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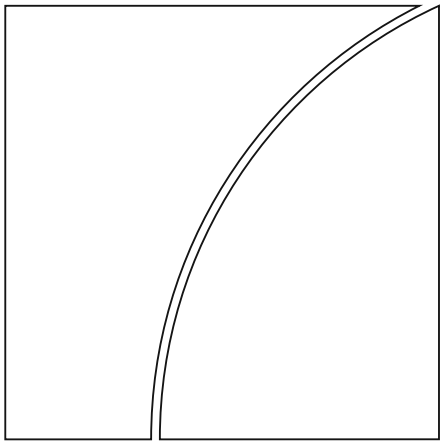

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# Stress testing in Latin America: A comparison of approaches and methodologies

Report submitted by a study group established by the BIS CCA Consultative Group of Directors of Financial Stability (CGDFS) and chaired by Pamela Cardozo, Bank of the Republic, Colombia.

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The views expressed are those of the authors and not necessarily the views of the BIS.

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# Executive summary

Since the Great Financial Crisis, bank supervisors and central banks have greatly increased and intensified their use of stress tests. The literature on stress testing has also expanded, but it generally focuses on the practice of policymakers in advanced economies and the challenges they face. Less is known about stress testing in emerging market economies and Latin American countries in particular. The purpose of this report is to fill this gap.

The report is based on the information gathered by a study group on stress testing formed by the Consultative Group of Directors of Financial Stability (CGDFS) and comprising selected central banks in the Americas. The study group held several meetings in person and through video conferences, conducted surveys and undertook a common exercise. The common stress-testing exercise proved particularly informative. Each participating jurisdiction ran their typical top-down stress tests under an agreed common scenario, making it easier to compare methodologies and approaches. To the best of our knowledge, this is the first report that systematically compares the stress test methodologies of Latin American central banks.

The report finds that the main type of test run by central banks is a top-down solvency stress test. Supervisory agencies conduct banking stress tests independently, usually of the bottom-up type. Coordination between the central bank and the supervisory agency, usually informal, is widespread. It takes place regularly, with the aim of facilitating the efficient exchange of information and opinions, the comparison of stress test results, and the provision of feedback on methodologies. Central bank stress tests focus mainly on banks, including all banking system participants. In some cases, they also include other deposit-taking institutions. The number of entities covered, as well as the sample composition, varies greatly between jurisdictions.

Credit and market risks are the main risk categories assessed, usually over a horizon of two or three years. Some jurisdictions also cover other risks or the strength of transmission channels using specific models distinct from the main stress test engine. Central banks rely on supervisory bank-level data to run their stress tests, sometimes disaggregating loans by sector and using banks' income statements. Credit risk assessment requires data on loans, charge-offs and loan loss provisions for commercial, consumer and mortgage loans at a system level as well as data on credit portfolios using broad and historic information on defaults at the bank/category levels. The assessment of market risk usually requires individual bank information, such as detailed portfolio holdings by institution, and financial market data such as interest rate curves and exchange rates. Assessing the strength of contagion requires detailed information on interbank exposure. The frequency of the data used in the stress tests usually depends on their availability.

As baseline scenarios, central banks typically use market surveys or projections produced by other central bank departments. The design of the stressed scenarios involves specifying the magnitude, direction and dynamics of the shocks to the key macroeconomic variables. The methodologies used include multivariate econometric models, replication of historical events or statistical rules applied to some or all variables in the scenario. In addition, central banks commonly use expert judgment,

and in some cases, also the financial and macroeconomic risks identified by private sector.

A variety of satellite models are used to estimate the impact of a given stress scenario on bank soundness and, for similar models, approaches to estimation also vary significantly. Generally, the assumed timing of the shocks within the horizon of the exercise differs for credit and market risk: while credit risk is often assumed to occur throughout during the exercise horizon and to be more persistent, market risk is often assumed to materialise at the beginning of the horizon and be short-lived. Assumptions on how banks will shore up their balance sheet in stress periods (future path of credit and funding growth, distribution of dividends, lending standards and portfolio allocation) are quite heterogeneous. Capital ratio calculations depend on the Basel regime followed, which also varies between countries. The degree of freedom that banks have in the theoretical models, together with the Basel standards considered for measuring capital, have a substantial impact on the results for the overall system.

The common exercise identified further differences. Starting from the basics, central banks have different ways of defining and measuring similar variables included in their models (eg credit). There are also differences in the sample of institutions included, specifically its composition (eg size and types of bank). As central banks make different assumptions regarding bank reaction to shocks (eg deleveraging) or how each system responds to regulatory constraints (eg provisioning), some banking indicators showed very different dynamics in the common exercise even when the starting points and shocks were comparable across jurisdictions. These differences can lead to significant divergences in the final impact on the banking sector within the same stress scenario.

Finally, the report discusses whether central banks are lagging behind international best practice. Not all central banks can count on high-quality data, robust IT systems, or even the staff resources needed to put together teams dedicated to stress tests alone. In several cases, a sole expert is responsible for running the stress tests, compiling the documentation and improving the methods used. That said, central banks are continuously working on improving their stress-testing methodologies and disclosing more information about them to the public, even though stress tests are not usually used as policy tools. Measuring how effectively stress test results are communicated is still not common practice.

# Introduction

Bank supervisors and central banks have increased and intensified their use of stress tests since the Great Financial Crisis (GFC), which showed that losses in individual institutions could threaten the entire financial system (Anderson et al (2018)). The literature on macroprudential or surveillance stress testing generally deals with the models and methodological challenges faced by policymakers in advanced economies.[1] This reflects the fact that the advanced economies are the most likely to comprehensively document their stress-testing methodologies.[2] By contrast, less is known about how stress tests are conducted in emerging market economies. In Latin America for instance, details of the stress-testing methodologies used by central banks are available only for Chile (Alfaro and Sagner (2011) and Martinez et al (2017)); Colombia (Gamba et al (2017)); and Uruguay (Illanes et al (2016)).

From 2017, the BIS Americas Office has coordinated a study group on stress testing for the central banks of a selected group of countries in the Americas.[3] The aim was to learn more about the stress-testing methodologies and their implementation in each jurisdiction. For this purpose, and given the lack of literature on stress test methodologies used by these countries, virtual and physical meetings among the participants were organised to discuss stress test-related issues.[4] We also conducted surveys on the methodologies, data requirements, policy uses and communication of stress tests.

Additionally, an exercise was conducted where each study group member ran their usual top-down stress tests under an agreed common scenario. The aim was not to assess the soundness of each financial system but to allow stress-testing methodologies and approaches to be compared from a practical perspective. For this purpose, each country started its exercise at a specific point in history. The criteria for this starting point were therefore defined with that goal in mind. First, the initial state of each country's financial system had to be at or close to its historical median, and it had to coincide with an expansionary phase of the business cycle. Second, to build a common scenario, the trajectory of the macroeconomic variables in the exercise horizon was assumed to be of comparable magnitude and to follow an equal pattern,

[1] Examples of the recent literature are Baudino et al (2018), Kapinos et al (2018) and Schuermann (2014).

[2] For instance, Budnik et al (2019) provide details of the macroprudential stress tests for the euro area; the Reserve Bank of New Zealand presents the key aspects of its stress tests on its webpage (for details of the RBNZ's stress-testing methodology, see also Dunstan (2018)); Andersen et al (2019) present the macroprudential stress-testing framework used in Norway; Buncic and Melecky (2013) present the Riksbank's method for stress testing banks; Burrows et al (2012) present the RAMSI model of the Bank of England (and an introduction to stress tests is given in Dent et al (2016)); and the Federal Reserve regularly publishes online its Dodd-Frank Act Stress Tests (DFAST) and Comprehensive Capital Analysis and Review (CCAR) methodologies and results.

[3] The participating countries were the BIS CCA members, that is, staff and officials of the financial stability departments of the central banks of Argentina, Brazil, Canada, Chile, Colombia, Mexico, Peru and the United States. Uruguay was also included. Canada and the United States did not participate in the common stress-testing exercise. Pamela Cardozo from the Central Bank of Colombia chaired the group.

[4] The topics covered in the meetings were the definition and consistency of the macro scenario and assumptions for stress tests; different types of risk in stress-testing practices and their interactions; assessment of spillover risks within the financial sector; feedback effects from the real economy to the banking sector; and communication and policy uses of stress test results.

capturing an instantaneous, unexpected and permanent shock. This let us identify more precisely the methodological elements behind the differences in the stress test outputs.

This document compares the stress-testing methodologies then used by the Latin American central banks that participated in the study group. To the best of our knowledge, this is the first time that the stress-testing methodologies of Latin American central banks have been comprehensively compared. The following major differences in stress test implementation were identified. Starting with the basics, central banks have different ways of defining and measuring their model variables. There are also differences in the sample of institutions included, specifically its composition (eg size and types of bank). Moreover, central banks choose different assumptions regarding bank reaction to shock (eg deleveraging) or how each system responds to regulatory constraints (eg provisioning). The common exercise revealed that these differences can lead to significant divergences in the final impact of a stress scenario on a given banking sector.

Regarding their similarities, we first noticed that the selected countries pursue similar objectives when running stress tests, and have similar institutional frameworks. The aims of stress tests are well established, taking into account the most relevant risks for each country. They also share some broad methodological characteristics, such as using stress tests in a similar way and placing more emphasis on credit risk. The approach to communicating stress test results is well established in all jurisdictions.

One important contribution of our work is that it gathers all the information shared through the different initiatives of the study group (meetings, surveys and the common exercise) in a coherent fashion, ie we analysed this information according to the different stages of a typical stress test, helping to identify specific methodological aspects beyond those covered in the theoretical literature. When needed, this information is complemented with details drawn from the main publications of Latin American central banks on their stress-testing methodologies. We believe that the results presented in this document will help practitioners consider a broader set of elements when seeking to improve their stress tests or incorporate new methodologies.

This report is organised as follows. Section 1 details the basic features of a stress test and outlines the stress-testing approaches of the Latin American participants in the study group. This outline follows the stages of a stress test: definition of objectives, scope and risks to be assessed; evaluation of data requirements and availability for the scope chosen; choice of methodologies for the quantification of macroeconomic shocks, and their impact on the financial condition of the entities under examination. In Section 2 we assess the differences in stress tests across countries that emerge from the results based on a common scenario. Section 3 discusses whether stress tests performed in Latin American central banks accord with the principles proposed in post-crisis international policy discussions, to which we link the results of the survey on communication and policy uses of stress tests. The last section sets out our conclusions and touches on future challenges for stress testing in the region.

# 1. Stress-testing practice in Latin America

Stress tests are used to assess the impact of severe but plausible adverse scenarios on the resilience of individual financial institutions, or groups of them, or an entire system. As such, stress tests consist of identifying and assessing the impact of possible sources of risks that, when adverse shocks materialise, can affect the financial condition of the banking system.

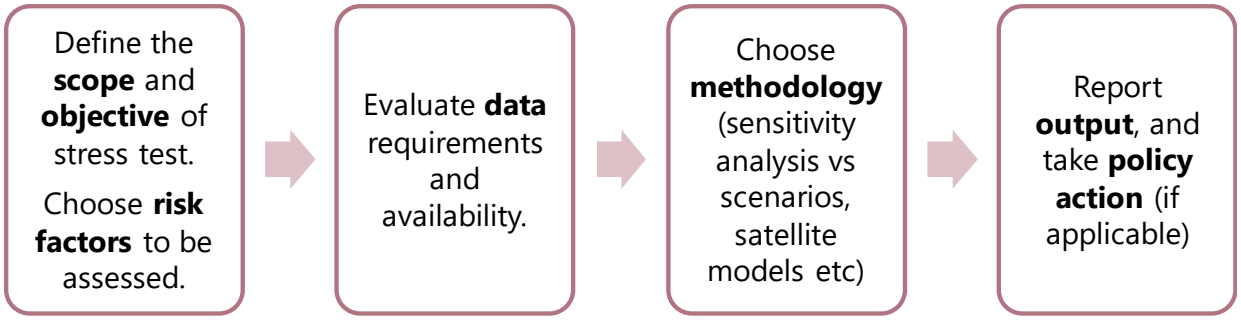
Stress tests can be run by financial institutions for risk management purposes or by the authorities (supervisors or central banks) for surveillance or prudential policy purposes. In either case, practitioners usually follow the sequence shown in Graph 1 below.

The scope of the stress test refers to the choice of financial entities to be put under examination, and of the time horizon on which these entities are examined. Stress tests are used to assess the resilience of banks and the entire banking sector in an economy, and they are also referred to as banking stress tests in the literature. That said, part of the literature focuses on other sectors of the economy, such as non-financial firms, pension funds or households.

Stress tests can also be categorised according to their objectives and uses. For example, stress tests can be used for assessing financial stability risks, improving the capabilities of the entities under examination or crisis management. They can also focus on the assessment of solvency or liquidity of an entity or a system.

Stress tests can take a top-down or a bottom-up approach. According to IMF (2012), top-down stress tests are defined as those conducted by the national authorities using bank-by-bank data and applying a consistent methodology and assumptions. In turn, bottom-up exercises are carried out by individual financial institutions using their own internal data and models, often under common assumptions. The choice between bottom-up or top-down stress tests depends on the availability of sufficiently granular data.

General steps of stress tests — Graph 1




Source: BIS, based on Perez and Trucharte (2013).

Usually, stress tests focus on credit and market risks, although funding, liquidity and contagion risks are also assessed either within or separately from stress-testing exercises. The choice of the risks to be assessed is idiosyncratic to each financial system, and based on the choice of risks, the practitioner also faces the challenge of choosing the most appropriate methodology. Finally, the ultimate use of the results

will determine which indicators the practitioner chooses to disclose to its targeted audience. As will be seen in later sections, this might be other policymakers, a selected group of financial institutions, or the general public.

In the following subsections, we describe the key elements of banking stress tests implemented by the LA-7 countries – Argentina, Brazil, Chile, Colombia, Mexico, Peru and Uruguay – that participated in the study group on stress testing coordinated by the BIS Americas Office. As explained above, the outcome of the study group's activities allowed us to gather detailed information on several aspects of stress tests performed by the LA-7 countries. This information, combined with the publicly available documents that partially describe their stress test methodologies, was analysed by the study group and the BIS secretariat in a way that follows the general stress test sequence outlined above.

We start by describing the aims of these stress tests, and their coordination with those of other institutions that also run stress test models. Then, we summarise the data requirements for the scope chosen, the methodologies used for the definition of macroeconomic stressed scenarios, the assessment of the scenario's effect on different risk components, and the final impact on bank balance sheets.

## 1.1. Objectives and coordination

In almost all countries surveyed, the central bank and the supervisory agency each conduct banking stress tests independently.

Surveillance is the most common goal of the central bank when performing top-down stress tests; supervisory reasons are second on the list (Table 1). Central banks usually focus on top-down solvency stress tests, although the central banks of Brazil, Chile, Colombia and Uruguay also perform top-down liquidity stress tests.

Top-down stress tests are usually run by the central banks, while bottom-up stress tests are the supervisor's responsibility. The reason is that central banks usually run their top-down stress tests using aggregated data, while supervisors use granular data to perform their bottom-up stress tests. This practice differs from the above-mentioned definitions proposed by the IMF (2012), where top-down exercises are conducted by the national authorities while bottom-up exercises are carried out by individual financial institutions.

Coordination between central banks and supervisors is common and usually informal. When central banks do not have supervisory responsibilities,[5] the entities each run their stress tests separately due to different methodological approaches and objectives. Differences in objectives are particularly important as supervisor tests could have regulatory consequences. Communication between the central bank and the supervisor takes place regularly, usually aiming to ease the flow of information and opinions, the comparison of stress test results, and feedback on methodologies.

For our comparisons across jurisdictions, we focus below on the methodologies used by central banks to carry out their solvency top-down stress tests.

[5] Of the LA-7 countries, those where supervision is conducted by the central bank are Argentina, Brazil and Uruguay.

Objectives of top-down stress testing

Table 1

| | Argentina | Brazil[3] | Chile[4] | Colombia | Mexico | Peru | Uruguay |
|---|---|---|---|---|---|---|---|
| Surveillance (macroprudential)[1] | | | | | | | |
| Solvency | | | | | | | |
| Authorities' own assumptions, by individual bank | | • | | • | • | | • |
| Authorities' own assumptions, by group of banks | | • | | | | • | |
| Authorities' own assumptions, system-wide | | • | • | | | • | • |
| Liquidity | | | | | | | |
| Authorities' own assumptions, by individual bank | | • | • | • | | | • |
| Authorities' own assumptions, by group of banks | | | | | | | |
| Authorities' own assumptions, system-wide | | • | | | | | • |
| Supervisory (microprudential)[2] | | | | | | | |
| Solvency | • | • | | | | • | • |
| Liquidity | • | • | | | | | • |

[1] Solvency and liquidity are jointly assessed in the macroprudential top-down stress tests of Brazil and Colombia. [2] Solvency and liquidity are jointly assessed in the microprudential top-down stress tests of Argentina. [3] The Central Bank of Brazil also performs analysis based on group of banks whenever required by the Board. [4] The Central Bank of Chile also performs liquidity assessments by bank, but results are not reported.

Source: BIS survey on stress test communication and policy uses (2018).

## 1.2. Scope: financial entities and risks

The choice of entities to be included in top-down solvency stress tests varies across the analysed countries (Table 2). The central banks that include all entities participating in their banking or deposit-taking system are Argentina, Brazil, Chile, Colombia and Peru, although the latter excludes public banks. Uruguay includes only a subset of the banking sector, basing its sample choice on systemic importance. The Bank of Mexico includes only commercial banks, since public banks are development banks with different aims and characteristics.

Entities included in top-down solvency stress tests

Table 2

| | Number of entities | | | | Share of total banking sector assets (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | Private sector: domestic-owned commercial banks | Private sector: foreign subsidiaries commercial banks | Public banks (state-owned) | Other | Private sector: domestic-owned commercial banks | Private sector: foreign subsidiaries commercial banks | Public banks (state-owned) | Other |
| Argentina | 32 | 17 | 13 | 17 | 28 | 26 | 41 | 4.9 |
| Brazil | 61 | 65 | 13 | | 17 | 39 | 44 | |
| Chile | 10 | 9 | 1 | | 47 | 37 | 15 | |
| Colombia | 15 | 9 | 1 | 25 | 66 | 25 | 4 | 4.6 |
| Mexico | 23 | 14 | | | 29 | 71 | | |
| Peru | 4 | 12 | | 37 | 30.4 | 59.7 | | 9.9 |
| Uruguay | | 10 | 2 | 1 | | 49.98 | 49.96 | 0.06 |

Source: BIS survey on stress test data, methodologies and assumptions (2019).

Most jurisdictions focus on the banking sector. However, some jurisdictions also include non-bank financial institutions in their stress tests; for example, the central banks of Argentina, Colombia and Peru also include commercial credit institutions, financial cooperatives, and municipal and rural credit unions, although these generally represent only 5–10% of total banking sector assets. The number of entities included in each central bank's stress tests as well as the types of entity varies greatly across jurisdictions, from 13 financial institutions in Uruguay to 139 in Brazil.

The number of public banks included in stress tests changes dramatically across countries as well. Argentina and Brazil report including over 10 public banks each, contrasting with two public banks in Uruguay, one in Chile and one in Colombia. That said, in most cases only a small number of banks account for the reported share of total assets in public banks. For example, in Brazil only two public banks account for most of the share of total assets in their category (49%). In Uruguay, the two public banks included in stress tests account for 50% of total assets. Except for Chile and Colombia, foreign subsidiaries account for a relatively larger share of total assets than domestic private banks, with Peru exhibiting the largest share of total assets for this category.

Countries in LA-7 include chiefly credit and market risks within their stress tests.[6]

Credit risk is the possibility that a counterparty will not meet its obligations, mainly related to lending. Shocks in macroeconomic and financial variables trigger changes in the probability of default (PD), loss-given-default and credit growth, affecting non-performing loans (NPL). These shocks also affect loan loss provisions through changes in expected losses, and net interest margins through interest rate income and expenses. This affects profits and capital ratios. Macroeconomic shocks also affect credit ratings via downgrades, eroding the quality of the loan portfolio. Credit ratings of specific sectors identified as vulnerable are downgraded.

[6] Alessandri and Drehmann (2010) and Drehmann et al (2010) note that these are the most important risks in a stress test.

Market risk is the possibility of the bank's assets and liabilities losing their value due to shocks in the market prices of financial instruments. The latter can also affect the riskiness of the market portfolio. Market risk involves assessing both interest rate and exchange rate risks. Interest rate risk is usually the greatest component of market risk (Kumar (2014)). Movements in interest rates can cause capital losses through changes in the banking and trading book. Changes in net interest income or margins arise when there are cash flow mismatches (fixed assets or liabilities) or repricing dates (floating assets or liabilities). Interest rate increases, reflected in the yield curve, affect the price of financial instruments (loss of value in the trading book, or valuation effect) and intermediation margins (additional cost of rollover, or repricing effect). Exchange rate risk is associated with the effect that changes in foreign exchange rates could have on the open positions in foreign currencies on the bank's balance sheet, depending on the currency mismatches of the bank and of its clients.

Interest rate risk is usually assessed by estimating the shocks of macroeconomic variables to yield curves and balance sheet exposures, generally using VAR models. Exchange rate risk is commonly assessed as the accounting loss of net assets after the chosen shock in the bilateral exchange rates of the main currencies to which banks are exposed.

Some jurisdictions also cover other risks, but in most cases the assessment is conducted in separate models that are not embedded in the stress test engine. For example, Argentina, Brazil, Colombia, and Peru also assess funding risks; Brazil, Chile, Colombia, and Uruguay also assess liquidity risks; and Brazil, Chile, Colombia, and Mexico also assess contagion risks. As explained below, not all risks assessed are reported to the public.

The horizon for the stress tests can be two or three years. The central banks of Argentina, Chile, Colombia, Peru and Uruguay project the impact of stress scenarios two years ahead; the central banks of Brazil and Mexico over a three-year horizon.

## 1.3. Data requirements

Data requirements and the evaluation of its availability depend on the scope of the financial system to be assessed, the specific risks to assess, and the banking conditions under study.

In general, central banks rely on supervisory bank level data to run their stress tests, which in some cases are disaggregated at the bank level. Bank positions included in stress tests are total loans, trading book portfolios and derivatives and other off-balance sheet transactions. The central banks of Argentina, Chile, Colombia and Uruguay also disaggregate loans by sector, ie to the non-financial private sector, to financial institutions, and to the public sector. Argentina, Brazil, Colombia and Mexico also use regulatory reports (data from supervisory report systems and surveys). The Central Bank of Brazil also uses the banks' income statements.

The assessment of market risk usually requires individual bank information, such as detailed portfolio holdings by institution, and financial market data such as interest rate curves and exchange rates. The assessment of credit risk requires data on loans, charge-offs and loan loss provisions for commercial, consumer and mortgage loans at system level; credit portfolios by broad categories (commercial loans, mortgages, consumption loans) and historic information on defaults at bank/category levels (to estimate PD). Contagion risk requires detailed information on interbank exposures (direct lending, repos, derivatives etc) for all institutions. Concentration risk requires

detailed credit information at firm level for the largest borrowers in the financial system.

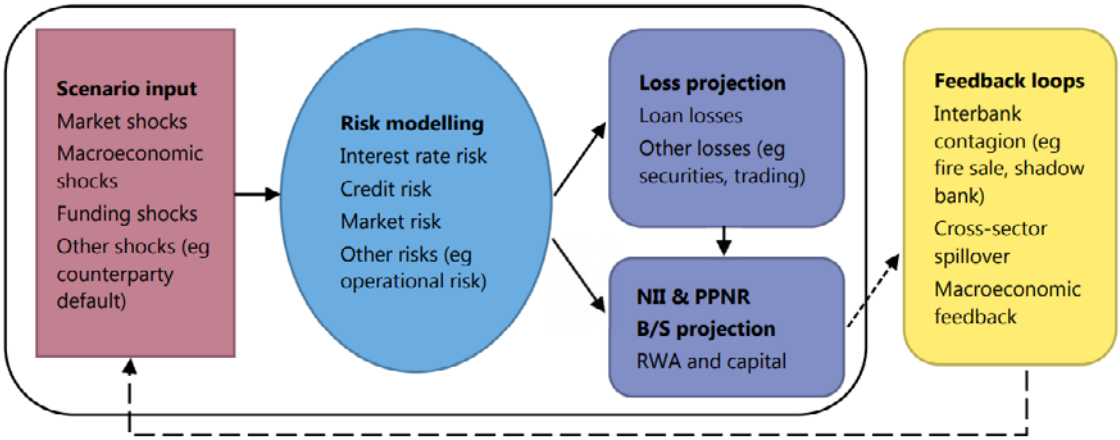
The frequency of the data chosen for the stress tests usually depends on its availability. The Central Bank of Argentina uses monthly data and presents the results annually; the central banks of Brazil, Colombia and Uruguay use quarterly data; and those of Chile, Mexico and Peru use monthly data. Note that, although the Central Bank of Chile uses monthly data in its analysis, the exercise is usually performed every six months and results are reported semiannually.

## 1.4. Methodologies

Once the central bank has defined the scope and degree of disaggregation, selected the risks to assess, and evaluated data requirements and availability, it must choose the most appropriate methodology for stress testing. In most of the countries under study, stress tests follow a scenario approach, which consists of three basic steps (Graph 2):

1. Adverse scenario design (choice of macroeconomic variables to be stressed and definition of the magnitude and direction of shocks to be applied).
2. Estimation of satellite models to quantify the transmission of shocks on the financial indicators of banks (credit growth, delinquency ratios etc) and their risk exposures (credit, market, funding, liquidity etc).
3. The assessment of the total capital losses that banks will incur due to the increase in risks.

Major modelling steps in a solvency stress test — Graph 2




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

Source: Baudino et al (2018).

An additional step recently considered by some central banks is to incorporate feedback effects into the stressed scenarios and evaluate them again through the entire stress-testing model. For instance, the Colombian DGSE and banking models have one variable in common, credit growth. This is so that the financial results of the institutions are reflected in the credit supply, therefore affecting GDP growth. The

Central Bank of Brazil evaluates feedback resulting from corporate and household defaults and bank failures. However, it does not include the feedback effect in the stress test scenario. Instead, it uses a different framework (real sector contagion), where shocks in the real sector (firms and their employees) affect the financial system through credit exposures.

Given that feedback effects are still work in progress for the LA-7, in the next subsections we focus on the three steps mentioned above.

### 1.4.1. Design of adverse scenarios

Evaluating the impact of macroeconomic shocks on the financial system requires the stressed scenario to be defined and compared with a baseline scenario. For the definition of baseline scenarios, central banks can use market surveys or projections of the official fan charts produced by other departments at the central bank.

For each stressed scenario, the magnitude, direction and dynamics of the shocks to the economy's key macroeconomic variables need to be specified. These can be defined using a variety of tools and rules. For instance, the macroeconomic variables within the horizon of the exercise are usually modelled using multivariate econometric models (VAR, VEC or DSGE). Jurisdictions also consider replicating historical events – for example, the sharp decline observed during the GFC – or apply a more generic statistical rule, such as basing the size and direction of shocks on historical standard deviations. Another common rule is to define the shocks based on the official projections of the central bank with a 1% probability of occurrence (provided that the central bank produces fan charts). Expert judgment is commonly taken into account, and in some cases jurisdictions can also combine their assessment with the financial and macroeconomic risks identified by private sector stakeholders, as expressed in formal meetings.

The methodologies used to define the stressed scenarios for the exercise vary across jurisdictions, as does the number of scenarios considered. The Central Bank of Brazil considers a structural break scenario and a historical worst-case scenario. The Central Bank of Chile includes one scenario based on previous periods of financial fragility – which is comparable across exercises – and one scenario corresponding to the lowest percentile of the macroeconomic projections. The Bank of the Republic, Colombia builds different sets of shocks that generate a GDP growth path corresponding to a specific probability level using the IMF's methodology of GDP at risk. The Bank of Mexico usually presents three scenarios based on a balance of risks. More recently, the Bank of Mexico has also included sets of historical scenarios. For each stress exercise, they consider several sets of 2,000 paths each, and report the results of the impact of these scenarios in terms of posterior distributions. The Central Reserve Bank of Peru considers the scenario corresponding to the first percentile of macro model projections, and occasionally other special scenarios generated by idiosyncratic shocks (domestic demand shock, supply shock, among others). The Central Bank of Uruguay uses a grid of 18 stressed scenarios, where the most stringent one resembles the banking crisis of 2002; additionally, on a quarterly basis, they set up specific stressed macroeconomic scenarios based on a risk analysis.

### 1.4.2. Transmission of stress to the financial system and satellite models

In Section 1.2, we introduced the concept of risk assessments and detailed the risks assessed by the LA-7 countries. In this section, we describe the methodologies used to estimate these factors.

Usually, central banks follow the scenarios approach and use satellite models to clarify the transmission mechanism of macroeconomic shocks to the financial condition of banks.[7] Satellite models assess how financial variables that are important for bank balance sheets respond to these shocks. These might include the impact of changes in macroeconomic variables on the default probability of banks (individually, by sector or for the entire system), which generates loan loss provisions; or on other financial variables that affect the banks' positions (eg asset valuation), which can have an impact on lending.

When the LA-7 central banks assess credit and market risks, they use different methodologies. For instance, the Central Bank of Brazil uses panel data estimations for credit growth and NPLs, and then projects profit and losses and its impact on capital and risk-weighted assets. The central banks of Chile, Colombia, Mexico and Peru use VAR models to link macroeconomic variables with loans (disaggregated by portfolio type) write-offs, loan loss provisions, PDs and LGDs. In the Bank of Mexico, credit risk is assessed using projections for the probabilities of default and the credit portfolio, which allows credit portfolio profits and losses to be estimated for each scenario.

Generally, the timing of the shocks depends on whether the exercise addresses credit or market risk. As evidenced in many countries surveyed by the Basel Committee,[8] credit risk tends to materialise after a certain lag. By contrast, market risk can sometimes materialise instantaneously, ie during the first period of the horizon.[9]

Approaches also differ with regard to the future path of credit and funding growth, distribution of dividends, lending standards and portfolio allocation. On the one hand, bank assets are usually set to grow according to credit growth, whether or not this would be the bank's choice in a stressed period. On the other hand, there are several differences in the choices that banks do have in the theoretical models, as embedded in the stress tests, concerning changes in their balance sheet.

- *Dividends distribution*: during the stressed period, dividends are usually paid under certain conditions. For example, in the stress tests of the Central Bank of Brazil, the assumption is that dividends are distributed according to each bank's policy. In the stress tests of the Central Bank of Chile, banks distribute 70% of their dividends when these are positive, while in the stress tests of the Bank of Mexico banks do so as long as capital in period *t* is greater than the initial capital. The models of Colombia and Peru do not allow for endogenous distributions of dividends.
- *Lending*: in the Colombian case, lending depends on the DSGE model and the portfolio restrictions of each bank.[10] In the Mexican model, bank credit growth can be constrained if the capital ratio of the banks falls below the regulatory minimum. In the case of Brazil, lending during the ST horizon is

[7] Stress tests can also consider the sensitivity analysis approach, ie shifting risks individually.

[8] See BCBS (2017a).

[9] The exception is the methodology of the Central Bank of Uruguay, which does not account for the dynamics of either risk type, ie their stress test horizon comprises only one period.

[10] Specifically, their model assumes that banks will allocate new resources (new funding and loans amortisation) to different asset classes while seeking to keep their portfolio structure constant, and taking into account solvency and liquidity regulatory limits. Therefore, credit supply could be affected by funding, solvency and liquidity.

only considered if the bank has enough capital to do so. When its capital is too scarce compared with its RWAs, they apply a cap on credit growth.

- *Portfolio allocation*: in some models, there is no reallocation, such as in that of Chile. In others, reallocation can occur as long as the structure of the portfolio remains unchanged and while it complies with regulatory restrictions. Such is the case of the Colombian stress test, where banks assign available resources – first to portfolio, then investment – aiming to restore the pre-stress structure of the balance sheet, subject to regulatory restrictions.[11] In the Mexican model, when the credit portfolio contracts, banks invest those resources in 10-year government securities, which are subject to a market risk capital requirement.[12]

The liability side of banks' balance sheets, or more precisely, the choice of models and assumption for this side, is another important aspect of stress testing. The Bank of Mexico models only the changes of the average deposit rate that each bank faces with respect to changes in the reference interest rate. For the Central Reserve Bank of Peru, deposits are forecast using a VAR with an exogenous block model, while most of other liability components grow at the deposit rate, although the model may include capital contributions. In the Brazilian model, changes in funding are set equal to changes in credit. Similarly, in the Colombian case the aggregate liabilities growth is consistent with credit growth in the financial DSGE model. Then, liabilities in each period are distributed among institutions so that healthier institutions (more profitable, more solvent and with better-performing loans) receive more resources. In Chile, banks are assumed to keep the same funding structure. However, in the market risk component, the central bank also evaluates, based on detailed data from the banking book, the bank's capacity to roll over its debt and the extra cost of any sudden interest rate increase (repricing effect).

As mentioned above, some countries also assess contagion risk. This can be evaluated within the stress tests (as in the case of Mexico and Colombia), using separate models (as in Chile), or both, as in Brazil, where the contagion module is included in the top-down stress test but can also be run separately. In particular, the Central Bank of Brazil estimates an interfinancial contagion; that is, it simulates the failure of each financial institution – one at a time – and assesses the impact on its counterparties and the whole system. Contagion risk is embedded in the stress tests of the Bank of Mexico within the market risk module, and through estimations of the impact on asset fire sales in the case of Colombia. In Chile, the central bank uses a separate model of interconnectedness to assess contagion.

Once the changes in banks' balance sheets and profitability under the stressed macroeconomic scenario are estimated and projected onto the testing horizon, solvency is assessed through the calculation of the new capital ratios according to each jurisdiction's rules. Although all countries use regulatory capital ratios – capital to risk-weighted assets (RWAs) – as a measure for capital adequacy, the calculations of the factors that the indicator comprises differ, given the assumptions of each central bank and that the weights in the RWAs vary according to the applicable Basel regime. While RWAs for Argentina, Brazil, Mexico, Peru and Uruguay depend on the

[11] Banks follow the provisioning scheme of the Financial Superintendence standard model.

[12] Capital requirements for operational risk are estimated with a proxy for Basel II's Basic Indicator Approach.

rating of the loans (Basel II and III), in Colombia and Chile weights are static (Basel I).[13] For Colombia, this implies that, in stress scenarios, the solvency ratio increases as credit contracts. To avoid this, in the Chilean stress test only positive loan increases are added to the RWAs.

Hurdle rates[1] Table 3

| | Argentina | Brazil | Chile | Colombia | Mexico | Peru | Uruguay |
|---|---|---|---|---|---|---|---|
| Levels (%) | | | | | | | |
| Core Tier 1 capital | 4.5 | 5.125 | 4.5 | 4.5 | 4.5 | | 4.5 |
| Tier 1 capital | | 6 | 6 | | * | | 6 |
| Total capital | 8 | 10.5 | 8–10 | 9 | 8 | 10 | 8 |
| Additional capital conservation buffer | | 0.625 | * | | 2.5 | | 2.5 |
| Additional cushion for G-SIBs | | 1 | * | | 0.6–1.5 | | 0.5–2.0 |

[1] Asterisks indicate those rates that, according to respondents, are not defined by the regulation in their jurisdictions.

Source: BIS survey on stress test data, methodologies and assumptions (2019).

Hurdle rates are used to determine whether a bank passes or fails the stress tests – eg when banks end up with capital levels below the regulatory minimum or are considered bankrupt and unable to meet their obligations in the interbank market. Table 3 shows the levels of Core Tier 1 capital, Tier 1 capital, total capital, additional capital conservation buffer and the additional cushion for G-SIBs, as considered by the central banks in their stress tests and defined in local regulation. In some cases, although defined by regulation, the criteria for determining whether a bank passes or fails the stress test may include other aspects. For instance, in the Brazilian case, the assessment of contagion risk assumes that financial institutions with a Core Tier 1 capital ratio below 4% propagate contagion, although they may not necessarily be in default. In Peru, the failure of the tests are defined by the capital adequacy ratio.

## 2. The common stress-testing exercise: setup, output and differences

In order to evaluate how differences in methodological approaches translate into differences in the stress test output, the LA-7 central banks carried out an exercise where they performed their usual stress tests, but replaced their usual main stressed scenarios with one that was common to all. The starting points were not required to be the same; however, the date chosen as the starting point was supposed to reflect similar initial conditions, whenever feasible, across jurisdictions. The guidelines of the common stress-testing exercise are detailed in the following subsections.

[13] That said, the new General Banking Law came into force in Chile in January 2019. The law aims at bringing the banking system closer to international practice by strengthening bank solvency requirements in accordance with Basel III. In addition to raising Tier 1 capital requirements, the law introduces the capital conservation buffer and allows the inclusion of new capital instruments (perpetual bond and preferred stock) in regulatory capital. It also allows the authority to set a countercyclical capital buffer and impose higher requirements on systemically important institutions, and to require additional capital for supervisory purposes (Pillar 2).

## 2.1. Setup

The setup for the common stress-testing exercise carried out by the LA-7 countries had two steps. The first step each country had to take before running their stress tests under the common scenario was to choose its starting point, that is, the period t=0 of each individual exercise. The chosen starting point was intended to position each country's financial systems in a "comparable" or "alike" state. To this end, the starting point would be a date when the financial system of each country was at or close to a "historical" median for the range period 2010–17.[14]

The reference variable to establish the historical median was the aggregate return-on-assets (RoA) at a monthly frequency. The advantages of using this variable are that it is an easily comparable, widely available indicator, common in most individual stress tests, and it is available to all countries. A second condition was that the selected period coincided with an expansionary phase of the business cycle. If two or more periods equally satisfied this condition in the window defined, the preferred starting date would be the one with the highest aggregate solvency ratio following a phase of expansion in the business cycle.

The second step was to establish the macroeconomic scenario. As mentioned before, there are several ways to define macroeconomic scenarios; this can be another impediment to the comparability of stress tests across countries. Taking this into account, the participants agreed that the scenario to be used in their stress tests should be designed in a similar way. Therefore, the stressed macroeconomic scenario proposed for the exercise consisted of an instantaneous, unexpected and permanent shock, causing the macroeconomic variables to jump permanently to a worse level and remain there for two years.

The specific set of macroeconomic variables to be stressed and the magnitude and direction of each shock are summarised in Table A.1 in the Annex. Although the scenario attempted to include all macroeconomic variables used in the stress tests of all participating jurisdictions, participants were encouraged to include other variables relevant for their jurisdiction. To estimate the magnitude of each shock, participants considered data between 2000 and 2017 for each variable whenever possible.[15]

The guidelines for the starting point and the stressed scenario were applied by all participants in their respective exercise, although they had to adapt them to the availability of data or specific conditions of their jurisdictions. More details of the specifics of the implementation can be found in the Annex.

[14] There were two reasons why the "historical" period was defined to be from 2010 to 2017 for the definition of the starting point. The first was to avoid the quarters around the GFC. The second reason was that several of the financial data series required for the exercise are not available prior to the 2000s. That said, the window period was not entirely restrictive: in case jurisdictions wished to use longer data sets in a given component of stress-testing methodologies (for example, if they estimate certain parameters using time series or panel data models) they could do so. Whether this date is a month, quarter, semester or year will depend on the frequency of the data used in each jurisdiction's methodology.

[15] Again here the window period was not restrictive and jurisdictions could use a different historic period if their models required.

## 2.2. Output of the exercise: commonalities and differences

This section summarises the output of the exercise and tries to uncover the possible drivers of the differences in the results across jurisdictions.

Participants were asked to report the results according to Table 4. The table also details the variables that each jurisdiction could actually report for this exercise. Meanwhile, Graph 3 and Table 5 show the results reported.[16]

In general terms, we first noticed that, although trends are coherent with the stressed scenario proposed, the magnitude of the final impacts on the banking indicators sometimes show important differences. These differences in the results may arise from a variety of methodological factors (see Annex). First, as explained in previous sessions, the treatment of the input variables vary across jurisdictions. Specifically, countries use different data frequencies for their analysis, different measurement of the variables (eg variables enter the models as levels, ratios or changes), and different variable definitions (eg loan losses measured as non-performing loans, delinquency rates, charge-offs, or derived from different provisioning dynamics). Additionally, the fact that LA-7 countries follow different Basel standards means that the output indicators are not necessarily comparable, for example due to the differences in calculations of capital and RWAs.

Another important source of differences is that the common scenario proposed for the exercise did not result in the same level of severity for all countries. One reason for these discrepancies is the different financial conditions experienced by each country during the period 2010–17, even though this period excludes the GFC. Another reason is that the exposures to the shocks in the scenario differ across countries, which means that a one or two standard deviation increase in certain variables may hit banks differently.

It is also the case that bank financial conditions and different business models (and thus different bank exposures) imply that the responses of revenues, expenses and losses have different sensitivities to different risks. Some banking sectors are more exposed to commodity price changes and some others (for example, in highly dollarised economies such as Uruguay) are more exposed to foreign currency risk and credit risk. Other banks are more exposed to market risk as their investment banking and trading activities are larger than those of banks in other jurisdictions.

Other less explicit factors can explain the differences in the results, in particular, related to the dynamics of some indicators throughout the horizon. For instance, aggregate credit slows down or decreases after the shock but, in some cases, a partial recovery is observed. The dynamics of aggregate provisions expenditure follow patterns similar to the ones described for credit growth. Apart from the fact that econometric specifications might differ across jurisdictions, these differences can also be attributed to the underlying assumptions for the reaction of banks to the stress mentioned in Section 1.4.2, eg fixed versus a growing balance sheet, no impact on deposits versus deposit runs, and different feedback and contagion effects.

The total cumulative losses can in some cases be significant, but the contribution of the cumulative losses associated with credit and market risks are not always similar across countries. Moreover, when considering the cumulative losses arising from

[16] Results disaggregated by country are, by design, purposefully not disclosed in this part of the document to ensure that the reader focuses on comparing methodologies rather than the financial stability stance of each participating jurisdiction.

these two risks, it may also be the case that the contribution of each risk differs significantly. Also, countries with similar credit risk-related losses can show very different credit plus market risk-related losses that arise from the same set of causes. We also see important differences in the resultant solvency of each country's banking system, which is not necessarily proportional to the differences in total cumulative losses, due to differing assumptions on credit growth dynamics.

The distributions of final impacts on RoA and solvency across banks in each jurisdiction suggest heterogeneity on several fronts. First, while in some cases standard deviations of the individual RoAs and/or solvency ratios decrease in the stress test horizon, other cases show the opposite. Second, while in some banking systems the distribution for both indicators changes in similar ways, in others they are less symmetrical. Finally, the size of the standard deviations is not necessarily related to the share that banks included in the stress tests represent in the total financial/banking sector, but rather to the composition of the sample of banks. Recall that, while some jurisdictions include all banks, others select the entities according to their systemic importance, and that the share of public banks also varies. Moreover, in some cases, the standard deviations are calculated with a truncated sample, in order to account for outliers or less representative banks.

## Stress test output

Variables considered by each country — Table 4

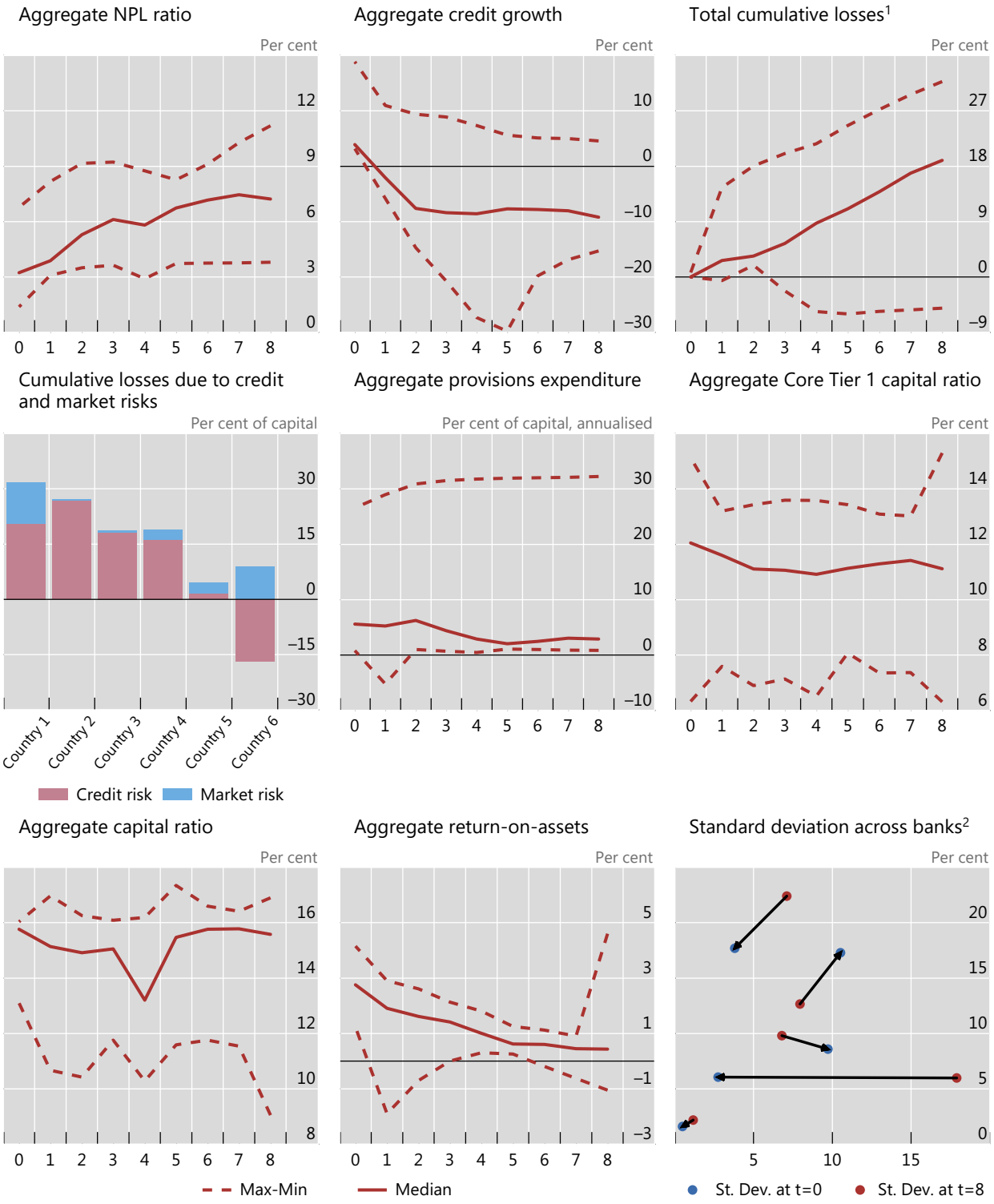
| | Argentina | Brazil | Chile | Colombia | Mexico | Peru | Uruguay |
|---|---|---|---|---|---|---|---|
| Aggregate NPL ratio | • | • | | • | • | • | • |
| Commercial credit NPL ratio | | • | | • | • | • | • |
| Consumer credit NPL ratio | | • | | • | • | • | • |
| Housing credit NPL ratio | | • | | • | • | • | • |
| Aggregate credit growth | • | • | • | • | • | • | |
| Commercial credit growth | | • | • | • | | • | |
| Consumer credit growth | | • | • | • | | • | |
| Housing credit growth | | • | • | • | | • | |
| Total cumulative losses for the financial system (% of capital), *of which:* | • | | • | • | | | • |
| Credit risk | • | • | • | • | • | • | • |
| Market risk | • | • | • | • | • | • | • |
| Funding risk | • | | | | | | |
| Liquidity risk | | | | | | | |
| Contagion risk[2] | | | | • | • | | |
| Solvency risk | | | | | | | |
| Aggregate Core Tier 1 capital ratio | • | • | • | • | • | | • |
| Aggregate provisions expenditure (% of capital) | • | • | • | • | • | • | • |
| Aggregate capital ratio | • | • | • | • | • | • | • |
| Aggregate return-on-assets | • | • | • | • | • | • | |
| St. Dev. of solvency ratio across financial institutions | • | • | • | • | • | | • |
| St. Dev. of return-on-assets across financial institutions | • | • | • | • | • | | |
| Aggregate PER[1] (% loans) | | | • | | | | |
| Commercial credit PER (% loans) | | | • | | | | |
| Consumer credit PER (% loans) | | | • | | | | |
| Housing credit PER (% loans) | | | • | | | | |

[1] PER: Provisions Expenditure Ratio. [2] Since the common exercise, the Central Bank of Brazil has modified the methodology of its top-down stress test, by including a contagion risk module. In its current version, cumulative losses related to contagion risk can be calculated.

Source: Results of the stress-testing exercise under the common scenario, as reported by individual jurisdictions.

## Output of countries' stress tests under a common scenario

Graph 3




[1] Total cumulative losses as reported by individual central banks, otherwise it equals the sum of all risks reported. [2] Horizontal axis: standard deviation of RoAs. Vertical axis: standard deviation of solvency ratios.

Source: Results of the stress-testing exercise under common scenario, reported by individual jurisdictions.

Impact of the stress on banking indicators

Changes between initial and final period of the stress test horizon ($x_{t=8} - x_{t=0}$) Table 5

| | Minimum | Maximum | Mean |
|---|---|---|---|
| Aggregate NPL ratio | 2.41 | 7.88 | 4.92 |
| Commercial credit NPL ratio | –0.09 | 10.41 | 3.57 |
| Consumer credit NPL ratio | –0.04 | 8.88 | 4.61 |
| Housing credit NPL ratio | 2.06 | 7.33 | 4.61 |
| Aggregate credit growth (real annual) | –24.76 | –7.53 | –16.41 |
| Commercial credit growth | –11.42 | –4.31 | –7.86 |
| Consumer credit growth | –7.94 | 1.86 | –3.04 |
| Housing credit growth | –4.36 | 0.60 | –1.88 |
| Total cumulative losses for the financial system (% of capital) | 4.60 | 52.01 | 25.11 |
| Credit risk | 1.60 | 35.58 | 18.45 |
| Market risk | 0.62 | 13.60 | 6.05 |
| Aggregate Core Tier 1 capital ratio | –4.60 | 0.46 | –2.17 |
| Aggregate provisions expenditure (% of capital, annualised) | –1.46 | 13.71 | 4.44 |
| Aggregate capital ratio | –4.60 | 0.48 | –2.45 |
| Aggregate return-on-assets (annual returns) | –4.41 | –1.23 | –2.55 |
| St. Dev. of solvency ratio across financial institutions | –4.62 | 3.12 | –0.25 |
| St. Dev. of return-on-assets (annual returns) across financial institutions | –8.75 | 15.15 | 1.09 |

Source: Based on results of the stress-testing exercise under common scenario, reported by individual jurisdictions.

## 3. Do central bank stress tests in the LA-7 follow international best practice?

The BIS has contributed to the policy discussion through studies on different aspects of stress testing. For example, the Basel Committee recently published an update of its stress-testing principles (BCBS (2018)), which can be read as a compendium of internationally agreed best practices. The principles are: (1) stress-testing frameworks should have clearly articulated and formally adopted objectives; (2) stress-testing frameworks should include an effective governance structure; (3) stress testing should be used as a risk management tool and to inform business decisions; (4) stress-testing frameworks should capture material and relevant risks and apply stresses that are sufficiently severe; (5) resources and organisational structures should be adequate to meet the objectives of the stress-testing framework; (6) stress tests should be supported by accurate and sufficiently granular data and by robust IT systems; (7) models and methodologies to assess the impacts of scenarios and sensitivities should be fit for purpose; (8) stress-testing models, results and frameworks should be subject to challenge and regular review; and (9) stress-testing practices and findings should be communicated within and across jurisdictions.

While the study group coordinated by the BIS Americas Office did not explicitly assess – either through its videoconferences, common exercise or workshop – whether central banks follow these principles, some of the survey responses do

indicate whether the LA-7 central banks observe them.[17] These responses, as well as feedback from meetings with the LA-7 country representatives, suggest that all the central banks aim to follow the BCBS principles when applicable. As mentioned in previous sections, the objectives of stress tests in the LA-7 are well established and take into account the key risks for each country. Although stress tests are not usually used as policy tools, and the degree of sophistication of the models used across jurisdictions is varied, the direction of central banks is towards adopting more robust methodologies.

However, according to the survey responses from the LA-7 countries participating in the study group, central banks inevitably lag behind in some of the principles.[18] For instance, some central banks are not always able to count on high-quality data,[19] robust IT systems, or even the staff resources required to dedicate teams solely to stress testing. In fact, in several cases, a solitary expert is responsible for running the stress tests, compiling the documentation and improving the methods used – and this in addition to other duties.

At the same time, some of the principles pose issues yet to be explored. One of them relates to the severity of stressed scenarios. As proposed by Borio et al (2014), there are three key practices that could ensure the usefulness of stress tests: (1) having the will to really stress the system; (2) ensuring buy-in by all the stakeholders; and (3) formulating a clear follow-up plan in line with the specific objective of the exercise. The methodologies followed by the LA-7 countries show heterogeneity across the stressed scenarios used, which suggests an ad hoc understanding of the convention "severe but plausible". While stressing the system more severely than some countries currently do could lead the public to take the results and the official assessment less seriously, not doing so might lead to results that are less useful for policymaking purposes.

The principle that was explicitly explored in one of the surveys and its follow-up discussions was communication. The main takeaways of that survey are the following:

- The results of top-down solvency stress tests run by central banks are usually shared and discussed with supervisory institutions and financial stability committees (FSCs) for policy purposes. Generally, the purpose of communicating stress test results to other policymakers is to keep them informed, discuss the results and share opinions. When other policymakers also run parallel stress tests, communication allows to compare the results and check for consistency in the models. A side benefit of communicating the results to other policymakers is that it encourages information and data-sharing. Several central banks reported that information-sharing occurs informally on an ongoing basis. Usually, both aggregated and disaggregated results are disclosed at formal meetings with other policymakers around the time when the central bank is writing its financial stability report (FSR), which

[17] Note that, in order to make a complete assessment of whether the LA-7 countries follow best international practices in their stress tests, one must also consider the stress tests run by supervisory entities. As previously acknowledged, the LA-7 countries where supervision is conducted by the central bank are Argentina, Brazil and Uruguay.

[18] Note that the IMF regularly performs more detailed evaluations of stress test methodologies at a country level, through its Financial Stability Assessment Program (FSAP). The results are publicly reported. Recent assessments of selected LA-7 countries are IMF (2016a), IMF (2016b) and IMF (2017).

[19] For more details on the data used by central banks in their stress test models, see Section 1.3.

occurs either biannually or annually. These meetings can also occur more frequently.

- Stress test results for individual financial institutions are sometimes disclosed to the institutions under examination. This is done to convey the central bank's view regarding the resilience of the financial institutions included in the stress tests, to enquire about aspects of their performance and receive feedback, or when it is required by law. Results are usually disclosed to financial institutions in the same format as they are to other policymakers and FSCs.
- Aggregate results are communicated to the general public in all jurisdictions. The communication is done via the FSR for transparency or as required by law. There is no consensus on the pros and cons of disclosing disaggregate results to the public. According to the Fed's experience, disclosing disaggregated results has helped to improve market confidence, encourage market discipline and sharpen banks' risk management. On the negative side, banks might become less willing to share their information with the supervisor. The decision to start disclosing bank-level results should be motivated by a clear objective and preceded by an evaluation of the benefits and needs.
- All jurisdictions make their methodologies public, using a variety of formats. In some cases, stress test data, methodologies and estimations are thoroughly explained in technical documents. In other cases, brief explanations of the methodologies are reported in annexes or boxes within the FSR. Changes in methodology can also be communicated via FSRs or public announcements.
- A common rationale for disclosing stress test scenarios is to help the audience understand the context in which stress tests are performed as well as improve the understanding of the results and how they compare with previous exercises. However, not all jurisdictions disclose the scenarios used. Reasons for not disclosing the scenarios to the public could be the possibility that the scenarios are perceived as official forecasts when they are not, or the need to protect the confidentiality of non-public forecasts (for use only within the central bank).
- Stress test results are not used as a significant input into the monetary policy process. In some cases, the results are shared with the monetary policy (studies) department or the board of the central bank, but they do not carry a relevant weight in monetary policy discussions. Basing policy actions on stress test findings is less common. However, discussions with other policymakers are believed to contribute to the resiliency of the banking system as, once vulnerabilities are assessed, micro- and macroprudential measures can be designed, adjusted or strengthened. That said, the LA-7 central banks do not measure the effectiveness of communication of their stress test results.[20]

[20] In the survey conducted by the study group, the central banks were asked: "Do you have a measurement of the effectiveness of, or how your targeted audience perceive, the communication of your stress test results?". For instance, whether a central bank expected the communication of the results of the stress tests to have an effect on the behaviour of certain agents.

These results suggest that the communication of stress tests is well established across the LA-7 countries. However, only aggregate results have so far been disclosed to the public. While protecting the confidentiality of bank information can protect the entire system, disclosing disaggregated information could also promote better practice in the industry as it makes for greater accountability. Unfortunately, it is not a widespread practice to measure the effectiveness of communicating stress test results. Many argue that to do so would take up scarce resources and, since stress tests are not currently used as a policy tool, the necessary efforts would be better directed to more pressing issues. Nor do any of the countries view the communication of stress tests as an indirect policy tool.

## 4. Conclusion

This report details different aspects of the stress-testing practices of seven Latin American countries, finding similarities among them. The results of surveys and the common exercise indicate that the LA-7 countries pursue similar objectives when running stress tests, and share similar institutional frameworks. They also concur in some broad methodological characteristics, such as placing more emphasis on credit risk, and applying this analytical tool in similar ways. The approach to communicating stress test results is also similar across jurisdictions.

At the same time, the common exercise revealed important differences in the ways that the participant authorities implement stress tests, which can lead to significant divergences in the final effects of a stress scenario on the banking sector. Central banks have different ways of defining and measuring their model variables. There are also differences in the sample of institutions included, specifically its composition (eg size and types of bank). Moreover, central banks make different assumptions on banks' reactions to shock (eg deleveraging) or how each system responds to regulatory constraints (eg provisioning). Furthermore, other factors may have contributed to the heterogeneity in the results of the common exercise. Given the differences in economic experiences across jurisdictions, scenarios based on historical data varied greatly in their severity. In addition, the current state of the economy at the chosen starting points for the common exercise was not the same for all jurisdictions because, even when business cycles were expanding, the financial conditions (credit cycle) of these country were at different stages. Finally, although all central banks use capital adequacy as a measure of their banking sectors' solvency after the stress, the calculations of the components of capital ratios differed across countries due to differences in the applicable Basel regime.

By assessing and comparing methodologies, this report will allow central banks of the region to learn from each other's practices. In fact, the study group on stress testing served as a forum for sharing knowledge and discussing different ways to assess risks, taking into account the similarities and differences of each economy. Participating jurisdictions have expressed the intention, or are already planning, to improve their existing stress-testing frameworks or further develop them. In some cases, they have been motivated to do so by the progress of their peers.

In terms of the *existing framework*, Brazil is currently working on its liquidity contagion framework so that it will simulate funding run-offs not only from banks with solvency issues but also from banks similar to the ones with capital concerns. In addition, fire sales are also simulated and the impact of the discounted prices on banks' balance sheet is estimated. Brazil is also working on the development of new

forecast models for credit growth/provisions and profits/losses, modelled individually (for each institution), in order to improve the accuracy of projections for each bank. Colombia indicated that it would benefit from modelling loan and deposit interest rate dynamics more granularly for consistency with the macroeconomic scenario, and incorporating changes to the maturity of assets and liabilities in the banking model. Mexico indicates that one area of improvement would be modelling different regimes in terms of variance/covariance estimation for scenario generation. Peru and Uruguay indicated that they would improve their credit risk models. In particular, Peru aims to connect its credit and market satellite models and improve the mapping of credit risk arising from exchange rate volatility.

In terms of *future work*, Brazil plans to incorporate market liquidity and funding risks into its top-down stress test with the main aim of measuring spillover effects stemming from risks related to liquidity (funding and market liquidity). Peru also mentions plans to include liquidity risk in its stress-testing framework. Chile, Mexico and Uruguay aim to include feedback effects, either by extending their existing VAR models for scenario definition, or by developing general equilibrium models to capture the effects between the real and financial sectors. Peru indicates that it places importance on building market risk models for insurance companies and pension fund portfolios.

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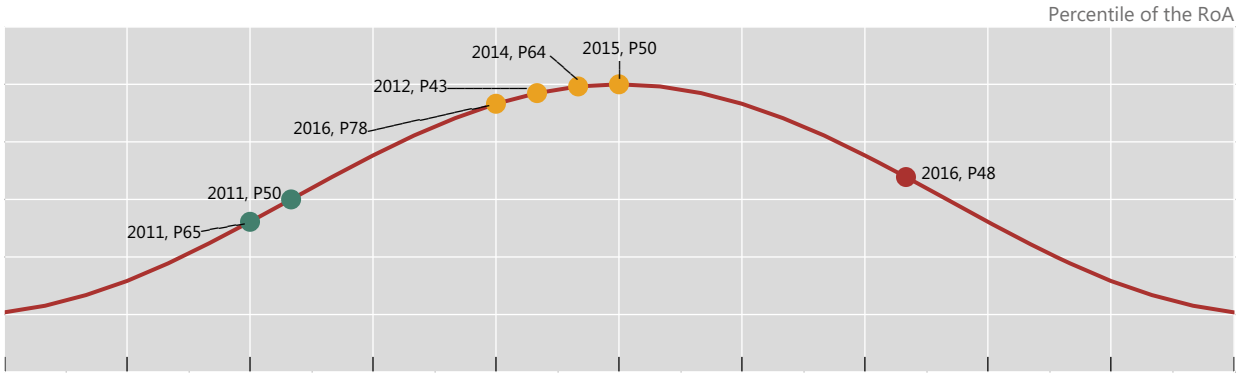
# Annex: How the common exercise was conducted

## Starting point

As explained in the main text, we proposed that participants of the study group should choose their own starting point, following certain criteria that would reflect similar conditions across countries. However, the criteria could not be met by all participants as some did not experience business cycle expansions between 2010 and 2017. Graph A.1 shows the starting points chosen by each jurisdiction. Only the central banks of Peru and Uruguay were able to pick starting dates where their RoAs were exactly at the 50th percentile. The RoAs of Argentina, Mexico and Colombia fell above the historical median in their chosen starting dates (78th, 64th, and 60th percentile, respectively), while the RoAs of Chile and Brazil at their chosen starting points were below the historical median (43th and 48th, respectively).

Participants were asked to report the state of their credit cycles at chosen starting points according to their own criteria, which is also illustrated in Graph A.1. The central banks of Argentina, Chile, Mexico and Peru reported that their economies were at the end of their credit cycle expansion phase; Colombia and Uruguay were in an ongoing expansion of their credit cycle and Brazil was experiencing an ongoing contraction in their credit cycle at its chosen starting point.[21] Graph A.1 also illustrates the RoA percentiles and the reported stages of credit cycle when each economy was at the chosen starting point.

Credit cycle phases at starting points[1] Graph A.1




[1] Credit cycle assessment given by individual countries. Labels indicate the year of the starting points chosen and the respective percentile of the historic distribution of RoAs for each country.

Source: Based on results of the stress-testing exercise under the common scenario, as reported by individual jurisdictions.

[21] Brazil reported that it was only able to choose a starting date in or after 2015 because of a change in the regulation that altered the composition of banking groups from financial conglomerates to prudential conglomerates.

## Macroeconomic scenario

As mentioned above, participants agreed on a common scenario to be applied to the key macroeconomic variables for their individual stress tests (Table A.1). However, not all central banks were able to meet the criteria of the range period considered (2000–17) and the variables to be included. First, due to data availability, the central bank of Brazil reported that it could use data only from 2003 to 2017 for its proxy for GDP growth,[22] while the central bank of Uruguay could use data only from 2001 to 2017 for EMBI+. In Colombia, given that some information was not available at the beginning of the sample, interest rate structures and liquidity were taken from the nearest available dates. Second, Argentina, Brazil and Chile reported the use of additional variables, not included in the scenario proposed but central to their respective stress test methodologies. Third, variables of the proposed macroeconomic scenario were also replaced; for example the central bank of Uruguay chose three-month Libor instead of the three-month US T-bill rate.

The proposed stressed scenario also defined the magnitude and directions of shocks, criteria that were not suitable for all jurisdictions when variables were endogenous in the stress-testing methodologies.[23] For instance: T-bond rates were implied in the paths of other variables in the stress tests of the central bank of Argentina; in the Colombian framework, local yield curves are endogenous, estimated as Diebold and Li's factors on a VAR with macroeconomic variables; in Chile both local and foreign currency interest rates at three months and 10 years are not explicitly incorporated, but derived from estimated yield curves modelled using Nelson and Siegel's approach. In some countries, some shocks were not included. For example, Colombia did not take into account the effect of depreciation on bank balance sheets. The central bank of Argentina did not run a new exercise using the common scenario; instead, the reported results are those of a stress-testing exercise corresponding to the chosen starting point, in which the characteristics of the scenario were the closest to the proposed shocks.

There were also cases where shock magnitudes and dynamics had to be set differently to accommodate the methodologies in place, or to reflect a stress situation. For instance, Colombia assumed that the nominal aggregate annual deposits growth rate was set to fall from 19.4% to 5.6% and to remain at that level during the horizon, according to the worst trajectory during the GFC, in order to obtain the changes in credit growth; additionally, spreads on loans interest rate paths were set to their maximum since 2002 (commercial 7.3% in December 2008; consumer 2.5% in May 2002; and mortgage 14.9% in January 2003), to have an impact on NPL. For Chile, the shock to EMBI+ is a constant spread of 100 bp – higher than the proposed two standard deviations – while the shock applied to the lending interest rates comes from the one to the local yield curve in real terms. These rates are in real terms; thus, the application of the 0.5 standard deviations above the monetary policy rate proposed in the common scenario is more complex. Finally, there were also some measurement changes to the scenario proposed. For example, the Brazilian

[22] The Central Bank of Brazil does have a longer data series for GDP, starting in 1947. However, their top-down stress-testing framework requires the use of the IBC-Br index (Economic Activity Index), which is only available from 2003 onwards.

[23] Similarly, the L-shaped trajectory proposed for the shocks could not be implemented in all countries. For instance, Uruguay does not usually include dynamics in their stress tests. Thus, in order to present more comparable results, this central bank assumed that around 80% of the shock occurred in the first quarter of the horizon and around 98% in the first year.

framework requires macroeconomic series to be at quarterly changes. The Chilean model considers the real exchange rate as the nominal exchange rate adjusted by local inflation, and its local real housing price is expressed in annual changes.

Common stressed macroeconomic scenario

Table A.1

| | Variables | Shock | |
|---|---|---|---|
| | | Magnitude | Direction |
| Domestic | Real GDP growth | 2 SD | ↓ |
| | Unemployment rate | 2 SD | ↑ |
| | Inflation rate | 2 SD | ↑ |
| | Nominal exchange rate (local currency vs USD) | 2 SD | ↑ |
| | Real exchange rate (local currency vs USD) | 2 SD | ↑ |
| | Real wages | 2 SD | ↓ |
| | Monetary policy rate | 1 SD | ↑ |
| | Local stock exchange index | 2 SD | ↓ |
| | Local yield curve (three months, annual nominal rates) | 1 SD | ↑ |
| | Local yield curve (10 years, annual nominal rate) | 1 SD | ↑ |
| | Local real housing price index | 2 SD | ↓ |
| | Lending interest rates[1] | 0.5 SD | ↑ |
| | Deposit interest rate[1] | 1 SD | ↑ |
| External | WTI | 2 SD | ↓ |
| | US IPI | 2 SD | ↓ |
| | VIX | 2 SD | ↑ |
| | Dow Jones index | 1 SD | ↓ |
| | EMBI+ | 2 SD | ↑ |
| | Treasury Bill rate (three months) | 1 SD | ↑ |
| | Treasury Bill rate (10 years) | 1 SD | ↑ |

[1] Magnitude of the shock for lending interest rates: 0.5 standard deviations of the monetary policy rate. Magnitude of the shock for deposit interest rates: one standard deviation of the monetary policy rate.

Source: Outline for the stress-testing exercise under the common scenario of the CGDFS study group on stress testing.

Finally, the severity of the shocks resulting from the macroeconomic stressed scenario proposed for the common exercise differed from the usual stress tests. The central banks of Argentina and Uruguay reported that the common scenario proposed in this exercise was as severe as those normally used for their recurrent stress tests. Despite this, there was no recovery in the dynamics of the shocks proposed, and the central banks of Brazil and Colombia indicated that the common scenario was less severe than their usual scenarios. By contrast, Chile, Mexico and Peru indicated that the common scenario was more severe than those usually considered in their stress tests. To illustrate this, Graph A.2 compares the magnitude of the shocks to GDP – the variable most commonly included in all countries stressed scenarios – with the magnitudes of the shocks reported in the FSRs around the t=0 for each country, when possible. Interestingly, in all cases the GDP-negative impact in the common exercise was stronger than in the actual stress test.

## GDP cumulative shock of stressed macroeconomic scenarios

Graph A.2


Source: National Financial Stability Reports, different publication dates; results of the stress-testing exercise under the common scenario, as reported by individual jurisdictions.

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