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## Quantitative Assessment of the Financial Sector: An Integrated Approach

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**Abstract**

**This Working Paper should not be reported as representing the views of the IMF.**

The views expressed in this Working Paper are those of the author(s) and do not necessarily represent those of the IMF or IMF policy. Working Papers describe research in progress by the author(s) and are published to elicit comments and to further debate.

This paper suggests a strategy designed to make best use of the available quantitative techniques of financial sector assessment. It incorporates early warning systems, financial sector forecasts, stress tests for systemically important financial institutions, interbank contagion analysis, and corporate and household financial indicators. It will seldom be possible to employ every one of these techniques, but the wider the range of methodologies used, the greater may be the insight into the strengths and vulnerabilities of the financial sector. The quantitative assessment is always complemented by a qualitative assessment, including reviews of relevant standards and codes.

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## I. INTRODUCTION

The high incidence of financial instability and crisis, from the late 1990s to the present time, has spurred the development of analytical methods for the assessment of the robustness of the financial sector, its exposure to risk and its vulnerability to shocks. The present article reviews the quantitative methodologies which are currently available, discusses how they are employed, and outlines a framework within which they may be combined. The quantitative framework fits within the broader framework for financial stability, which also includes the assessment of the financial sector infrastructure (see Houben, Kakes and Schinasi, forthcoming<sup>2</sup>). In practice, quantitative methodologies, such as those discussed here, are used together with expert judgment and a wealth of institutional and legal circumstance, to assess financial system stability. Quantitative tools include indicators of financial sector soundness, early warning systems, sensitivity analysis and extreme scenarios (“stress tests”), and financial forecasting. Many of these tools are used by central banks and other regulatory bodies, the Bank for International Settlements, the World Bank and the IMF, though some which have been suggested in the academic literature are not yet in common use.

Surveys of methodologies for financial sector analysis include the Bank for International Settlements (BIS, 2001), Evans and others (2000), Blaschke, Jones, Majnoni and Peria (2001), and Sundararajan and others (2002). The BIS volume comprised papers reporting on the financial assessment practices of the European Central Bank and supervisory agencies of selected member countries of the Organisation for Economic Cooperation and Development (OECD), including the Bank of England, the Bank of Mexico, the Norwegian central bank, the Bank of Finland and the U.S. Federal Reserve. At the time of the survey, some central banks relied mainly on the use of aggregate macroeconomic and prudential data, while others made extensive use of supervisory data on individual financial institutions. Some relied heavily on models of the financial sector, while others used a more eclectic approach.

Evans and others (2000) popularized the use of what are now referred to as financial soundness indicators (FSIs)<sup>3</sup> among the IMF’s membership. Blaschke, Jones, Majnoni and Peria (2001), which surveyed stress test methodologies, has become an essential manual in the conduct of this type of analysis in the Financial Sector Assessment Program (FSAP), a service offered jointly by the IMF and the World Bank to member countries. It provides a comprehensive guide to a variety of test methodologies, and a step-by-step procedure for setting up the tests. Sundararajan and others (2002) reported on the results of a survey of Fund member countries’ usage of FSIs. That survey has played an important role in ongoing efforts to identify those indicators which are most informative of the strengths and vulnerabilities of the financial system, and the preparation of definitions which will allow

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<sup>2</sup> In addition to the quantitative analysis which is the focus of this paper, the Houben-Kakes-Schinasi paper also implies a need to address a hitherto neglected aspect of their comprehensive definition of financial stability, viz., the cost of allocation inefficiencies, across sectors and over time.

<sup>3</sup> Referred to in that volume as “macroprudential indicators.”

them to be measured uniformly for comparative purposes. A recent survey of stress tests undertaken by IMF and World Bank FSAP missions has been published on the IMF's website.<sup>4</sup>

In this paper, quantitative methodologies are discussed in three categories: use of FSIs, including establishment of benchmarks and the development of early warning systems for financial distress; methods for sensitivity analysis and scenarios, usually referred to as stress tests; and financial forecasts, linked to, or derived from, macroeconomic forecasts. Sections II to IV of this paper deal with each of these categories in turn. Section V describes a framework for a comprehensive quantitative assessment of the financial sector, incorporating all the available techniques. It is suggested for use, as at present, in conjunction with qualitative analysis, which is not the subject of this paper.<sup>5</sup> This paper reflects the state of the art; these techniques are all under development, and major deficiencies remain to be addressed (for example, see Goodhart, 2004).

## II. USE OF FINANCIAL SOUNDNESS INDICATORS

Much analysis of the financial sector, by national institutions as well as the Fund and the World Bank, is based on the use of a composite of macroeconomic and prudential indicators, which economic literature suggests should capture sources of vulnerability to widespread financial failure or crisis. They include macroeconomic variables that have a direct impact on the balance sheets and profit and loss of financial institutions, such as interest rate changes or other financial prices; macroeconomic variables that have an indirect effect, for example by reducing collateral values or borrowers' ability to service their obligations to banks; prudential indicators of the adequacy of bank capital, the quality of bank assets, the efficiency of management, the robustness of earnings, the adequacy of liquidity, and the coverage of market risk (the CAMELS ratios); measures of exposure to interbank contagion; and measures of exposure to contagion from abroad. Comprehensive discussion of FSIs appears in Sundararajan and others (2002) and Evans and others (2000), and the IMF has issued a draft guide for their compilation (IMF, 2003a).

### A. Judgmental Use of FSIs

Most current analysis of FSIs is judgmental, in conjunction with other tools of financial assessment. The Financial System Stability Assessments (FSSAs), published by the IMF for several countries, to provide a comprehensive, concise overview of the findings of FSAP teams, all now include a table of FSIs, and a discussion of their trends and implications. The IMF's periodical *Global Financial Stability Report* also makes use of FSIs, including, in the December 2002 issue, a novel risk appetite index, and similar indices from the private

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<sup>4</sup> <http://www.imf.org/external/np/fsap/2003/review.htm>.

<sup>5</sup> For a discussion of the other elements that go into the IMF-World Bank financial sector assessments, see IMF and World Bank (2003).

financial sector. FSIs are prominent in the discussions in the financial stability reports published by several central banks. The Bank of England (2003), whose report is typical, includes a discussion of trends and prospects of ten largest banking groups' profits, equity, assets, funding, liquidity, credit quality, market risk, interest rate risk and exposure to inter-bank contagion. There is detailed discussion of factors that might affect the FSIs, such as international financial developments, corporate performance in the United Kingdom and the macroeconomic outlook (see the Appendix).

There are ongoing attempts to provide benchmarks and norms for the evaluation of FSIs. A database of comparable information is the first step in this direction. The draft manual on FSIs previously mentioned provides a basis for building such a database, by ensuring that data from national sources are comparable. For the time being, and in the absence of benchmarks, the analysis of FSIs has depended on the identification of changes in trend, major disturbances and other outliers.

The analysis of FSIs at the aggregate level may be complemented by an examination and discussion of FSIs for individual institutions. How this might most usefully be done will depend on the characteristics of the banking system. A possible point of departure is to identify outliers, banks whose indicators are substantially worse than their competitors'. Where there is a sufficiently large number of banks, peer groups of banks with similar characteristics (size, ownership, specialization) may be set up for this comparison, and competitive norms for various indicators may be inferred, for each group.<sup>6</sup> In countries where the banking system is heavily concentrated, it may be sufficient to focus on those major banks that are of systemic importance.

## **B. Signaling Models**

There are several suggested ways of combining FSIs, so as to provide a better overall assessment of vulnerabilities, and, possibly, early warning of systemic financial losses. They include Caprio's (1998) scoring system to show whether a banking system is predisposed to crisis, and models by Kaminsky, Lizondo and Reinhart (1998), Goldstein, Kaminsky and Reinhart (2000), and Edison (2000), based on thresholds for different lists of selected FSIs, with different weighting schemes for combining them. The thresholds were chosen with a view to maximizing the signal-to-noise ratio for each variable. Methodologies of this kind are used by the IMF for the *Global Financial Stability Report*, by the Bank of England (See Haldane, Hoggarth and Saporta, 2001), and others (usually in combination with other quantitative methodologies). Weighted averages and similar combinations of FSIs are used by financial institutions in the private sector to provide summary indices for financial markets. The *Global Financial Stability Report* compares the results of the IMF's in-house analysis with selected private sector risk indicators, in arriving at an overall assessment.<sup>7</sup>

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<sup>6</sup> A method of establishing peer groups, for the Eastern Caribbean Currency Union, appears in Sahely and Jacobs (2000).

<sup>7</sup> These indicators include a risk appetite index (based on a correlation of rank of risk and rank of excess returns); a liquidity, credit and volatility index (published by J. P. Morgan),  
(continued)

### C. Logit, Probit, and Discriminant Models

A more statistically robust relationship between a variety of indicators, and financial system weaknesses, is specified in models using probit and logit estimation, and discriminant analysis. Probit models are used to estimate the contribution that each FSI in a multivariate equation makes to the probability that financial failure (however defined in that equation) will occur. (The logit model is similar, and uses a logistic specification.) Discriminant techniques allow for the identification of those FSIs which signal the presence of financial failure, with the highest probability. Logit models were proposed and estimated by Demirgüç-Künt and Detragiache (1998), Gonzalez-Hermosillo (1999), Mulder, Perrelli and Rocha (2001), and Bussiere and Fratzcher (2002). Of these, Gonzalez-Hermosillo combines prudential indicators and macroeconomic variables, and Mulder, Perrelli and Rocha also include corporate balance sheet indicators and scores based on institutional features; the others use macroeconomic variables only. Discriminant analysis, incorporating macroeconomic and prudential variables, appears in Worrell, Cherebin and Polius-Mounsey (2001), and in Polius and Sahely (2003).

The unsatisfactory out-of-sample forecasting power of available models has led to what, in the author's opinion, is an unjustified waning of interest in this type of modeling. Logit/probit type models are currently employed only in countries like the United States, where the large number of institutions makes frequent on-site inspections impractical. However, models of financial failure may yet fulfill their early promise, as databases of observations on the prudential variables expand and multiply. In addition, many of the models tested for the probability of systemic financial failure or financial crisis, which, though very costly, is, for individual countries, a relatively rare occurrence. Single country models are appealing, because their parameters will more faithfully reflect the many country-specific circumstances affecting financial performance.<sup>8</sup> However, it is often not possible to obtain sufficient crisis points, for a single country, to permit country-by-country testing, and it is difficult to find a definition of financial crisis sufficiently general to allow for cross-sectional tests. A more promising approach, reflected in the papers by Polius and Sahely (2003) and by Worrell, Cherebin and Polius-Mounsey (2001), is to test for the risk of failure of individual financial institutions, and use the results to forecast whether there is high risk of failure of a large number of institutions, institutions with a large market share, or institutions with the potential to cause contagion. Models of this kind do not forecast crises, and therefore do not suffer from the problems of identification, discussed in Bell and Pain (2000), which plague early warning models of crisis.

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which combines yield differentials in U.S. treasuries, U.S. dollar swap spreads, and a variety of other financial prices; and an index published by Credit Suisse, which draws on similar range of market variables, in an econometric model (see IMF, 2002, Box 3.1).

<sup>8</sup> For example, parameters might vary with the degree and nature of financial competition, access to international financial markets, and the quality of supervision and regulation.

#### **D. Forecasts of Volatility**

Extreme volatility of financial prices, which may be interpreted as a reflection of market uncertainty, should in principle help to warn of impending financial failure. A potentially fruitful research program, therefore, seeks to forecast these volatilities, which may then be used to define thresholds or norms for vulnerability indicators, or be incorporated into probit or logit equations, along with other indicators. However, studies of financial volatility to date have only hinted at this possible use of volatility measures. Morales and Schumacher (2003) suggest the use of market volatility as a financial soundness indicator, offering an example from Israel. Also, in a test of the volatilities of interest rates, exchange rates and stock market indices for a large number of countries, Worrell and Leon (2001) were not successful in identifying reliable thresholds, a result they attributed to the low frequency of their (mostly monthly) observations. An extensive discussion of volatility and its financial implications appears in Aizenman and Pinto (2004); their chapter on finance and volatility is generally skeptical of the results to be expected from early warning systems.

### **III. STRESS TESTS**

Tests of the sensitivity of the financial sector, to extreme events, extreme scenarios and contagion among financial institutions, have become an integral part of the regular financial reports published by many central banks and regulators, and the reports of FSAPs. Stress tests are designed to explore vulnerabilities to events which have a low probability of occurrence, but which, should they occur, could prove extremely costly. They are also helpful for contingencies whose probability of occurrence it is difficult to estimate. They complement analyses which deal with vulnerabilities which are highly probable, for which expected losses are small, unless the financial system is on the brink of a crisis.<sup>9</sup> Most common are tests of sensitivity to individual risk factors, such as a sharp rise in interest rates, a rapid depreciation of the exchange rate, or a collapse of asset prices. Sensitivity tests are often combined with exercises to adjust the balance sheets of financial institutions to reflect perceived weaknesses such as overvaluation of assets. Evaluation of the financial system's resilience to scenarios which combine several shocks is also quite common. Stress tests usually focus on the adequacy of the capital base of the financial system, were it to be faced with a shock, with a few tests also considering the implications for profitability and liquidity of the financial system.

Stress tests are rough estimates of the losses that might be incurred in any given contingency, and there are many imponderables in setting them up and calibrating the size of the shock to be tested (see Hilbers, Jones and Slack, forthcoming). In practice there is often a wide range of opinion as to what constitutes a plausible, if improbable, shock. Historical experience may

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<sup>9</sup> When they are undertaken at the level of the individual institution, therefore, stress tests complement banks' internal models of risk exposure, such as value-at risk (VaR) models, which are often used to measure risks from events that have high probability of occurrence (see Austrian National Bank, 1999).



not be a useful guide, because there has been no recent crisis, or because recent macroeconomic or environmental shocks have had little adverse impact on the financial sector, or because there have been important changes in financial structure since the last crisis. Moreover, the stress test methodologies available do not fully capture the multifarious and dynamic financial system responses to any shock, and some balance sheet positions may fluctuate rapidly and with wide amplitude, so that results vary depending on the time of test.

### **A. Individual Shocks and Balance Sheet Adjustments**

Many sensitivity tests for individual shocks and balance sheet adjustments consist of applying changes directly to the most recent balance sheets and profit and loss statements of individual financial institutions. In the case of very large financial institutions with internal systems of risk measurement, these institutions may be required to conduct the test, using their own value-at-risk (VaR) models, to determine sensitivity to shocks specified by the regulator. The selection and magnitude of the shocks to be evaluated is a matter of informed judgment, taking account of the country's economic characteristics (for example, openness to trade and finance), the structure of the financial system (for example, the relative importance of banks), and historical crisis episodes. If the number of institutions is unmanageably large, a subset may be chosen, of institutions with sufficient coverage to include all systemic vulnerabilities. In an internal review of FSAPs recently conducted by the IMF, the most frequent tests were for shocks to interest rates, exchange rates, credit quality, and the prices of equity and real estate. Liquidity shocks were also a source of financial vulnerability, especially in countries which are heavily dollarized.

### **B. Aggregate Shocks and Correlated Shocks**

Recent financial crises have witnessed simultaneous shocks to most or all of the variables just mentioned. Stress tests therefore routinely include an evaluation of the simultaneous impact of most or all shocks, usually by simple aggregation of the effects of the outcomes of the individual shocks.<sup>10</sup> Increasingly, however, shocks to credit quality are being derived from models in which credit quality depends on economic performance and prices, through which shocks to output, exports, interest rates, terms of trade or other prices may be transmitted to financial institutions.<sup>11</sup> Examples include Arpa, Guilini, Ittner and Pauer (2001), Andreeva (2004), and Kalirai and Scheicher (2002). A few central banks have linked their financial sectors to macroeconomic forecasting models, allowing them to test the financial implications of scenarios in which a single shock, such as a sharp exchange rate

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<sup>10</sup> Often a single shock will have effects via more than one channel (for example, an interest rate change may affect both credit and market risks), and these effects should also be aggregated.

<sup>11</sup> Models of this kind are surveyed in Blaschke, Jones, Majnoni and Peria (2001). Alternative measures of the impact of exchange rate changes on credit quality have been suggested, for example, by Wilson, Saunders and Caprio (2000). The relationship between credit risk and economic cycles is explored in Lowe (2002).

depreciation, generates shocks to domestic prices, interest rates and financial balances. Models of this kind are discussed in Section IV.

### **C. Interbank Contagion**

Contagion within the financial system, from one institution to others, may be a source of vulnerability, providing a mechanism by which the failure of an institution which is not itself of systemic importance may trigger widespread failure. Healthy financial institutions may be affected by means of their interbank exposures, or through their participation in settlement systems for large value payments and securities. The actions of a failing bank, if it is large enough, may cause contagion through its impact on other institutions with which many other banks have exposures. Another channel of interbank contagion, suggested in recent literature (Diamond and Rajan, 2002), may arise where a bank that is subject to a deposit run reduces aggregate liquidity available to the financial system, as it liquidates assets in an attempt to meet its depositors' claims. The ensuing liquidity shortage affects other institutions, and may spur additional insolvency, should the first bank fail.

Quantitative measures of the risk of contagion, suitable for use in financial sector assessment, are now being developed.<sup>12</sup> Assessment of vulnerability to interbank contagion is reported in very few countries. At the Bank of England, it is based on analysis of interbank exposures, and common ownership patterns among financial institutions (see Bank of England, 2003, and Wells, 2002). The Sveriges Riksbank conducts stress tests for bank defaults on the interbank market, failure of foreign counterparties, and loss of foreign exchange settlement exposures (Blavarg and Nimander, 2002). In a survey of tests of systemic risks, De Bandt and Hartmann (2000) listed other empirical tests of interbank contagion:

- tests of autocorrelation of bank failures with later bank failures;
- tests to determine whether the survival time of banks decreased during bank panics or periods of failure of other banks;
- tests of the effect of 'news' on bank failure; and
- tests of the effect of news on market perception of bank soundness, reflected in interbank risk premiums.

Such tests have been used in academic studies, but only for the U.S. Also, there are no empirical methodologies in use for testing contagion across borders at the level of the individual institution (for a survey of cross border empirical tests of contagion, see Pesaran and Pick, 2003).

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<sup>12</sup> For example, see Elsinger, Lehar and Summer (2002).

#### **D. Impact of Deterioration of Corporate and Household Balance Sheets**

A growing number of financial sector assessments, both by central banks and by FSAP teams, include an analysis of vulnerability to deterioration of corporate and household balance sheets. It is to be expected that a severe contraction in income or a sudden liquidity shortage will impair the capacity of highly-indebted firms and households to honor their obligations to financial institutions. The deterioration of corporate finances has been blamed for magnifying the scope and depth of the East Asian crisis, in particular (see Kim and Stone (1999), Lim (2003) Claessens, Djankov and Xu (2000) and Lindgren and others (1999)). A growing number of studies have explored the channels by which macroeconomic shocks, corporate finance and the banking system interact. The most common and direct is the effect that a large devaluation may have on the debt service costs of corporations that have borrowed in foreign currency (see, for example, Wilson, Saunders and Caprio, 2000), but other more complex interrelationships have been estimated. For example, Bris and Koskinen (2002) show how exporting firms' debt servicing capacity may improve, and their investment incentives strengthen, with a devaluation, even when the firm has borrowed in foreign exchange; Kim and Stone (1999) demonstrate that the attempts of highly leveraged firms to sell assets in order to avoid bankruptcy may cause a liquidity crunch for the system as a whole; and Eijffinger and Goderis (2002) show how the possibility of widespread corporate bankruptcy may affect exchange rate policy and financial stability.

Member countries of the IMF are encouraged to compile, monitor and disseminate indices of corporate and household indebtedness, earnings, and debt service, and a record of corporate bankruptcies (Sundararajan and others, 2002). Many published financial stability reports (FSRs) contain assessments of corporate and household balance sheets and financial indicators, and some also discuss the possible impact on credit quality of shocks to indicators, such as debt-to-income ratios, debt-to-asset ratios and liquidity ratios, of nonfinancial institutions.

There is ongoing interest in the improvement of econometric methodologies for forecasting corporate and household financial performance, and their impact on the financial system. The Norges Bank has compiled a unique database of bankruptcy probabilities for corporates, which is being incorporated, along with variables such as interest rates and house prices, in estimates of the vulnerability of banks to credit loss (see Andreeva, 2004, and Froyland and Larsen, 2002). The Bank of England also employs a large database of corporate and household financial indicators, described in Benito and Vliege (2000), in analyzing the vulnerabilities of nonfinancial sectors and the risks to which they may be exposed under contingencies such as a fall in asset prices (Benito, Whitley and Young, 2001, and Bunn, 2003). Other approaches which have appeared in recent literature include Gray's (1999) model for estimating the sensitivity, to exchange rate and interest rate changes, of the present value of corporate liabilities; the use of an indicator such as the interest coverage ratio<sup>13</sup> to infer the sensitivity of asset quality to corporate financial performance (Heytens and

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<sup>13</sup> The ratio of interest payments to earnings before interest, taxes, depreciation, and amortization (EBITDA).

Karacadag, 2001); and the use of the contingent claims approach to determine corporate and economy-wide vulnerabilities (Gapen, Gray, Lim and Xiao, 2004). Mulder, Perrelli and Rocha (2001) include corporate indicators, along with macroeconomic variables, financial sector variables and institutional scores, in an early warning model of exchange rate crises, which, as is shown later, may be used in financial stability assessment.

#### **IV. MODEL-BASED FINANCIAL FORECASTS**

##### **A. Use of Macroeconomic Forecasts as Inputs**

Both early warning systems, discussed in Section II, and stress tests, discussed in the previous section, are designed to explore the implications of extreme situations: in the first case, to determine the likelihood of a crisis, and in the latter, the capacity of the financial system to survive a crisis. However, most financial sector analysis begins with a discussion of the probable outlook for the financial sector, rather than these possible, but unlikely, eventualities. With few exceptions, the outlook is based on a qualitative analysis of FSIs, but in a few cases the financial outlook is derived from the central bank's macroeconomic forecasts.

At the Norges Bank, for example, an overall financial forecast is derived from a structural macroeconomic model, and this provides inputs for the analysis of debt capacity of firms and households, and banks' credit quality. The analysis also incorporates a separate model for risk classification of enterprises, based on leverage and liquidity indicators (see Eitrheim and Gulbrandsen, 2001). The Bank of Finland combines analysis based on FSIs and a banking sector forecast which is characterized as a "satellite model" of the Bank's macroeconomic model. Mutual interaction between the financial and real sectors is allowed for, in an iterative process which allows for judgmental inputs. The forecast is then subjected to sensitivity tests (see Virolainen, 2001). The Bank of England conducted a model-based assessment of banks, at the time of the IMF FSAP for the United Kingdom: scenarios for stress tests were derived from the central bank's structural macroeconomic model, the parameters of the shock variables were calibrated using the forecast variances of the model, and the banks undertook stress tests based on these parameters, reporting the results to the Bank of England. These results were compared with aggregated stress tests performed by the authorities (see Hoggarth and Whitley, 2003). A model-based financial forecast has been proposed – but has not yet been implemented – for the Central Bank of Barbados (see Greenidge, Ward and Chase, 2001). Forecast values of capital adequacy, profitability and liquidity of the financial system, derived from the Central Bank of Barbados' structural macroeconomic model, are used as benchmarks for comparisons of alternative scenarios, including the extreme scenarios used in stress tests.

##### **B. Early Warning of Exchange Rate Crises**

In contrast to the situation with respect to the financial sector, there is a wealth of early warning models of exchange rate crises (which we will refer to as EWS-ER models). They may be used in the analysis of financial sector stability because, as is widely documented, exchange rate crises are often accompanied by financial crises, and the source of financial

sector vulnerability is often exchange rate or foreign currency risk. A useful survey of the so-called first and second generation of currency crisis models (where speculative attack is motivated by inconsistent policies and self-fulfilling prophecies, respectively) is to be found in Flood and Marion (1999). In the *Global Financial Stability Report*, the IMF uses, among several other tools, EWS-ER forecasts derived from a model that uses only macroeconomic variables, and a second that also includes corporate indicators and a legal regime variable (Berg, Borenzstein, Milesi-Ferretti and Pattillo, 2000). The Kaminsky-Lizondo-Reinhart model, often quoted, uses a larger number of aggregate macroeconomic and aggregate financial variables. These models are valuable because they provide estimates of the probability associated with exchange rate forecasts, rather than for their admittedly questionable ability to predict crises.

## V. QUANTITATIVE ASSESSMENT: AN INTEGRATED APPROACH

Using these available tools, it is possible to design a set of interdependent tests which together give an exhaustive picture of the health of the financial system, subject to qualifications to be mentioned in the conclusion. Such an assessment might include the following:

- An early warning system for individual financial institution failure, which may be termed the Early Warning System for Financial Institutions (EWS-FI), predicting which institutions are most vulnerable to failure;
- A financial sector forecast, derived from the macroeconomic forecast, for countries where macroeconomic forecasts are routinely produced;
- Stress tests of individual financial institution balance sheets and income-expenditure statements, adjusted for known or suspected weaknesses, and incorporating financial sector forecasts (if the number of institutions is too large, these tests would be conducted on a selected group of systemically important institutions, as is the current practice);
- Interbank contagion tests, associated with each of the above outcomes for individual financial institutions;
- Forecasts of corporate and household performance, and their impact on the financial sector; and
- Estimates of the probability of exchange rate crisis from an EWS-ER model, used as a benchmark for re-calibrating the exchange rate shock, if necessary.

### A. Early Warning Systems for Financial Institution Failure (EWS-FI)

The development of econometric models to predict bank failure is a potentially fruitful exercise, even though early results are often unreliable because of the paucity of observations. Polius and Sahely (2003) use an approach which enriches the set of impaired institutions, by using as the dependent variable banks that are subject to intensive central bank scrutiny, before they have reached the stage of failure. In general and over time, observations will accumulate, including instances of failure. Also, it may be possible to extend data sets by incorporating near-banks and non-bank deposit-taking institutions, or by carefully mining archival data. Meanwhile, vital work can be done on the refinement of models. With time, richer data sets and more robust specifications should produce more

reliable forecasts. The best available specification would appear to be a logit model, with individual financial institution impairment, solvency or failure as the dependent variable, and, as arguments, selected CAMELS ratios, interest rate changes, inflation, exchange rate changes, asset price changes, and indices of real output or sectoral growth. Considerable experimentation will be needed, for each country, to find the most informative mix of variables, taking account of the number of available observations and the need for high degrees of freedom for robust estimation. Until reliable models are developed, this aspect of the assessment will continue to be based on the qualitative analysis of FSIs.

### **B. Financial System or Financial Institution Forecasts**

A second element of the integrated system for quantitative assessment is a framework for deriving forecasts of financial sector variables from a macroeconomic forecast. If possible, this should be done at the level of individual financial institutions. That would permit use of predicted financial variables in the forecast of financial institution failure, using an EWS-FI model, as well as the use of predicted financial variables as points of departure for stress tests. In effect, the expected evolution of financial performance would be stressed, rather than the actual performance. However, frameworks for linking the performance of individual financial institutions to macroeconomic performance are not well developed, and, for the most part, only aggregate forecasts are possible. It may still be possible to derive an approximation of individual financial institution performance, for example by applying the current distribution of individual financial system indicators to the forecast. In this example, if the forecast is made up of the mean value of NPLs, let us say, the distribution of NPLs around the most recent value of the mean is applied to the forecast value of the mean. Failing this, the aggregate forecasts are useful in evaluating the assumptions used for EWS forecasts and stress tests. Reverting to the example of NPLs, the assumptions about individual financial institution NPLs, employed in the EWS or stress tests, can be accumulated for the system as a whole, and compared with the aggregate forecast. This offers a measure of the probability associated with the assumptions used for the EWS and stress tests.

The variable most often forecast econometrically is NPLs; deposits and loans are sometimes also forecast with the aid of econometric models. Financial prices such as interest rates, exchange rates and securities market prices are usually available from macroeconomic forecasts or as policy inputs. Other financial variables such as the supply of government securities are also output by macroeconomic models, varying with expected economic performance and fiscal and monetary responses. In sum, at the aggregate level it may be possible to forecast aggregate financial balance sheets, profit and loss, deposits, loans and NPLs. At the level of individual financial institutions, it may be possible to forecast selected CAMELS, either directly or by derivations from an aggregate forecast.

### **C. Stress Tests**

Forecast financial variables provide valuable material for the analysis of financial vulnerability, in circumstances that have a high probability of occurrence. The EWS-FI, forecast using financial variables predicted by a macroeconomic model, or using assumptions based on informed judgment, yields a forecast of financial institutions in danger of failure, with a high degree of probability. Armed with this information, one may proceed to define

stress tests which go beyond these probable outcomes, to probe the resilience of the system in circumstances which (a) are possible, but beyond what is likely, or (b) where there is little historical experience on which to calculate the probability of an occurrence. The procedure might be along the following lines:

- Correct individual financial institution data for known and suspected balance sheet weaknesses such as under reporting of NPLs, under provisioning, overvaluation of capital, etc., and generate adjusted values of selected CAMELS ratios;<sup>14</sup>
- Input the forecast balance sheet variables, profit and loss, and other financial variables such as interest rates, and generate new values for the selected CAMELS ratios;
- Apply shocks to individual financial variables such as credit quality, interest rates, asset prices, and exchange rates, and generate selected CAMELS ratios;
- Apply shocks, such as exchange rate depreciation, changing terms of trade, accelerated inflation, falling growth rates, etc., to the macroeconomic model, derive values of financial sector variables, and repeat the first and second steps above;

#### **D. Refinements**

In order to fully assess financial system risks, it is necessary to include the analysis of interbank contagion, for each of the outcomes generated by the tests described above. Financial institutions which appear to be healthy may be at risk because of exposures to institutions which are predicted to fail, or become illiquid, in the preceding scenarios. A battery of contagion tests should be conducted, for each failure generated by any of the above tests.

The next level of refinement is to incorporate an analysis of corporate and household balance sheet effects. An analysis of trends in corporate and household indicators, taking account of macroeconomic changes that might impact on them (exchange rate changes, for example), can help to identify scenarios for further stress tests, based on predicted corporate and household debt servicing capacities. Some Scandinavian countries with a wealth of corporate data are able to link macroeconomic forecasts to corporate indicators, thereby deriving corporate forecasts from their macroeconomic forecasts (see the Appendix).

#### **E. Early Warning Systems for Exchange Market Pressure (EWS-ER)**

Since early warning models of exchange rate crises (EWS-ER) are so much in advance of models for the financial sector, it may be instructive to forecast exchange rate changes, or exchange market pressure (EMP) variables from an EWS-ER model, and incorporate the

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<sup>14</sup> The most commonly used are the risk-weighted capital assets ratio, the return on assets or equity, and the liquid assets ratio.

outcome into the financial sector scenarios. The impact of a predicted exchange rate change, or change in the EMP variable, might be incorporated into the stress tests, both direct effects on financial institutions and indirect effects through corporate and household balance sheets and incomes. The EWS-ER predictions may also be used to evaluate the probability of exchange rate changes, and may help to define the extreme values of the exchange rate which are appropriate for the stress tests.

## VI. CONCLUSION

The methodology of financial soundness assessment is still in its infancy, and refinements and upgrades should be expected, as experience with these assessments accumulates. Each of the available techniques offers only a partial analysis, subject to a variety of qualifications and assumptions, and it is therefore necessary to employ a combination of approaches, both qualitative and quantitative. This paper suggests an assessment strategy designed to make best use of the available quantitative techniques in a complementary way. It incorporates early warning systems, financial sector forecasts, stress tests for systemically important financial institutions, interbank contagion analysis, and corporate and household financial indicators. This framework allows for individual assessments to be tailored to the structure and characteristics of each country's financial system, for example, to reflect the relative importance of nonbanks or the scope of activity undertaken by commercial banks. It will seldom be possible to employ every one of these techniques, but the wider the range of methodologies used, the greater may be the insight into the strengths and vulnerabilities of the financial sector. In addition, awareness of the available techniques and their usefulness may provide an incentive for the collection of data that could widen the scope of financial system analysis that is possible.

Nevertheless, there remains a large agenda of work to improve the tools available for quantitative assessment of the financial sector. The combination of techniques suggested in this paper does not address all the weaknesses of the available methodology, and assessments must remain qualified until issues such as the choice of time horizon and the appropriate degree of risk aversion are better understood. Also, quantitative techniques are more highly developed for analysis of banks than for other financial institutions, and more work needs to be done on methodologies for quantifying risks in insurance, superannuation funds, and capital markets, for countries where these markets are of systemic importance.



### SELECTED FINANCIAL STABILITY REPORTS

Of the countries reviewed in this note, Finland and Norway appear to have the most comprehensive approach to financial sector assessment, as reflected in their published financial stability reports (FSRs). They combine a financial forecast, consistent with the forecasts produced by their macroeconomic model, with actual and forecast indicators of corporate and household financial strength, banking and other financial soundness indicators, and stress tests. Many other countries' financial stability reports are based on FSIs, using trends and international benchmarks to inform a qualitative judgment of the systematic risks they imply. In addition, many of these FSRs employ stress tests, mostly of financial shocks such as changes in interest rates, exchange rates and credit quality, but also, in some cases, of real sector shocks. Most FSRs include an assessment of the impact of changes in corporate and household finances on the financial system, using a range of indicators, and, in some cases, an empirical test of the impact of these indicators on bank loan quality.

#### *Austria*

The Austrian National Bank's *Financial Stability Report* (Austrian National Bank, 2003) bases its financial stability assessment on an analysis of the market risk exposure of banks, indicators of corporate and household financial strength, and the performance of nonbank financial institutions. Banks are required to conduct and report the results of interest rate stress tests, and these are summarized and reported by the central bank, along with stress tests of exchange rate changes. Stress tests are not conducted for equity price changes because equities are a trivial part of banks' portfolio. The analysis of the financial strength of the banking system also includes an examination of trends in profitability, capital adequacy and liquidity. The discussion includes trends in a wide range of corporate and household indicators, such as debt to equity ratios, credit growth, number of bankruptcies, new share issues, internal financing of firms, home ownership and the share of capital market instruments in the financial assets of households. The projected growth of pension fund assets, and the search for adequate rates of return on them, was the major concern in the nonbanking sector, in the most recent report.

#### *Brazil*

The Banco Central do Brasil's *Financial Stability Report* (Banco Central do Brasil, 2003) focuses on trends in financial indicators and stress tests for the banking system, which accounts for 98 percent of financial assets. The range of FSIs examined includes the rate of growth of credit, capital adequacy, loan quality, provisioning for losses and default percentages. A credit transition matrix is employed to detect possible signs of deteriorating loan quality. Stress tests are reported for interest rate changes, exchange rate changes, deteriorating credit quality, and a combination of all these, using both a value-at-risk (VaR) model and an alternative.<sup>15</sup> In each case the impact on capital adequacy is reported.

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<sup>15</sup> A hybrid nonparametric model, based on historical data, and applying exponential smoothing.

### ***European Central Bank***

The ECB's report on banking sector stability (European Central Bank, 2003) has chapters entitled "bank performance" and "bank risk outlook." The former looks at trends in profitability, asset growth, risk management indicators, costs and capital adequacy. The risk outlook is based on trends in bank share prices, compared to the overall market performance, capital adequacy trends, subordinate debt spreads, corporate indebtedness indicators (and comparisons with international trends), sectoral loan concentrations, and housing and commercial property prices. The ECB also performs stress tests, and does modeling to link macroeconomic and prudential indicators (see Sahel and Vesala, 2001), but these results are not reported publicly.

### ***Finland***

The Bank of Finland's financial stability analysis (see Bank of Finland, 2003) employs the usual FSIs – profitability, income and expenditure ratios, capital adequacy, loan quality, current risk exposure indicators – as well as a forward-looking assessment. The latter departs from a benchmark forecast of bank profitability and solvency indicators, over a 2 year horizon, derived from a system which uses the forecasts of the Bank's macroeconomic model as its inputs (see Virolainen, 2001, and Koskenkyla, 1999). The Finnish Financial Stability Authority conducts stress tests of the effects of changes in interest rates on profits, losses from stock exchange valuation changes, via the banks' insurance affiliates, and losses due to declining property values. The Bank of Finland conducts scenario tests, comparing its benchmark forecast of capital adequacy with capital adequacy ratios (CARs) under alternatives such as stagnation of real output, a collapse of asset prices, and financial asset contagion.

### ***Indonesia***

The Bank Indonesia's *Financial Stability Review* (2003) bases its bank risk assessment on FSIs and stress tests. Trends are analyzed, and comparisons made with other Asian countries, for growth in lending, liquidity, maturity mismatches (both domestic and foreign currencies), capital adequacy, and profitability. The performance of bank shares on capital markets is also monitored. Stress tests are performed for loan quality deterioration, exchange rate and interest rate changes.

### ***Netherlands***

De Nederlandsche Bank's financial stability reports (see De Nederlandsche Bank, 2003) are based on FSIs for banks, nonbanks, corporate entities and households. They include bank profitability, CAR, loan concentration, and foreign exchange exposure; corporate bankruptcies, and new corporate bond issues; housing prices, forced sales, and the average period residential property remained on the market; stock market performance, and pension fund coverage of their estimated future liabilities. The bank uses these indicators in a flexible manner in its analysis, and the principal focus tends to change with every new issue of the report.

### *Norway*

Norway uses a structural model for financial stability analysis. An overall financial forecast is derived from the model, and this provides inputs for the analysis of debt capacity of firms and households, and banks' credit quality. The analysis also incorporates a risk classification model, where firms are classified based on the percentage of their own financing, the percentage of equity financing, and liquidity ratios (See Eitrheim and Gulbrandsen, 2001). The Norges Bank report on financial stability (Norges Bank, 2003) analyses trends in FSIs such as the spread between the yields of bank and government bonds, banks' share prices, the return on portfolios of bank shares, the volatility of returns on bank shares, the implied volatility from equity options,<sup>16</sup> and bank solvency. Projections are then made for households and firms. The household projections are based on current trends in debt expansion, and an alternative of decelerating credit growth, with interest rates in line with money market expectations. The impact of a projected fall in household consumption (in the most recent report) on firms is estimated by applying the "debt weighted probability" from the Norges Bank bankruptcy prediction model, and comparing with a baseline reported in the central bank's *Inflation Report*. The bankruptcy prediction model estimates the probability of firm bankruptcy as a logit function of firm financial indicators, size, age, and financial indicators for the industry to which the firm belongs (see Bernhardsen, 2001). The forecast nonperforming loans (NPLs) are the product of the banks' exposure to firms in the comprehensive sample, and the firms' bankruptcy probabilities. The results are compared with Moody's KMV model of the probability of debt default. The forecasts are tested for resilience to a demand shock (a decline in petroleum revenues), whose effects are traced through their impact on unemployment and property prices, which provokes a monetary response via the Taylor rule, leading to a fall in household disposable income and a worsening of NPLs, through the mechanism just described.

### *Spain*

The Banco de España's *Estabilidad Financiera* (2003) discusses trends in banking risk indicators (NPLs, credit to volatile construction and real estate sectors, emerging market risk indicators and risk management by banks), bank profitability, and bank solvency (solvency ratios, reserves, provision cover of NPLs). It also examines corporate sector indicators and household credit growth trends. As an aid to the assessment of asset quality, NPLs are presented as a function of the type of financial institution, the number of banks that lend to a given borrower, the size and term of loan, the type of guarantee, and whether the loan is denominated in euros.

### *United Kingdom*

Because of London's importance in international finance, the Bank of England's financial stability assessment (Bank of England, 2003) is based on a review of global trends in

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<sup>16</sup> Explained in Syrdal (2002).

exchange rates, capital flows, hedge funds, and the activities of major financial intermediaries and leading industrial countries, as well as a discussion of the U.K. environment with respect to household and corporate indicators and commercial property indicators. FSIs are used to infer the impact of recent developments on large U.K.-owned banks, including trends in profits, CAR, liquidity, links between financial institutions and payments exposures. Direct exposure to market risk is estimated using VaR methodologies. In the June 2003 *Financial Stability Review*, results from the IMF's Financial System Stability Assessment for the United Kingdom are referred to, but no independent stress tests undertaken by the Bank of England, are reported.

The Financial Services Authority, which is responsible for prudential and conduct of business regulation in the United Kingdom, also publishes an annual *Financial Risk Outlook*. This considers the range of economic, financial, political and legal risks facing the financial services sector in the United Kingdom, including the financial risks faced by households. The analysis is based on supervisory and other intelligence. Alternative economic scenarios are considered, along with their implications for firms and consumers.

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