted assets
Nonperforming loans net of provisions to capital	Capital adequacy	Indicates potential size of additional provisions that may be needed relative to capital
Nonperforming loans to total gross loans	Asset quality	Indicates the credit quality of banks' loans
Sectoral distribution of loans to total loans	Asset quality	Identifies exposure concentrations to particular sectors
Return on assets Return on equity	Earnings/profitability	Assesses scope for earnings to offset losses relative to capital or loan and asset portfolio
Interest margin to gross income	Earnings/profitability	Indicates importance of net interest income and scope to absorb losses
Noninterest expenses to gross income	Earnings/profitability	Indicates extent to which noninterest expenses weaken earnings
Liquid assets to total assets Liquid assets to short-term liabilities	Liquidity	Assesses the vulnerability of the sector to loss of access to market sources of funding or a run on deposits
Net open position in foreign exchange to capital	Exposure to FX risk	Measures foreign currency mismatch

1/ These may be grouped in different categories based on control, business lines, or group structure.

Table 2. Encouraged Set of Financial Soundness Indicators

Indicator 1/ I	ndicates	Comment
<i>Deposit-taking institutions 2/</i>		
Capital to assets	Capital adequacy	Broad measure of capital adequacy which is a buffer for losses
Large exposures to capital	Asset quality	Identifies credit exposure to large borrowers
Geographical distribution of loans to total loans	Asset quality	Identifies credit exposure concentrations to particular countries by the banking system
Gross asset position in financial derivatives to capital	Exposure to derivatives	Provides a crude indicator of exposure to derivatives
Gross liability position in financial derivatives to capital	Exposure to derivatives	Provides a crude indicator of exposure to derivatives
Trading income to total income	Earnings/profitability	Indicates the dependence on trading income
Personnel expenses to noninterest expenses	Earnings/profitability	Indicates the extent to which high noninterest expenses reduces earnings
Spread between reference lending and deposit rates	Earnings/profitability	Indicates level of competition in banking sector and dependence of earnings on the interest rate spread
Spread between highest and lowest interbank rate	Liquidity	Market indicator of counterparty risks in the interbank market
Customer deposits to total (noninterbank) loans	Liquidity	Assesses the vulnerability to loss of access to customer deposits
Foreign currency-denominated loans to total loans	Foreign exchange risk	Measures risk to loan portfolios from exchange rate movements
Foreign currency-denominated liabilities to total liabilities	Foreign exchange risk	Measures extent of dollarization
Net open position in equities to capital	Equity market risk	Measures exposure to equity price movements
<i>Other financial corporations</i>		
Assets to total financial system assets	Size	Indicates size and significance within the financial sector
Assets to GDP	Size	Indicates size and significance within the financial sector
<i>Nonfinancial corporate sector</i>		
Total debt to equity	Leverage	Provides indication of credit risk since a highly leveraged corporate sector is more vulnerable to shocks
Return on equity	Earnings/profitability	Indicates extent to which earnings are available to cover losses
Earnings to interest and principal expenses	Debt service capacity	Indicates extent to which earnings cover losses are reduced by interest and principal payments
Net foreign exchange exposure to equity	Foreign exchange risk	Reveals vulnerability to exchange rate movements
Number of applications for protection from creditors	Bankruptcies	Indicates corporate sector distress
<i>Households</i>		
Household debt to GDP	Leverage	Provides an indication of credit risk: a highly leveraged household sector is more vulnerable to shocks
Household debt service and principal payments to income	Debt service capacity	Indicates household's ability to cover their debt payments
<i>Market liquidity</i>		
Average bid-ask spread in the securities market 3/	Liquidity	Indicates liquidity in the securities market
Average daily turnover ratio in the securities market 3/	Liquidity	Indicates liquidity in the securities market
<i>Real estate markets</i>		
Real estate prices	Real estate prices	Measures trends in the real estate market
Residential real estate loans to total loans	Exposure to real estate	Measures banks' exposure to residential real estate sector
Commercial real estate loans to total loans	Exposure to real estate	Measures banks' exposure to the commercial real estate sector
Other relevant indicators that are not formally part of the encouraged set of financial soundness indicators 4/		

1/ Where available and relevant.

2/ These may be grouped in different categories based on ownership, business lines, or group structure.

3/ Or in other markets that are most relevant to bank liquidity, such as foreign exchange markets.

4/ Other indicators such as additional balance sheet data (e.g., maturity mismatches in foreign currency), data on the life insurance sector, or information on the corporate and household sector may be added where available and relevant.

## B. Constructing Scenarios

Once the key questions or main vulnerabilities of interest have been identified, the next stage is to construct a scenario that will form the basis of the stress test. This phase of the process involves an examination of the available data and models to determine what can be used to understand the behavior of the system with respect to the main vulnerabilities. Using this data, a scenario can be constructed in the context of some overall macroeconomic framework or model, depending on the complexity of the system and the availability of a suitable model.

### Use of a macro model

Ideally, a macroeconometric or simulation model should form the basis of the stress testing scenarios. This is because one objective of system-focused stress tests is to understand the impact of major changes in the economic environment on the financial system. Using a macro model provides a forward-looking and internally consistent framework for analyzing key linkages between the financial system and the real economy.

Drawing on the main macroeconomic vulnerabilities identified in the previous section, the analyst should arrive at a consensus for the key macro and financial variables that are the most volatile, misaligned, or likely to have the greatest impact on the financial system. Typically, such misaligned variables are susceptible to major shocks or realignments, and thus can form the basis of a realistic simulation scenario. Depending on the structure and features of the macro model that is available, the simulation can produce a range of economic and financial variables as outputs. The feasibility of this approach will vary according to the range of modeling expertise available, as well as the type of macro model in place. Some of the considerations involved in using a macro model are discussed in Box 3.<sup>8</sup>

Some hypothetical examples of the process of developing a scenario may prove illustrative:

- *Example 1:* Suppose that housing prices had risen sharply on the strength of rapid employment growth, rising household disposable incomes, and low interest rates, fuelling a mortgage lending boom.<sup>9</sup> An analysis of bank balance sheets and income statements shows a strong dependence on mortgage lending in both the stock of assets and in the flow of income. One possible scenario could involve a shock to employment (a rise in unemployment), a fall in disposable incomes, and a sharp rise in interest rates affecting the debt servicing capacity of households. The outputs from a macro model could provide a range of information on employment, real incomes,

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<sup>8</sup>For an interesting example of the use of macroeconomic modeling to assess the potential impact of specific vulnerabilities, see Gereben, Woolford, and Black (2003) for a scenario analysis for New Zealand.

<sup>9</sup>See also Hilbers, Qin, and Zacho (2001).

prices, and interest rates, which could be used to formulate a specific stress test for bank balance sheets.

- *Example 2:* Suppose the macro level analysis indicated an overvalued exchange rate caused by strong capital inflows, with associated credit growth financing a surge in construction investment. An analysis of structural data on institutional balance sheets and income statements reveals a sharp increase in exposure to foreign-currency denominated real-estate loans, and micro-level indicators of FSIs and individual balance sheet information shows rising defaults on property loans. One scenario might include a sudden reversal of capital flows and a rapid depreciation of the exchange rate. Macro simulations of this scenario could produce a range of outputs, including real GDP growth, the price level, interest rates, and the exchange rate. These outputs could then form the basis of a stress test of balance sheets for individual institutions.
- *Example 3:* Suppose financial deregulation and low interest rates, together with strong wage and economic growth has fuelled a sharp rise in consumer (nonmortgage) lending. An analysis of balance sheets and income statements reveals bank and nonbanks now earn over a quarter of their income from this lending, with exposures (and credit extended to consumers) growing rapidly. Furthermore, nonbanks are funding their lending largely through commercial paper placements. While FSIs show only modest rises in delinquency rates and nonperforming assets, there are concerns about credit quality going forward. One possible scenario might involve a sharp rise in interest rates, increasing banks' funding costs and (temporarily) narrowing their margins, perhaps caused by a policy response to increased inflationary pressures or an external shock. The output of a macro model could be used to analyze the possible impact on household incomes and the debt-servicing capacity.

Some authorities may not have a well-developed macro model available. Even if a model is in place, there may be difficulties in using it to simulate relevant shocks. Some models may not be tractable for the type of economic shock that the analyst wishes to consider, while others may not incorporate a financial sector or may not allow for a policy reaction by authorities. Thus, it may not always be feasible to generate a macro scenario using a consistent macro model. In the absence of a macro model, it may be necessary to rely on more rudimentary approaches. Even in these circumstances it is still possible to frame the analysis in the context of an internally consistent, forward-looking macroeconomic scenario by using textbook macro models, supplemented by existing empirical research, or by using models developed for another country that has a similar structure.

### Box 3. Simulations Using Macro Models: Some Considerations

Using a macro model to simulate a range of macroeconomic scenarios raises a series of questions. Some of these considerations include the following:

- What are the baseline assumptions? The baseline assumption could be no change from the latest data, or the central forecast or most likely scenario from the most recent forecasting exercise.
- What policy responses are assumed? Depending on the model, different policy reaction functions may be imbedded in the model (such as a Taylor rule relating monetary policy instrument settings to deviations in inflation and output from their targets) or an assumption of no change in policies may be used. Assuming no policy response will typically imply a larger macroeconomic effect of any shock, but this will depend on the model and scenario.
- What is the time horizon of the simulations? If a quarterly model is available, it may be possible to produce forecasts over the next six to eight quarters. When applying the scenarios to individual balance sheets, however, a shorter time horizon is desirable if no reaction by institutions is assumed (i.e., if it is assumed that institutions do not adjust their balance sheets, the results can be interpreted as a comparative static exercise)
- Which variables are assumed fixed, and which are shocked? Many macroeconomic models use a large number of exogenous variables. Implementing a particular scenario requires judgment as to which variables are assumed constant. Changing a large number of exogenous variables may make the scenario unnecessarily complex, with little benefit in terms of realism and less acceptance of the results by participants.
- What size of shocks should be used? Shocks can be calibrated on historical experience (e.g., largest change over the chosen time horizon seen in the last ten years), or can be set on the basis of a hypothetical scenario (e.g., a 20 percent fall in the exchange rate). Historical experience may be more intuitive and easier to justify, but major structural changes may invalidate historical calibration (e.g., deregulation may change fundamental economic relations).

The objective of using an explicit macroeconomic model is to link a particular set of shocks to key macro and financial variables in a consistent and forward-looking framework. This does not necessarily require a large research effort, but can leverage existing expertise and research. The key reason for using this approach is to bring the discipline and consistency of an empirically-based model and an explicit focus on the link between the macroeconomy and the main vulnerabilities.

#### **C. Balance-Sheet Implementation**

Once a set of adjustment scenarios has been produced in a consistent macro framework, the next step is to translate the various outputs into the balance sheets and income statements of financial institutions. There are two main approaches to translating or “mapping” scenarios into balance sheets: the “bottom-up” approach, where estimates are based on data for individual portfolios, which can then be aggregated, and the “top-down” approach, which uses aggregated or macro-level data to estimate the impact.<sup>10</sup>

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<sup>10</sup>See Hoggarth and Whitley (2003) for further details, and a discussion of how the approach was used for the U.K. FSAP.

Under the bottom-up approach, the response to various shocks in a scenario is estimated at the portfolio level, using highly disaggregated data from individual financial institutions. The results of the bottom-up approach can then be aggregated or compared to analyze the sensitivity of the entire sector or group of institutions. The bottom-up approach has the advantage that it makes better use of individual portfolio data, but if individual institutions provide their own estimates, then the approach may introduce some inconsistencies in how each institution applies the scenario and produces its numerical estimates.

The top-down approach is used to estimate the responsiveness of a group of institutions to a particular scenario. Under this approach, a common parameter is derived from all institutions in the data set (e.g., using a regression of aggregated information on macro variables) to arrive at an estimate of the aggregate impact. The top-down approach is often easier to implement, since it requires only aggregated data, and is a consistent and uniform method, but is based on aggregate historical relationships that may not hold in the future. Ideally, both methods should be applied, but data limitations may preclude this in many countries.

The remainder of this section discusses the various steps involved in implementing a system-focused stress test, by addressing a series of key questions. These questions include: who should perform the empirical analysis? Which institutions should be included? What are the data constraints? How large should the shocks be? How do we link the macro adjustment scenarios to individual balance sheets and income statements?

### **Execution, scope, and coverage**

The first question to consider in implementing a system-focused stress test is *who crunches the numbers*: the supervisor/central bank or the institutions themselves? Ideally, individual institutions should be as heavily involved in the process as possible, irrespective of whether a top-down or bottom-up approach is used. This is because individual institutions will typically have the best access to data and knowledge of their own portfolios. For institutions with sophisticated risk management systems or significant international operations, most will have systems and stress-testing procedures in place as part of their own internal risk monitoring processes (see Box 4).<sup>11</sup> For countries with financial institutions that have more rudimentary systems and less expertise in modeling their portfolios, involvement in the process may be beneficial by expanding their knowledge. In these circumstances, it may be necessary for the central bank or supervisory agency to provide guidance or even undertake parts of the empirical analysis, but this should still involve individual institutions as much as possible. Having institutions cooperate in a stress-testing exercise may require some moral suasion or other incentives, including the ability to benchmark their own results against their peer

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<sup>11</sup>Banks that follow the Basel Committee's internal-ratings based approach are required by their supervisors to have a comprehensive stress testing program in place. Many large banks have Value at Risk frameworks in place for internal monitoring of risk positions. See Jorion (2001) for a survey of Value at Risk methods.

groups or the ability to learn from other participants. The top-down approach is best undertaken by the agency with best access to the data and expertise necessary to perform the exercise.

#### Box 4. Stress Testing of Banks and the Basel Capital Accord

In 1996 the Basel Committee on Banking Supervision (1996, 1998) recommended that banks using the internal models approach to capital adequacy for market risk have in place a “rigorous and comprehensive stress testing program.” This recommendation gave impetus to a growing awareness and familiarity of stress testing by banks.

The 2004 revised Framework for the New Basel Capital Accord (or Basel II) issued by the Basel Committee on Banking Supervision (2004) goes even further in its recommendations with regard to stress testing, in line with the increased emphasis on the use of the internal ratings based approach. Basel II now calls for banks to use stress tests for a variety of purposes:

- Banks should use stress tests to take account of the illiquidity of lower quality assets (para. 158).
- Banks must have stress testing processes for use in the assessment of capital adequacy (para. 434): “*Stress testing must involve identifying possible events or future changes in economic conditions that could have unfavourable effects on a bank’s credit exposures and assessment of the bank’s ability to withstand such changes. Examples of scenarios that could be used are (i) economic or industry downturns; (ii) market-risk events; and (iii) liquidity conditions.*”
- Supervisors must have minimum quantitative standards with regard to stress testing (para. 527j): “*A rigorous and comprehensive stress-testing programme must be in place. Banks are expected to subject their internal model and estimation procedures, including volatility computations, to either hypothetical or historical scenarios that reflect worst-case losses given underlying positions in both public and private equities. At a minimum, stress tests should be employed to provide information about the effect of tail events beyond the level of confidence assumed in the internal models approach.*”
- Supervisors should consider how a bank provides for unexpected events in setting capital levels (paragraph 750): “*This analysis should cover a wide range of external conditions and scenarios, and the sophistication of techniques and stress tests used should be commensurate with the bank’s activities.*”
- Banks should stress test credit concentration risk (para. 775): “*A bank’s management should conduct periodic stress tests of its major credit risk concentrations and review the results of those tests to identify and respond to potential changes in market conditions that could adversely impact the bank’s performance.*”

Implementing a stress test also requires us to address the question: *which institutions should be included in the exercise?* The coverage of the stress testing exercise should be broad enough to represent a meaningful critical mass of the financial system, while keeping the number of institutions covered at a feasible level (e.g., less than twenty). The total market share of the institutions involved (either in terms of assets, deposits, or some other criteria such as importance in the payment system) can be used to determine a cutoff point, as the exercise may become unwieldy if too many institutions are involved. Depending on their interlinkages and systemic importance, both banks and nonbank financial institutions should be included in the analysis, although this may present some difficulties if they are supervised by different entities or have different balance sheet reporting dates or practices. (See Box 5 for a discussion of stress testing insurance companies) In countries with a large number of small institutions, consideration could be given to either aggregating smaller institutions into

a single balance sheet or taking a representative sample of institutions, or even ignoring them if they are not systemically important. Stress tests can also be applied to nonfinancial companies to understand the sensitivity of corporate sector balance sheets (see Box 6).

### Box 5. Stress Testing of Insurance Companies

Stress testing of insurance company balance sheets and income statements is not as well-developed as stress testing of banks. This is due in part to the history of stress testing (banks were early proponents), and also due to regulatory impetus (Box 4). Furthermore, insurance companies are generally considered to represent a lower level of systemic risk than banks, mainly due to the different character of their liabilities, which often have a longer duration than banks. However, distress in the insurance sector can have important systemic implications, including through ownership relations with the banking sector and its impact on confidence in the financial sector as a whole. For insurance companies, the revised Insurance Core Principles issued in 2003 by the International Association of Insurance Supervisors (IAIS 2003a, p. 35) includes stress tests as an advanced criterion for Principle 20: “The supervisory authority requires that insurers undertake regular stress testing.” The IAIS (2003b) also issued a guidance paper on stress testing by insurers. These documents provide a broad set of principles for stress testing that companies should follow, recognizing the importance of stress testing as a risk management tool.

Because insurance companies have a different balance sheet structure to banks, stress tests of their balance sheets may present unique challenges. Insurance companies face underwriting risk, catastrophe risk, and risks on technical claims provisions. On the asset side, more or less similar to banks, they also face market risk, credit risk, liquidity risk, operational risk, group risk, and systemic risk, in differing degrees to those faced by banks and other financial institutions. The complexity of the contracts underlying insurance company balance sheets can create difficulties in revaluing liabilities, and may require detailed data on a contract-by-contract basis to enable an accurate assessment of the impact of changes in risk factors. Stochastic techniques are sometimes used by insurers to assess their resilience to shock. Such techniques are complex, and account for the probability of a range of possible outcomes. Alternatively, simple deterministic tests, for example, shifts in loss ratios or gauging the effect of specified catastrophic events can reveal useful information about immunity to shocks.

The results of insurance company stress tests are often expressed in terms of their impact on the solvency margin. The required solvency margin is the minimum level of capital and reserves (or surplus of assets over liabilities) required by the supervisor, which is intended to ensure with a high probability the insurer’s ability to meet its obligations on an ongoing basis. If the financial position of an insurance company deteriorates below the required solvency margin, a series of corrective actions need to be initiated by the supervisor. The numerical estimate of the impact of a stress test can be expressed as a percent of the required solvency margin, to indicate the potential severity of the shock.

Aggregating the results of stress tests of insurance company balance sheets with the results for banks (e.g., within a conglomerate, or in aggregating the results for the two sectors) may be complicated, because of differences in the accounting and regulatory treatment of assets and liabilities. Differences in the definition of capital and the market valuation of investments may be particularly acute. If this is the case, a separate presentation of results may be warranted.

### Box 6. Stress Testing of Corporate Sector

In many countries, loans to the corporate sector account for a significant portion of total lending. Thus, stress testing the balance sheets of the corporate sector can provide useful information on the underlying credit quality of bank portfolios.

Corporate sector balance sheets can be stressed to understand their sensitivity to various risks:

- Sensitivity to interest rate risk can be assessed by examining the impact of interest rate changes on net interest expenses and interest earnings;
- Sensitivity to foreign exchange rate risk can be examined by considering the effect of a change in the exchange rate on foreign earnings and interest expenses on the stock of foreign-currency denominated debt;
- Sensitivity to macroeconomic cycles can be estimated by considering the impact of changes in sales and firm income.

The impact of these various shocks on the ability of firms to service their debts can be measured using the interest coverage ratio, often defined as the earnings before interest, taxes, depreciation, and amortization divided by interest expenses. Firms that fail to maintain their interest coverage ratios above one must eventually liquidate assets or gain new funding, renegotiate their debt contracts, or default. The proportion of firms or their debts that have low interest coverage ratios (e.g., below one) provides a rough proxy for potential loan defaults.

Stress tests can show what effect different shocks have on interest coverage ratios and the proportion of firms that are at greater risk of defaulting. Thus, stress tests of the corporate sector can provide a useful indicator of the sensitivity of the underlying credit quality of bank loans to a variety of shocks.

See Glen (2004), Goldman Sachs (1998, 2000), and Heytens and Karacadag (2001) for examples of this approach.

Another important question to consider in conducting a stress test is: *what are the data constraints?* The availability and quality of data impose major constraints on the nature of stress tests that can be performed. As noted in IMF and World Bank (2003), data limitations can come in four forms:

- *Basic data availability*, especially in countries where information on balance sheet exposures may not be available;
- *Difficulty isolating specific exposures*, especially among financial institutions in the case of large complex financial institutions or institutions that are active in the derivative markets;
- *Lack of risk data*, e.g., duration or default measures, in countries where risk management systems are less sophisticated; and
- *Confidentiality issues*, or limitations on what supervisors are legally able to share with other parties.

To overcome these difficulties, it may be possible to work with the larger and more sophisticated institutions to get better data or to calibrate some parts of the exercise. For example, if the exposure of interest is the aggregate exposure to a specific borrower or sector,

individual institutions may be able to produce information on that exposure from their internal risk monitoring systems, even if they do not report data to the authorities in that particular format. When confidentiality issues do arise, it may be possible for the institution with access to the data to conduct the stress testing based on agreed assumptions and methodologies and to share the results in a form that is sufficiently informative of the risk exposures, but would not breach confidentiality laws or protocols.

### **Calibrating shocks**

Another key question to address in implementing a system-focused stress test is *how big are the shocks?* Stress-testing involves discovering the impact of *exceptional but plausible* events, so the scenarios considered should be beyond the normal range of experience. Scenarios can be based on historical data (e.g., using the largest observed changes or extreme values over a specified period), or they can be hypothetical and involve large movements thought to be plausible. Historical scenarios can be more intuitive since they were actually observed, but hypothetical scenarios may be more realistic, especially if the financial structure has changed significantly (e.g., with deregulation, liberalization, changes in monetary policy operating procedures, or changes in supervisory policies). Experiences of other countries can be a useful guide as well.

While the object of stress-testing is not to apply shocks until all major financial institutions fail,<sup>12</sup> it is exceptional outcomes that precipitate financial instability. Thus, in assessing the vulnerability of financial systems, it is important to consider a range of movements that is wide enough to capture such outcomes. For example, a simple sensitivity test can be calibrated according to the largest change in a risk factor over the past ten years. It is important to bear in mind that the relevant empirical measure for scenarios is the joint probability of all factors moving simultaneously, which may be difficult to assess empirically.<sup>13</sup> Since it is often difficult to attach a probability to hypothetical scenarios, some judgment is involved, but this can also be guided by historical experience. It may also be the case that small changes in key variables are sufficient to precipitate difficulties in some institutions.

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<sup>12</sup>In some cases it may be useful to calibrate the size of shocks to cause one or more of the institutions involved to breach their minimum capital requirement, in order to determine the magnitude of shocks necessary to cause such a “failure.”

<sup>13</sup>For example, a change in overnight domestic and foreign interest rates at the same time can be assessed using a multivariate normal distribution if the variables are well described by the normal distribution, but this is often not the case for extreme events, and so calculating a joint probability measure becomes more problematic. See Hoggarth and Whitley (2003) for further discussion.

### **Mapping macro scenarios to balance sheets: the bottom-up approach**

Translating a broad macroeconomic framework into the balance sheet of a financial institution requires a mapping of macro variables into a set of common risk factors that can be applied to stress individual balance sheets (bottom-up). Since most portfolios have numerous instruments, each with their own unique price, the process of revaluing an individual portfolio may require knowledge of hundreds (and potentially thousands) of market prices. Financial institutions typically simplify this process by mapping each element of a portfolio into a smaller set of common risk factors. Thus, two mappings are required to implement a system-focused stress test: one mapping from the macro adjustment scenarios to the set of common risk factors, and another mapping from the common risk factors into all of the instruments in a portfolio.

Depending on the macro model being used, the financial variables available from the scenarios may be quite detailed (if the model includes a lot of features of the financial system), or fairly limited. For a financial institution, implementing a stress test typically requires a range of indicators on: interest rates (such as the term structure of the risk-free rate, and credit quality spreads), exchange rates (such as spot and forward, bilateral and trade-weighted), asset prices (such as aggregate indices of market prices), and credit exposures and quality. Thus it may be necessary to supplement the output of the macro model with additional estimates of what each scenario would imply in terms of these common risk factors.

Some financial institutions have their own internal models that link macroeconomic factors to the performance of their balance sheet, which can be used to help calibrate this mapping to a set of common factors. Other potential sources of information to flesh out the details of this mapping could include studies performed on the domestic economy addressing the term structure of interest rates, or models used to estimate the equilibrium real exchange rate. Some examples of this process may prove illustrative:

- Suppose the macro model only produces two interest rates: an overnight cash rate and a 10 year bond rate. An empirical model of the term-structure of interest rates could be used to produce an estimated set of interest rates for a larger set of maturities. In turn, this data could be used to derive credit spreads.
- Suppose the macro model only produces a trade-weighted exchange rate, or a single bilateral exchange rate. To get a broader range of exchange rates, it may be possible to use the weightings implicit in the trade-weighted index to produce a set of bilateral exchange rates. Producing a range of exchange rates from a single bilateral exchange rate forecast from a macro model can be accomplished by assuming some pattern of cross rates (e.g., assuming that cross rates are unchanged or change based on forecasts for the different rates).

Once the macro scenarios have been mapped into a set of common risk factors, the next step is to map the risk factors into the portfolios of individual institutions. The party that is

usually best placed to construct such a mapping is the individual institution involved in the stress-testing exercise. This is because it typically has the best access to expertise and detailed information on the portfolio itself, and may have a well-developed risk management model capable of performing many of the calculations. As mentioned above, some financial institutions have macro frameworks that can be used to link the larger macroeconomic picture (unemployment rate, GDP growth, sectoral growth rates etc.) to portfolio performance, and so can map the adjustment scenarios directly into their own balance sheets and income statements via their internal models.

In many circumstances, individual institutions will not have internal models capable of translating broad macroeconomic developments, but will have their own internal models or expertise that can be utilized to construct an appropriate mapping. For example, many banks have internal models that use credit scores, transition matrices, or default probabilities as key parameters in understanding the evolution of credit risk in their portfolio. Banks can estimate the impact of macroeconomic changes on these internal risk model parameters, or can use the most recent economic downturn as a guiding rod for assessing the impact of broad economic changes on their portfolio. In some cases it may be necessary to rely on the expert judgment of risk managers in adjusting these key parameters, particularly if the systems have only been in place for a relatively short period of time, and thus have not spanned an entire economic cycle.

### **Top-down approach**

Conducting a “top-down” approach to stress testing provides a useful check on the results based on individual balance sheet information (the bottom-up approach). Furthermore, financial institutions in some countries may not have the capacity to estimate the impact of a given set of shocks on their portfolio. In this case, the agency coordinating the stress-testing exercise could adopt a “top-down” approach and apply adjustment parameters based on system-wide estimates. For example, a regression model of loan loss rates for the entire banking system could be used to estimate the impact of a macro adjustment scenario on the credit quality of an institution. Some examples of this approach include the following:

- Frøyland and Larsen (2002) model losses for Norwegian banks on household loans as a function of household debt, wealth, and unemployment. They also model losses on loans to enterprises as a function of risk-weighted debt and collateral. Andreeva (2004) models the loan loss ratio (to assets) of loans to Norwegian enterprises as a function of bankruptcy probabilities and a variety of economic factors, including the unemployment rate and the real interest rate.
- Benito et al (2001) extend the Bank of England’s macro model by incorporating household and corporate balance sheets. They then perform a stress test by incorporating a fall in housing prices and a rise in interest rates, examining their impact on a variety of indicators, including mortgage arrears.

- Hoggarth and Whitley (2003) describe the process of using the Bank of England’s macro model, as well as using the top-down approach to estimate the impact of macro variables on new provisions by banks.
- Arpa et al (2000) estimate the effect of macroeconomic factors (real GDP, real estate prices, inflation, and real interest rates) on risk provisions and on earnings for Austrian banks. Kalirai and Scheicher (2002) model loan loss provisions in Austria as a function of various macroeconomic indicators, and then use the model to conduct a series of sensitivity tests.
- Pesola (2001) examines the Nordic banking crisis by estimating a model of loan losses as a function of GDP, indebtedness, unexpected changes in income and interest rates, and deregulation.

The estimated equations from these papers are all examples of how the authorities or individual institutions can use the top-down approach to approximate the impact of economic developments on individual portfolios or to calibrate the parameters used in their stress tests. It is important to note that regression-based estimates have their limitations, since they are often only providing a partial equilibrium estimate of some effect, and so care should be taken in interpreting the results of such estimates.

#### **D. Second-Round Effects**

Most stress testing approaches assume there is no change in the behavior of the portfolio or no realignment of the portfolio structure in response to the change in risk factors. Stress tests are typically applied to a balance sheet at a point in time or in conjunction with a forecast over a specific horizon, and the impact is calculated as if the shock was “marked-to-market” or valued at market prices. This approach is valid if the time horizon is relatively short, or if changes in the underlying portfolio take time to implement. For example, assuming only a limited behavioral response in a large loan portfolio over a one- to three-month horizon may be a reasonable assumption, since it is often difficult to restructure a portfolio in less time without incurring losses from “fire-sale” prices.<sup>14</sup> Such an assumption may also be justifiable for an individual institution that does not have a large impact on the financial system or the macroeconomy, i.e., the feedback effects are relatively small. But once the time horizon of a scenario or shock extends beyond a year or more, the assumption of no behavioral response becomes harder to justify. Similarly, for systemically important institutions or for systems as a whole, the assumption of no feedback effects implicit in many stress tests may be an oversimplification. The policy environment may change over a longer horizon, as monetary or supervisory authorities react to a given set of shocks. Financial sector safety nets may also provide a buffer over longer horizons.

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<sup>14</sup>Although the increasingly widespread use of derivatives may permit a more rapid adjustment in exposures.

As Hoggarth and Whitley (2003) note, second round effects can be manifest as direct credit losses from counterparty failures, as increased funding costs for weakened banks, and as portfolio adjustments (such as a tightening of lending criteria) affecting aggregate demand. These effects may all be present during periods of stress, particularly ones with longer time horizons. The challenge in incorporating these effects into a system-focused stress test is in understanding the complexity of the links between institutions.

One approach that is often used to consider second round effects and linkages between institutions is the use of contagion models.<sup>15</sup> These models attempt to estimate the impact of the failure of key institutions on other institutions and hence the overall financial system. The exercise typically has two stages, beginning with a stress test to individual balance sheets and income statements. The second stage involves an examination of counterparty exposures to the institutions made most vulnerable by the stress test, for example, through interbank loans, cross shareholdings, deposits, or other exposures. By examining the impact of difficulties in one institution on the health of other institutions, it is possible to consider second round effects in a relatively simple and intuitive manner. The results of this type of analysis can even be used to construct indices of systemic risk, based on the impact of the failure of key institutions.

### **E. Interpretation**

Experience in conducting stress tests suggests they are a useful tool for identifying latent risk exposures and the likely significance of losses in a systematic and intuitive manner. Stress tests can be particularly useful when they are conducted on a regular basis, as this can provide information about changes in the risk profile of the system over time. While stress test results are useful to evaluate effects of large movements (tail events) in key variables, care should be taken not to portray them as providing a precise measure of the magnitude of losses. As the Committee on the Global Financial System (2000) noted: typically, there are no probabilities attached to the outcomes of stress tests.

If the underlying model being “stressed” is incorrectly specified or estimated, then the conclusions drawn from a stress test may be invalid. This potential for “model error” highlights the usefulness of comparing stress test results with other complementary measures of risk exposure, such as financial soundness indicators. Stress tests are also unlikely to capture the full range and interaction of risk exposures (such as operational risk and legal risk), and may give only a partial picture of the true nature of risk-taking by participating institutions. Finally, stress tests typically consider only part of a bank’s income generating operations, and thus banks may have significant income flows that are unaffected in performance or value by the specific stress test scenarios analyzed.

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<sup>15</sup>See Čihák (2004a,b) for further details. Upper and Worms (2002), Furfine (1999), Degryse and Nguyen (2004), and Gropp and Vesala (2004) also examine interbank contagion.

The analysis and discussion of stress testing results can be facilitated and enhanced by a clear presentation of the output generated by stress tests, and of the underlying assumptions and judgments used to generate the results. An overview of the stress tests results can be conveyed by grouping the aggregate (sector level) impact of the stress tests by type of risk and/or by scenario. The composition of expected losses (as a proportion of capital or income for instance) can be used to summarize the central results. For bottom-up approaches, descriptive statistics (e.g., mean, median, standard deviation, minimum, maximum, and number of institutions in each decile) and peer group analysis can be used to convey how the impact at the aggregate level is distributed across individual institutions. This can be important to the analysis because significant exposures in systemically important institutions could raise concerns even if the net exposure of the sector is relatively small.

If the aggregate results are based on stress tests of individual bank portfolios under the bottom-up approach, there can be difficulties of comparability since each institution may employ different models and modeling assumptions. Having the supervisory agency conduct some stress tests on the balance sheet data reported to it by financial institutions using a common framework and methodology can play a useful role in acting as an accuracy and consistency check of the results provided by individual institutions.

### **Publication of results**

Public dissemination of the results of stress-tests can present some difficulties with regard to confidentiality and interpretation of results. Participating institutions may be reluctant to have any information disclosed that could identify specific firms, out of concern that markets may interpret such information negatively, or competitors may take advantage of the information. Some analysts may also interpret the particular scenarios chosen as reflecting an official view on the most likely scenario or the most problematic, which may not be the case. Nevertheless, the publication of summary or aggregated information on stress test results by a wide variety of countries (see Box 7) suggests that these difficulties can be overcome. Disclosure of some summary information on the results (such as the mean and the range) can be informative for financial markets and individual institutions wishing to benchmark their own results against their competitors, without revealing the identities of individual institutions. Disclosure of the scenarios undertaken can also raise awareness of different risks for institutions to consider and incorporate into their own stress testing programs.

### Box 7. Financial Stability Reports

A growing number of central banks regularly produce stand-alone publications devoted to assessing the condition and stability of the financial system, generally making use of a range of financial sector indicators to guide and illustrate the analysis.

Selected Financial Stability Reports 1/

Country	Name of Institution	Frequency	Starting Date	Supervisory Functions
Austria	Austrian National Bank	Semi-annually	2001	No
Belgium	National Bank of Belgium	Annually	2002	No
Brazil	Central Bank of Brazil	Semi-annually	2002	Yes
Canada	Bank of Canada	Semi-annually	2002	No
Denmark	National Bank of Denmark	Annually	2000	No
Finland	Bank of Finland	Annually	2003	No
France	Bank of France	Semi-annually	2002	Yes
Hungary	National Bank of Hungary	Semi-annually	2000	No
Indonesia	Bank Indonesia	Semi-annually	2003	Yes
Norway	Bank of Norway	Semi-annually	1995	No
Sweden	Bank of Sweden	Semi-annually	1997	No
United Kingdom	Bank of England	Semi-annually	1995	No

1/ Based on IMF (2003b).

Within this group, several central banks have published the results of stress tests of the domestic financial system, for example:

- A range of macroeconomic stress tests carried out in the context of IMF's FSAP in the United Kingdom are described in the Bank of England's June 2003 Financial Stability Review. See Hoggarth and Whitley (2003).
- Sensitivity analyses and stress tests examining whether earnings and capital of the Danish banking system are sufficient to withstand predetermined risk scenarios are reported in the National Bank of Denmark's 2003 Financial Stability Report. See National Bank of Denmark (2003).
- Stress tests focusing on the interdependence of banking sector credit risk and economic developments in Austria are reported in the Austrian National Bank's Financial Stability Report (Number 3). See Kalirai and Scheicher (2002).
- The effect of interest rate and credit shocks on the capital position of the Hungarian banking system are reported in the Hungarian National Bank's December 2003 Report on Financial Stability. See Hungarian National Bank (2003).
- The effect of changes in NPLs on the capital position of the Indonesian banking system are reported in Bank Indonesia's June 2003 Financial Stability Report.
- A summary of stress test results from selected FSAP missions have also been published by the IMF as part of Financial System Stability Assessments, available at <http://www.imf.org/external/np/fsap/fsap.asp#cp>.

#### IV. SUMMARY OF FINANCIAL SECTOR ASSESSMENT PROGRAM (FSAP) EXPERIENCE<sup>16</sup>

Stress tests are an integral part of FSAPs conducted by the IMF and World Bank, and have been performed for every country participating in the FSAP. They are designed to provide a quantitative measure of the vulnerability of the financial system to different shocks. They complement the insights gathered from other components of the assessment that focus on key elements of the legal, institutional, regulatory, and supervisory framework; the observance of key financial sector standards and codes; the analysis of the financial system structure and key vulnerabilities; and the empirical analysis of financial soundness indicators. The IMF has also broadened its application of stress testing techniques into other areas (see Box 8).

Data availability is a key factor in determining the approach and sophistication of stress tests performed as part of the FSAP. Most analyses are performed on a bank-by-bank (bottom-up) basis, based on single factor and scenario approaches. Contagion risks and second round effects have typically not been addressed in many FSAPs, although some have incorporated elements of interbank contagion into the exercise. The involvement of the authorities has varied, according to their expertise and ability or willingness to provide data, with some country authorities precluded from providing data on individual institutions by bank secrecy laws or conventions. For countries that have published the IMF's summary assessment of the FSAP mission (the *Financial System Stability Assessment*), most have included a summary of the stress testing results.<sup>17</sup>

The overall approach and implementation of stress tests as part of the FSAP has evolved over time. Some recent trends include:

- Country authorities and individual financial institutions now play a greater role in the design and implementation of stress tests, as familiarity and use of the techniques have spread. Increased reliance is being placed on using the internal models of banks to evaluate the impact of shocks, including their off balance-sheet exposures.
- The use of macro-simulation models to calibrate a macro scenario has increased.
- Coverage of nonbank financial institutions has increased, with large insurance companies now being included in many cases as part of the analysis.
- Many country authorities are now implementing their own stress-testing programs, partly as a result of FSAP-related work (Box 7).

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<sup>16</sup>This section is based on IMF and World Bank (2003).

<sup>17</sup>See <http://www.imf.org/external/np/fsap/fsap.asp#cp> for copies of published reports.

### Box 8. The IMF, Scenario Analysis, and Stress Testing

As familiarity with stress testing concepts and techniques has spread, the IMF has begun to incorporate stress testing into more of its work. Some examples include:

- *The Financial Sector Assessment Program (FSAP)*: Stress tests are a key component of the FSAP, and aim to assess the impact of exceptional but plausible shocks to key macroeconomic variables on the soundness of the financial system. See IMF and World Bank (2003).
- *Technical assistance*: As a follow-up to the FSAP program, the IMF has begun to offer technical assistance on implementing stress testing programs for central banks and supervisors.
- *Analysis of debt sustainability*: Recent proposals call for greater use of scenario analysis in analyzing debt sustainability. See IMF and IDA (2004).
- *Surveillance*: In evaluating the IMF's role in recent capital account crises, the Independent Evaluation Office concluded that IMF surveillance "should be oriented toward looking for points of vulnerability, and developing and analyzing stress test scenarios, rather than toward simply trying to predict the future." See IMF (2003c, p. 29).
- *Assessing the risks to the IMF's balance sheet*: There have been recent proposals to use financial scenario analysis to assess the potential impact of nonpayment by a Fund member on the IMF's precautionary balances. See IMF (2004).

## V. CONCLUDING REMARKS

Stress testing is best seen as a process of identifying vulnerabilities and providing a rough estimate of sensitivity of balance sheets to a variety of shocks. System-focused stress tests attempt to marry a forward-looking macro perspective with an assessment of the sensitivity of a collection of institutions to major changes in the economic and financial environment.

The process of conducting a system-focused stress test begins with the identification of specific vulnerabilities or areas of concern, followed by the construction of a scenario in the context of a consistent macroeconomic framework. Isolating key vulnerabilities is an iterative process involving both qualitative and quantitative elements. A range of numerical indicators can be used to help isolate potential weaknesses, including the "big picture" or macro-level indicators, broad structural indicators, and more institution-focused or micro-level indicators. Ideally, a macro-econometric or simulation model should form the basis of the stress-testing scenarios. A working group of selected experts may facilitate the process.

Once a set of adjustment scenarios have been produced in a consistent macro framework, the next step is to translate the various outputs into the balance sheets and income statements of financial institutions. There are two main approaches to translating macro scenarios into balance sheets: the "bottom-up" approach, where the impact is estimated using data on individual portfolios, and the "top-down" approach, where the impact is estimated using aggregated data.

A variety of metrics can be used to summarize the results of stress tests, with the most common ones being measures of capital, assets, or profitability in the denominator. Public

dissemination of the results of stress tests may present some challenges, but the publication of results by a broad range of countries has shown that these are not insurmountable.

Experience with the IMF/World Bank FSAP process has shown that stress tests are useful because they provide a quantitative measure of the vulnerability of the financial system to different shocks, which can be used, with other analyses, to draw conclusions about the overall stability of a financial system. Recent trends show a shift toward greater integration of a macroeconomic perspective, more involvement by country authorities and individual institutions, and greater coverage of the financial sector.

## ANNEX

### I. DATA ISSUES

Since the ultimate intent of a stress test is to produce a numerical estimate of a particular sensitivity, the process can be extremely data intensive. The object of this annex is to provide an overview of the data and issues relevant to implementing a stress test.

#### **Identifying vulnerabilities**

A variety of macro-level, structural, and micro-level indicators can be useful in helping to identify key vulnerabilities in the financial system.<sup>18</sup> Macroeconomic indicators of the type listed in Section III.A are generally available from the central bank, finance ministry, statistical agency, or from the IMF.<sup>19</sup> The object of these indicators is to identify common economic factors that can influence the operating and financial environment of financial institutions and their customers. The economic variables that may be useful in this process are similar to those typically analyzed in a financial stability report (see Box 7 for examples), and include:

- national accounts data and other real sector data, including data on labor markets, production, prices, and household and corporate sector performance;
- fiscal accounts, including government operations (revenues and expenses) and debt stocks;
- External sector accounts, including information on the balance of payments, international investment position, international reserves and liquidity, exchange rate developments; and
- Financial sector accounts, including the accounts of banks and the central bank, the structure of interest rates, trends in asset prices, etc.

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<sup>18</sup>Sahel and Vesala (2001) describe a range of indicators that may be useful for financial stability analysis.

<sup>19</sup>See the IMF's Dissemination Standards Bulletin Board <http://dsbb.imf.org/Applications/web/sddsnsdppage/> for data on countries that subscribe to the Special Data Dissemination Standard and <http://dsbb.imf.org/Applications/web/gdds/gddscountrylist/> for data on countries subscribing to the General Data Dissemination System. See also <http://www.imf.org/external/country/index.htm> for copies of IMF surveillance documents and Article IV Reports, which include macroeconomic data and analysis.

Structural indicators on ownership and market shares, aggregated balance sheet data, and flow of funds accounts can all provide useful information on the structure of financial markets. This information is typically available from the central bank or supervisor. Financial soundness indicators of the type listed in Tables 1 and 2 provide useful information on the health of the financial sector,<sup>20</sup> and are generally available from these agencies.

### **Constructing and calibrating scenarios**

Historical data on financial market prices can be useful in constructing scenarios and calibrating the size of shocks. A long time series of daily data (e.g., ten years) on key variables such as interest rates, exchange rates and equity prices (including the major stock market indices) can provide useful context for the size of shocks. For example, knowing the largest change in interest rates, exchange rates, and equity prices over a one day, one month, and one year horizon can help to inform the discussion of plausible orders of magnitude for shocks. A similar time series for broader macroeconomic variables (discussed above) can prove helpful in calibrating the simulation model.

### **Balance-sheet implementation**

Implementing a stress test requires a broad array of information on the balance sheet and income position of financial institutions. Ideally, data should be collected on an institution-by-institution basis, to enable the researcher to understand the location of different risks and concentrations and enable a comparison across institutions.<sup>21</sup>

One component of stress testing of financial systems is the use of sensitivity tests or single-factor stress tests, where the sensitivity to a single factor (e.g., a change in the exchange rate) is assessed. Information that may be useful for conducting sensitivity tests include the following:

- For *interest rate risk*, data on the maturity breakdown (or maturity “buckets”) for assets and liabilities can be useful in understanding balance sheet sensitivities. This data shows the time to next repricing of assets and liabilities, classified by maturity (e.g., one day or less, one day to one month, one month to three months, three months to six months, six months to one year, one to five years, over five years etc). If available, maturity breakdowns of assets and liabilities in local and foreign currencies can also be used to understand sensitivity to foreign interest rate shocks. Data on the duration of each bucket or of the overall asset and liability portfolio can also prove

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<sup>20</sup>See IMF (2003b) for a discussion of financial soundness indicators, and IMF (2003a) for information on their compilation.

<sup>21</sup>The U.S. Securities and Exchange Commission’s EDGAR Database has a wide range of information on large, internationally active banks, including their financial reports. See <http://www.sec.gov/edgar/searchedgar/webusers.htm> for further details.

very useful for understanding sensitivity to interest rate risk, although this data is usually more difficult to obtain.

- For *foreign exchange rate risk*, data on the net open position by currency can be used to understand the sensitivity of balance sheets according to different currencies.
- For *credit risk*, data on the loan-loss provisions held by the banks against various categories of assets and exposures can be used to understand the credit quality of the existing loan book, while new provisions provide an indication (albeit lagging) of the evolution of credit quality. For financial institutions that have more sophisticated risk management systems, information on banks' own internal credit ratings distributions and associated metrics (such as default and recovery rates, transition matrices, etc.) can be used to understand portfolio characteristics and dynamics. Data on exposures by geographic region, industry, or product type can provide additional information on concentrations of risk.
- For *liquidity risk*, data on the sources and uses of funds, broken down by maturity, can enable an analysis of the sensitivity of balance sheets to liquidity risk. This data could include the structure of deposits and other liabilities (including interbank lines) and their associated turnover rates, and on the assets side the stock of liquid and near-liquid assets that could be used as collateral or sold quickly to realize cash.

### **Data quality**

A professional approach to the statistical issues involved in stress testing is crucial to obtaining support and collaboration of banks and other cooperating institutions and ensuring the quality of the results. The IMF has developed a framework for assessing data quality and addressing and promoting good statistical practices, called the Data Quality Assessment Framework (DQAF).<sup>22</sup> Key elements of this framework include assurances of integrity, methodological soundness, accuracy and reliability, serviceability, and accessibility.

In some instances, for example where the quality of reported data or the interpretation of accounting standards are subject to debate, it may be desirable to adjust the balance sheet numbers prior to being shocked, or after the fact when expressing the results in terms of capital or some other ratio. Such an adjustment may be justified if the supervisor or regulator has reason to doubt the accuracy of balance sheet information, or if they feel that making some adjustments to the data (e.g., disallowing some items in the definition of tier one capital) provides a more accurate picture of the true risk underlying a portfolio.

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<sup>22</sup> <http://dsbb.imf.org/Applications/web/dqrs/dqrsdqaf/>

## Interpretation of results

Once a numerical estimate of a stress test is produced, it is often useful to scale the result to make it comparable across institutions and time. Indeed, the results of stress tests are often expressed in the form of a financial soundness indicator. Typically three types of denominators are used: capital (representing the ultimate ability of an institution to bear losses), income (representing the ability of an institution to absorb losses from ongoing operations without resorting to capital or other sources of funds), and assets (representing the significance of the shock to the total balance sheet of the institution involved). Thus, to facilitate the interpretation of results, it is useful to have information on the capital, income, and assets of the institutions involved in the stress test:

- For *capital*, information on tier one capital,<sup>23</sup> particularly shareholders funds (consisting of common stock, disclosed reserves, and retained earnings) provides a useful measure of the ability of the institution to absorb losses that is not affected by the treatment of goodwill, deferred tax credits, or innovative financial instruments. Total capital also provides information on additional sources of funds to absorb potential losses.
- For *income*, a range of definitions can be used, including core cash flows such as EBITDA (earnings before interest, taxes, depreciation, and amortization), ordinary income (operating income plus nonoperating income and expenses before deduction of extraordinary items) and profits before and after taxes.
- For *assets*, total assets provides a useful measure of the scale of the balance sheet. Other potential measures include quick assets (generally cash and marketable securities and short-term receivables, which is a rough estimate of assets that can be liquidated at short notice), and current assets (generally quick assets plus inventories).

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<sup>23</sup>Often referred to as core capital or original own funds.

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