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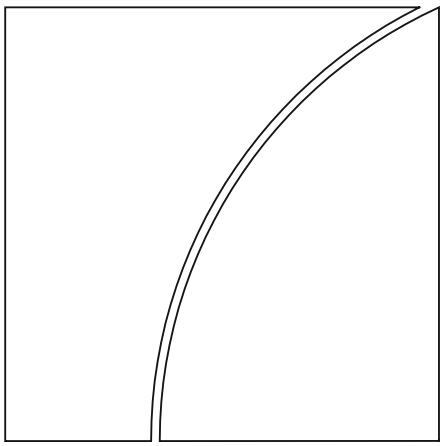

Stress-testing banks – a comparative analysis

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Executive summary

Stress tests have become well established tools for authorities to assess the resilience of individual banks and of the banking sector, especially since the Great Financial Crisis (GFC). Stress tests are forward-looking exercises that aim to evaluate the impact of severe but plausible adverse scenarios on the resilience of financial institutions. Initially developed with a focus on individual banks, they were first used in a systematic way and with a financial sector-wide perspective by the International Monetary Fund (IMF) and the World Bank starting in May 1999, as part of their Financial Sector Assessment Program (FSAP). Following the successful experience in response to the GFC, stress tests have become common practice among authorities, mostly for banks, which is what this paper focuses on.

Sector-wide stress tests differ widely in their design and implementation. A comparison of country practices, complemented by a review of the literature, shows that authorities design stress tests in different ways, with some employing more than one type of test. To better understand these differences and their drivers, the Financial Stability Institute (FSI) conducted a comparative analysis, for which extensive information was gathered from selected authorities across the globe. In particular, the paper covers practices on system-wide stress tests for banks, ie stress tests that cover a significant part of the banking sector in the euro area, Japan, Switzerland and the United States. It presents information in a consistent way across exercises on how these are conducted by central banks and supervisory authorities in these jurisdictions.

Stress tests can have a microprudential or macroprudential policy objective. In a stress test with a microprudential objective, the exercise, albeit system-wide, is focused on assessing the resilience of individual banks, providing authorities with information on whether these banks should take remedial actions (such as increasing regulatory capital, reducing risk exposures or improving their capital planning processes). In turn, stress tests with a macroprudential objective focus on system-wide risks and their aggregate impacts. They may also be used by authorities as an input to calibrate macroprudential measures. In exceptional circumstances, ie at times of systemic financial crises, stress tests can be and have been used to provide information about recapitalisation needs for both individual banks and the banking system, and they can also help restore market confidence.

This paper identifies three building blocks in the setup of any stress test and relates them to policy objectives. These building blocks are governance (responsibilities and coverage), implementation (technical requirements and design) and outcomes (results and communication). Each building block comprises various elements, and authorities need to make decisions on them in the light of their policy objectives. Authorities' decisions may also be affected by operational constraints, such as data and resource availability.

Stress tests are most effective when their design is fully aligned with the policy objectives associated with them. It is crucially important that authorities make an early decision about why they would like to run a stress test, and how they plan to use the results. For given operational constraints,

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authorities' policy objectives are the most effective criterion to select the preferred approach within each of the three above-mentioned building blocks. This also brings internal consistency within the exercise, as all decisions will be driven by the same goal. Consistency with the high-level principles for stress testing recently published by the Basel Committee on Banking Supervision (BCBS (2018)), which also cover objectives, governance, technical implementation and communication, is an important step in this regard.

However, stress tests are no panacea, and are best used in combination with other tools. Although stress tests are a powerful tool to understand conditions in the banking sector, or of individual banks, the validity of their results is affected by a number of factors, such as data quality and availability, model risk and models' capacity to capture contagion effects and interlinkages, both within the banking sector and beyond. Moreover, since the results are conditional on assumptions in the methodology and the scenario design, a stress test should not be expected to accurately predict the impact of a specific, forthcoming crisis. It is rather a hypothetical exercise intended to assess the resilience of a bank or the banking sector against various potential shocks. Stress tests are therefore best complemented by other tools available to the authorities to achieve their policy objectives, such as systemic risk monitoring or capital planning reviews.

Stress testing is being continually improved, and further developments could help to enhance the implementation and the policy use of stress tests. There are several areas where stress tests could be improved, such as, on the implementation side, the joint treatment of solvency and liquidity risks or the specification of second-round, spillover and contagion effects. On the policy side, more authorities could use stress tests as an input to the calibration of macroprudential measures, and stress tests could be further integrated into regular supervisory reviews. Some of these changes will be driven by progress in research or advances in technology, while others will be dependent on gaining enough practical experience, especially in the macroprudential sphere. From a global perspective, a dialogue among relevant authorities regarding a common scenario design for large and cross-border active banks would be a helpful addition to the stress testing landscape.

Section 1 – Introduction and definitions

1. **This section provides an introduction and overview of stress test programmes implemented by public authorities such as central banks and supervisors.** This FSI Insights paper focuses on stress tests for the banking sector conducted by such authorities, therefore not covering financial institutions other than banks. The focus is on stress tests that are conducted on a sample of banks which is comprehensive enough for the exercise to be termed system-wide. This section introduces the motivation for such stress tests and how they emerged and have evolved over time. A few important definitions and concepts used throughout the paper are also introduced here.

What are stress tests?

2. **For the banking sector, stress tests are simulation exercises conducted to assess the resilience to a hypothetical scenario of either a single bank or the system as a whole.** IMF (2012) describes stress tests as a quantitative "what if" exercise to estimate the resilience of banks or the financial systems as a whole if certain shocks were to materialise. In general, there are two types of tests: (1) system-wide stress tests conducted by central banks and/or supervisory agencies; and (2) stress tests that focus on individual banks and that can be carried out by banks themselves or supervisors. This paper focuses on the first type of exercise, ie system-wide stress tests used by authorities to evaluate how a significant sample of individual banks' or the system as a whole can withstand shocks.

3. **Stress tests that address bank solvency have become an important supervisory and policy tool.** System-wide stress tests have emerged as a key risk management tool to guide bank recapitalisation, especially since the Great Financial Crisis (GFC). The emphasis on stress tests to assess and replenish bank solvency was justified by the fact that capital is at the core of a bank's ability to absorb losses and continue to lend. Solvency stress tests help to assess banks' capital planning as well as their capital adequacy, thereby reducing the likelihood of failure. Stress tests could also focus on liquidity, by examining if a bank has enough cash inflows to withstand cash outflows in a stressed scenario. Solvency and liquidity risks are often connected, as suggested in BCBS (2015) and other related studies. However, in comparison with solvency stress tests, the development of system-wide liquidity stress tests has generally lagged behind.[2]

4. **Stress tests can fulfil a variety of policy objectives.** Stress tests are more than just numerical calculations of the impact of a scenario. They can help policymakers to set microprudential measures to ensure that individual banks are adequately resilient. By subjecting banks to the same adverse scenario, stress tests can also be used to inform macroprudential policy settings. For example, stress tests can be used to determine the resilience of the banking system to some common economic or financial risks, or to support the calibration of macroprudential instruments.

5. **While stress tests have gradually become mainstream, it is important to keep in mind their limitations.** Stress test results are vulnerable to many factors, including limitations in data quality and granularity, severity or scope of the scenarios, and model risk – especially in relation to complex methodologies and related assumptions. They do not "forecast" future banks' performance under stress; rather, they aim to identify the impact on banks of a specific stress scenario, based on a number of given assumptions.[3]

[2] According to Schmieder et al (2012), until the GFC systemic liquidity risks were considered to be less of an issue. Moreover, liquidity crises are lower-frequency events – which greatly reduces the scope of historical data to calibrate the models – and liquidity crises can take different forms to solvency crises.

[3] See eg Borio et al (2012) for a discussion on limitations of macro stress tests.

A brief history of stress testing

6. **The first use of stress tests can be dated back to the early 1990s, when they were mainly run by individual banks for internal risk management purposes.** Stress tests' design and functions have significantly evolved over time. Prior to the GFC, most of the exercises were small-scale and were used to complement other statistical tools available to bank management to evaluate a bank's trading activities (Blaschke et al (2001)). The practice of using stress tests to evaluate trading portfolios was formalised in the 1996 market risk amendment to the Basel Capital Accord (BCBS (1996)). In addition, in 2004, with the Basel II framework, banks were asked to apply rigorous internal stress testing exercises in both Pillar 1 and Pillar 2. However, Basel II was not universally implemented, and most internal stress testing models were found to be still at the developmental stage prior to the onset of the GFC (BCBS (2009), Senior Supervisors Group (2009)). Moreover, stress tests were typically conducted only for individual institutions. Nevertheless, already in the early 2000s authorities started to consider the possibility of system-wide exercises, and to analyse the complexities of aggregating bank-level results based on different methodologies and scenarios (CGFS (2000)[4]).

7. **System-wide stress tests, led by authorities, were introduced by the IMF and the World Bank, prior to the GFC.** The establishment of the Financial Sector Assessment Program (FSAP) in 1999 recognised the impact of financial stability on economic growth and financial markets. Since its inception and up to mid-2018, there have been 346 FSAP assessments across 173 jurisdictions.[5] Stress tests are a key component of the FSAP and they have been performed for every participating country since the programme's inception. The tests involve a quantitative vulnerability assessment of a country's financial system to adverse macro-financial scenarios.

8. **Increasing attention was drawn to stress testing during the GFC, and authorities in the United States and the European Union in particular used stress tests in their crisis response.** The financial crisis illustrated how the economy could be seriously damaged when banks become distressed and restrict lending, and it highlighted deficiencies in risk management across the financial system. In response, in the United States the Federal Reserve's Supervisory Capital Assessment Program (SCAP) in 2009 evaluated whether the largest domestic banks had sufficient capital resources to absorb losses and continue to operate. The results were publicly disclosed, and the US Department of the Treasury provided a backstop guarantee. The exercise was assessed to have helped to restore broader market confidence and stabilise the financial system (Bernanke (2013) and Schuermann (2014)). In the European Union (EU), stress tests were performed by the Committee of European Banking Supervisors (CEBS) as of 2009. In particular, in 2010 CEBS conducted an EU-wide exercise with extensive disclosure about individual banks' estimated capital impact and their risk exposure (see ECB (2010) for a comparison between these two crisis-time exercises).

9. **System-wide stress tests have been conducted on a regular basis since the GFC.** Since then, stress tests have risen to a prominent role in many jurisdictions (BCBS (2017)). For instance, since 2011 a series of exercises have been performed by the European Banking Authority (EBA), establishing regular supervisory exercises across the EU.[6] In the US, supervisory stress tests have been conducted on an annual basis since 2011.[7] In all of these cases, the focus has generally shifted away from the immediate need to

[4] The CGFS also reviewed stress testing practices as they developed over time; see CGFS (2001, 2005).

[5] FSAP processes are described in IMF (2014a). An introduction to stress testing in FSAPs can be found in Cihak (2017). For a more encompassing discussion of macro-financial stress testing approaches, see IMF (2012, 2014b).

[6] At the time when the Single Supervisory Mechanism (SSM) was launched in 2014, a fully fledged Asset Quality Review was conducted by the SSM along with the stress testing exercise (see ECB (2014) for details on the latter).

[7] In particular, the Dodd-Frank Annual Stress Test (DFAST), since 2013, and the Comprehensive Capital Assessment Review (CCAR), since 2011.

recapitalise individual banks towards a regular surveillance of the adequacy of banks' capital resources and to informing broader prudential policies, with primarily a focus on microprudential measures.

10. **Therefore, there is now a wide body of experience and a substantial literature on stress testing.** Since the GFC, there has been significant advancement in the implementation and use of stress testing conducted by national or regional authorities (see eg Dent et al (2016)), involving international organisations, national authorities, academics and the banking industry. In the regulatory community, the Basel Committee on Banking Supervision (BCBS) reviewed practices (BCBS (2017)) and issued principles for sound stress testing already in 2009, updating them in 2018 (BCBS (2009, 2018)). The official community has also promoted the inclusion of a macroprudential dimension in stress testing (see BCBS (2015)), and there is now a burgeoning literature documenting progress in this direction (eg Anderson et al (2018) and Demekas (2015)). National or regional authorities in charge of microprudential and macroprudential stress tests have themselves documented their stress testing approaches to exercises, and how these have developed over time.[8]

Scope of the paper and relevant definitions

11. **This FSI Insights paper discusses stress tests conducted by authorities in four jurisdictions: the euro area, Japan, Switzerland and the United States.[9]** These jurisdictions have been selected as a representative sample group of advanced economies with a large and complex financial sector, with a view to highlighting and comparing key features of the stress tests they conduct. They also represent a geographically diverse group, and have been among the ones at the forefront in developing stress testing frameworks. The authorities in charge, and covered in the paper, are: for Japan, the Bank of Japan (BoJ) and the Financial Services Agency, Japan (JFSA); for the euro area, the European Central Bank (ECB),[10] including its supervisory function (SSM); for Switzerland, the Swiss National Bank (SNB) and the Swiss Financial Market Supervisory Authority (FINMA); and for the US, the Board of Governors of the Federal Reserve System (FRB).[11]

12. **This paper complements the existing body of work on stress testing by providing granular details on stress testing exercises, in a consistent fashion across four major jurisdictions.** As discussed in the following section, there is a growing body of literature on stress testing, including by authorities in countries that have run such exercises for some time. However, each authority typically presents the features and lessons of its exercises in comparison to its own past practices, or to the relevant, albeit still limited, academic literature. Cross-country analysis of stress testing exercises is less frequent,

[8] See eg: for the UK, Bank of England (2015, 2017, 2018a,b); for the US, FRB (2018a,b,d); for Japan, Kitamura et al (2014) and Bank of Japan (2017); for the ECB, Henry and Kok (2013), Dees et al (2016), Dees et al (2017), Mirza and Żochowski (2017), ESRB (2018); and for the EU, EBA (2018a,b). Other authorities such as the central banks of Austria, Canada, the Netherlands, Norway and Singapore provide more irregular disclosure and information about progress in their stress tests, as documented in eg Feldkircher et al (2013), Anand et al (2014), Daniëls et al (2017), Syversten et al (2015) and MAS (2017).

[9] For the purposes of this paper, the euro area is considered a single jurisdiction. The denomination is used for convenience, and it reflects the competencies of the ECB and the ECB/SSM in terms of supervision and the conduct of stress testing (especially for the banks under the direct supervision of the ECB).

[10] Once every two years, the microprudential exercise conducted by the SSM is incorporated in the EU-wide exercise led by the EBA, using the same scenario and methodological guidance. This was the case, for instance, in 2014, 2016 and 2018.

[11] The Dodd-Frank Act requires two types of stress tests: Section 165(i)(1) requires the Federal Reserve to conduct supervisory stress tests for relevant financial companies, and Section 165(i)(2) requires the federal banking agencies including the FDIC and OCC to issue regulations requiring relevant financial companies to conduct company-run stress tests. For stress tests run by the authorities, which are the only ones covered in this study, the Federal Reserve Board is the sole federal regulatory agency.

and when it is conducted, it tends to focus on specific aspects, eg macroprudential stress testing (Anderson et al (2018)).

13. **The paper also aims to identify key features of solvency stress tests, on the basis of the review of the selected jurisdictions and relevant literature, and maps them against the objectives of a given exercise.** The paper identifies the building blocks of a stress test, as well as its possible objectives, and compares how stress tests have been implemented in the four selected jurisdictions. The goal of the analysis is to understand what can lead the authority in charge to make different choices on the typical building blocks of a solvency stress test. In particular, it does so by comparing the design and technical implementation features of a stress test to the policy objectives it is expected to serve. This review can help to draw lessons and identify best practices in stress test implementation. The paper mainly focuses on solvency stress tests, following their predominance up to now in system-wide stress testing.

14. **Conducting a comparative analysis requires defining a few relevant concepts.** Although stress tests have become widely used, there is no consistent definition of key terms across all jurisdictions that run such exercises, and the meaning of some commonly used terms can become ambiguous. To help readability, the following definitions are used throughout the paper.[12]

In terms of degree of severity, a scenario can be described as either "baseline" or "adverse":

a) **Baseline scenario:** a set of economic and financial conditions that is generally consistent with the projection of a likely path for future economic and financial conditions. The baseline scenario usually does not lead to a stressed result.

b) **Adverse scenario:** a set of economic and financial conditions which is designed to stress the performance of the banking sector or an individual bank. The level of stress is significantly stronger than in a baseline scenario. Stress factors could be drawn from historical events or hypothetically created.

In terms of policy objectives, a stress test can be classified as "macroprudential" or "microprudential":

a) **Macroprudential stress test:** a stress test designed to assess the system-wide resilience to financial and economic shocks, which may include effects emerging from linkages with the broader financial system or the real economy. Interactions between individual banks can also be taken into account.

b) **Microprudential stress test:** a stress test designed to assess the resilience of an individual bank to macroeconomic and financial vulnerabilities and respective shocks. Instruments, mechanisms and measures available to the supervisor are usually applied at the bank level.

In terms of who performs the exercise, a stress test can be either "top-down" or "bottom-up":

a) **Top-down stress test:** a stress test performed by a public authority using its own stress test framework (data, scenarios, assumptions and models). Either bank-level or aggregated data may be used, but always in models with consistent methodology and assumptions, generally developed by the authority.

b) **Bottom-up stress test:** a stress test performed by a bank using its own stress test framework as part of a system-wide exercise, or as part of a stress test where authorities provide banks with common scenario(s) and assumptions.

[12] These definitions build on the corresponding ones in BCBS (2017).

Finally, in terms of balance sheet projections, they can be described as "dynamic" or "static":

a) **Dynamic balance sheet (DBS):** an assumption that the size, composition or risk profile of a bank's balance sheet are allowed to vary over the stress test horizon.

b) **Static balance sheet (SBS):** an assumption that the size, composition and risk profile of a bank's balance sheet are invariant throughout the stress testing time horizon.

15. **The rest of the paper is organised as follows.** Section 2 identifies and discusses the building blocks of a stress test, with references to the relevant literature. Section 3 provides examples of how these elements have been shaped in the selected four jurisdictions. Section 4 presents challenges for stress testing going forward and new avenues for development in this field. Section 5 takes a broader perspective, drawing lessons on how authorities can design stress tests' building blocks based on given policy objectives. Section 6 concludes. The Annex[13] provides a detailed description of the stress tests in the euro area, Japan, Switzerland and the United States.

Section 2 – Key elements of a stress testing framework and related literature

16. **This section reviews the main characteristics of stress testing exercises for banks, as conducted by public authorities, against selected literature.** Stress tests are complex exercises, the implementation of which comprises many technical components and involves a number of agents. Identifying the characteristics of such exercises helps to better understand and compare them, as is done in the subsequent section. In this section, emphasis is put on the existing, mostly institutional, literature, with a focus on implementation aspects, including their development over time. The literature review is necessarily selective, given the extensive scope of the paper.

17. **A stress test can be characterised by its objectives and its key technical features.** Stress tests can have different objectives, and their conduct requires the specification of a number of key features. These features can be organised along three building blocks, which are common across stress testing exercises. They are the governance around the exercise, its implementation (technical requirements and design) and outcomes (results and publication). These general concepts are discussed in this section, building on the existing related literature.

Objectives and use of stress tests

18. **In microprudential exercises, authorities use stress test results as part of the supervisory review to assess the strategies, processes and risk resilience of individual institutions.** Here, the supervisory authorities use the results as an important input into the supervisory review process. They complete the qualitative part of the supervisory assessment of the banks by providing a wealth of granular information on each individual bank. In this context, some authorities use stress tests for reviewing and validating the Internal Capital Adequacy Assessment Process of banks (BCBS (2017)), for determining the Pillar 2 capital requirements or for checking the soundness of individual banks' capital planning.

19. **Macroprudential stress tests focus on assessing the system-wide resilience to shocks, going beyond the simple addition of bank-level results.** In line with this goal, and as argued eg in Demekas (2015), macroprudential stress tests aim at capturing the behavioural responses of affected institutions as well as the interactions of these institutions with each other and with other economic agents. This is an overall challenging task, and can at least partly explain why macroprudential stress tests have

[13] The Annex is available as an online appendix and can be found on the BIS website.

developed only recently. In practice, one implementation option is to conduct a stress test addressing both macroprudential and microprudential objectives (eg Bank of England (2015)). Alternatively, the system-wide perspective may be implemented as extensions to bank-level approaches (ie by aggregating results for individual banks and explicitly adding interactions) or as completely separate approaches (using more bank-level, aggregate or market-based data).[14] For instance, a self-contained microprudential part can drive a macroprudential exercise (see Dees et al (2017)) for the ECB) or the interaction between the aggregate behaviour of banks and macroeconomic activities can be explicitly modelled (eg Kitamura et al (2014) for the BoJ). However, many aspects of macroprudential stress tests remain works in progress. Challenges largely stem from the fact that simply adding bank-level results would not necessarily deliver a relevant aggregate picture for the system, given the interactions at play.[15]

20. **Macroprudential stress tests can also be used as an input in the calibration of macroprudential instruments.** Following the GFC, macroprudential instruments, such as countercyclical capital buffers (CCyB) or limits on relevant ratios such as the loan-to-value or debt-to-income ratios, have been used by various authorities, and some of these instruments have become part of the regulatory framework (eg the CCyB). In order to estimate the suitable value of an instrument such as the CCyB, some authorities use stress tests (see eg Bank of England (2015, 2018a).

21. **Stress testing exercises at crisis times, which combine macroprudential and microprudential objectives, are one of the authorities' tools for crisis management.** In crisis times, bank-specific and systemic risks tend to coincide, as all banks are affected by the system-wide disturbance. For this reason, stress test exercises during systemic crises bring together elements of macroprudential and microprudential stress tests, as addressing the weakness of many banks coincides with addressing system-wide failures. What sets apart crisis-times stress tests is their primary objective of supporting authorities' responses to contain and manage the crisis. In these circumstances, stress tests provide authorities with estimates of the capital gaps at individual banks, and, if results are to be published, they can help to restore market confidence. The difference in use between crises and normal times has sharpened over time, and, as explained in Section 1, especially during and after the GFC.[16] Since then, the difference between microprudential and macroprudential stress tests has also become more marked.

22. **Solvency stress tests can include minimum capital thresholds, ie hurdle rates**. These thresholds can be used as the basis to conclude whether banks have passed or failed the exercise. Such hurdle rates are typically used in crisis times, when possible recapitalisation needs and a clear distinction between strong and weak banks are important. They can also be used in microprudential or macroprudential stress tests in normal times, depending on the policy approach taken by the authority in charge. Setting hurdle rates, when employed, is a key element in some stress tests, contributing to define their overall level of severity.

Governance – responsibilities and coverage

23. **Typically, either the supervisory authority or the central bank leads a stress test exercise.** These authorities' roles and responsibilities in an exercise, as well as the interaction between them, typically mirror their respective mandates for monitoring, assessing and supervising individual banks and system-wide aspects of the banking sector. Ideally, the extent to which the exercises take a more micro- or a macroprudential approach influences the designation of the authority in the lead. In some countries, the

[14] For a more detailed discussion about practices related to system-wide approaches, see eg IMF (2012), Demekas (2015) and Anderson et al (2018).

[15] For instance, while considerable progress has been achieved by authorities in modelling direct interbank exposures, there is currently no consensus on how to incorporate indirect contagion effects due to fire sales, herding and information asymmetry. Similarly, work on integrating the non-bank financial sector into the analysis is still at very early stages (Anderson et al (2018)).

[16] See Schuermann (2016) for a comparison of objectives of stress tests between crisis and normal times.

central bank and supervisors both run a stress test exercise, but independently of one another, with the central bank's exercise taking primarily a macroprudential perspective, and the supervisor's primarily a microprudential one (eg Switzerland and Japan). In other cases, the system-wide exercises are run by a single authority, which assumes both micro- and macroprudential functions (eg the euro area, the United Kingdom and the United States). According to BCBS (2017), the majority of supervisory authorities do not have a formal process for coordinating supervisory stress testing frameworks with other domestic authorities.

24. **Operational constraints are another important factor affecting the setup and coverage of a stress testing exercise.** The number of banks covered and the overall share of total banking assets they represent; resources, both in terms of number of staff and their technical skills; and data availability and access to it all have a decisive impact. Access to granular bank-specific data may depend on authorities' remit,[17] legal constraints and availability of historical data. Resources that can be devoted to a stress exercise may impact sample coverage, the number of stress scenarios and modelling choices.[18]

Implementation – technical requirements and design

Scenario design

25. **The starting point of a stress testing exercise is the stress scenario(s) underpinning it.** The scenario is a combination of macro-financial variables that are expected to affect the resilience of individual banks and of the financial sector. Stress scenarios simulate a severe, broad-based downturn affecting the real economy as well as financial markets and asset prices. The stress scenario, which can be one or more, is a defining feature of a stress test exercise. It can correspond to a historical or hypothetical crisis configuration, depending on the underlying narrative. Based on the risk factors under consideration, it determines the intensity of the shocks, the transmission channels and time horizon over which the stress factors can affect the banks. In all cases, it is a fundamental driver of the quantitative results of the exercise.[19]

26. **A scenario can be designed in at least three different ways.**[20] One approach is to focus on macroeconomic variables. This requires including shocks to some key macroeconomic variables (eg unemployment rate, asset prices) that are most affected during a recession. The shocks to other macro-financial variables are set consistently in terms of magnitude and direction, also in line with the narrative. A second approach to specify the shocks underlying the scenario is to derive them by aggregating information on individual bank portfolios and corresponding granular risk factors. This approach is typically used in bottom-up stress tests, and its applicability largely hinges on the availability of relevant data. A third option is reverse stress testing, whereby the scenario is calibrated so as to deliver a given estimated likelihood or an expected capital ratio post-stress (see eg Breuer et al (2012)). While helpful to identify additional vulnerabilities going forward, this approach is challenging to implement and to interpret for policy purposes, due eg to the diversity and complexity of interactions across risk types and factors.

27. **Different types of stress tests will have different time horizons.** Any stress test requires the specification of a time horizon, and the choice depends on the type of the exercise and its objective. For a solvency stress test, the typical stress scenario horizon can run between two to three, or in some cases

[17] This could affect the extent to which authorities can access group- or entity-level data, which in turn would have a bearing on the capacity of the exercise to include linkages within the group.

[18] Based on a recent report, it appears that for nearly all authorities the adequacy of resources is one of the biggest challenges in conducting a supervisory stress testing framework (BCBS (2017)).

[19] Examples of stress scenario specifications may, be found in eg FRB (2018a), ESRB (2018) or Bank of England (2018a).

[20] For example, see discussion in Henry (2015) and Rebonato (2010) on discussions of scenario design.

five, years. In contrast, in other cases, eg for liquidity stress tests, the projection horizon is much shorter (for example, one day to a few months), given the rapid, or even instantaneous, transmission of liquidity shocks. When it comes to the objective of the exercise, macroprudential exercises may require a longer time horizon than microprudential ones, to allow for the full extent of the propagation of the initial shocks in the financial system and beyond.

28. **Measuring the severity of an aggregate stress scenario is not straightforward.** Because a scenario affects banks differently depending on their relative exposures to risk drivers and there is no single indicator that can capture all such drivers, the measurement of a scenario's severity is challenging. Nonetheless, various approaches have been employed to this aim. For instance, as a common goal in stress testing exercises is to apply severe but plausible shocks, the size of shocks can be calibrated to replicate stressful past experience. This can be based on statistical approaches or be narrative-driven.[21] Comparing a scenario (or parts of it) to similar historical scenarios may also help to provide an intuition about its severity.

29. **A countercyclical feature can be incorporated in the design of stress test scenarios.** In practice, this requires designing more severe scenarios for use during economic expansions, and relatively lighter ones in downturns.[22] As a result, banks will be expected to hold higher capital buffers when cyclical risks are high – ie at times when credit growth is strong and asset prices appear overvalued – and lower when such risks have already materialised.

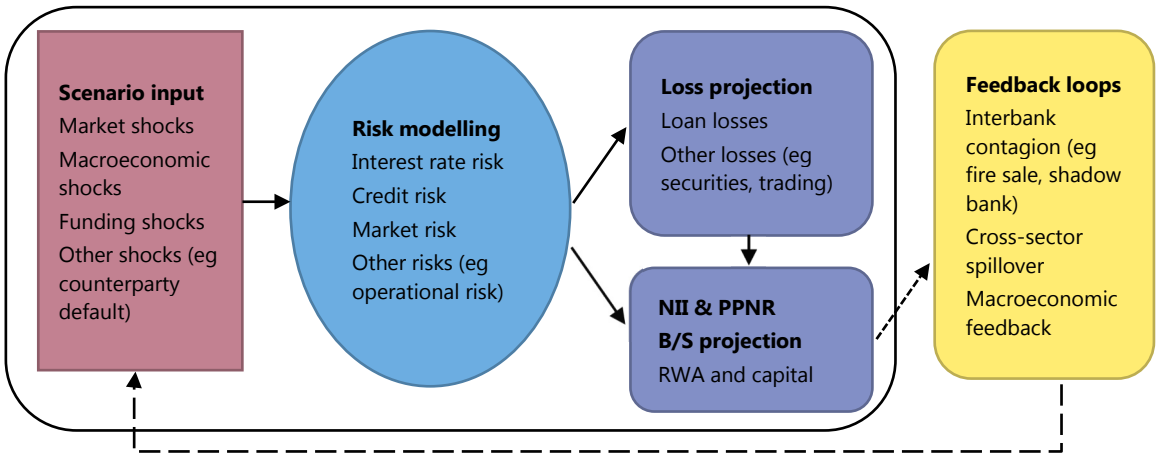
Modelling approaches and methodologies

30. **In general, a stress test is composed of various modelling blocks, which interact with one another to produce the overall results.** Key modelling aspects include risk coverage, granularity of data input and risk representation, translation of macro shocks to micro risk drivers, extent of dynamic projections, inclusion of behavioural reactions, as well as consideration of system-wide interactions and endogenous contagion (Figure 1). The choice on the inclusion and design of these modelling blocks depends on data availability, objectives, resources and technical capacity. Modelling blocks and their interaction have evolved over time, becoming increasingly more numerous and sophisticated (for an overview, see eg IMF (2014b) and Siddique and Hasan (2013)). However, in all cases, the level of sophistication of individual models usually depends on the materiality and complexity of covered risks, the stress scenarios and the business model of banks in the sample (see BCBS (2017), IMF (2012), and Anderson et al (2018)).

[21] Statistical approaches include, for example, "worst-in-a-decade" events, "one per cent probability" tail events, or an "x standard deviation" shock (see IMF (2012)), or selection by empirical likelihood (see Glasserman et al (2014)).

[22] For instance, the annual cyclical scenario can be calibrated to reflect policymakers' judgment on the state of the financial cycle (Bank of England (2015)).

Figure 1: Major modelling steps in a solvency stress test



NII = net interest income; PPNR = pre-provision net revenue; B/S = balance sheet; RWA = risk-weighted asset.

Source: FSI staff.

31. **The impact of the scenario on banks can be summarised by specific metrics.** In general, in a stress testing model, the scenario translates into changes in bank-level parameters, which are then used to determine the impact on some metric of bank resilience. Usually, in line with the primacy of solvency-related assessments, the impact measure refers to some form of regulatory capital metrics (possibly both risk-weighted and leverage ratios). In this case, models quantify the impact on eligible capital, primarily through profit and loss (P&L) effects. In addition, some forms of liquidity stress can be included in solvency stress testing – such as increased funding spreads[23] or asset value shocks due to a shortage of market liquidity – as they could hinder a bank's capital-generating capacity and its solvency. While following the introduction of the stress test-based liquidity coverage ratio by the BCBS (2013) dedicated liquidity stress test have become more common, they are typically conducted separately and therefore use different metrics. Overall the interaction between liquidity and solvency stress tests is complex (see eg BCBS (2015, 2017), Dent et al (2016), Halaj and Henry (2017) and Anderson et al (2018) for related discussions).

32. **A high level of modelling sophistication is achieved when separate models are created and applied to different risk types or portfolios**. In this case, the impact of a macroeconomic stress scenario is differentiated by risk factor and type of bank exposure. Separate models for different risk and portfolio categories allow to take into account the specific features of the individual risk drivers. This approach therefore usually includes separate models for major credit portfolios, (eg mortgages) and major market risk categories (eg available-for-sale assets), and differentiates the scenario impact on net interest income, fee and commission income and business expenses. Interaction between these various risks, eg credit defaults and interest income, can also be modelled (see eg Drehmann et al (2010)). Operational risk, for instance conduct risk, can also be covered by using statistical approaches (see eg Kerbl (2014)).

33. **Modelling approaches range from granular to aggregate models.** For each risk type, it is possible to take a granular approach that reflects the detailed structure of banks' balance sheets, in terms of eg liquidity, maturity or riskiness. In such a case, while some model parameters can be estimated, a number of additional technical assumptions have to be made (eg on repricing or rollover rates). More aggregated models can also be employed, linking eg overall loan losses or interest incomes to macro-financial determinants, in which case model parameters are more likely to be estimated (see IMF (2012, 2014b) and Demekas (2015)). Given the range of available models and explanatory variables, specific

[23] For example, BoJ (2018).

techniques can also be employed to address the implied model uncertainty (see eg Gross and Población (2015)).

34. **The applicability of granular modelling approaches depends heavily on the availability of bank-level data.** A major factor affecting the level of modelling granularity is the availability of sufficiently detailed current exposure data (to differentiate among risks) and historical data (to develop, calibrate and test models). Bank-specific data can range from transaction or position-level to aggregate balance sheet items. If granular exposure data are not available, some alternative approaches may be used for specific elements of a stress testing model. For instance, a relationship between banks' profitability and prevailing macro conditions may be derived from historical P&L data, if possible by differentiating between relevant P&L components and by controlling for bank-specific effects. Survey data could also be used to calibrate behavioural equations.[24]

35. **When access to bank-level data is an issue, some authorities have used market price-based stress testing approaches.** Market price-based models are based on summary bank default measures embedded in asset prices (such as bank stocks, bonds and derivatives). These measures are extracted from market prices by solving for the default probability implicit in them using standard pricing formulas.[25] However, there are limitations to using such data, as the extraction of meaningful information depends on the reference markets being sufficiently liquid and well-functioning. These models can nonetheless be used to valuably complement the regulatory/accounting perspective explored in the granular balance sheet-based approaches with a more explicit economic perspective. This approach has been used, inter alia, by the IMF in the context of FSAPs (see IMF (2012) and Demekas (2015)).

36. **When it comes to stress testing methodologies, one of the key assumptions is about the developments of banks' balance sheets over the stress horizon.** Comparability and accountability principles lead a number of microprudential stress test exercises to be designed with static balance sheets. This assumption also implies that authorities expect banks not to shrink their balance sheet during a period of stress. On the other hand, a system-wide risk perspective typically requires macroprudential stress tests to be designed with dynamic balance sheets. This is because banks' risk profile (ie composition of the balance sheet, maturity structure and risk characteristics of individual portfolios) depends on banks', clients' and markets' reactions to the stress scenario. Moreover, changes in banks' risk profile over the scenario horizon may collectively have a significant impact on the severity of the stress outcome. The overall stress impact including that to the broader economy may also be amplified by macro-financial linkages. Furthermore, when a bank is about to undergo some major restructuring, eg mergers and acquisitions or sale of part of its business, the size of its balance sheet over the stress horizon will change substantially, requiring an ex ante decision as to the possibility of including such changes in the exercise.

37. **Another key assumption in the methodology is about the development of income sources over the stress horizon.** The need for methodological guidance in bottom-up stress tests or specific assumptions in top-down ones arises from the fact that a stress scenario may imply that an increase in interest rates has a positive impact on net interest income (NII). The latter could, in some cases, offset credit risk losses, including the adverse impact on risk-weighted assets, and market risk losses (such as on available-for-sale securities and trading assets). To address this issue, authorities typically include some restrictions on the development of NII under stress, so that increases in NII do not offset losses from the materialisation of risks. Other income sources, such as fees and commissions, can also be set in line with historical developments at times of crises, under the adverse scenario, in order to ensure an appropriate level of conservatism.

[24] For example, the survey by Brinkhoff et al (2018).

[25] For example, see Acharya et al (2014) for a discussion of using market data to forecast capital shortfalls.

38. **For macroprudential stress test exercises, additional modelling elements are needed to reflect the system-wide aspects they aim to cover.** While microprudential stress tests focus on first-round effects,[26] macroprudential stress tests need to consider second-round effects.[27] Following the initial impact on banks, second-round effects may occur as a response from banks, depositors, financial markets, policymakers or other economic agents. Such effects involve concepts such as contagion and feedback loops within the network of banks, which are critical in measuring systemic effect of shocks (see eg Glasserman and Young (2016) and Gai et al (2011) on contagion in financial networks). Interconnectedness among banks can also be accounted for to assess the systemic impact of stress (see eg Espinosa-Vega and Solé (2010)). Spillover effects between the real economy and the banking sector and the financial system may also need to be modelled in such stress tests (see eg Krznar and Matheson (2017) on macro feedback effects). Banks' deleveraging under stress could also affect items other than credit, with a subsequent impact on market prices for those assets that are shed, leading to generalised, lower valuation of mark-to-market assets (Cont and Schaaning (2017) and Gray and Jobst (2013)).

39. **In addition to its quantitative analysis, a stress test may also include a qualitative review of banks' stress testing capabilities.** 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 (see eg FRB (2018c) and Bank of England (2015)). Such qualitative reviews are usually embedded in the supervisory review process and address primarily microprudential objectives.

Outcomes – results and communication

40. **Communication about the results of a stress testing exercise can be broken down according to several dimensions.** Communication can take different forms, eg in terms of the recipients (the banks involved in the exercise and the general public), the extent of disclosure (aggregate or bank-level) and its granularity. Disclosure can be limited to a single metric that summarises the stress test results (eg final capital ratios after the stress test), or include various metrics (eg more than one type of capital ratios, including leverage ratios), or include some of the parameters used in the exercise (eg loss-given-default (LGD), probability of default (PD)). It can also cover the scenario (eg baseline, adverse scenarios) and the methodology (eg guidance provided to banks about assumptions concerning the static or dynamic balance sheet assumptions). In practice, while many authorities publicly disclose aggregated results of stress test exercises and high-level methodology and scenario features, very few release bank-specific details and announce follow-up actions, eg depending on passing or failing the exercise against a given hurdle rate.[28] A sizeable minority does not publish any results at all (BCBS (2017)). The level of disclosure may also be subject to legal requirements (eg for confidentiality constraints). On the other hand, securities market regulators may require that any price-sensitive information be disclosed to the public to conform to market conduct requirements. Apart from the disclosure by authorities, banks themselves can also decide to release their own results.

41. **Communication can contribute to market confidence in the banks' resilience, but there are also risks around it.** On the one hand, comprehensive disclosure of results, according to a granular template, can boost confidence by enhancing transparency, and support the market assessment of banks

[26] First-round effects are defined as the direct impact of shocks on individual banks' P&L and balance sheet, taking each bank in isolation.

[27] Stress tests that serve both purposes can use bottom-up first-round results, and overlay or incorporate analysis of potential second-round effects to combine microprudential and macroprudential perspectives.

[28] Examples of bank-specific disclosures include EBA (2018b), Bank of England (2017) and FRB (2018c).

or banking sectors based on the stress test results.[29] On the other hand, there is a risk of destabilisation, if results affect specific banks or banking sectors in an unexpectedly adverse manner and no backstops are in place. The reputation of the authority running and disclosing the results of the exercise is also at stake.[30] Another issue arises when disclosing methodological and modelling features, ie there is a risk to promote a "model monoculture" in which both authorities and banks use the same models to evaluate risks and thus increase the vulnerability of the financial system to model risk (Tarullo (2016)).[31]

42. **Transparency may help, especially in crisis times, when complemented by other measures.** Especially at times of systemic crises, lack of clarity about banks' risk and prospects can create an adverse feedback loop. A negative assessment of a bank may trigger self-fulfilling liquidity and possibly solvency crises. Credible and detailed information on banks' resilience via stress tests can help anchor market assessment of banks, provided that comprehensive and sufficiently severe adverse scenarios are used. When combined with robust follow-up actions for banks that perform poorly in the stress test and credible and well-funded backstops, disclosure can make stress tests useful tools to respond to a crisis (ECB (2010) and Bernanke (2013)).

Section 3 – Key aspects of selected system-wide stress test frameworks

43. **While Section 2 defines the building blocks of a stress test exercise and reviews the literature, this section focuses on selected examples.** By looking in detail at four jurisdictions, it aims at providing practical examples of the approaches taken and their variety. The jurisdictions under analysis have achieved considerable experience in designing and conducting a variety of system-wide stress testing exercises over the years. To keep the number of cases under discussion manageable, only the latest approaches, according to information collected over 2018, are described.

44. **This section shows how authorities in the euro area, Japan Switzerland and the United States have conducted their system-wide stress tests.** As these four jurisdictions have taken different approaches on some aspects, and similar ones on others, the comparison among them can shed light on areas where there may be more room for practices to vary across countries, and others where common practices are by now established. A comparison of their approaches can therefore provide useful insights into how frameworks may be shaped to address specific objectives and countries' idiosyncratic conditions. The annex provides a full description of all aspects of stress testing exercises investigated for the selected jurisdictions.

45. **In all of the four jurisdictions under review, there is more than one system-wide exercise conducted by the central bank or the supervisory agency.** Table 1 summarises the 10 types of stress tests that are covered in this study: for the euro area, (i) the European Central Bank Single Supervisory Mechanism stress test (SSM ST), (ii) the Top Down Macroprudential stress test (MTD ST) and (iii) the Macroprudential Extension stress test (MPE ST); for the United States, (iv) the Dodd-Frank Supervisory Stress test (DFAST) and (v) the Comprehensive Capital Analysis and Review (CCAR); for Japan, (vi) the Bank of Japan stress test (BoJ ST) and (vii) the Financial Services Agency, Japan, stress test (JFSA ST); for Switzerland, (viii) the Building Block Analysis-Large Banks (BBA-LB), (ix) the Building Block Analysis-Domestically focused banks (BBA-DFB) and (x) the Financial Market Supervisory Authority stress test (FINMA ST). Some of these stress tests are macroprudential and others microprudential, with a

[29] See eg Philippon et al (2017) on their assessment of the information content of stress tests, based on backtesting of the EU bank stress tests.

[30] See Goldstein and Sapra (2013) for a discussion of the optimal level of stress test results disclosure as well the associated cost-benefit analysis.

[31] See also Niepmann and Stebunovs (2018) for potential issues involved in bottom-up stress testing approaches where banks may choose to arbitrage projections for purposes such as capital distribution to investors.

combination of bottom-up and top-down approaches, as defined in Section 1. The table also provides the breakdown of these 10 exercises along the relevant dimensions presented in Section 1.

System-wide stress tests conducted in the selected jurisdictions Table 1

	Macroprudential objective	Microprudential objective
Top-down approach	(2) EA ECB Macroprudential Top Down ST (MTD ST) (3) EA ECB Macroprudential Extension ST (MPE ST) (6) JP BoJ ST (8) CH BBA-LB* and (9) CH BBA-DFB*	(4) US DFAST* and (5) US CCAR* (8) CH BBA-LB* and (9) CH BBA-DFB*
Bottom-up approach		(1) EA Single Supervisory Mechanism ST (SSM ST) (7) JP JFSA ST* (10) CH FINMA ST

* Although primarily macroprudential (or microprudential), microprudential (or macroprudential) objectives are also assessed in these stress test exercises.

Source: FSI survey. The 10 exercises in this table are those listed in paragraph 45.

Objectives and use of stress tests

46. **All four jurisdictions run microprudential stress test exercises, as part of a supervisory review process, with broadly similar aims.** In line with the nature of microprudential exercises as defined in Section 1, individual bank data are collected and used in all microprudential stress test exercises in the sample, to assess, at a minimum,[32] the solvency risk of individual banks (Annex Table 1). Such exercises are used to enhance banks' awareness and preparedness for risks, and in at least some cases (BoJ ST, FINMA ST, JFSA ST, US CCAR and DFAST), stress tests are used as a communication tool for conveying a supervisory perspective to banks.

47. **A distinctive objective of the US CCAR, and, partially, of the JFSA ST, is the assessment of banks' capability of "continuing business as usual", even under severely adverse stressed conditions.** The US CCAR specifically assesses sufficiency and appropriateness of banks' practices under the stress scenario, for given capital plans that each bank has designed. In turn, the Federal Reserve may object to these capital plans. Specifically, the assessment in the CCAR exercise is composed of two parts, a quantitative and a qualitative assessment, and an objection may be issued by the Federal Reserve on either part. In a similar vein, but in a more flexible way, the JFSA stress tests also have the policy objective of assessing a financial institutions' ability to maintain business continuity under stress.

48. **In the euro area, Japan and Switzerland, some authorities also run exercises that are primarily of a macroprudential nature.** Although these exercises typically still measure individual banks' solvency results under stress, their system-wide perspective, with the possible inclusion of feedback effects on the macroeconomy, gives authorities a sense of the banking system's resilience as a whole (Annex Table 2). These exercises are also used to provide input into macroprudential policy analysis.

[32] Resilience to liquidity risk is another significant area of stress testing. On this front, independent liquidity stress test exercises either have been or are in the process of being implemented.

Governance – responsibility and coverage

49. **In all selected jurisdictions, the authorities in charge of the supervisory function oversee microprudential exercises while central banks are in charge of macroprudential exercises.** Microprudential stress tests are conducted by the ECB, the Federal Reserve, the JFSA and FINMA, where the institutions are mandated by law, inter alia, to conduct microprudential supervision (Annex Table 5).[33] Similarly, top-down macroprudential stress tests are conducted by the central banks, as the authority in charge of the financial stability function, as seen in the euro area, Japan and Switzerland.[34] Resources allocated to these stress tests vary across institutions (Annex Table 5).

50. **There can be interaction between the exercises conducted by these two authorities, but overlaps are typically limited to systemically important banks.** Because of their systemic importance, these banks are highly relevant for both microprudential and macroprudential stress tests. As a consequence, in some cases authorities in charge of these two types of stress tests have drawn valuable information from a comparison between macroprudential and microprudential results (Annex Table 8). For instance, the results of the bottom-up stress tests of some Japanese banks can be benchmarked against those of the BoJ ST, and the BBA-LB results (top-down stress test results of the two Swiss Global Systemically Important Banks (G-SIBs)) by the SNB are shared with FINMA, which conducts the FINMA ST (bottom-up stress tests of the two Swiss G-SIBs). For the euro area, the top-down stress tests results inform the quality assurance of the microprudential exercise, the results of which can also be used as input to ensuing macroprudential stress tests.[35]

51. **In order to account for differences in size (and hence materiality / systemic importance) or risk profiles of the banks, some degree of proportionality is applied in the selected stress testing exercises.** Within the sample of institutions that are subject to stress test exercises, examples of proportionality applied to smaller (and in some cases less complex) institutions include a less burdensome exercise, less granular forms of data collection or simplified stress test modelling approaches (Annex Tables 6 and 7). In some cases, there is a clear differentiation between exercises for G-SIBs and non-G-SIBs. For example, in the US only the largest and most complex firms are subject to the qualitative assessment of the CCAR exercise. Also, only firms with large trading operations incorporate global market shocks as part of the exercise.[36] In the euro area, the SSM ST is limited to designated Significant Institutions (SIs), which are banks under direct ECB supervision. In Switzerland, the regular FINMA ST is restricted to the two G-SIBs. [37] The coverage of the SNB's BBA exercises is broader, but a specific, granular data collection mechanism has been introduced only for the two G-SIBs, while for the other banks data available from existing banking statistics are used.

Implementation – technical requirements and design

Scenario design

52. **All sampled stress test exercises include a baseline scenario, and at least one severe but plausible stress scenario.** All microprudential and macroprudential stress tests involve at least one, and in many cases several, stress scenarios (Figure 2 and Annex Table 9). A typical stress scenario consists of an economic recession that is "calibrated" (ie not purely modelled) at least partly on the basis of past crisis

[33] In the US, the DFAST is required under the Dodd-Frank Act and CCAR is governed by the capital plan rule in Regulation Y.

[34] See Hirtle (2018) for a discussion of the cyclical and structural macroprudential objectives of supervisory stress tests.

[35] See ECB (2016) for further discussions on ECB MPE ST and ECB (2018) for further discussions on ECB MTD ST.

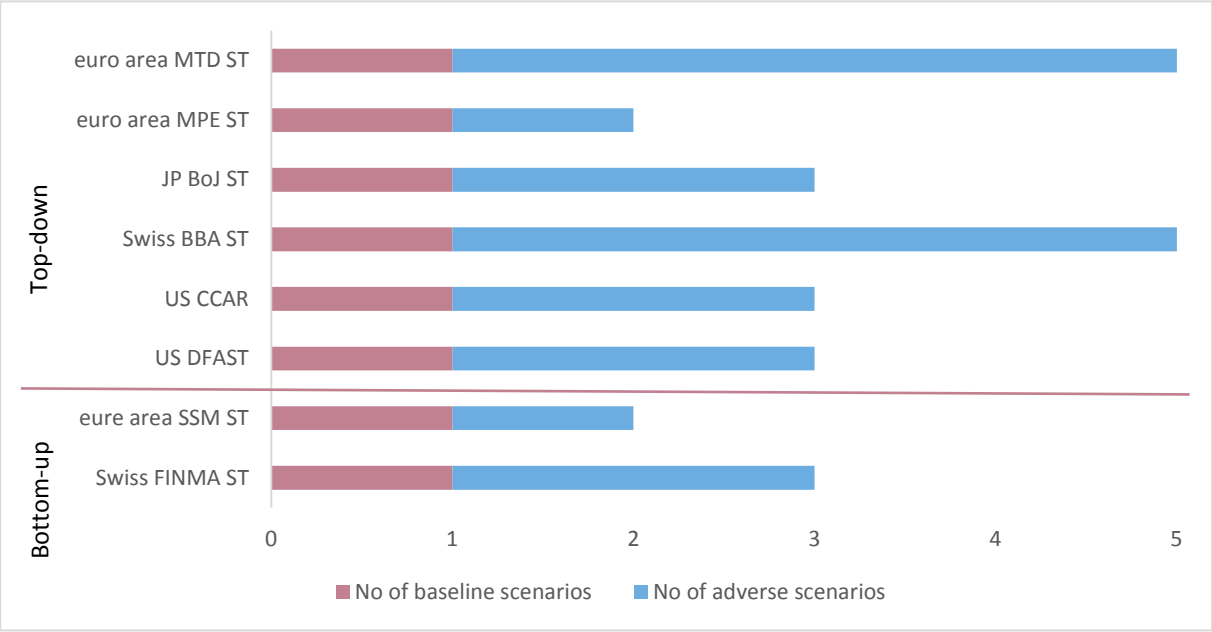
[36] The Federal Reserve has recently put forward a proposal on proportionality, including in the use of stress testing (FRB (2018e)).

[37] For other banks, FINMA performs horizontal stress testing activities covering specific risk categories, eg mortgage risk or interest rate risk in the banking book.

periods (eg the GFC). For example, for the "severely adverse" scenario used in the DFAST/CCAR exercises, the Federal Reserve uses a "recession approach", which is a calibration of a path of macro and financial variables to reflect conditions that typically characterise a recession. In a similar vein, the BoJ uses an economic downturn narrative in its "tail event" scenario. FINMA periodically uses two severely adverse global shock scenarios tailored to measure banks' specific vulnerabilities.

53. **In all cases under study, top-down stress test exercises tend to incorporate a higher number of adverse scenarios.** For instance, the euro area top-down macroprudential ST uses up to four adverse scenarios, which do not necessarily replicate the macro-financial assumptions of the scenario in the SSM STs. For the latter, only one stress scenario is used. Incorporating more than one adverse scenario in the euro area SSM ST would be an operational challenge for the more than 100 banks in scope – this could in turn decrease the overall quality of the bottom-up exercise and impose an additional burden on the quality assurance stage of the exercise. In Switzerland, the SNB regularly explores around five adverse scenarios in its top-down BBA approach, exploring banks' vulnerabilities to a range of global as well as domestic shocks, whereas FINMA focuses on the two adverse scenarios that are most relevant for monitoring large banks' resilience.

Figure 2: Typical number of scenarios in system-wide solvency stress tests in selected jurisdictions



Source: FSI survey.

54. **Approaches to measure and set the severity of the adverse scenario vary across the selected jurisdictions.** Some authorities anchor the severity to one specific key variable – for instance, in the case of the Fed, the unemployment rate to reflect conditions that have generally characterised post-World War II US recessions. Other macroeconomic risk factors are then specified based on their relationships with the unemployment rate, and this ensures consistency of risk variables in a given scenario (Annex Table 10). Other authorities consider a variety of indicators for overall severity. For instance, in the BoJ exercise the severity of scenarios is calibrated to reflect situations where economic and financial developments domestically and internationally would deteriorate to levels comparable to the GFC. From the ECB perspective, although the starting point is a tail value of the probability of the initial shocks, the overall severity is adjusted on the basis of expert judgment, comparing, inter alia, the model-based scenario with past crises, also accounting for additional country-specific risks.

55. **Some of the sampled authorities incorporate countercyclical features in their scenario, ie harsher in good times, and less so in bad times.** The US stress test exercises are a case in point, where the scenario design includes a rule whereby the unemployment rate can be the higher of 10% or the

current rate plus 3 to 5 percentage points.[38] In a similar vein, the BoJ exercise also follows a rule-based approach ensuring countercyclicality, but using the output gap instead of the unemployment rate. On the other hand, in the SNB exercise, the severity of the adverse scenarios relative to the baseline is kept broadly constant over time, ie it is not explicitly adjusted in a countercyclical manner.

Modelling approaches and methodologies

56. **Both microprudential and macroprudential exercises in the four jurisdictions cover most standard risk categories of bank portfolios.** The euro area SSM ST, MPE ST and MTD ST, the US DFAST/CCAR exercises, the BoJ ST, the JFSA ST and the Swiss BBA and FINMA exercises, to various degrees, cover the standard categories of risk exposures, such as credit risk, market risk, interest rate risk and operational risk (Annex Table 12). Not all risks may be treated together in all exercises or with the same depth, partly due to the technical complexities associated with covering many risk factors at the same time. Typically, credit risk has been covered most extensively, not least given its large impact on banks' balance sheets.

57. **Risk modelling depends upon several factors in all selected countries, such as whether the exercise is bottom-up or top-down, or operational factors, including the availability of representative historical (and sufficiently granular) data.** For example, in bottom-up exercises, such as the euro area SSM ST, banks can use their own models for credit risk, which would typically involve the estimation of credit losses using projections of credit risk parameters (eg PDs, LGDs, exposure at default). For top-down exercises, such as the MPE ST or MTD ST, credit risk is modelled at the macro-sectoral level with scenario variables determining PDs (eg for mortgage loans, in a given country). The approach taken to model credit risk also depends on data availability and the vulnerability of portfolios to structural changes. For instance, in Switzerland, in the BBA exercises, the impact of a systemic shock on Swiss mortgage portfolios is considered to depend significantly on portfolio properties and their dynamic evolution under stress. Accordingly, structural approaches have been developed, combining micro and macro properties based on structural relationships, to model the credit loss process. For other portfolios, for which historical data are considered to be representative and granular enough to simulate forward-looking stress events, regression-based approaches are used.

58. **Liquidity risk is either modelled in the form of shocks to funding costs in solvency stress tests, or covered separately in targeted liquidity stress test exercises.** Among the selected jurisdictions, liquidity risk in solvency stress tests is mostly captured via additional funding costs or risk premia (see BoJ, ECB, SNB and DFAST and CCAR exercises[39]). Liquidity stress testing can also be covered in a separate stress testing exercise, for instance in Switzerland, or in the case of the US, in the Comprehensive Liquidity Assessment Review (known as the CLAR).

59. **In some cases, second-round effects are modelled, mostly for macroprudential stress tests.** Second-round effects are usually not explicitly captured in microprudential stress test (SSM ST, DFAST/CCAR, FINMA ST), as the focus of the analysis is on the direct impact of the shocks on each individual bank's balance sheet (Annex Table 15). At the same time, in these approaches the impact of second-round effects at an aggregate level can be captured to some extent by a more severe calibration of adverse scenarios, although the individual, bank-level breakdown of the aggregate impact could be uncertain. On the other hand, macroprudential stress tests attempt to explicitly incorporate second-round effects, at least to some degree, in the model setup. Depending on the objectives and the development status, practices range from capturing feedback effects at the level of individual banks and selected interbank contagion (SNB, ECB) to modelling macro-financial linkages (euro area macroprudential ST, BoJ).

[38] See FRB (2018c) for more details on scenario design policy. See also Edge and Lehnert (2016).

[39] To date, DFAST and CCAR scenarios have not incorporated stress to funding markets. In 2017, the Federal Reserve Board made a proposal to suggest including variables or additional components in the scenario to capture shocks to funding costs, particularly wholesale funding. For more details on the proposal, see FRB (2017b).

Given the technical complexities, second-round effects have usually been modelled via selected transmission channels that are already relatively well established in central banks' models (eg bank lending, asset prices, credit risk, funding markets, interbank markets, asset cross-holdings).

Feedback effect and balance sheet adjustment (macro- vs microprudential ST) Table 2

	First-round effect	Second-round effect*	Mostly static B/S	Mostly dynamic B/S
EA MPE/MTD ST	■	■		■
JP BoJ ST	■	■		■
CH BBA ST	■	■		■
EA SSM ST	■		■	
CH FINMA ST	■		■	
US DFAST/CCAR	■			■

*: see Annex Table 15.

Source: FSI survey.

60. **Most stress tests allow for some adjustment in banks' balance sheets over the stress horizon.** For instance, in the euro area, the MPE ST and macroprudential top-down ST have been designed to incorporate dynamic balance sheets. There the model setup can incorporate a simple deleveraging scenario, possibly accompanied with equity issuance by banks to counter the effect of shocks to their capital levels. Instead, the SSM ST assume static balance sheets to ensure that the complexity of the exercises is kept to a minimum and results are comparable. For the BoJ exercises, a dynamic balance sheet is assumed specifically for the loan portion of the total portfolio, but other possible management actions are now being considered for inclusion. The approach in the SNB BBA exercises depends on the materiality of the impact of dynamic reactions. Where relevant, dynamic changes in the composition of banks' balance sheets are allowed, especially for the projection of NII cash flows or when considering portfolio changes in estimating credit losses. Taking a slightly different perspective, the size of banks' balance sheets in the US exercises is designed to change in line with projected industry average growth over the stress time horizon.[40] Finally, concerning balance sheet changes due to restructuring, practices vary. For instance, in the US, the balance sheet projections will incorporate material changes in bank's business plan, such as a planned merger, acquisition, consolidation or divestitures, which are likely to have a material impact on its capital adequacy and funding profile.[41]

61. **Some of the selected stress test exercises include restrictions on various components of income.** For example, in the SSM ST, in line with the EBA methodology, NII cannot increase under the adverse scenario. On the other hand, macroprudential exercises can waive these restrictions should these assumptions not reflect actual or estimated behaviour, for instance because of sectoral or bank-level idiosyncrasies. For instance, the BoJ exercise does not include explicit assumptions regarding income and earnings under stress. In the US, core components of pre-provision net revenue are forecast separately and each component is scaled by the corresponding asset or liability on the balance sheet. In the Swiss BBA ST, granular assumptions are used to limit NII under specific scenarios, eg a zero lower bound for retail deposit rates in the territory of negative market rates or the explicit modelling of losses due to maturity mismatches between assets and liabilities in case of rapidly increasing interest rates.

62. **Authorities mostly update their models and methodologies only gradually.** As modelling techniques and capacities evolve, authorities are generally keen on introducing improvements in their

[40] However, this may be subject to change: the proposed "Stressed Capital Buffer" proposal would move to a static balance sheet.

[41] The inclusion of the effects of such expected changes to a firm's business plan does not – and is not intended to – express a view of the Federal Reserve on the merits of such proposals and is not an approval or non-objection to such plans.

framework. At the same time, they consider it important to be able to trace back any potential changes in outcomes from one round to the next to changes in key drivers, such as models, methodologies, scenarios and data (Annex Table 13). For instance, the Federal Reserve introduces material changes into the stress tests gradually, to ensure that changes in projections primarily reflect changes in underlying risk and not simply in methodologies or models (FRB (2017b)). In turn, changes in applicable accounting standards or tax rules will be applicable right away, accepting that this will nonetheless hamper the comparability in the results of two consecutive rounds of stress tests. This was, for instance, the case of the changes in the stress test methodology to account for the tax changes in 2018, in the US, and for the introduction of IFRS 9, in 2018 in the euro area.

63. **In terms of data for stress tests, in some cases individual bank data are used for top-down macroprudential stress tests.** The euro area MPE ST covers roughly the same sample of banks (SIs) and utilises the same individual bank data, collected for supervisory review purposes, as in the SSM STs. The US exercises use bank portfolio data collected through the Capital Assessments and Stress Testing information collection (FR Y-14A/Q/M), specifically designed for the purpose of the DFAST and CCAR, alongside third-party industry data. In Switzerland, for the BBA-LB ST, the SNB utilises a structured data collection mechanism where information that is granular and specific to risk categories is collected from the two G-SIBs.

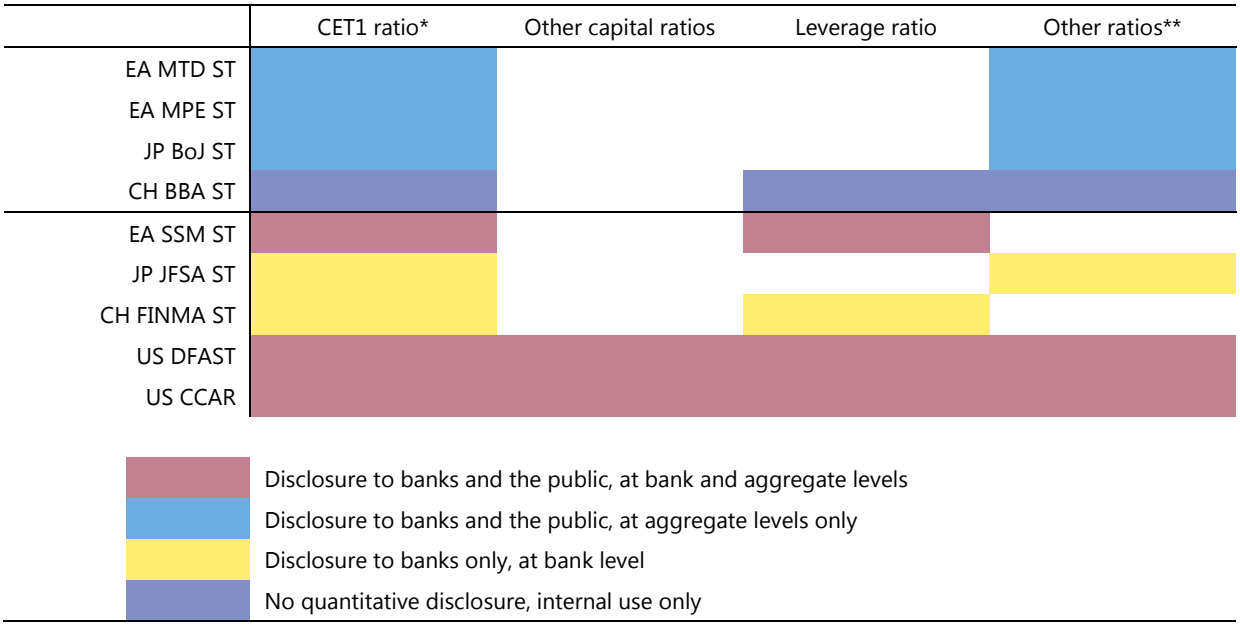
64. **Stress testing exercises can also include qualitative reviews of banks' stress testing capabilities.** For instance, in the US CCAR qualitative assessment, the objective is to evaluate the reliability of a bank's analysis for capital planning, focusing on the areas that are most critical to sound capital planning and the bank's control and governance around those practices. The assessment is tailored to the largest and most complex banks, to relieve the operational burden on small banks (FRB (2017a)).

Outcomes – results and communication

65. **Authorities in the four jurisdictions usually communicate to each bank their top-down results over the course of the exercise.** One of the objectives of microprudential stress test exercises is to increase banks' awareness and preparedness to potential risks (Annex Table 3). In the euro area SSM ST, the SSM discloses to each bank separately the results of the quality assurance process, as an integral part of the stress test exercise. Similarly, in the US CCAR exercise, after the completion of the exercise, a letter is sent to each participating bank noting areas where the bank's capital planning analyses and processes exhibit weaknesses, and actions the banks must take to address them. There is also ongoing monitoring of outstanding findings and periodic horizontal examinations that give banks regular feedback so they know the issues they face and can make improvements throughout the year and before the following CCAR. In the case of the FINMA ST in Switzerland, FINMA discloses its major conclusions on the appropriateness of banks' results to participating banks. Disclosure in the Swiss BBA ST focuses on qualitative elements.

Level of disclosure of results in system-wide solvency stress tests in selected jurisdictions

Table 3



* CET1= for common equity tier 1.

** Eg GDP losses for a macroprudential exercise and the projected loan loss rates by portfolio type at bank level for a microprudential exercise.

Source: FSI survey.

66. **There is also some disclosure of the results to the general public in most of the sampled exercises, usually at the aggregate level.** In all cases, authorities consider transparency useful to support market discipline, but there are differences in the degree of disclosure, also depending on the type of exercise (Table 3 and Annex Table 20). For instance, the US authorities disclose the bank-level post-stress capital ratios of the CCAR and DFAST, both with a bank's original capital actions and any adjusted actions for the CCAR.[42] These are published and available to the general public. In addition, the US authorities are considering enhanced transparency of the supervisory stress test results, by proposing to further disclose information on the range of loss rates, estimated using the top-down models, for loans held by the banks and portfolios of hypothetical loans (FRB (2017b)). By doing so, they aim to provide insight into how the stress test results are determined. In the euro area, the results from SSM ST exercises have been released to the public in a broadly constant and granular format over time. Results are made available for each bank in scope of the EBA EU-wide regular exercises. Macroprudential stress test results, in turn, when released (typically in regular ECB publications), refer to aggregates for the euro area as a whole. Similarly, the BoJ only discloses the aggregate results, as well as the parameter specifications of many of the structural equations used to produce the results, to both the banks and the general public. In contrast, the SNB uses the BBA ST results as a basis for communication with the banks and the public on financial stability issues, but does not disclose the quantitative ST results themselves.

[42] In the CCAR, the Federal Reserve provides each bank with a one-time opportunity to adjust its planned capital distributions after it receives the preliminary estimates of the post-stress capital ratios.

Section 4 – Challenges and future developments

67. **The literature review in Section 2 and the cross-jurisdictional review conducted in Section 3 have identified some open issues in the area of stress testing.** This section provides an overview of the emerging challenges for authorities, on both the policy and implementation fronts, and consider how they could be tackled. In some areas, progress could be achieved within the next couple of years. In the more remote future, policy and technical developments could further reshape the stress-testing landscape in various ways. These future developments are discussed in broadly the same order as the presentation of a stress test's building blocks in Sections 2 and 3.

68. **The scope of microprudential stress testing, while already well anchored, could be extended.** Supervisory measures can be derived mechanically from the stress results (especially in a pass/fail exercise) or remain an input into a judgmental multifactor decision. The approach eventually chosen would have to be consistent with that for setting Pillar 2 buffer requirements. In turn, the use of the qualitative component of stress tests could be become more widespread, to assess banks' capital planning, data quality and risk management, taking advantage of the discipline that such exercises impose on participating banks. Further supervisory consistency can be achieved by incorporating and integrating stress test results into regular capital compliance requirements and routine risk monitoring process.

69. **The use of stress testing for calibrating macroprudential policy measures would also benefit from more experience before becoming standard.** As the use of stress tests for the calibration of macroprudential measures is still in its infancy, it can further develop and also make an important contribution to the measurement of buffers against system-wide risks, including contagion effects. The calibration of other macroprudential measures – for instance borrower-based ones (eg debt-to-income ratios) – could also benefit from the use of stress tests, by including macro-financial linkages and using micro data.

70. **The increasing awareness of global interconnectedness and the role of large and complex global banking groups (LCBGs) would warrant enhanced coordination among authorities.** Such coordination efforts, which would help to better include a global perspective of risks in stress testing exercises, could relate to global scenarios, network data, methodologies and exchange of insights. In particular, the availability of agreed global scenarios would allow authorities concerned with the impact of global risk factors to implement stress exercises in their jurisdiction on the basis of commonly defined scenarios. The latter would not substitute for locally relevant scenarios that cover country or region-specific risks. They would instead be a complement, and would have to be constructed under simplified assumptions, which would allow them be applicable across countries. Although based on differing models, the impact analysis would give the home authorities of these banks the relevant sensitivity information on LCBGs' operations across the globe. The results could be more easily produced if generated in a top-down fashion by the various authorities with a view to reducing the costs implied by such exercises. Sharing the scenario specification with banks in scope may also help their own risk and capital management.

71. **Further model developments are required to capture additional effects of stress.** While the estimation of first-round impacts of a given scenario on banks' balance sheets is by now broadly standardised, the explicit modelling of second-round, spillover and contagion effects has not yet reached a mature stage. Progress on this would be an essential step to develop macroprudential applications of stress testing. In particular, this could cover real-financial linkages, via both price and quantity channels, using possibly both macro- and microeconometric models. Such effects would also play out possibly over a longer span of time than usually covered by stress tests, requiring the calibration of longer-horizon scenarios. Scenarios would also need to differentiate between cyclical and tail risk analyses in line with the policy objective (eg to set CCyBs vs to assess systemic resilience). Instead, the specification of contagion mechanisms, including going beyond direct exposure channels, is already quite developed, in particular via network modelling, albeit without a consensus yet on how to proceed. In this regard, the nascent use

of agent-based modelling, while promising,[43] will remain subject to uncertain assumptions on individual behaviour as well as on the sequence of moves by agents involved, hence calling for a cautious approach to such results. This approach would nonetheless provide a relevant alternative to reduced-form modelling, such as that based on correlation methods, which is quite well established to date.

72. **The interaction between solvency and liquidity stress tests could be enhanced, with liquidity stress testing developing further into financial system-wide stress testing.** As mentioned in the previous sections, designing and running a joint exercise for both solvency and liquidity is very complex. Stress test results become even more dependent on assumptions to capture mechanisms of differing nature and frequency. A workable approach could be to build further bridges between the two types of exercises, which would allow potential cross-feedbacks to be better captured. For instance, stressed solvency ratios would weigh on funding costs, thereby stressing liquidity needs as well as the banks' P&Ls. Similarly, fire sale prices would affect mark-to-market assets and collateral valuation, damaging solvency and liquidity together. Solving such interactions in a single step could prove too intricate, so that an iterative process could be envisaged. In it, for instance, solvency stress test results, eg based on annual data, would feed into liquidity exercises run at higher frequency. Their results could even then update the solvency ones. Further, reflecting market structure development, liquidity stress testing could be extended to a system-wide dimension, ie beyond banks, by considering other key players such as insurers, pension funds, hedge funds, asset managers or even market infrastructures. Such a liquidity stress test for the banking system could be integrated with similar exercises involving other agents in a more straightforward manner than solvency stress tests, for which scenarios and solvency concepts widely differ across financial institutions.

73. **Technological developments could offer new possibilities that could reshape stress testing, in terms of both data coverage and sophistication in modelling approaches.** Big data infrastructure combined with high power computing, is expected to facilitate the large-scale use of loan or transaction data. The improvement is likely to be most material in areas where stress tests have not been conducted as often or ever so far due to data computation constraints, such as derivatives or repo markets. Accordingly, new granular models could make use of these new data and investigate in more detail the corresponding items on the banks' balance sheets.[44] Powerful IT platforms would also make it easier to refine top-down frameworks, by integrating models of various types resorting to a variety of data sources. Moreover, multiple scenarios and even stochastic simulations could be performed, providing more information on the range of possible outcomes and additional sensitivities, including seeking a worst case scenario. New models could also be developed to address emerging risks, such as cyber-security and climate change, that may also require the collection of dedicated new data and the design of original, tailored scenarios. For bottom-up exercises, the automatisation of data collections and processing could allow all banks to apply a given methodology set by the supervisor in an efficient and harmonised manner – with far lower costs for quality control as a result.

Section 5 – Considerations on decisions over stress test design options against policy objectives

74. **This concluding section draws lessons from the analysis in the preceding ones to highlight how authorities planning to run a stress test may design it in the most effective way, given their policy objectives.** Using the same building blocks of a stress test used for the analysis in Sections 2 and 3, this section reviews options that authorities face when deciding about a stress test's governance,

[43] See eg Baptista et al (2016) for a discussion of application of agent-based model in the UK housing market.

[44] For market and credit risk, this would also apply to underlying collateral.

implementation and outcomes, against their objectives and the planned use of stress test results. This section therefore moves away from a pure description of practices and aims at a broader assessment linking these features to specific policy needs, with the associated implications for the design of a stress testing framework and its implementation.

75. **An important reference is the updated principles on sound stress testing practices published by the BCBS in October 2018.** They replace the BCBS 2009 stress testing principles (BCBS (2009, 2018)). The 2018 document sets high-level principles to guide all elements of a sound stress testing framework, applicable across banks and jurisdictions worldwide. They are structured along a sequence composed of objectives, governance, technical implementation and communication, which closely resemble the framework presented in this paper. However, there are some differences, as the discussion here focuses on technical implementation aspects, from the point of view of the authorities, while some of the BCBS principles, which are in all cases high-level, are addressed to the banks themselves. This paper also covers in detail macroprudential stress tests and maps the three building blocks it has identified (governance, implementation and outcomes) against the authorities' policy objectives, from an operational perspective. At the same time, the BCBS principles provide helpful guidance to the authorities for considering the implementation of the choices discussed in the rest of this section.

Objectives and use of stress tests

76. **Consistency between approaches and objectives is essential.** Authorities may have different objectives when setting up a stress test exercise, depending on how they plan to use the results or whether the banking sector is going through a systemic crisis. As explained in the rest of the paper, depending on these conditions, the design of the exercise would accordingly need to be different. It is therefore important that authorities identify in advance the goal and use of the exercise, so that decisions for all its main building blocks (governance, implementation and outcomes, and their sub-elements) are aligned, and respond to the policy needs that have justified the use of a stress test in the first place.

77. **While stress tests are useful tools, authorities also need to be aware of their limitations.** Stress tests should not be seen as a panacea. For instance, there is no commonly accepted view on how to derive capital buffers from stress test results. Stress test results are moreover conditional on given assumptions and subject to model risk. Both limitations inevitably introduce uncertainty about whether all relevant risks are captured and their impact is adequately measured. Results therefore need to be used together with other information sets in most cases. Stress tests are indeed best used in combination with other supervision tools to assess bank and systemic vulnerabilities and their resilience. Moreover, especially for bottom-up exercises, banks may get accustomed to stress testing approaches that do not evolve sufficiently, thereby diminishing the information gained from these exercises over time.

Governance – responsibilities and coverage

78. **Reflecting the institutional allocation of responsibilities in a jurisdiction in the governance of stress tests enhances their effectiveness.** This is the case for every stage of the stress test process, ie when it is launched, designed and validated. In particular, macroprudential exercises may be best placed with authorities in charge of monitoring system-wide risks (ie macroprudential authorities) and similarly microprudential stress tests with supervisory authorities.

79. **The governance of the exercise is also affected by whether the stress test takes a bottom-up or top-down approach.** Exercises with a dominant macroprudential focus can require top-down approaches. Even for supervisory exercises that may need to involve a bottom-up approach, the use of top-down modelling may be valuable to achieve easier control and harmonisation of the results across banks. At the same time, top-down modelling may not capture all bank -or sector-specific features. Given the limitation of both top-down and bottom-up approaches, a combination of the two may increase the

robustness of the results. Because the authority in charge of a top-down or bottom-up exercise may not be the same, combining the perspectives of these two approaches requires cooperation between the respective authorities.

80. **Clearly defining the sample of banks covered by the stress tests is particularly important.** Authorities can define the sample depending on legal requirements or be guided by ad hoc policy objectives, such as reviewing specific business models or exposures. The sample may change over time, and authorities may consider that crisis-time exercises usually have wider coverage, as the whole system is deemed at risk. In normal times, authorities may pay more attention to proportionality, with requirements scaled down or lifted for institutions deemed less systemic or with a less complex group structure. When authorities are more interested in groups of banks exposed to specific risks, the focus of a stress test can be adjusted accordingly. In macroprudential stress tests, in turn, more parsimonious samples may be selected, as long as they capture the systemic risk dimension.

81. **The level of resources for stress testing strongly affects the approach that authorities can take.** Complex exercises, covering many banks and requiring sophisticated modelling approaches, require a large amount of resources – regardless of whether they are run bottom-up or top-down. It is therefore important that resourcing reflects the level of ambition of a given exercise and the role it plays in the supervisory or financial stability surveillance process.

Implementation – technical requirements and design

82. **Stress tests require at least two scenarios, a baseline and an adverse scenario, and their design needs to be aligned with authorities' objectives.** For instance, for macroprudential exercises, the selection of risk factors could be based on systemic and macro-financial considerations rather than a review at the individual bank level, which could be done for microprudential purposes. In selecting the number of adverse scenarios, authorities also need to consider operational constraints, which could be an issue in bottom-up exercises involving many banks or authorities. In turn, top-down exercises could deal more easily with a multiplicity of scenarios. Having multiple scenarios mitigates the risk that the otherwise single narrative would not be the one materialising going forward. It also helps to address unexpected developments between scenario preparation and result finalisation.

83. **The severity of a stress test scenario is a policy choice that authorities need to make depending on their risk tolerance and the use of the test results.** The calibration of severity, reflects a policy choice, linked to the risk tolerance of a given authority as well as its interest in specific risk areas. Because a scenario analysis represents a "what if" analysis, the plausibility and occurrence probability of the "if" remain subject to judgment, bearing in mind that a scenario should reflect tail risks and therefore be severe enough. For macroprudential purposes, when deciding on the level of severity, authorities may also take an explicit countercyclical approach, which then renders severity point-in-time dependent, and therefore relatively less stringent in downturn phases.

84. **Authorities may need to collect stress test-specific data in order to achieve the relevant risk coverage, in particular for microprudential exercises.** Dedicated data collections can facilitate robust modelling, boost analytical work, enhance the understanding of banks' behaviour and support granular supervisory work and action. Regular, ie non-stress-test specific, data collections may not be comprehensive enough to cover stress testing needs, but concerns about reporting burden and proportionality considerations may limit the possibility of introducing additional, stress test or even risk-specific data collections. It is important for banks to have IT systems that deliver adequately accurate data, at the level of breakdown and frequency that would be required by the authorities leading the stress test.

85. **Stress test methodologies require careful reviews, especially wherever stress tests are used to impose specific requirements on banks.** For bottom-up exercises, authorities need to periodically review methodologies to address new risks, evolving regulatory or accounting requirements, or lessons from previous exercises. For top-down exercises, as the methodology boils down to models employed by

the authority in charge, these would need to be subject to a rigorous review process, which could be internal or external, but need to be of a quality comparable to that employed by supervisors for banks' model validation. This is especially important if model results can be binding for banks.

86. **A crucial decision is the choice between a dynamic or static balance sheet approach.** A DBS approach is generally more suitable in the case of macroprudential exercises, in order to capture changes in banks' risk profile over the scenario horizon, as well as to ensure consistency of credit and economic activity in the adverse scenario (Constâncio (2015)). Nonetheless, it has to be recognised that there is model uncertainty as to how to set the target for credit developments themselves, with impacts of the implied deleveraging on income and capital being bank-specific. For microprudential exercises, authorities face a trade-off between conservatism and realism, broadly mirroring the choice between the SBS and DBS options. The SBS approach, while counterfactual, is straightforward to implement and review. This holds especially if there is a large number of banks in scope or the exercise is bottom-up. The decision also relates to the subsequent use of results and the objectives of the exercise.

87. **Finally, for macroprudential purposes, going beyond a simple sum of individual banks' first-round results is desirable.** Although some microprudential exercises may partially capture spillovers across banks arising from interconnectedness or exposure commonalities, an articulated and explicit approach to such second-round effects may be preferable. This is because overall results would depend on specific assumptions or behaviour driving these effects. Capturing the latter in a controlled manner would be easier to achieve within a top-down setup.

Outcomes – results and communication

88. **Various metrics can be considered to summarise the results of the stress test, ideally in line with the applicable bank regulation.** In addition to the capital ratios (CET1, Tier 1 overall capital) for solvency stress tests, authorities can also choose to provide information on other dimensions, as applicable, such as liquidity or leverage ratios. For microprudential purposes, the most relevant results will need to be produced at the individual bank level. For broader macroprudential purposes, next to regulatory ratios reported in average terms for the system, results can also cover aggregate credit, as well as GDP in case of sizeable second-round effects. Aggregate results from microprudential exercises, as well as bank-level outcomes of macroprudential exercises, could also be valuably exchanged across the respective authorities in charge, to the extent permitted by legislation.

89. **If the exercise is geared towards recapitalisation, disclosure of results against a "pass/fail" hurdle can be used.** A pass/fail approach may be more appropriate in this case, so that banks ending up with a solvency ratio below a given hurdle rate have to follow a special course of action post-stress test. A publicly set threshold enhances transparency and helps pin down market expectations. However, it also imposes constraints on the supervisory follow-up, the design of which may require additional elements on top of capital available under stress. This approach may be especially relevant in times of crisis. Financial stability concerns may also justify communication of the pass/fail outcome for banks.

90. **While disclosure is usually desirable, the level of information received by the general public may be more limited than that conveyed to banks.** Disclosure to the public can strengthen the accountability and credibility of the stress test. In addition, more detailed disclosure to banks can be especially beneficial, as it can help them to better understand and evaluate risks in their own portfolio or compare the losses from their own models to the losses from the regulatory/supervisory models. At the same time, it is important that it does not incentivise banks to possibly mimic the authority's approach. This would undermine the banks' own risk management capacities or even help them to circumvent stress test requirements. In all cases, the context prevailing, ie crisis vs normal conditions, needs to be considered when deciding the degree of public disclosure, with more possibly warranted in troubled times.

Summary – mapping of objectives and stress test features

91. **As a summary of the analysis conducted in the paper, Table 4 maps key features of stress tests against the policy objectives of the authorities.** The table summarises the links established between specific features of stress tests (ie the three building blocks and their components, on the horizontal lines) and their policy objectives, ie macroprudential and microprudential. An additional column provides information on stress testing exercises that take a more narrow focus on specific vulnerabilities. Each cell represents the interaction between a given policy objective and a stress test feature. The information provided in each cell represents the more likely approach for this combination, based on the analysis presented in the paper. Cells marked "not critical" indicate that the policy objective per se does not determine a specific approach to the technical feature.

Illustrative mapping between stress test features and the exercise focus Table 4

Key features	1. Macroprudential	2. Microprudential	3. Risk-specific
Governance	Central bank	Supervisor	Not critical
Implementation			
Exercise severity	Not critical	Not critical	Stronger on specific areas
Scenario coverage	Systemic risks	Also idiosyncratic risks	Specific risk factors
Bank coverage	Systemic banks	Broad-based	Specifically exposed banks
Information granularity	Contained	Extensive	Granular for that risk
Top-down / bottom-up	Top-down favoured	Bottom-up helpful	Not critical
Dynamic vs static B/S	DBS favoured	SBS sufficient	Not critical
Second-round effect	Explicit account favoured	Not critical	Not critical
Outcomes			
Results disclosure	Aggregate	Bank-level	Risk-specific metrics

Blue cells indicate that a given decision on a (horizontal) feature is guided by a specific approach in response to a (vertical) policy dimension.

Source: FSI. Entries in the table are based on FSI staff interpretation of authorities' practices.

92. **While the mapping is not automatic, the table above contains the key takeaways for authorities planning to conduct a system-wide stress test.** For instance, when authorities have a macroprudential objective, it is more likely that the central bank is in the lead given the underlying financial stability or broader economic objectives. Accordingly, a scenario for a macroprudential exercise would include all relevant systemic risks, while a microprudential exercise would need to give more weight to idiosyncratic risks. If authorities want to conduct a stress test focusing on specific risks (such as for interest rate risk in the banking book or real estate), risk factors should cover these in more depth and the corresponding severity be tougher. In terms of banks in scope, macroprudential exercises would need to include the systemic banks, but not necessarily all banks, while microprudential ones may tend to use a broader base. Single risk-focused stress tests would consider exposed banks, which may not all be systemic. As for information requirements, data needs would probably be less granular for macroprudential exercises. The latter would also favour a top-down and DBS approach to duly capture second-round effects. Disclosure strategies would also be purpose-specific, with more bank- or even portfolio-level releases for microprudential or risk-specific exercises.

Section 6 – Concluding remarks

93. **Authorities run stress tests for macroprudential or microprudential purposes.** When macroprudential in scope, stress tests focus on system-wide risks, and support authorities in their assessment of risks in the banking sector. When microprudential in scope, stress tests are focused on the resilience of individual banks, so that authorities can decide whether to require remedial actions from the banks. In very special circumstances, ie in crisis times, microprudential and macroprudential objectives can be jointly met, when stress tests are used to provide information about banks' recapitalisation needs, results are disclosed and accompanied by credible actions to restore market confidence.

94. **There is no single way of designing and conducting stress tests.** While there are a number of common features shared across stress tests conducted by the authorities, there is no uniformity in approaches when conducting such exercises. Practices vary mostly due to differences in policy objectives, but also in terms of resource constraints, technical expertise, data availability and modelling strategies.

95. **A stress test is most effective when its design is closely aligned with the policy objectives.** When deciding on each of the building blocks of a stress test exercise, and its overall design, authorities can choose from a range of options. Depending on the objectives associated with each stress test, authorities can select the most suitable approaches in terms of framework design and its technical implementation. Consistency between design and objectives best ensures that an exercise provides the type of information that authorities need. Recently published high-level principles by the BCBS on supervisory stress tests provide guidance in this regard, especially for microprudential exercises (BCBS (2018)).

96. **While stress tests can support authorities in reaching their policy objectives, they are no panacea.** Stress tests are a useful tool to support authorities' assessment of risks and their impact on the financial sector. However, their results cannot be read in isolation, as they are conditional on a number of factors. These include the assumptions, especially the scenario under which they have been derived; data availability; specific methodological guidance for the banks, if applicable; model risk; and the extent to which propagation effect may play out along the channels that were expected.

97. **As the development of stress tests continues, new features are becoming available and could be incorporated, but challenges remain.** With stress tests now firmly established in the authorities' toolkit, there are ongoing efforts in academia and policy circles to enhance stress tests and possibly extend their use. Some possible changes relate to policy use, others to implementation challenges, and some of these changes may be within reach in the near term. Further into the future, deeper changes could be introduced as well, also to keep stress tests on par with broader improvements in modelling techniques and data availability, so that they remain relevant as a policy tool.

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Online Annex – Key aspects of system-wide stress tests (ST) for banks in selected jurisdictions

The Annex is available as an online appendix and can be found on the BIS website.