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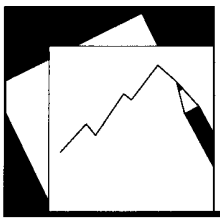

IMF Working Paper

Stress Testing at the IMF

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Stress Testing at the IMF

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Abstract

For almost a decade, the IMF has been using stress tests to identify vulnerabilities across institutions that could undermine the stability of a country's financial system. This working paper focuses on the IMF's experience with stress testing in the Financial Sector Assessment Program (FSAP). It provides background on the nature of an FSAP and the role of macro stress testing within it. It also describes how the methodology of stress testing in FSAPs has been evolving and what are fairly common approaches now being used. Finally, it discusses the main strengths and challenges for future development of macro stress testing in FSAPs and provides an overview of stress testing practice in European FSAPs.

JEL Classification Numbers: G10, G20

Keywords: Stress testing, financial stability, credit risk, market risk, liquidity risk

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[1] International Monetary Fund. The views expressed in this working paper are those of the authors and do not necessarily represent those of the IMF or IMF policy.

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I. INTRODUCTION[2]

For almost a decade, the IMF has been using stress tests to identify vulnerabilities across institutions that could undermine the stability of a country's financial system. Stress tests are typically performed as part of the Financial Sector Assessment Program (FSAP)—a joint effort by the IMF and the World Bank. Since the program's inception in 1999, the FSAP has become an essential element of the Fund's engagement on financial issues with its member countries. FSAPs have been or are being carried out for over 120 countries—two-thirds of Fund membership. FSAP reassessments (that is, updates of the original, first assessment) are also taking place, with more than 40 FSAP Updates completed or underway. Some form of stress testing has been universal in these assessments, ranging from very simple to more sophisticated exercises with associated macro modeling.

Reflecting the growing integration of financial sector work into Fund surveillance, Article IV teams have also started experimenting with stress testing as part of regular consultations.[3] It is very early days yet, and such exercises will probably be done on only a subset of countries and in a more limited fashion than what could be undertaken in an FSAP, given the broader scope of Article IV surveillance. But the direction of movement over time seems clear. It is in turn facilitated by the rapid expansion of interest in, and capacity for macro stress testing amongst the authorities in an increasingly wide range of countries.

Technical assistance on stress testing is another area of the Fund's work that has been expanding in recent years. Authorities often request technical assistance following FSAPs, with a view to improving their stress testing approaches and receiving assistance in applying the techniques. The IMF also cooperates with a number of central banks and supervisory agencies in less formal ways, such as joint projects on stress testing-related issues—projects are ongoing for instance with the European Central Bank and the Deutsche Bundesbank on innovative stress testing methodologies.

Parallel to concrete applications is methodological work on the development of stress testing techniques. This work program aims at enhancing the quality of stress tests being performed in-house as well as by country authorities. The thrust of much of this work is to take better account of macro-financial linkages, using a range of different analytical perspectives and, where feasible, using their results as cross-checks. Feedback on the different methodologies from

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[2] This paper will also be published as a chapter in a comprehensive book on stress testing, edited by the Bank of Italy and published by the Cambridge University Press.

[3] Under Article IV of the IMF Articles of Agreement, member countries undertake to collaborate to promote the stability of the global system of exchange rates and, in particular, commit to run their domestic and external policies in keeping with an agreed code of conduct. Article IV also sets forth an obligation for the IMF to "oversee the compliance of each member with its obligations under Article IV," which it does through (typically annual) Article IV consultations and reports.

inside and outside the Fund is critical in pointing to the more promising approaches for the IMF to develop and apply further.

Last but not least, the IMF has been serving as a hub for promoting macro stress tests and for fostering cooperation in this field among central banks. One example is the Expert Forum on Advanced Stress Testing Techniques, launched by the IMF in 2006. It meets approximately every year and a half with the participation of supervisory agencies and central banks that are leading the work on stress testing.[4]

This working paper focuses on the IMF's experience with the more comprehensive form of stress testing in FSAPs. Section II provides background on the nature of an FSAP and the role of macro stress testing within it. Section III describes how the methodology of stress testing in FSAPs has been evolving and what are fairly common approaches now being used, at least for more advanced economies. Finally, Section IV discusses the main strengths and challenges for future development of macro stress testing in FSAPs. The appendix provides an overview of stress testing practice in European FSAPs.

II. Background: Overview of the FSAP

The broad objective of the FSAP is to help strengthen and deepen financial systems and enhance their resilience to potential financial crises. Supported by experts from a range of national agencies and standard-setting bodies, work under the program seeks to identify the strengths and vulnerabilities of a country's financial system; to determine how key sources of risk are being managed; to ascertain the sector's developmental and technical assistance needs; and to help prioritize policy responses. The program is designed to assess the stability of financial systems as a whole, rather than individual institutions, and to emphasize prevention and mitigation rather than crisis resolution.

A key feature of the FSAP—perhaps the defining feature—is that it endeavors to take a relatively broad, holistic view of system-level risks and vulnerabilities. This means not only the main structural, institutional, and market features and activities of the financial sector, but also the financial policy framework within which the financial sector operates—in particular the strengths and weaknesses of arrangements to prevent or manage financial sector crises, and how these in turn affect financial sector behavior.[5]

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[4] The first Expert Forum took place in May 2006 at IMF headquarters; the second in November 2007 hosted by the Nederlandsche Bank; and the next meeting is scheduled for May 2009 and will be hosted by the Deutsche Bundesbank in Berlin. The IMF also participates in external working groups and programs that are active in this area, such as the Basel Committee for Banking Supervision, the Electronic Platform on Stress Testing of the Deutsche Bundesbank, and the Regulation and Financial Stability Program of the Financial Markets Group Research Centre at the London School of Economics.

[5] See IMF-World Bank (2005).

It also means applying a range of both quantitative and qualitative tools and methodologies to get at the important issues. Formal assessments of international standards and codes relevant for the financial sector, for example, are one important tool on the qualitative side, but are not always the most suitable (or cost effective) way of addressing policy issues.

Likewise, stress testing is a key quantitative tool in FSAPs but not the only one. A number of indicators are also used as a basis for analyzing the health and stability of the financial system. Among them are financial soundness indicators (FSIs)—that is, aggregated data on individual banking institutions and their non-bank clients, and indicators that are representative of the markets in which these institutions operate—and, where feasible and available, market-based data drawn from price and volatility measures of various capital market instruments. Analyses of aggregate balance sheets (macro, sectoral) and (supervisory or other) early warning systems are also used in the FSAP context.

III. STRESS TESTING IN FSAPS[6]

There is an important point of principle underlying this rather eclectic approach, under which—to reiterate—stress testing is a key tool in FSAPs, but one that is supplemented by both qualitative analysis and other forms of quantitative analysis. As stated succinctly by Bunn et al. (2005):

> *"....no single model is ever likely to capture fully the diverse channels through which shocks may affect the financial system. Stress testing models will, therefore, remain a complement to, rather than a substitute for broader macroprudential analysis of potential threats to financial stability." (p.117)*

Thus, FSAP stress testing is not interpreted as providing numerical estimates that are in themselves very precise. Rather, the benefit lies as much in the analytical process undertaken by the FSAP team and the authorities in constructing the stress testing as a means to explore potential vulnerabilities in the financial system. Stress tests are an instrument for a useful dialogue on these issues, and often too a useful learning experience.

It is also fair to say that the FSAP stress testing process has often had a longer lasting effect on countries—quite apart from helping assess financial stability at the time of the FSAP. In particular, it has encouraged policymakers to further develop their own capacities in this area, as part of the broader process of building a more specific financial stability assessment function and capacity.[7] At times this has been directly supported by Fund technical assistance, notably with a view to putting models and procedures in place which could then be uses both for FSAP stress testing and by the authorities on a more frequent, regular basis.

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[6] This section draws especially on Blaschke et al. (2001), Jones et al. (2004), and Čihák (2007).

[7] See also on this the report of the IMF's Independent Evaluation Office (2006).

FSAP stress tests are tailored to country-specific circumstances, both as to the different types of potential vulnerabilities to be subjected to stress testing, and the exact nature, coverage, and size of the shocks applied to the various risk factors. In combination with the ongoing evolution of stress testing methodologies, this has therefore resulted in quite a wide range of approaches.[8] Within this, some basic principles of "good practice" in FSAP stress testing have developed over time and are continuing to evolve.

A. Stress Testing Approaches

Stress tests in FSAPs come in several broad varieties, but are all aimed at examining the potential vulnerabilities at the system level.

On one dimension, they may either be in the form of a range of sensitivity tests addressing the impact of shocks to single risk factors in each test, possibly in a rather ad hoc and atheoretic fashion; or they may be tests focusing on scenarios in which multiple risk factors change in a fashion that is intended to be internally consistent.

On a second dimension, FSAP stress tests can be either bottom up, run by individual financial institutions, or top down, run by an organization with a focus on the stability of the whole financial system. Such an organization is typically the central bank, the financial supervisor, or the IMF. The terms bottom-up and top-down are not universally defined to mean the above, and are sometimes used to refer to another distinction described in the next bullet point.[9]

On a third dimension, and notwithstanding the ultimate focus on the system level, FSAP stress tests can be either bank-by-bank, run on the portfolios of individual financial institutions, or at the aggregate level, based on an aggregate system-wide model.

First, given the IMF's focus and comparative advantage, it is perhaps not surprising that FSAP stress tests have increasingly emphasized the design of adverse macroeconomic scenarios, and the impact of these scenarios on the creditworthiness of financial institutions and the stability of the financial system as a whole. The construction of such macro scenarios—and more generally the identification of the macro-level risk factors to be shocked—is a critical exercise in the FSAP stress testing process, whether the scenarios are applied in a bank-by-bank exercise, or only at the aggregate level.

Second, since FSAP stress tests are fundamentally intended to address the risks that arise from

[8] See the appendix for a summary of practices for FSAP stress testing in European countries. The focus is on Europe as the region with most extensive FSAP coverage to date.

[9] Financial institutions use the concepts of bottom-up and top-down stress tests in yet another way. A top-down test typically entails a common scenario or inputs applied consistently across portfolios and business units. Bottom-up tests are carried out independently by the various business or risk management units and then aggregated at the central risk management level.

common shocks, the essence of FSAP stress testing is that the same shocks are applied uniformly to all institutions—again, whether the methodology follows a bank-by-bank or an aggregate approach.[10]

Third, no careful analysis of system-level stability can afford to look only at the system-level aggregates and averages. Some attempt also needs to be made to understand the nature of the dispersion underneath the aggregates and averages, since concentrations of exposures and vulnerabilities that may be important for the system can be hidden beneath more benign-looking aggregates. Some form of bank-by-bank testing is therefore critical in FSAPs, whether or not this is informed by well-integrated and internally consistent macro scenarios. Indeed, for FSAPs the merit of purely aggregate tests lies mainly in providing supplementary analysis, especially—in the spirit of the principle of not relying too heavily on any one model—as a means of partially cross checking the results of bank-by-bank tests.

In terms of the calibration of the scenarios and shocks, the basic underlying principle for FSAP stress testing is that the shocks should be "extreme but plausible." What that translates to in any particular case can vary quite widely depending on circumstances. Some FSAP stress tests calculated the impact of the same shock or scenario for different data points in time. This procedure shows the changing risk profile over time, thereby making up to some extent for the uncertainty in the parameterization. In other FSAPs, reverse-engineered stress tests were used, i.e., the shocks were identified that bring the system's capitalization to a certain threshold (e.g., a CAR of 8 percent).

B. Stress Testing Experience

As already noted, stress testing processes and methodologies in FSAPs have evolved quite significantly since the early days of the program, and in a number of ways, as summarized in Table 1.[11] The following main points are to be highlighted.

First of all, most FSAPs conduct single-factor sensitivity analysis, but these have evolved from being central to the analysis to being more supplementary, for instance, as a means of obtaining some sense of the partial derivatives that may be associated with a broader, multi-factor scenario. In contrast, more recent FSAPs have increasingly involved explicit macroeconomic scenario analysis, of varying natures and degrees of complexity.

The testing increasingly involves national authorities directly at all levels, from the design of the methodology and selection of scenarios and shocks in agreement with the FSAP team, to the implementation or coordination of the tests, and the analysis of test results (Appendix Table 2).

[10] That is, the same shocks are applied to a given set of institutions covered within a given stress test.

[11] Appendix Table 1 lists the European countries whose FSAPs are covered in this survey. The survey focuses on European FSAPs, as Europe is the continent with the most complete coverage of FSAPs.

It also increasingly involves financial institutions directly, at least in relatively advanced systems. Institution-by-institution implementation uses the banks' own models, analyses, and judgments about the impact of the given scenarios and shocks.

In terms of risks to be considered, interbank contagion is becoming more commonly integrated into the stress testing to examine further, indirect effects of the common shocks. Typically this has been based around a matrix of mutual exposures in the domestic interbank money market.

Finally, nonbank financial institutions are also increasingly covered in FSAP stress testing, mainly insurance companies and to a lesser degree pension funds (Appendix Table 3). Most commonly, nonbanks are tested separately from the banking sector, but in a number of cases, cross-sectoral conglomerates have been tested at the overall group level.

Table 1. Evolution of Stress Testing Methodologies in European FSAPs

(In percent of all FSAPs initiated in the period)

	2000–02	2003–05	2006–07 2/
Scenario analysis	64	95	82
Contagion analysis 1/	11	38	55
Insurance sector stress testing	25	37	9

1/ Includes cross-border and interbank contagion.
2/ Includes a high proportion of less advanced countries.

Sources: Čihák (2007); and IMF staff calculations.

C. Risks Addressed in FSAP Stress Tests

FSAPs have addressed a range of different risks in stress tests, within the broad categories of credit risk; market risk (interest rate, exchange rate, volatility, and equity, real estate and other asset price risks); liquidity risk; and contagion risk.

Credit risk

Credit risk has been a key focus of FSAPs, reflecting the fact that in many countries it remains the main overall source of risk for banks, as typically reconfirmed by the stress tests themselves. At the same time, both in the FSAP context and more generally, it is also a risk area in need of enhanced assessment and management tools.

A fairly typical approach in the early days of the FSAP and still common in less developed systems or as part of single-factor sensitivity tests are mechanical exercises (Appendix Table 4). In these simple tests, banks' balance sheets are shocked directly, i.e., shocks are directly applied to nonperforming loans (NPLs) or provisions and a link to the macro economy is not modeled explicitly. Typical tests assess what would happen if banks raise their provisioning to reflect loan quality deterioration either overall or in particular parts of their portfolio, or if their largest borrowers default (concentration risk). The NPL migration and loan reclassification analysis is still an essential part in most FSAPs as part of the single-factor sensitivity tests.

Increasingly, more advanced approaches have been used that are based on loan performance data and regressions (single equation, structural, vector autoregression). A typical stress test in this category models NPLs or loan-loss provisions as a function of various macroeconomic variables.[12] Increasingly, this has also been undertaken through more sophisticated analyses of probabilities of default (PDs) and loss given default (LGD). For example, the Austria FSAP modeled default rates as a function of macro variables (see Appendix Table 4). Stressed default rates can then be used by the FSAP team and/or the authorities to conduct top-down stress tests using off-site supervisory data; or can be provided as inputs to the banks, for them to calculate (un)expected losses bottom-up using their internal models. It is also useful to analyze and discuss differences between the outcomes of the bottom-up and top-down approaches.

In this category of more advanced approaches, two methodologies the IMF has been working on are worth highlighting.

The first methodology is a portfolio credit risk model based on CreditRisk+ that has been complemented with models of PDs and LGDs with specific links to macro-financial factors.[13] The model can be applied with obligor-level or more aggregate supervisory data. Because it uses as basic input the same data required by the Basel II internal ratings-based (IRB) approach, it provides a valuable tool for financial supervisors to benchmark their credit risk evaluations. This model has been applied in several FSAPs (e.g., within Europe, Greece), and in the context of technical assistance; it has also been shared with various authorities, including the European Central Bank, the central banks of Argentina, Iceland, and Portugal, and the bank superintendencies of China, Costa Rica, Colombia, and Morocco.

The second approach uses nonparametric techniques to addresses two major constraints faced by standard macro stress testing: short time series of risk variables and lack of default dependence information. It combines three quantitative tools: (i) the conditional probability of default (CoPoD), which measures default risk through time with short time series; (ii) the consistent information multivariate density optimization (CIMDO), which measures portfolio credit risk; and (iii) the CIMDO-copula, which measures default dependence under data-constrained environments.[14] This framework for macro stress testing can be used to look at the effects of shocks on individual banks as well as at the system's level.[15] In particular, this approach allows to better quantify the impact of macroeconomic shocks on individual banks'

[12] Household and corporate portfolios are sometimes modeled separately or, data permitting, the corporate sector is disaggregated further.

[13] See Avesani et al. (2006).

[14] See Segoviano (2006a, 2006b, 2008).

[15] See Segoviano and Padilla (2006) and Segoviano and Goodhart (2008). The framework also allows to calculate a stability measure of the banking system and to measure liquidity risk and counterparty risk.

economic capital and on the banking system's economic capital—despite short time series of default probabilities and accounting for changes in correlations among banks' assets through the economic cycle. This model was used for instance in the Denmark and Lithuania FSAPs. Input data is also in line with the Basel II IRB approach.

Loan performance could also be linked to macro variables using corporate sector data (e.g., leverage and interest coverage) and possibly household data. Such approaches consider explicitly borrower characteristics that have a bearing on the ability of corporates and households to pay down their loans. Yet this requires series of microeconomic data that are often not available. Working with micro data is also time-consuming. Hence, these approaches have not been used yet in FSAPs.

The credit risk scenarios used in FSAPs have depended crucially on country circumstances and data availability. For the mechanical approaches, shocks to NPLs or provisions are typically ad hoc or based on historical banking system data or on cross-country evidence. For the more advanced approaches, scenarios are common and cover a set of macro variables such as GDP, interest rates, and exchange rates. Depending on country circumstances, the scenarios are calibrated using macroeconomic models (mostly those of central banks), the IMF's macroeconomic framework, or historical data for the country or for comparable countries. The scenarios typically range from less severe to crisis-type scenarios and include both domestic downturns and external shocks. Other specific issues have been examined where they were particularly relevant, such as cross-border lending (e.g., Austria, and Spain), foreign currency lending (e.g., Croatia), country exposure (e.g., Luxembourg), or loan concentrations in general (e.g., the Netherlands and Russia) or to specific sectors (e.g., agriculture in Belarus, information and communication technologies in Finland).

Market risk

Market risk has tended to show smaller effects in FSAPs, partly due to the shorter horizon but also presumably reflecting the fact that it is often an area better managed by banks. The analysis of market risks has used a range of different approaches. For interest rate risk analysis, some FSAPs have looked at repricing and maturity gaps, others have looked at duration, and other at value at risk (VaR) (Appendix Table 5). For exchange rate risk analysis, tests focused on net open positions in some cases and on VaR measures in other cases (Appendix Table 6).

Market risk shocks have been built on ad hoc, hypothetical, or historical movements in the relevant variables. In the case of interest rates, this may involve a parallel shift in the yield curve or a steepening or flattening of the yield curve (Appendix Table 7). For exchange rate shocks, it may involve ad-hoc devaluations or historically large depreciations and/or appreciations (Appendix Table 8). Some other risks have been tested where relevant, including equity and real estate price risk, commodity price risk, credit spread risk, and the impact on interest margins of competition risk (Appendix Table 9).

Liquidity risk

Stress tests for liquidity risk have become an essential part of the most recent FSAPs (Appendix Table 10). These stress tests have assumed shocks to deposits and wholesale funding and often include a cross-border scenario in which foreign investors and parent banks stop funding the domestic banks. In addition to funding liquidity, a few FSAPs have also stressed market liquidity by assuming haircuts on quasi-liquid assets. The shocks have been calibrated based on historical data (e.g., Croatia and France), but often had to be assumed ad hoc (e.g., Austria) as the available time-series did not include significant liquidity shortages. The results of the stress tests have most often been reported in terms of changes to a liquidity ratio measure, which has been the regulatory ratio or defined ad hoc. Some FSAPs reported the days until the banks become illiquid. Those FSAPs that looked at market liquidity also sometimes quantified the effect of shocks to liquidity on the banks' CAR.

Contagion risk

Stress testing contagion risk is an important complement to stress tests of individual institutions faced with common shocks. As noted earlier, stress testing contagion risk is becoming more common in FSAPs (see Appendix Table 10). These tests often focus on "pure" contagion, i.e., they assess whether the (random) failure of a bank causes a substantial deterioration in the capital adequacy in other banks. They are typically run in several iterations, as the contagion-induced failures can in turn induce failures in other banks, which can again lead to further failures, and so on. The channel of contagion that is mostly examined is through net domestic, uncollateralized interbank exposures (e.g., Belgium and Croatia).

While this "pure" contagion analysis is useful, it does not look at the likelihood of the failures that trigger the contagion. Hence, some FSAPs analyze interbank contagion triggered by factors influencing the whole system at the same time. To do so, outcomes of stress tests are typically used as inputs into the contagion exercise, which then quantifies the knock-on effects. The mechanics of such a macro-linked contagion analysis are similar to the simple contagion test, but it takes place in a weakened system and takes into account the likelihood of the failures that trigger the contagion. This approach was used for instance in Poland, Russia, and Austria.

IV. FSAP Stress Testing Going Forward

As the FSAP continues and is increasingly dominated by reassessments (or FSAP Updates), a range of issues arise on how its stress testing component might or should evolve further. Some of these are narrower issues about how the underlying analytical methodologies could evolve, and some are broader issues having more to do with the stress testing process in FSAPs.

A. Methodological Agenda

Looking at the methodologies first, it seems clear that the IMF, like other macro stress testers, will want to continue to work on the further development of credit risk modeling. This would

include specific modeling of distributions of PDs and LGDs, as well as correlations between banks and between portfolios to better reflect credit risk at the system level. But there are also a range of other specific areas for further development, or at least consideration in light of the challenges they may pose to stress testing:

On risk types, further work on liquidity risk is warranted, expanding existing work on funding and market (asset) liquidity risk as well as to incorporate off-balance sheet concentration risk (e.g., excessive committed and uncommitted credit lines to a single counterparty). In addition, the joint analysis of market, credit, and liquidity risk requires strengthening. Typically, the impact on bank capital of different types of risks is assessed separately and then, if anything, added up, which may be technically incorrect since VaR measures are not additive. The correlations between credit, market, and liquidity risks could be examined at several levels. First, the joint analysis of indirect credit risk (banking book effects arising from changes in key market prices) alongside the associated market risk (trading book) effects could be strengthened. Second, wider-ranging scenarios could be considered that directly include funding or market liquidity stresses (a liquidity run) as well as the more normal macro effects (so that the shocks represent more of a "perfect storm").

Also, contagion stress testing needs further development. One form that could be explored, in line with the analysis undertaken by some central banks, would be to examine mutual exposures in payment and settlement systems. Another would be to consider possible liquidity contagion, especially where there is experience from past runs. Yet another component that could be considered is the scope to use extreme value theory (EVT) to explore correlations between institutions as the basis for a contagion stress test.[16] Cross-border transmission channels also need more consistent coverage in FSAP stress testing, including cross-border contagion between financial institutions.

Scenario analysis could be conducted using the contingent-claims approach (CCA). The CCA methodology combines balance-sheet and market information with widely used finance techniques to construct risk-adjusted balance sheets that better reflect credit risk. By using a factor model to determine which key domestic and international factors drive changes in the financial institution's assets, it is possible to link macro shocks to credit risk indicators. This approach can be applied to a wide range of financial institutions (provided they issue securities in sufficiently deep markets). This approach is particularly useful when detailed obligor-level data are not available. The CCA was implemented in a working paper on Chile,[17] and its use is envisaged for future FSAPs.

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[16] This would examine correlations between extreme negative movements in institutions' distances to default, and result in an inter-institutional matrix that might be able to be used in a fashion analogous to an interbank exposures matrix. For a recent EVT analysis, though not linked to a stress test, see Chan-Lau et al. (2007) and Čihák and Ong (2007).

[17] See Gray and Walsh (2008).

While stress testing of insurance companies and financial conglomerates will likely continue to become more common, an open question to be considered is how far FSAP stress tests should go towards including other nonbank financial institutions directly in the quantitative stress testing analysis.

There are also challenges to model the behavioral responses of different players under stress events. While monetary policy reaction functions are sometimes built into the formulation of macro stress testing, what should be done, if anything, about the reaction functions of the financial institutions? On the one hand, these may mitigate the effects of shocks on individual institutions, but if they allow for common reactions, herding behavior, fire-sales and the like, the opposite may well be true at the system level.

From a pure modeling perspective, the potential presence of nonlinearities and structural breaks in behavioral relationships can seriously reduce the reliability of the stress test.[18] This issue arises in virtually all stress tests we do, but appreciating the potential implications is crucial. One quite common example in an FSAP context is modeling the impact of a major devaluation in a hard currency peg country. Past time series for such a country may be of very limited use given a lack of past exchange rate volatility. However experience from other countries and expert judgment can often play a key role in calibrating such a test. Various authors have tried to model nonlinearities more explicitly, though this is still largely uncharted territory.

Finally, there is an increasing need of taking into account second-round feedback effects—from the financial sector back to the macroeconomic environment—in the quantitative modeling. The modeling here typically gets complex quite quickly. This literature is relatively new, but there are already a number of papers that look into possible feedback loops.[19]

B. Other Aspects on the Agenda

At the level of FSAP processes more generally, there are also a couple of important broader points. First, FSAPs need to further improve the integration of stress testing and other modes of quantitative analysis. This includes continuing to improve the availability of FSIs, an ongoing medium-term work plan in the IMF that builds on the recent "coordinated compilation exercise." And relatedly, further "benchmarking" of FSIs, not in any mechanistic sense, but built around a growing understanding of how different countries' FSIs need to be interpreted. Finally, it also means more widespread use of market-based indicators and analysis thereof, both as modes that are complementary to stress test analysis and also, where feasible, actually reflected directly in the stress test analysis.

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[18] See also CGFS (2000, 2005) and Sorge (2004) for further discussion on this and other challenges.

[19] See for instance Aspachs et al. (2006), Segoviano et al. (2006), Goodhart et al. (2008a, 2008b), Gonzalez-Hermosillo and Segoviano (2008), Maechler and Tieman (2008).

Second, the rather wide range of practice to date raises a question: should FSAP stress testing be more standardized? More precisely, what is the appropriate balance between cross-country uniformity of stress tests, versus continuation of the case by case approach. The consensus amongst FSAP stress testers is that, while more uniformity would have its attractions, standardizing the shocks and their sizes across countries would not in fact achieve much real uniformity because of the different natures, activities and potential vulnerabilities of different countries' systems: what might look like standardization could be quite misleading. That said, there may be scope to standardize FSAP stress testing more at the level of broader good practices, within a flexible overall framework. Initial steps have been taken in this direction,[20] and an adaptable "template" for smaller and less complex financial systems has been made publicly available.[21]

In seeing how much further to go in this direction, we also have to keep in mind that macro stress testing is still a new field which will continue to evolve. And in this context, there is a basic trade-off to be struck between the general desirability of greater analytical rigor and accuracy, including through the use of multiple approaches as consistency checks; and the non-negligible resource costs, computational burden, and data availability issues.

Some of those costs are more in the nature of startup, rather than ongoing, costs, and the trade-off has been eased as an increasingly wide fraternity of macro stress testers has invested time and effort in pushing out the boundaries of the feasible. But the trade-off has not gone away and FSAP stress testers in particular will continue to face it. In managing this over time, we will want to continue to have close dialogue with stress testing counterparts amongst policymakers and academics.

[20] See IMF-World Bank (2005).

[21] See Čihák (2007).

Appendix. Stress Testing in European FSAPs[22]

Table 1. FSAPs Covered in This Survey

	FSAP	Update
Austria	2003	2007
Belarus	2004	
Belgium	2004	
Bosnia and Herzegovina	2005	
Bulgaria	2001	
Croatia	2001	2007
Czech Republic	2000	
Denmark	2005	
Estonia	2000	
Finland	2001	
France	2004	
Germany	2003	
Greece	2005	
Hungary	2000	2005
Iceland	2000	
Ireland	2000	2006
Israel	2000	
Italy	2004	
Latvia	2001	2007
Lithuania	2001	2007
Luxembourg	2001	
Macedonia, Former Yugoslav Republic of	2003	
Malta	2002	
Moldova	2004	2007
Montenegro	2006	
Netherlands	2003	
Norway	2004	
Poland	2000	2006
Portugal	2005	
Romania	2003	
Russian Federation	2002	2007
Serbia	2005	
Slovak Republic	2002	2006
Slovenia	2000	2003
Spain	2005	
Sweden	2001	
Switzerland	2001	2006
Ukraine	2002	
United Kingdom	2002	

[22] This appendix updates Čihák (2007), Appendix III. It covers FSAPs initiated between 2000 and 2007.

Table 3. Who Did the Calculations in European FSAP Stress Tests? 1/

	FSAP
Supervisory agency/central bank	Austria (2003, 2007), Belgium (2004), Denmark (2005), Estonia (2000), Finland (2004), Germany (2003), Hungary (2005), Ireland (2000, 2006), Israel (2000), Italy (2004), Latvia (2007), Lithuania (2007), Malta (2002), Moldova (2007), Netherlands (2003), Norway (2004), Portugal (2005), Russia (2007), Slovakia (2007), Spain (2005), Sweden (2001), Switzerland (2001, 2006), United Kingdom (2002)
FSAP team	Belarus (2004), Belgium (2004), Bosnia and Herzegovina (2005), Croatia (2001, 2007), Czech Republic (2000), Denmark (2005), Estonia (2000), Hungary (2000), Iceland (2000), Ireland (2000), Israel (2000), Latvia (2001, 2007), Lithuania (2001, 2007), Macedonia (2003), Moldova (2004, 2007), Montenegro (2006), Norway (2004), Poland (2000, 2006), Portugal (2005), Romania (2003), Russia (2002), Serbia (2005), Slovakia (2002, 2007), Slovenia (2000), Spain (2005), Ukraine (2002), United Kingdom (2002)
Financial institutions	Austria (2007), Belgium (2004), Denmark (2005), Estonia (2000), Finland (2004), Germany (2003), Greece (2005), Ireland (2000, 2006), Israel (2000), Italy (2004), Lithuania (2007), Luxembourg (2001), Malta (2002), Netherlands (2003), Norway (2004), Portugal (2005), Russia (2007), Spain (2005), Switzerland (2006), United Kingdom (2002)

1/ In some FSAPs, calculations were done by several parties, as indicated in the table.

Table 4. Institutions Covered in European FSAP Stress Tests

Institutions Covered	FSAP
All banks (bank by bank)	Belarus (2004), Belgium (2004), Croatia (2007), Italy (2004), Latvia (2007), Lithuania (2001), Moldova (2004, 2007), Montenegro (2006), Poland (2006), Russia (2007), Slovakia (2007), Slovenia (2003), Switzerland (2006), Ukraine (2002)
Large/systemically important banks (bank by bank)	Austria (2003, 2007), Belgium (2004), Bosnia and Herzegovina (2005), Croatia (2001), Czech Republic (2000), Denmark (2005), Estonia (2000), Finland (2001), France (2004), Germany (2003), Greece (2005), Hungary (2005), Iceland (2000), Ireland (2000, 2006), Israel (2000), Italy (2004 1/), Latvia (2001), Lithuania (2007), Luxembourg (2001), Malta (2002), Netherlands (2003), Norway (2004), Poland (2000), Romania (2003), Russia (2002, 2007 2/), Serbia (2005), Slovakia (2002), Slovenia (2000), Spain (2005), Sweden (2001), Switzerland (2001, 2007 2/), United Kingdom (2002)
Insurance companies	Belgium (2004), Denmark (2005), Finland (2001), France (2004), Italy (2004), Netherlands (2003), Norway (2004), Portugal (2005), Spain (2005), Sweden (2001), Switzerland (2006), United Kingdom (2002)
Pension funds	Netherlands (2003), United Kingdom (2002)
Mortgage banks	Ireland (2006)

1/ For part of the top-down stress tests.
2/ For bottom-up stress tests.

Table 4. Approaches to Credit Risk Modeling in European FSAPs

Approach to Credit Risk Modeling	FSAP
NPLs, provisions: historical or macro-regressions	Austria (2003), Czech Republic (2000), France (2004), Iceland (2000), Ireland (2006), Israel (2000), Romania (2003), Russia (2002), Sweden (2001)
NPLs, provisions: ad hoc approaches	Belarus (2004), Bosnia and Herzegovina (2005), Bulgaria (2001), Croatia (2001, 2007), France (2004), Hungary (2000, 2005), Ireland (2000), Israel (2000), Latvia (2001, 2007), Lithuania (2001), Macedonia (2003), Malta (2002), Moldova (2004, 2007), Montenegro (2006), Poland (2000, 2006), Russia (2007), Serbia (2005), Slovakia (2002, 2007), Slovenia (2000, 2003), Switzerland (2001), Ukraine (2002)
Shocks to probabilities of default based on historical observations or regressions	Austria (2003, 2007), Belgium (2004), Denmark (2005), Greece (2005), Lithuania (2007), Luxembourg (2001), Russia (2002), Spain (2005)
Shocks to probabilities of default (ad hoc)	Germany (2003), Italy (2004), Netherlands (2003), Norway (2004), United Kingdom (2002)
Shocks to profits based on regressions	Switzerland (2006)
Explicit analysis of cross-border lending	Austria (2003, 2007), Spain (2005)
Explicit analysis of foreign exchange lending	Austria (2003, 2007), Croatia (2001, 2007)
Explicit analysis of loan concentration	Greece (2005), Latvia (2007), Malta (2002), Moldova (2007), Montenegro (2006), Netherlands (2003), Poland (2006), Russia (2002, 2007), Serbia (2005)
Explicit analysis of sectoral shocks	Belarus (2004), Finland (2001), Greece (2005), Latvia (2007), Moldova (2007)
Analysis of LTV ratios, mortgage PDs	Croatia (2001), Sweden (2001)

Table 5. Approaches to Interest Rate Risk Modeling in European FSAPs

Approach to Interest Rate Risk Modeling	FSAP
Repricing or maturity gap analysis	Austria (2003, 2007), Belarus (2004), Belgium (2004), Croatia (2001, 2007), Czech Republic (2000), Greece (2005), Hungary (2000, 2005), Ireland (2006), Italy (2004), Latvia (2007), Lithuania (2001, 2007), Macedonia (2003), Malta (2002), Moldova (2004, 2007), Montenegro (2006), Poland (2000, 2006), Romania (2003), Russia (2002, 2007), Serbia (2005), Ukraine (2002)
Duration	Belgium (2004), Greece (2005), Iceland (2000), Ireland (2006), Israel (2000), Italy (2004), Latvia (2001, 2007), Norway (2004), Poland (2006), Slovakia (2002, 2007), Switzerland (2001)
Value at Risk	Denmark (2005), Finland (2004), Germany (2003), Israel (2000), Italy (2004), Netherlands (2003), Switzerland (2006), United Kingdom (2002)
Others (e.g., Δ NPV of balance sheet, Δ market value of bank capital, regressions, simulations)	Austria (2007), Norway (2004), Sweden (2001)

Table 6. Approaches to Exchange Rate Risk Modeling in European FSAPs

Approach to Exchange Rate Risk Modeling	FSAP
Sensitivity analysis on the net open position	Austria (2003, 2007), Belarus (2004), Belgium (2004), Bulgaria (2001), Croatia (2001, 2007), Czech Republic (2000), Hungary (2000, 2005), Iceland (2000), Ireland (2006), Latvia (2001, 2007), Lithuania (2001, 2007), Macedonia (2003), Malta (2002), Moldova (2004, 2007), Montenegro (2006), Norway (2004), Poland (2000, 2006), Romania (2003), Russia (2002, 2007), Serbia (2005), Slovakia (2002, 2007), Slovenia (2000, 2003), Sweden (2001), Switzerland (2001), Ukraine (2002)
Value at Risk	France (2004), Germany (2003), Israel (2000), Netherlands (2003), Switzerland (2006), United Kingdom (2002)

Table 7. Interest Rate Shocks in European FSAPs

Interest Rate Scenarios Used	Examples of Shock Sizes
• Ad hoc or hypothetical interest rate increase	• 3 standard deviations of 3-month changes
• Parallel shift in yield curve	• 50%-100% increase
• Flattening/steepening of yield curve	• three-fold increase in nominal rate
• Historical interest rate increase	• 100 basis point shock to interest rates
• Basel Committee Amendment to Capital Accord to incorporate market risk	• 100 basis point shock to dollar interest rates and a concomitant 300 basis point shock to local currency interest rates
	• 300 basis point increase
	• +500, +200, +0 (+0, +200, +500) basis point increase in interest rates for 3 month, 3 month to 1 year, and over 1 year

Table 8. Exchange Rate Shocks in European FSAPs

Exchange Rate Scenarios Used	Examples of Shock Sizes
•Ad hoc or hypothetical devaluation	• 20%-50% devaluation
•Historical large exchange rate changes	• 30% devaluation
	• 10% depreciation
	• 20% depreciation/appreciation
	• 40% depreciation/appreciation of Euro/Dollar exchange rate

Table 9. Approaches to Modeling Other Market Risks in European FSAPs

Risk Modeling Approaches	FSAP
Shock to main stock market index	Austria (2003, 2007), Belgium (2004), Croatia (2007), Finland (2001), France (2004), Germany (2003), Greece (2005), Israel (2000), Italy (2004), Latvia (2001, 2007), Lithuania (2001, 2007), Malta (2002), Netherlands (2003), Norway (2004), Russia (2007), Slovakia (2002), Switzerland (2006), United Kingdom (2002)
Spread risk	Greece (2005), Russia (2007), Switzerland (2006)
Implied volatility of options risk	Austria (2007)
Housing price shock	Ireland (2006), Lithuania (2007), Netherlands (2003), Norway (2004), Slovakia (2007), Ukraine (2002), United Kingdom (2002)
Commodity price	Finland (2001)
Competition risk (interest rate margin)	Lithuania (2001), Slovenia (2000, 2003)

Table 10. Approaches to Liquidity and Contagion Risk Modeling in European FSAPs

Risk Modeling Approaches	FSAP
Liquidity risk (ad-hoc decline in liquidity)	Austria (2003, 2007), Belarus (2004), Belgium (2004), Bosnia and Herzegovina (2005), Croatia (2007), Germany (2003), Greece (2005), Ireland (2006), Italy (2004), Latvia (2007), Lithuania (2001), Montenegro (2006), Netherlands (2003), Poland (2006), Russia (2002, 2007), Slovakia (2007), Spain (2005), Switzerland (2006), Ukraine (2002), United Kingdom (2002)
Liquidity risk (historical shock)	Croatia (2001), France (2004), Lithuania (2007), Moldova (2007)
Interbank contagion	Austria (2003, 2007), Belgium (2004), Croatia (2007), Greece (2005), Luxembourg (2001), Netherlands (2003), Romania (2003), United Kingdom (2002)

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