

# Stress testing of banks: an introduction

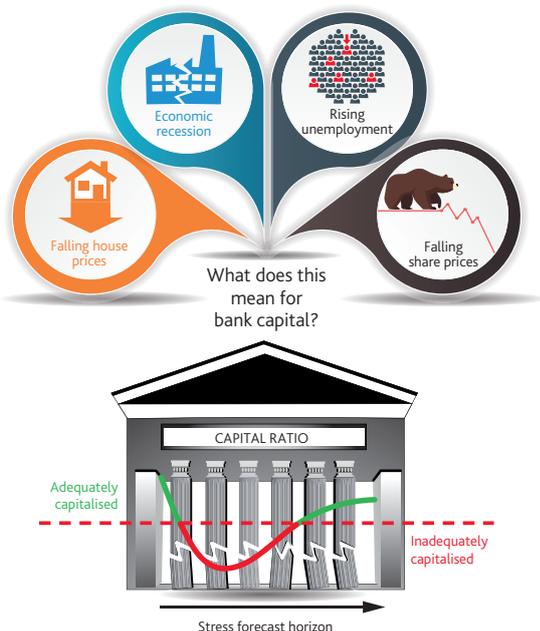
By Kieran Dent and Ben Westwood of the Bank of England's Stress Testing Strategy Division and Miguel Segoviano of the International Monetary Fund's Financial Sector Assessments and Policies Division.

- The usage and prominence of bank stress tests has risen substantially in the years following the global financial crisis. They are now established as a key part of the bank regulation toolkit.
- Typically, bank stress tests measure the resilience of banks to hypothetical adverse scenarios like severe recessions, with results used by central banks and regulators to measure risks and manage them through the setting of prudential policy.
- Over time, to enhance their usefulness to policymakers, stress tests are likely to develop further, for example by testing banks against a wider range of resilience metrics than capital, and further exploring how stresses might be transmitted across the financial system (eg through contagion).

## Overview

Stress testing involves putting a severe amount of pressure on an object or system, to test how resilient it is under extreme conditions. It is a tool used in a number of industries, from construction to cardiac health care. When applied to banks, stress testing involves analysing how these institutions would cope with hypothetical adverse scenarios, such as severe recessions or financial crises. The **summary figure** provides a stylised depiction of a bank stress test.

**Summary figure** Stylised depiction of a bank stress test



Prior to the global financial crisis, the use of stress tests by regulators was limited, particularly in the context of helping to set policy. But the crisis marked a step change, and several authorities have since started to develop and implement concurrent bank stress-testing frameworks.

A concurrent bank stress test is a simultaneous stress test of several banks carried out under the direction of a stress-testing authority, such as a central bank or banking system regulator. These tests are designed to look at the resilience of banks to potential future risks. They are ultimately aimed at helping authorities to understand and explain risks faced by banks, as well as, in some cases, contributing to setting policy aimed at promoting resilience.

Stress tests generally start with the specification of hypothetical stress scenarios. These scenarios tend to incorporate paths for economic and financial market variables, which together are more severe than the stress-testing authority's central expectations, and which might be expected to have an adverse impact on banks. A variety of different modelling techniques are then used to estimate the impact of the scenario(s) on banks' profits and balance sheets.

Bank stress testing is still a relatively new field, and is likely to develop further over time in order to improve its usefulness for policymakers, particularly with regards to setting policy aimed at promoting the resilience of banking systems as a whole.

## Introduction

In general, stress testing involves analysing how an object or system copes under pressure. Doctors perform cardiac stress tests by getting patients to run on treadmills and monitoring their pulse and blood pressure. Engineers stress test construction materials by measuring their behaviour when subjected to strain.

Bank stress testing is designed to test the resilience of banks to severe but plausible shocks. In practice, this typically means modelling the impact of hypothetical adverse macroeconomic and financial market scenarios on bank profitability and balance sheets.

Adverse scenarios typically contain hypothetical future paths for a set of economic and financial market variables, which together might be expected to stress bank business models and to lead to losses. These scenarios are designed to be much worse than stress-testing authorities' central expectations about how economic activity and financial market developments are likely to turn out. Examples might include scenarios resembling severe recessions with falling GDP, sharp contractions in house prices, and rising unemployment. Analysis of a scenario's impact involves modelling the way in which the scenario would be likely to affect different aspects of participating banks' businesses. For example, an increase in unemployment would reduce the income of some households and may mean that more households default on their mortgages and other loans.

From the perspective of central banks and bank regulators, stress tests have the potential to support both risk measurement and risk management. In other words, as well as helping to measure the impact of potential future shocks on individual banks and the wider banking system, they can also be used to help set prudential policy aimed at making sure that individual banks (microprudential policy) and the banking system as a whole (macroprudential policy) are adequately resilient. For example, stress-test results help policymakers set capital requirements, which are in place to ensure banks fund themselves with sufficient loss-absorbing capital to reduce their likelihood of failure.<sup>(1)</sup>

This article is an introduction to public, concurrent stress tests of banks, which focus mainly on banks' capital positions — otherwise known as solvency stress tests.<sup>(2)</sup> A concurrent stress test is defined as one carried out under the direction of an official body, such as a banking regulator, and in which the entire balance sheets of several banks are simultaneously subjected to the same adverse scenario. It is these stress tests that have received the most attention in the wake of the global financial crisis.

Concurrent stress tests have two main advantages relative to stress-testing exercises that do not impose common scenarios

and are not run simultaneously. First, by evaluating banks against a common scenario, concurrent exercises produce results that are more comparable across banks. This helps supervisory authorities responsible for promoting the safety and soundness of individual banks to conduct microprudential policy in a more consistent manner.

Second, by assessing the impact across banks at the same time, concurrent exercises allow policymakers to identify whether a particular shock is likely to affect many banks or just a few. This is helpful in determining the likely system-wide impact of the shock, and hence risks to the provision of financial services to households and businesses.

Related to that, concurrent exercises also support attempts to quantify the impact of the feedback and amplification channels that operate within the banking sector, and between banks, the broader financial system and the wider economy. These mechanisms serve to exacerbate the impact of an initial shock, and spread its effects across a larger number of institutions. For example, banks seeking to limit the impact of the stress may reduce their lending, thus contributing to an even larger squeeze on economic activity and further raising the likelihood that banks will make losses on their lending. Incorporating feedback and amplification channels into a stress test helps macroprudential authorities to quantify the system-wide impact of adverse events, and supports them in designing policies that apply to all banks with the aim of promoting and enhancing financial stability.

The first section of this article tracks the history of bank stress testing from its beginnings in the early 1990s to the emergence of concurrent regulatory stress tests in response to the financial crisis. The following section then discusses the main features of a concurrent stress-testing framework and compares the different approaches taken to concurrent stress testing internationally. The final section explores how concurrent stress testing might develop, as regulators strive to improve their frameworks in support of their policymaking objectives.

## A brief history of bank solvency stress testing

Prior to the financial crisis, stress testing of banks was largely conducted by banks themselves for internal risk management purposes. While some regulatory authorities did conduct stress tests before the financial crisis, these tended to be simple exercises with little direct impact on policy.<sup>(3)</sup>

(1) See Farag, Harland and Nixon (2013).

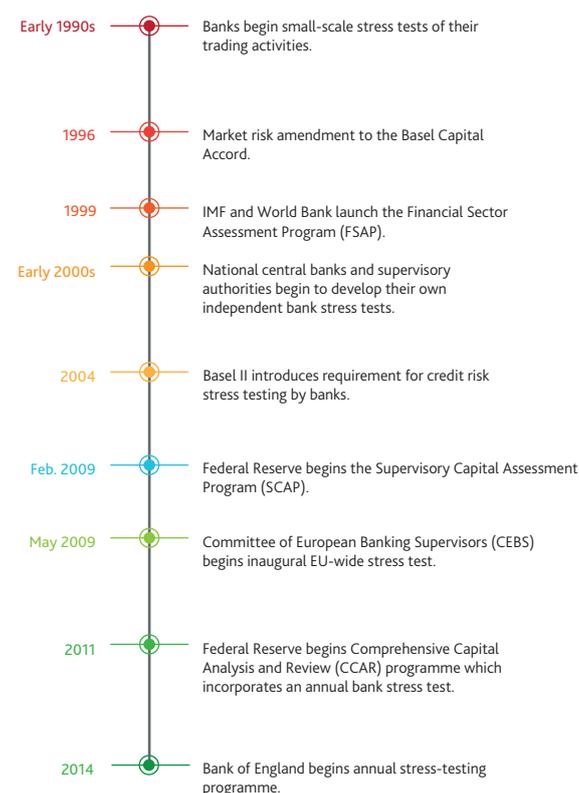
(2) Solvency-orientated stress tests focus on the implication of a stress for bank capital. Stress tests may also focus on bank liquidity, though these are not the focus of this article. Some solvency stress tests may also incorporate liquidity stresses, as the two are often connected.

(3) For example, simple stress tests were carried out on the French, UK and Finnish banking systems. See De Bandt and Oung (2004), Hoggarth, Sorensen and Zicchino (2005), Virolainen (2004).

Following the financial crisis, stress tests have taken on a much more prominent role within the regulatory toolkit. This section sets out that history.

Figure 1 provides a timeline of the key events that have shaped the development of bank stress testing.

**Figure 1** Timeline of key events in the development of bank stress testing



### The emergence of stress testing within banks

Within banks, scenario-based stress testing first emerged as a discipline within banks' trading activities in the early 1990s to complement other statistical techniques used to evaluate risks banks were running on their trading books (Blaschke *et al* (2001), McGee and Khaykin (2013)). Typically, trading desk managers would test their portfolios against both historical and hypothetical scenarios (Araten (2013)).

As the name suggests, historical scenarios were based on past extreme market events and were used to evaluate the impact that a repeat of these events might have on current trading portfolios. Table A describes some of the historical scenarios most commonly used by early stress-test practitioners.

While the severity of past events can provide a useful benchmark, past stress events have not tended to simply repeat themselves. Recognition of this fact led to demand for scenarios that could test banks against potential future risks, based on severe but plausible hypothetical events. In advanced economies, these hypothetical scenarios were often based on changes in economic growth prospects,

**Table A** Historical scenarios used by early stress-test practitioners

Scenario	Date	Description
Black Monday	1987	International equity market crash, which reduced the value of major international stock markets by between 19% and 40% over the month.
US interest rate shock	1994	A sharp, unexpected increase in US interest rates significantly reducing the value of bond portfolios. The resulting shock spread into the US equity market.
Mexican peso crisis	1994	A sudden, unexpected devaluation of the Mexican peso. This led investors to liquidate their positions in Mexico and other developing countries with contagion spreading throughout financial markets in Asia and Latin America.
Asian crisis	1997	A series of currency devaluations starting in Thailand, following speculative attacks on the baht, and subsequently spreading to other Asian markets. As the crisis spread, most of South East Asia and Japan saw significant currency depreciations and a collapse in the value of stock markets and other asset prices.
Russian crisis	1998	A shock to the value of Russian stock, bond and currency markets. This resulted from falling investor sentiment after a period of economic turmoil. In response, the Russian government devalued the rouble, defaulted on its domestic debt and suspended repayments on its foreign debt.

while emerging market scenarios often focused on discrete, disruptive events such as a government being unable to meet its debt obligations.

The manner in which these early stress tests were used varied greatly across banks. At some banks, they were aimed at quantifying the maximum loss a bank might incur on a trading portfolio, while at other banks they were aimed at determining trading limits, or quantifying the appropriate amount of capital to fund a particular portfolio (Committee on the Global Financial System (CGFS) (2000)).

The practice of using stress tests to evaluate trading portfolios was formalised in 1996 with an amendment to the international regulatory capital regime for market risk (the risk of losses on positions associated with changes in market prices).<sup>(1)</sup> Following this amendment, banks seeking to use their own internal models to quantify market risk for regulatory capital purposes were required to implement a bank-wide stress-testing programme for market risk.

While firm-wide stress testing for market risk went on to become standard practice at large international banks, the development of stress tests for credit risk — the risk associated with a bank's counterparties or borrowers failing to make payments — significantly lagged those of market risk. In 1999 the Basel Committee on Banking Supervision (BCBS) found that little progress had been made to develop techniques to implement credit risk stress tests (BCBS (1999)). This was

(1) 1996 market risk amendment to the Basel Capital Accord.

despite the fact that credit risk was the most significant risk facing most banks. In 2005, the CGFS reported that this was still the case, and highlighted the need to develop better stress tests incorporating loan portfolios, as well as instituting bank-wide stress tests aimed at capturing all of the risks banks faced.

The first steps towards addressing the lag between credit and market risk stress tests were taken in a revision to the international regulatory capital regime published in 2004, known as Basel II.<sup>(1)</sup> This sought to make it a requirement for banks using their own internal models to determine credit risk for regulatory capital purposes to have in place a programme of stress testing. Under these stress-testing programmes, banks would review the robustness of their model-based assessments and the adequacy of capital buffers above the regulatory minimum.<sup>(2)</sup> Upon implementation, all banks would be additionally required to subject their loan portfolios to stress tests regardless of whether or not they were using their own models to determine credit risk capital.

Basel II had not been universally implemented by advanced economies prior to the onset of the financial crisis. And even where it had, banks' stress-testing models for credit risk and for capturing both credit and market risk were still at a developmental stage (BCBS (2009)) and Schuermann (2013)).

### The use of stress testing by policymakers prior to the global financial crisis

Unlike the stress tests conducted by banks, which focused on the risks faced at the portfolio or individual institutional level, the stress tests conducted by policymakers prior to the financial crisis sought to capture the impact of severe, but plausible, shocks on the entire financial system or even the wider economy.

Although policymakers had been considering the potential impact of adverse events on the financial system for some time, the use of stress tests as a tool for doing so only emerged towards the end of the 1990s. This was spurred on by their use in the Financial Sector Assessment Program (FSAP) established by the International Monetary Fund (IMF) and the World Bank. The FSAP, launched in 1999, recognised the significant detrimental effects financial instability can have on economic growth and the workings of financial markets, as evidenced by the financial crises of the 1980s and 1990s.<sup>(3)</sup>

From its inauguration, stress tests have been a key component of the FSAP and they have been performed for every country participating in the programme. The purpose of these tests is to provide a quantitative measure of the vulnerability of a country's financial system to different macrofinancial scenarios and to complement the insights gathered from other components of the assessment. These include qualitative vulnerability assessments and a review of the regulatory and crisis management frameworks in place in a country.

The use of stress tests within FSAPs helped encourage national central banks to develop their own, independent stress tests. These often began as updates of previous FSAP scenarios with central banks developing models that considered the banking system as a single entity. Over time, these approaches started to evolve into the concurrent stress-testing frameworks widely used today.

Prior to the financial crisis, the concurrent stress tests conducted by policymakers rarely had a direct impact on regulatory or broader financial policy. But their outputs were often incorporated into broader financial stability assessments, with the results sometimes published in central bank publications such as *Financial Stability Reports*.<sup>(4)</sup>

### The development of stress testing since the global financial crisis

The global financial crisis highlighted substantial deficiencies in risk measurement and management across the financial sector.<sup>(5)</sup> With respect to stress testing by banks, the scenarios used prior to the financial crisis were revealed to be significantly more benign than the crisis itself, while the loss estimates these exercises generated were well below banks' actual loss experience (BCBS (2009)).

As well as exposing the shortcomings of stress-testing practices at banks, the financial crisis also brought with it a step change in the use of stress testing within the regulatory sphere. Regulatory stress tests moved from being small-scale, isolated exercises within the broader risk assessment programme, to large-scale, comprehensive risk-assessment programmes in their own right leading directly to policy responses.

The first prominent example of this new wave of stress tests was the US Supervisory Capital Assessment Program (SCAP) conducted by the Federal Reserve in early 2009. The SCAP stress test assessed whether the largest US banks had sufficient capital resources to absorb losses and continue to operate under a common stress scenario. By design, the scenario was significantly more severe than the expected trajectory for the economy at the time (Bernanke (2010)).

In a marked departure from the past, the results of the SCAP were publicly disclosed on a bank-by-bank basis. Those banks judged to need additional capital resources were given six months to raise that capital, with the US Treasury

(1) Basel II was the second of the Basel Accords, which comprise recommendations on banking laws and regulations issued by the BCBS. Following the financial crisis, substantial changes were made to the international regulatory framework under Basel III which was agreed upon by the BCBS in 2010–11.

(2) More specifically, banks using either the advanced or foundation internal ratings-based (IRB) approaches for credit risk were required to conduct credit risk stress tests as part of Pillar II.

(3) See IMF (2014).

(4) See, for example, Bank of England (2006), Box 6 in Section 3.

(5) See Haldane (2009).

Department providing a backstop in the event that any bank was unable to do so in private markets. In the event, almost all of the banks were able to raise sufficient equity privately so as not to need Treasury support. The SCAP is widely regarded to have made a significant contribution to stabilising the US financial system, and restoring broader market confidence with the Treasury backstop recognised as an important driver of its success (Krugman (2014), Schuermann (2013) and Zhang (2013)).

The success of the SCAP was followed by a proliferation of frameworks for regular concurrent stress testing across central banks and supervisory authorities. The first EU-wide concurrent stress test was conducted in late 2009 under the direction of the Committee of European Banking Supervisors (CEBS). This was followed by another exercise conducted under the direction of the CEBS in 2010, and a series of exercises conducted under the direction of the European Banking Authority (EBA) starting in 2011. In the United Kingdom, these EU-wide exercises initially served to complement the stress-test scenarios that were being provided to banks to run on a non-concurrent basis by the former Financial Services Authority (FSA), before the Bank of England launched its own concurrent stress-testing programme in 2014.

This greater regulatory focus on stress testing has helped to drive improvements in banks' own stress-testing capabilities and risk management practices, with sophisticated, bank-wide stress testing now common practice at systemically important banks. And as the immediate turmoil that followed the crisis has abated, the focus of regulatory stress-testing frameworks has shifted away from the immediate need to recapitalise the banking system towards an ongoing assessment of the adequacy of banks' capital resources and to informing broader micro and macroprudential policy (the box on pages 138–39 considers the current use of stress tests by selected regulatory authorities). The key features of these regulatory stress-testing frameworks are described in the following section.

## How concurrent stress testing of banks works at present

### A high-level description of modern concurrent stress testing of banks

Concurrent stress testing involves analysing the impact of one or more hypothetical stressful scenarios on the capital position of a selected group of banks.

The hypothetical stresses involved are designed to test the resilience of banks against the risks they face, and tend to be adverse macroeconomic and financial market scenarios, like a severe recession combined with financial market distress. These are not central case projections for the economy and

markets; rather they represent unlikely severe outcomes chosen by stress testers because they could have a material detrimental impact on banks. Were such hypothetical events to materialise, they would likely lead to banks making losses and reduce the amount of capital available to absorb further losses.

Stress-test practitioners often supplement these adverse scenarios with a baseline scenario under which the macroeconomic and financial environment evolves in line with their central expectations. Baseline projections can provide useful information about banks' expected strategies for the years ahead, as well as providing a benchmark against which to analyse results under the hypothetical stress.

Projections of banks' capital positions conditional on the stress scenario tend to be the headline results of a stress test. Results can be used for a number of purposes, with some authorities using them as a tool to highlight financial stability risks, some using them as part of their approach to setting individual bank capital requirements, and others using them to help set macroprudential policy as well.

**Figure 2** provides a stylised illustration of one type of concurrent stress test focused on individual banks. Other stress tests may include different or additional features, such as feedback loops from the projected behaviour of other financial market participants in response to the adverse scenario.

The following three sections discuss scenario design, the production of stress-test results, and uses of stress-test results for policy purposes in more detail.

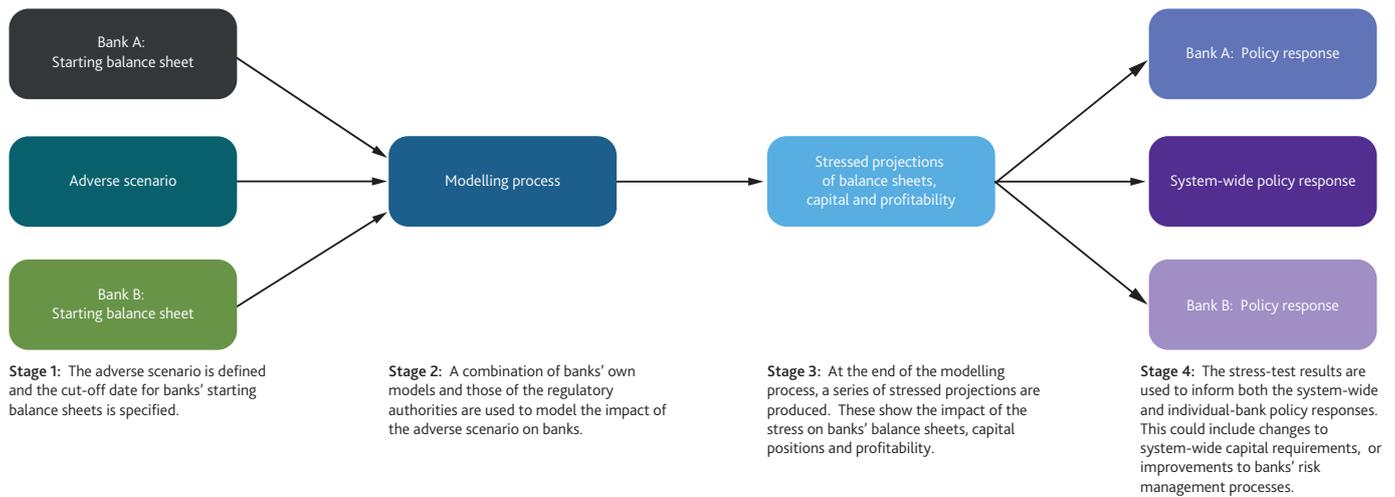
### Scenario design

Typically, the first stage in putting together a stress test is designing a scenario. The two key elements of this step are: (a) to select the types of risks to be explored by the test; and (b) to calibrate the severity of shocks.

At one extreme, the test may simulate a severe broad-based downturn affecting the real economy as well as impacting financial markets and other asset prices. This is the approach taken by the majority of stress-testing authorities. An advantage of this type of test is that it allows stress-testing authorities to factor in the correlation of different risks faced by banks, and their impact across different parts of banks' balance sheets. For such scenarios, authorities tend to use economic models to help design stresses that are coherent — ie scenarios in which the combination of shocks makes sense together.

Adverse scenarios of this type typically include projections for economic variables such as unemployment, output growth and asset prices, which are broadly consistent with the paths these variables might be expected to take during severe

**Figure 2** An illustration of a concurrent stress test



downturns. That means asset prices and output fall materially, while unemployment tends to rise substantially.

Broad-based adverse macroeconomic scenarios can impact banks' capital positions through a number of channels. For example, higher unemployment might reduce the ability of households to repay mortgages and unsecured loans. A fall in house prices might lower the value of collateral held against mortgages and therefore increase banks' losses when households default on those mortgages. The stress also increases the riskiness of banks' portfolios of performing loans. This, in turn, increases the amount of capital banks must fund themselves with, as stipulated under the regulatory capital framework.<sup>(1)</sup>

Beyond changes in losses on lending and increasing the riskiness of loan portfolios, adverse macroeconomic scenarios also tend to have other impacts. For example, the profits generated by banks' lending and deposit-taking activity — their net interest income — may fall if bank funding costs rise as a result of the stress.

Some stress tests also include adverse traded risk scenarios, where changes in financial market prices and conditions reduce the profitability of banks' trading operations. Stress tests may also contain elements less closely related to economic conditions, such as an increase in redress payouts relating to past episodes of misconduct.

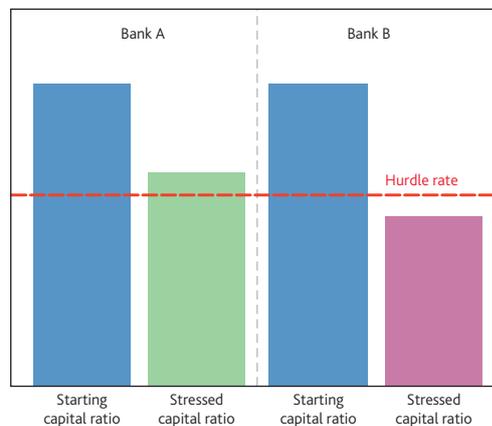
At the other extreme to broad-based tests, authorities may be interested in exploring a specific risk, and so run a narrower stress scenario.<sup>(2)</sup> Authorities may also choose to run more than one adverse scenario with different focuses.

The overall severity of a stress test can be thought of as the combined severity of the individual shocks incorporated in the test, together with any 'hurdle rate', which is the level of capital authorities stipulate that banks should be projected to

meet or exceed over the life of the stress. Where authorities set hurdle rates, different approaches are taken. For example, in some cases minimum regulatory requirements are used, while in others capital requirements and buffers applying to individual firms are incorporated.

**Figure 3** illustrates the projected impact of a stress scenario on two different banks relative to a hurdle rate, with Bank A exceeding the hurdle rate and Bank B falling short.

**Figure 3** An illustration of the impact of stress scenarios on different banks' capital positions



Given the range of options for calibrating stress scenarios, ultimately, the severity of a stress is likely to depend on a stress-testing authority's risk appetite. Since banks provide valuable services that support investment and economic growth, regulators try to ensure that bank failure is appropriately unlikely. The appropriate likelihood of bank failure will be a judgement for the relevant authority.

(1) The regulatory capital framework requires banks to fund themselves with a minimum amount of capital. This increases banks' ability to absorb losses that could otherwise threaten their solvency. For more details see Farag, Harland and Nixon (2013).  
 (2) For example, the Reserve Bank of New Zealand recently ran an exercise in which New Zealand's five largest lenders to the dairy sector were stress tested against sustained low milk prices and sharp falls in dairy land values. For more details see [www.rbnz.govt.nz/research-and-publications/reserve-bank-bulletin/2016/rbb2016-79-05](http://www.rbnz.govt.nz/research-and-publications/reserve-bank-bulletin/2016/rbb2016-79-05).

Based on evidence that adverse shocks are more likely when risks associated with the state of the financial cycle are elevated — that is at times when credit growth is strong and asset prices appear overvalued — some authorities judge that it would be better if banks had larger capital buffers to fall back on when cyclical risks are high. For authorities who wish to set system-wide capital in this way, another approach to calibrating the severity of stress scenarios is therefore to factor in the extent of these cyclical risks.<sup>(1)</sup>

There are several other facets of stress-test design not covered in this article, which vary across concurrent stress-test practitioners. For example, different authorities run their concurrent tests over different time horizons, and while some authorities produce results based on the assumption that bank balance sheets do not change during the stress, others allow balance sheets to vary in an attempt to capture banks' managerial responses to the stress. These choices are all likely to be linked to the objectives of the test in question, and the nature of the risks explored in the stress scenario. The practices of different authorities are summarised in the box on pages 138–39.

### Producing projections of bank profitability and capital

In general, producing stress-test results involves assessing the impact of both the baseline and stress scenarios on banks. This typically involves using models to produce projections of bank balance sheets, profitability and capital under each scenario.

There are a range of approaches to producing these projections. For example, they may be produced either by banks themselves, regulatory authorities, or by a mixture of the two. Likewise, they may be produced using top-down macro-models or bottom-up micro-models. Top-down models aim to assess the impact of the stress at a system-wide level, before considering its implications for individual banks. Bottom-up micro-models aim to assess the impact of the stress at the individual-bank level, before considering its implications for the banking system as a whole.

Bottom-up modelling may be undertaken by either the stress-testing authority or participating banks. The main advantages associated with banks producing bottom-up stressed projections are that they may have more detailed data and better customised models than regulatory authorities, for whom building specific models for each participating bank is costly. Where banks themselves are responsible for providing projections, authorities generally take on a quality assurance role, analysing banks' various approaches with the aim of making results as comparable as possible across institutions. Authorities may also produce their own bottom-up projections. This has the benefit of allowing greater control of the assumptions underlying projections, which helps to ensure comparability in results across institutions.

Meanwhile, the main benefit of employing top-down macro-models is that they are more likely to capture system-wide impacts of a stress, though the trade-off for this might be more uncertainty about the projections for individual banks. Top-down modelling is typically undertaken by stress-testing authorities. Banks are less able to factor in system-wide impacts because they do not have access to detailed information on other firms in the system.

A stress-testing authority's choice of approach will be influenced by their objectives. These include:

1. Measuring risks affecting both individual banks and the wider banking system.
2. Ensuring that individual banks are adequately capitalised and operating appropriate risk management and stress-testing policies.
3. Helping to set macroprudential rules — including minimum capital levels — for the system as a whole.

Different approaches to stress testing lend themselves to achieving different objectives. For example, an approach that places most emphasis on detailed modelling of the impact of the stress at a portfolio level within different institutions is likely to be more appropriate for authorities seeking to set capital for individual banks. Stress testers seeking to better understand systemic risks might be less interested in the insights to be gained from resource-intensive granular models, instead favouring macro-models that might better project the systemic impact of a stress.

Some authorities adopt a mixed approach whereby banks are responsible for producing their own projections, and authorities make adjustments to these based on a mixture of top-down and bottom-up analysis. Some of these adjustments may be intended to improve the consistency of projections across banks, whereas, in principle, others might be aimed at accounting for some of the system-wide impacts of the stress that would not necessarily be picked up by an individual bank's models.

In addition to the quantitative results of a stress test, some authorities place considerable weight on a parallel qualitative review of banks' stress-testing capabilities. The findings of these reviews provide an important indicator of the adequacy of banks' risk management practices. A qualitative review typically involves an assessment of banks' technical stress-testing capabilities, and the governance processes surrounding their stress-testing functions. Where deficiencies are identified, this may warrant remedial effort by the banks concerned, and potentially the addition of further safety buffers in the form of bank capital.

(1) For example, the Bank of England's annual cyclical scenario is calibrated to reflect Bank of England policymakers' judgement on the state of the financial cycle (Bank of England (2015)).

## Using stress-test results — communication and the policy reaction framework

The results of concurrent stress tests can be used in a number of ways. That said, in general terms, all stress tests are tools for measuring and managing the risks banks face on a forward-looking basis. For authorities concerned primarily with risk measurement, the results give a quantitative assessment of the scale of risks facing banks, while for those stress-testing authorities more heavily engaged in risk management, stress-test results are an input to their policy decisions. For microprudential policymaking authorities, how banks' capital positions fare under stress relative to specified hurdle rates or minimum capital requirements is one important yardstick to judge whether individual banks are adequately capitalised, and how they might need to adjust their capital plans. In some cases, overall stress-test results are also used to help macroprudential policymakers judge the appropriate level of system-wide bank capital buffers.

Ensuring that the way authorities intend to use test results is well understood can improve the effectiveness of stress tests. The communication of results and the policy reaction framework around the results are the two key elements of this.

Clear publication of details about stress scenarios along with stress-test results allows external observers to judge the resilience of banks to the various risks incorporated, and improves the accountability of the relevant stress-testing authority. It can also enhance the credibility of a stress test, provided markets judge that the test is adequately severe. And it gives investors another source of information about the risks facing banks, which should help them to make more informed decisions, and improve market discipline. This may equally apply to tests carried out by those concurrent stress-test practitioners not responsible for setting capital.

For authorities responsible for setting capital requirements, in general, publicising the policy reaction framework for a stress test means being clear about what would prompt them to take policy action, as well as what sort of policy actions might be taken in the event of different results. Again, a robust and well-publicised policy reaction framework can enhance the public credibility of the stress test. And the combination of a clear communication strategy and a well-articulated policy reaction framework might positively influence bank behaviour. For example, banks may take pre-emptive action to strengthen their capital position ahead of the release of stress-test results.

## The future of stress testing

Over the past 25 years, stress tests have moved from being an isolated risk management tool, used by banks to assess the resilience of their trading portfolios, to become a core part of the regulatory toolkit worldwide. But today's stress tests are not without limitations and there are a number of areas across

which further enhancements could improve their usefulness for policymakers.

## Limitations of stress testing

Within the broader regulatory capital framework, stress tests focused on banks' capital positions — otherwise known as solvency-orientated tests — are simply an analytical tool used to assess banks against the requirements set out in that framework. As such, stress tests are not a substitute for a robust capital framework but a complement to it. Similarly, stress tests cannot replace a robust supervisory regime that ensures banks have adequate risk management and governance processes in place.

Further, the results of stress tests are only as robust as the data and methodologies used, and assumptions made, in producing them. While significant progress has been made to develop these methodologies in recent years, stress-test results remain subject to a high degree of uncertainty. It is for this reason that stress-test results are used as just one input into the policymaking process when determining the appropriate level of bank capital.

This section considers three main areas across which policymakers may choose to focus their efforts in further developing stress tests to increase their usefulness for informing micro and macroprudential policy:

1. Improving the ability of stress tests to assess the resilience of individual banks by exploring different types of, and a broader range of, risks.
2. Integrating amplification and feedback mechanisms and incorporating behavioural responses into stress tests.
3. Extending the scope of stress tests beyond the core banking sector.

Figure 4 illustrates how some of these developments might work.

## Improving the ability of stress tests to assess the resilience of individual banks

By evaluating the impact of severe, but plausible hypothetical shocks on individual banks, stress tests provide useful information to microprudential supervisors about the resilience of regulated institutions. At present, the concurrent stress-testing frameworks run by many authorities are skewed towards assessing capital adequacy as opposed to other potentially important resilience metrics. Two closely related metrics that enhanced concurrent stress-testing frameworks might seek to capture are liquidity and funding resilience.

Liquidity resilience captures a bank's ability to meet its short-term obligations as they fall due and cope with a sudden, and unexpected, increase in withdrawals by its depositors and other creditors. It also measures the ease and speed with which the bank's assets can be converted into cash

## Comparison of international concurrent stress-testing practices

Stress-testing practices vary widely internationally, with several authorities still in the development stage of their stress-testing frameworks. This box summarises a selection of concurrent stress-testing frameworks, though this group is by no means exhaustive.

### Case study 1: the IMF

Stress tests performed by the IMF support financial stability assessments executed under the FSAP.<sup>(1)</sup> IMF stress tests normally include two or three adverse scenarios, constructed around the macrofinancial risks judged to be most significant for the economy concerned. Stress-testing approaches in FSAPs need to be adaptable to individual country circumstances. For example, data availability, the types of appropriate shocks and the level of development of the relevant authorities' own stress-testing framework are likely to vary.

Prior to 2009, FSAP stress tests tended to focus mainly on bank solvency risk. This has given way to broader risk coverage that now almost always includes market and liquidity risk. Stress tests have traditionally focused on the banking sector, but some FSAP stress tests have been applied to additional sectors, such as insurance and, more recently, money market funds.<sup>(2)</sup>

FSAP analysis of interconnectedness among financial institutions and of systemic risk continues to develop.<sup>(3)</sup> Analysis incorporates interconnectedness, factors related to direct and indirect linkages across entities, sectors (including banks and non-banks) and borders. While systemic risk assessments complement stress tests of individual entities in FSAPs, systemic risk amplifications have not yet been fully embedded into macroprudential stress-test frameworks. This is a key development aim for the IMF and a number of other authorities.<sup>(4)</sup> Through its FSAP-related stress-testing work, the IMF also aims to help individual authorities to develop their own stress-testing frameworks.

### Case study 2: the US Federal Reserve

Following on from the 2009 SCAP, in 2011 US authorities launched the Comprehensive Capital Analysis and Review (CCAR). The CCAR incorporates concurrent stress testing as well as the capital planning process for individual banks. CCAR takes into account results from concurrent stress tests, required under the Dodd-Frank Act (DFAST), alongside a qualitative assessment of banks' risk management, their capital plans and the results of stress tests banks carry out themselves on an individual basis. At the end of the process the authorities may object to banks' capital plans on either quantitative or qualitative grounds, requiring firms to amend them or submit entirely new plans.

The DFAST includes an adverse and severely adverse scenario — with the results from the severely adverse scenario used for the CCAR exercise. The severely adverse scenario is calibrated using outturns for macro variables observable during severe recessions. It has countercyclical elements inasmuch as unemployment has to rise to at least 10% in the severely adverse stress. So the lower unemployment currently is, the larger the shock to unemployment that will be required to hit that minimum. The adverse scenario incorporates somewhat less severe shocks to key macro variables, but incorporates different risks relative to the severely adverse scenario. The US Federal Reserve uses a dynamic balance sheet approach to model the impact of these scenarios. This approach allows bank balance sheets to evolve through the forecast horizon in line with banks' corporate plans. Banks with large trading operations take part in additional traded risk and counterparty default risk scenarios.

### Case study 3: the EBA stress test

The EBA conducted its first concurrent stress test in 2011, taking over responsibility for EU-wide stress testing from the CEBS. In 2016, 51 banks participated in the test from across the EU, representing a combined 70% of EU banking sector assets.

The EBA run a joined-up adverse macro scenario with a three-year horizon. The EBA test is conducted on a static balance sheet basis, meaning that bank balance sheets do not change through the forecast horizon. The adverse macro scenario is developed by the European Central Bank and European Systemic Risk Board (ESRB) and aims to capture the systemic risks representing the most material threats to the stability of the EU financial sector. This is accompanied by a traded risk stress incorporating an adverse scenario consistent with the macro scenario, and another two based on historical stress episodes.

### Case study 4: the Bank of England

The Bank of England ran its first concurrent stress test in 2014, though the 2016 test will be the first conducted under its new framework.<sup>(5)</sup> That framework incorporates an annual cyclical scenario and a biennial exploratory scenario, which the Bank intends to run for the first time in 2017. In the Bank of England's 2015 and 2016 stress tests, seven major UK banks took part. Together these institutions account for around 80% of the lending to the UK real economy.

(1) From its inception, in the aftermath of the Asian financial crises of the 1990s, up to end-2015, there have been almost 350 FSAP assessments across 170 jurisdictions.

(2) For example, the integrated framework for solvency and liquidity stress testing (Barnhill and Schumacher (2011); a primer for stress testing pension funds (Impavido (2011)).

(3) For example, the Systemic Risk and Interconnectedness (SyRIN) framework (Segoviano *et al* (2016), forthcoming) used in the 2015 US FSAP and 2016 UK FSAP.

(4) See Segoviano *et al* (2017), forthcoming.

(5) For more details see Bank of England (2015).

The severity of the annual cyclical scenario, which is run over a five-year horizon, is designed to vary with policymakers' judgements on risks associated with the state of the financial cycle.<sup>(1)</sup> This is judged using key indicators including credit variables, financial market and other asset prices. The Bank of England uses a dynamic balance sheet approach, and the stress test also includes a traded risk scenario calibrated to be consistent with the shocks in the macro scenario and an additional misconduct stress. The hurdle rate framework for the annual cyclical scenario is set according to individual firms' capital requirements and also includes buffers for systemically important banks. The hurdle rate is therefore greater than the internationally agreed minima applying to all banks.

### Case study 5: the Bank of Japan

The Bank of Japan runs a semi-annual top-down macro stress test, used for risk identification and communication purposes, the results of which appear in their *Financial System Report*. The scenarios employed reflect the state of economic and

financial conditions. The test results are not, however, used to set capital for banks.

The stress test incorporates data on more than 350 banks, from large banks to very small local banks holding deposit accounts with the Bank of Japan. The framework is designed to help the Bank of Japan to analyse feedbacks and spillovers in a stress, between the banking and macroeconomic sectors, as well as across banks.

**Table 1** summarises further detail on the stress-test frameworks described above. This is not an exhaustive list, however, as several other central banks and regulators also run stress tests of various types. In many cases, these frameworks are still developing.

(1) For details on the Bank of England's inaugural annual cyclical scenario, see Bank of England (2016).

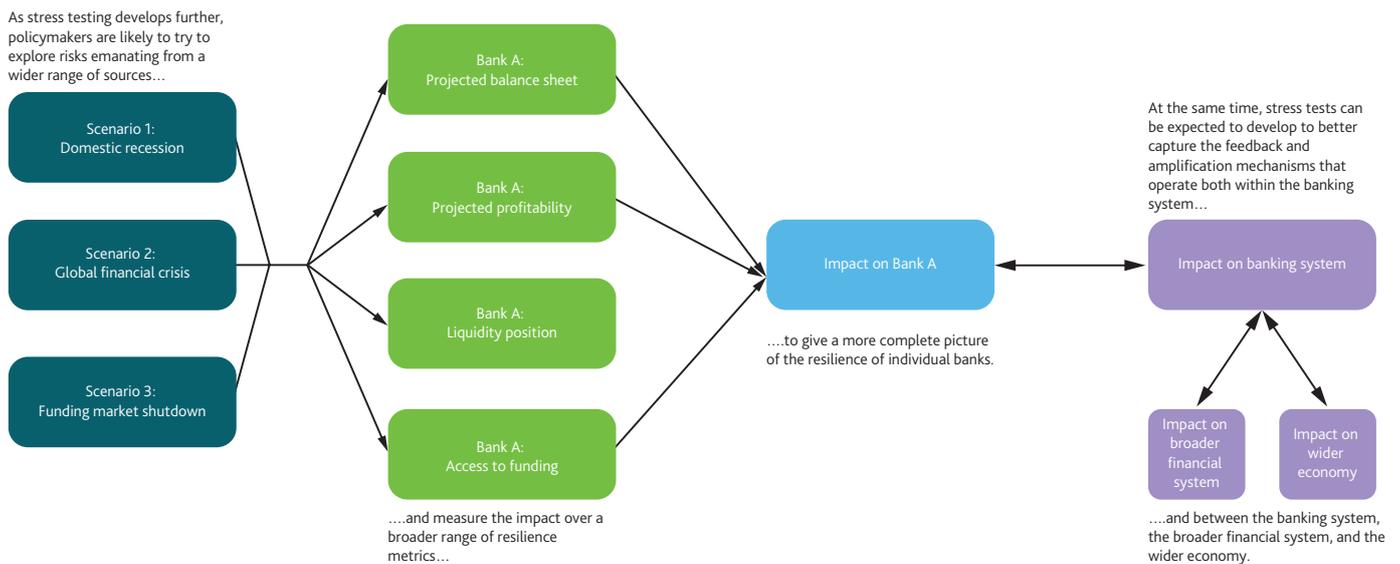
**Table 1** Summary of selected international stress-testing frameworks

	Bank of England	US Federal Reserve	European Banking Authority	IMF	Bank of Japan
<b>Design</b>					
Bank inclusion threshold	£50 billion retail deposits	US\$50 billion total assets	At least €30 billion total assets	Varies according to country circumstances	More than 350 banks are part of the test, including 10 major banks.
Comprehensive macro scenario	✓	✓	✓	✓	✓
Hurdle rate in excess of international minima	✓	✓	x	Varies according to country circumstances	x
Countercyclical	✓	Some elements	x	x	✓
Number of stress scenarios	1–2	2	1 macro	Varies according to country circumstances	2
Frequency	Annual	Annual	Biennial	With FSAP	Semi-annual
<b>Results production</b>					
Bottom-up (banks)	x	Collected but not typically driver of results	✓	x	x
Bottom-up (authorities)	x	✓	x	x	x
Top-down (authorities)	x	Produced but not typically driver of results	x	x	✓
Hybrid	✓	x	x	✓	x
Explicitly incorporates amplification and feedback channels	✓ (early stages of development)	x	x	Sometimes	✓
<b>Results use</b>					
Microprudential policy setting <sup>(a)</sup>	✓	✓	✓	Provides supporting information	x
Macroprudential policy setting <sup>(b)</sup>	✓	May feed in	Via link to European Systemic Risk Board	Provides supporting information	x
Systemic risk identification	✓	✓	Via link to European Systemic Risk Board	✓	✓

(a) For the purposes of this table, microprudential policy is defined as helping to set capital buffers for individual institutions and helping authorities judge whether institutions need to adjust their capital plans.

(b) For the purposes of this table, macroprudential policy is defined narrowly as helping to set system-wide capital buffers. The Bank of England has been explicit about the link between its stress tests and the setting of system-wide buffers.

**Figure 4** Illustrating potential developments in current stress testing



to satisfy such withdrawals. Funding resilience, on the other hand, measures the sustainability of a bank's funding profile. In times of stress, a bank's ability to roll over and raise funding may become impaired such that it is unable to raise sufficient funds, or can only do so at a much higher cost.

Seeking to capture liquidity and funding resilience more completely within concurrent stress-testing frameworks would give a more complete picture of banks' resilience to the stress scenario. While some authorities already operate liquidity and funding stress tests, they are generally less advanced (BCBS (2013)). And where regulatory authorities do perform liquidity, funding and solvency stress tests, they tend to operate them independently. Such an approach may miss the interconnections that exist between these different resilience metrics. For example, when a bank does not have sufficient liquid assets or is unable to raise sufficient funds, it may be forced into selling longer-term, illiquid assets at discounted prices to raise cash. In extreme cases, the losses made on such sales may bring the bank's solvency into question.<sup>(1)</sup>

Authorities are also likely to try to explore risks emanating from a broader range of sources. At present, the concurrent stress-testing frameworks of most regulatory authorities incorporate a single or dual scenario approach. But since any individual scenario is very unlikely to materialise, there is a case for trying to increase the flexibility of stress tests such that a greater number of scenarios can be explored in any given year. A multiple scenario approach also offers the flexibility to explore risks that may present new and emerging threats to financial stability, as well as testing bank resilience against a more regular and well understood set of risks.

This more flexible approach could significantly increase the resource burden stress testing places on both participating banks and regulatory authorities. As a consequence, over

time, authorities are likely to strive to make stress tests more systematic and automated to make the implementation of multiple scenario approaches more feasible.

Against these potential cost savings, stress-testing authorities may have to weigh the risk of making tests easier for participating banks to predict. This could focus banks' attention away from conducting a holistic risk management exercise towards simply passing stress tests. The qualitative reviews of bank risk management practices run by many regulatory authorities in conjunction with their stress-testing exercises could, however, help to mitigate this potential downside of further automation.<sup>(2)</sup>

### Integrating amplification and feedback mechanisms and incorporating behavioural responses into stress tests

Stress tests have arguably the greatest potential to add value from a macroprudential policy perspective through illustrating how a stress could impact the financial system as a whole (Demekas (2015)). From this perspective, it is often feedback and amplification channels that prove important in driving contagion losses and exacerbating the impact of an initial shock (Constancio (2015)).

For example, during the global financial crisis, significant losses at individual banks eroded their loss-absorbing capital resources and brought into question banks' ability to continue to meet their regulatory capital requirements. Market uncertainty over the solvency of different banks led to strains in bank funding markets, impairing banks' ability to raise funds.

(1) See Farag, Harland and Nixon (2013) for further explanation of how solvency and liquidity can interact in this way.

(2) For more details on the Bank of England's qualitative assessment of banks' risk management and planning capabilities, see Section 2.5 of Bank of England (2015).

In such circumstances, the behavioural responses of the banks themselves become another important feedback channel. If all banks respond to funding market strains by looking to substitute wholesale funding for retail deposits, increased competition in retail deposit markets is likely to drive up interest rates. This, in turn, is likely to have an adverse impact on bank profitability. Gaining a better understanding of such feedback and amplification channels, and the role they play in driving contagion losses and contributing to systemic risk is a key priority for policymakers.

Policymakers have a comparative advantage over individual banks in this area because they are able to access projections across stress-test participants. This enables them to take a view of the broader market conditions that might prevail during the stress, and judge the feasibility of individual banks' proposed responses in light of this. Several authorities have already made efforts to incorporate behavioural responses into their stress-testing frameworks, through the use of dynamic balance sheets and consideration of management actions (see the box on pages 138–39). But there remains a need for frameworks to assess the consistency of such actions, and analysis of other feedback and amplification channels is still at an early stage.

### Extending the scope of stress tests beyond the core banking sector

As the financial crisis demonstrated, interconnections between different parts of the financial system can serve to transmit stresses originating in a particular market segment across the broader financial system, amplifying the effects of the initial shock. A stress test investigating interconnections between banks and the wider financial system could explore both direct links (through financial transactions) and indirect links (through the behaviour of different financial institutions) that have the potential to transmit and amplify shocks.

Financial transactions create direct links between both banks and non-bank financial institutions. Repurchase agreements ('repos') are one example of such transactions, and in times of stress the haircuts — the discount applied to the asset used as collateral — demanded by buyers in repo transactions tend to increase, which can exacerbate funding difficulties faced by other financial institutions.

Even in the absence of direct links, the behaviour of different financial institutions in a stress could propagate shocks across the financial system. For example, some asset managers have mandates that prevent them from investing in assets with poor credit ratings. During the recent financial crisis, a significant number of financial assets had their credit ratings downgraded. This led to asset sales on a large scale which significantly reduced the prevailing market prices for these assets and forced losses on other institutions holding these same assets (Deb *et al* (2011)).

While macroprudential authorities are already engaged in analysis of interconnections between different parts of the financial system, no authority has yet undertaken a comprehensive system-wide stress test. Such a stress test would seek to incorporate other financial institutions, including central counterparties, hedge funds, insurers and money market funds. The precise form of a system-wide stress test might well differ from bank stress tests. But it could contribute to an improved understanding of how shocks can propagate through the financial system giving rise to systemic risk, which might also be reflected in banks' losses.

Extending the reach of stress testing beyond the core banking sector would help in guarding against any perverse incentives stress tests and broader bank regulation creates for institutions to move activities outside the core banking sector into the so-called 'shadow banking sector'. It may also inform policymaking to help ensure that banks and other regulated entities are resilient to contagion risk emanating from unregulated financial institutions. To this end, the Financial Stability Board (FSB) recently recommended that regulatory authorities should give consideration to system-wide stress testing (FSB (2016)).

## Conclusions

Since the 1990s, stress tests have evolved from being a risk management tool used by banks on specific portfolios, to being widely used by authorities as a regulatory tool, covering large banking systems. Authorities engaged in concurrent stress testing have a wide range of differing objectives and to some extent this is reflected in the different stress-testing practices they have adopted. For example, some without capital-setting powers use tests as a means to flag up financial stability risks, while others use tests to help to set capital for individual banks.

For stress testers using results to help set microprudential policy, a key area of potential future development is incorporating a greater range of risks in concurrent tests. For example, better integrating liquidity and funding risks within solvency-orientated stress tests should provide regulators with a more complete view of risks facing individual banks.

There are also several ways in which present stress-testing practices could be augmented to make tests better suited to mitigating system-wide risks. These include integrating amplification and feedback mechanisms into concurrent stress tests and incorporating behavioural responses, as well as extending the scope of stress tests beyond the core banking sector, to get a broader picture of the likely impact of a stress on the financial system. A forthcoming IMF paper suggests a way forward in that regard for authorities.<sup>(1)</sup>

(1) Segoviano *et al* (2017), forthcoming.

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## References

- Araten, M (2013)**, 'The advancement of stress testing at banks', in Zhang, J (ed), *CCAR and Beyond — Capital Assessment Stress Testing and Applications*, Risk Books.
- Bank of England (2006)**, *Financial Stability Report*, July, available at [www.bankofengland.co.uk/publications/Documents/fsr/2006/fsrfull0606.pdf](http://www.bankofengland.co.uk/publications/Documents/fsr/2006/fsrfull0606.pdf).
- Bank of England (2015)**, 'The Bank of England's approach to stress testing the UK banking system', available at [www.bankofengland.co.uk/financialstability/Documents/stresstesting/2015/approach.pdf](http://www.bankofengland.co.uk/financialstability/Documents/stresstesting/2015/approach.pdf).
- Bank of England (2016)**, 'Stress testing the UK banking system: key elements of the 2016 stress test', available at [www.bankofengland.co.uk/financialstability/Documents/stresstesting/2016/keyelements.pdf](http://www.bankofengland.co.uk/financialstability/Documents/stresstesting/2016/keyelements.pdf).
- Barnhill, T and Schumacher, L (2011)**, 'Modeling correlated systemic liquidity and solvency risks in a financial environment with incomplete information', *IMF Working Paper No. 11/263*.
- Basel Committee on Banking Supervision (1999)**, 'Credit risk modelling: current practices and applications', April.
- Basel Committee on Banking Supervision (2009)**, 'Principles for sound stress testing practices and supervision', May.
- Basel Committee on Banking Supervision (2013)**, 'Liquidity stress testing: a survey of theory, empirics and current practices', *BCBS Working Paper No. 24*.
- Bernanke, B (2010)**, 'The Supervisory Capital Assessment Program — one year later', available at [www.federalreserve.gov/newsevents/speech/bernanke20100506a.htm](http://www.federalreserve.gov/newsevents/speech/bernanke20100506a.htm).
- Blaschke, W, Jones, M, Majnoni, G and Peria, S (2001)**, 'Stress testing of financial systems: an overview of issues, methodologies, and FSAP experiences', *IMF Working Paper No. 01/88*.
- Committee on the Global Financial System (2000)**, 'Stress testing by large financial institutions: current practice and aggregation issues', *CGFS Paper No. 14*.
- Committee on the Global Financial System (2005)**, 'Stress testing at major financial institutions: survey results and practice', *CGFS Paper No. 24*.
- Constancio, V (2015)**, 'The role of stress testing in supervision and macroprudential policy', available at [www.ecb.europa.eu/press/key/date/2015/html/sp151029.en.html](http://www.ecb.europa.eu/press/key/date/2015/html/sp151029.en.html).
- De Bandt, O and Oung, V (2004)**, 'Assessment of stress tests conducted on the French banking system', *Banque de France Financial Stability Review No. 5*.
- Deb, P, Manning, M, Murphy, G, Penalver, A and Toth, A (2011)**, 'Whither the credit ratings industry?', *Bank of England Financial Stability Paper No. 9*, available at [www.bankofengland.co.uk/financialstability/Documents/fpc/fspapers/fs\\_paper09.pdf](http://www.bankofengland.co.uk/financialstability/Documents/fpc/fspapers/fs_paper09.pdf).
- Demekas, D (2015)**, 'Designing effective macroprudential stress tests: progress so far and the way forward', *IMF Working Paper No. WP/15/146*.
- Farag, M, Harland, D and Nixon, D (2013)**, 'Bank capital and liquidity', *Bank of England Quarterly Bulletin*, Vol. 53, No. 3, pages 201–15, available at [www.bankofengland.co.uk/publications/Documents/quarterlybulletin/2013/qb130302.pdf](http://www.bankofengland.co.uk/publications/Documents/quarterlybulletin/2013/qb130302.pdf).
- Financial Stability Board (2016)**, 'Proposed policy recommendations to address structural vulnerabilities from asset management activities', 22 June 2016.
- Haldane, A (2009)**, 'Why banks failed the stress test', available at [www.bankofengland.co.uk/archive/documents/historicpubs/speeches/2009/speech374.pdf](http://www.bankofengland.co.uk/archive/documents/historicpubs/speeches/2009/speech374.pdf).
- Hoggarth, G, Sorensen, S and Zicchino, L (2005)**, 'Stress tests of UK banks using a VAR approach', *Bank of England Working Paper No. 282*, available at [www.bankofengland.co.uk/archive/Documents/historicpubs/workingpapers/2005/wp282.pdf](http://www.bankofengland.co.uk/archive/Documents/historicpubs/workingpapers/2005/wp282.pdf).
- Impavido, G (2011)**, 'Stress tests for defined benefit pension plans — a primer', *IMF Working Paper No. 11/29*.

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**International Monetary Fund (2014)**, 'Review of the Financial Sector Assessment Program: further adaptation to the post crisis era'.

**Krugman, P (2014)**, 'Does he pass the test?', *The New York Review*, July 10.

**McGee, A and Khaykin, I (2013)**, 'Financial institution perspectives on the evolving role of enterprise-wide stress testing', in Zhang, J (ed), *CCAR and Beyond — Capital Assessment Stress Testing and Applications*, Risk Books.

**Schuermann, T (2013)**, *Stress testing banks*, Wharton Financial Institutions Center.

**Segoviano, M, Malik, S, Lindner, P and Cortes, P (2016)**, 'A comprehensive multi-sector framework for surveillance of systemic risk and interconnectedness (SyRIN)', *IMF Working Paper*, forthcoming.

**Segoviano, M, Espinoza, R, Alla, Z and Li, Q (2017)**, 'Systemic risk amplifiers in macroprudential stress testing: introduction to contagion effects', *IMF Working Paper*, forthcoming.

**Virolainen, K (2004)**, 'Macro stress testing with a macroeconomic credit risk model for Finland', *Bank of Finland Discussion Paper No. 18/2004*.

**Zhang, J (ed) (2013)**, *CCAR and Beyond — Capital Assessment Stress Testing and Applications*, Risk Books.