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BRAZIL

FINANCIAL SECTOR ASSESSMENT PROGRAM

TECHNICAL NOTE ON STRESS TESTING AND SYSTEMIC RISK ANALYSIS

November 2018

This Technical Note on Brazil was prepared by a staff team of the International Monetary Fund. It is based on the information available at the time it was completed on July 13, 2018.

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TECHNICAL NOTE

STRESS TESTING AND SYSTEMIC RISK ANALYSIS

Prepared By
Monetary and Capital Markets Department

This Technical Note was prepared by IMF staff in the context of the Financial Sector Assessment Program in Country. It contains technical analysis and detailed information underpinning the FSAP's findings and recommendations. Further information on the FSAP can be found at http://www.imf.org/external/np/fsap/fssa.aspx

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Glossary

AFS	Available-for-Sale
AOCI	Accumulated Other Comprehensive Income
BCBS	Basel Committee on Banking Supervision
BCB	Banco Central do Brasil (Central Bank)
BIS	Bank for International Settlements
BNK	Other Deposit-taking Institutions
CBS	Consolidated Banking Statistics
CCB	Countercyclical Capital Buffer
CCP	Central Clearing Party
CDI	Interbank Certificate of Deposits
CDS	Credit Default Swap
CET1	Common Equity Tier-1
CVM	Comissao de Valores Mobiliarios (Securities and Exchange Commission)
D-SIB	Domestic Systemically Important Bank
DSC	Debt Servicing Capacity
DTA	Deferred Tax Asset
DTC	Deferred Tax Credit
EBITDA	Earnings Before Income Tax, Depreciation and Amortization
ECB	European Central Bank
ELA	Emergency Liquidity Assistance
EMBI	Emerging Market Bond Index
ETF	Exchange-Traded Fund
FGC	Credit Guarantee Fund
FSAP	Financial Stability Assessment Program
FSB	Financial Stability Board
FX	Foreign Currency
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GFM	Global Macrofinancial Model
GOV	Government
HH	Households and Non-profit Institutions Serving Households
HQLA	High-Quality Liquid Asset
HTM	Held-to-Maturity
IBGE	Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics)
ICR	Interest Coverage Ratio

IFM	Monetary Investment Funds
IFNM	Non-Monetary Investment Funds
IL	Short-Term Liquidity Ratio (Developed by Banco Central do Brasil)
ILE	Long-Term Structural Liquidity Ratio (Developed by Banco Central do Brasil)
IMF	International Monetary Fund
INSPF	Insurers and Pension Funds
LCR	Liquidity Coverage Ratio
LTV	Loan-to-Value
MSMEs	Micro, Small and Medium-Sized Enterprises
NFCs	Non-Financial Corporates
NPL	Non-Performing Loan
NSFR	Net Stable Funding Ratio
PD	Probability of Default
RAM	Risk Assessment Matrix
ROE	Return on Equity
ROW	Rest of the World
SELIC	Sistema Especial de Liquidação e de Custódia
SLR	Structural Liquidity Ratio
SME	Small and Medium-Sized Enterprises
SNA	System of National Accounts
SOE	State-Owned Enterprise
T1	Tier-1
TNA	Total Net Assets
VAR	Vector Autoregression
WEO	World Economic Outlook

EXECUTIVE SUMMARY[1]

The financial system has been resilient through the severe recession. Banks and investment funds dominate Brazil's financial system landscape. The banking sector has continued to be well-capitalized, profitable, and liquid. Profitability has been supported by prudent lending standards, high interest margins and robust fee income, despite record loan losses. Outstanding nonperforming loans have increased marginally during the recession largely because banks have actively written off bad loans. The investment fund industry has also been solid, enjoying a steady growth of assets under management without experiencing net outflows, in aggregate, during the recession. Market-based indicators point to relatively low levels of systemic risk in 2017. However, the outlook for the nonbank sector will become more challenging in the environment of lower interest rates, as lower returns will affect investment income and a search for yield may increase risk-taking.

The FSAP assessed the resilience of the financial system to macrofinancial risks, with a focus on the banking sector and investment fund industry. The FSAP team, in close cooperation with the Banco Central do Brasil (BCB) and Comissão de Valores Mobiliários (CVM), (i) conducted bank stress tests to assess solvency strength and liquidity risk of Brazil's 12 largest banks (accounting for 90 percent of banking sector assets), (ii) analyzed interbank contagion, financial interconnectedness in Brazil, and cross-border spillovers, (iii) evaluated financial soundness of corporates and households, and (iv) assessed implications from large-scale redemptions in the investment funds' industry. The financial stability analysis was guided by three main macrofinancial risks faced by Brazil, including weak domestic growth due to loss of confidence, tighter and more volatile global financial conditions, and a significant slowdown in China and its spillovers.

Banks appear generally resilient to severe macrofinancial shocks. In the baseline, which envisages slightly compressed net interest margins and moderate credit growth, one domestic systemically important bank (D-SIB) may struggle to meet the capital regulatory requirements. In the adverse scenario, banks would be able to absorb sizeable credit and market losses owing to their existing capital and strong profitability buffers. Four banks could face some solvency difficulty, but capital shortfalls relative to the hurdle would be modest. Despite the prudential capital adequacy regulations in Brazil being Basel III compliant (as confirmed by the Basel Committee's Regulatory Consistency Assessment Program), there is some concern about the loss-absorbing capacity of deferred tax assets (DTAs), which account for a large share of common equity tier-1 (CET1) capital. With a full deduction of DTAs from CET1 capital, capital shortfalls would still be manageable although seven banks (two-thirds in terms of total assets in the sample) would find themselves

[1] This Technical Note was prepared by Phakawa Jeasakul (bank solvency stress testing and, household sector analysis), Majid Bazarbash (investment fund analysis and corporate sector analysis), Purva Khera (bank liquidity stress testing and bank contagion analysis), and Martin Saldias (interconnectedness analysis) under guidance of Ivo Krznar, with inputs from Fabian Bornhorst. The FSAP team is grateful for excellent cooperation with the Brazilian authorities and sharing necessary data for conducting stress testing and systemic risk analysis.

below capital requirements. The BCB stress tests broadly confirmed these results, though smaller capital shortfall in the adverse scenario.

Banks are exposed to concentration risk, exchange rate risk, and market risk owing to the holding of debt and equity securities. The default of the largest borrowers of individual banks and of the system could have a significant impact on capital. Despite banks' small net open foreign exchange positions, the impact of large exchange rate depreciation could arise from increased risk-weighted assets. Furthermore, two banks could experience significant losses when equity prices fall sharply, and most banks could face a large decline in their capital following an increase in bond yields. The latter reflects banks' significant exposure to Brazilian sovereign risk, giving a rise to a strong bank-sovereign nexus.

The use of Pillar 2 capital requirements could help mitigate identified risks, supporting the need to build additional capital buffers at some banks. Given concentration risk, including large holdings of debt and equity securities, capital add-ons based on individual banks' risk profiles should be considered. The BCB is already taking steps in this direction. Banks that would experience capital shortfalls in the stress tests should be encouraged to build capital buffers, for example, through restrictions on dividend distribution.

Banks are well-positioned to manage short-term liquidity pressures, but some would lack sufficient stable funding to support credit intermediation if faced with long-lasting, severe liquidity shocks. Results based on regulatory Liquidity Coverage Ratio (LCR) showed that Brazilian banks have ample liquidity buffers. Even under a stressed scenario of larger deposit outflows than the Basel III standards and significant stress in the bond market, only one D-SIB could face some difficulty in handling short-term liquidity pressures; a drawdown on all its required reserves combined with access to emergency liquidity assistance would enable it to cover liquidity shortfalls. Banks seem well prepared to implement the Net Stable Funding Ratio (NSFR) ratio. However, many banks (including all D-SIBs) under extreme stressed conditions might not be able to maintain the required stable funding profile within a one-year horizon. The cash-flow analysis, which assessed liquidity by maturity buckets, confirmed these results.

Contagion through interbank cross-exposures seems limited, but could amplify shocks when banks are under significant stress. Interbank exposures are relatively small, and a large share of these are secured. Only a default of one large bank could trigger another bank to fail, while contagion would be limited in other cases. However, in the adverse scenario of the solvency stress tests, more banks would not meet the hurdle due to credit loss related to interbank exposures; additional capital shortfalls would be still manageable.

Interconnectedness within Brazil is largely underpinned by the role of the government. Its central role arises from the presence of public banks and state-owned firms, the importance of repos collateralized by government securities, and the fact that government securities represent the main liquid financial instrument in Brazil. In addition, banks are the most interconnected sector by the size of exposures and their presence across all financial instruments. The investment fund

industry also has strong links with banks via repo transactions, and insurance and pension fund sectors, by lending to the former and receiving funds from the latter.

Investment funds could contribute to short-term price effects in the government bond market in the event of large-scale redemptions. The effects crucially depend on the underlying assumptions for calibration of redemptions. Three calibrations approaches, based on fund-homogeneity, fund-heterogeneity and fund-family, were accordingly used to assess price effects. The three exercises suggest that the funds would use R$437, R$215 and R$77 billion of their reverse repos to meet extreme redemptions, followed by a total sale of R$194, R$34 and R$10 billion of government bonds, respectively. This large-scale sale would respectively raise government bond yields by 62, 21 and 8 basis points on average under the 2017 market liquidity conditions. Under more severe market liquidity conditions of September 2015, the average increase in bond yields would be 99, 28 and 11 basis points.

The corporate sector shows moderate signs of recovery from the recession, but vulnerabilities linger among financially weak firms that constitute a large fraction of the sector. Profitability has improved and leverage has fallen since 2015. However, the shares of firms with negative equity, high leverage, and low debt servicing capacity remain elevated. Furthermore, the corporate sector is vulnerable to negative macrofinancial shocks that could substantially increase the amount of debt at risk. Given the large amount of debt belonged to financially weak firms, it would be useful to review the corporate insolvency regime to ensure efficient debt restructuring and recovery processes.

Notwithstanding the recent strengthening of their balance sheets, households are vulnerable to adverse macrofinancial shocks. Household debt relative to income has declined since early 2015, and household balance sheets have weathered the macrofinancial deterioration during the recession quite well. However, households are exposed to a liquidity squeeze given their large debt servicing obligations. The shares of financially weak households and corresponding debt at risk have increased marginally since 2013. Negative macrofinancial shocks would bring these figures above previous peaks. That's said, the financial stability implication would be limited given most debt at risk is covered by assets. Given the growing share of mortgage-related debt and the high share of mortgage borrowers who are relatively indebted and have large debt servicing obligations, the BCB should consider implementing limits on debt to income and debt service to income to contain a buildup of systemic risk in this lending segment.

Brazil embraces both inward and outward cross-border spillovers in the equity, sovereign credit risk and foreign exchange markets. For the equity and sovereign credit risk markets, spillovers are both inward and outward within the Latin America region, and Brazil also faces inward spillovers from Europe and the United States. For the foreign exchange market, both inward and outward spillovers are more concentrated among large and financially integrated emerging market economies, with Brazil generating outward spillovers to other smaller Latin American economies.

The BCB should continue its vigilant risk monitoring given existing vulnerabilities. Closed monitoring of vulnerabilities in the corporate and household sectors is warranted. The BCB's monitoring of bank liquidity risk could also be enhanced using the cash-flow analysis considering

varied degrees of stress in both local and foreign currencies. Given the prominent role of the government in the financial system, the BCB should take an integrated approach to assessing the financial-sovereign linkages, particularly the implications of the large holdings of liquid government bonds and effects of large-scale redemptions in the investment fund industry for government bond market liquidity that could have implications on banks' solvency and liquidity.

The BCB's stress testing framework is sound and could benefit from additional enhancements. The BCB's plan to develop the solvency-liquidity contagion module to better capture potential risk amplification is highly welcomed. The stress testing framework could benefit from better handling of overseas operations and estimation of credit loss based on default probability and loss given default. Given that the BCB is using various data sources, it would be important to improve data validation to ensure the accuracy and consistency of information and the reliability of analyses. Lastly, it would be important to validate the results produced by banks to reap the full benefit of the annual bottom-up stress testing exercise, including the improvement in banks' risk management capacity.

Table 1. Brazil: Recommendations on Mitigating Financial Stability Risks and Strengthening the Financial Stability Analysis	
Recommendations and Authorities Responsible for Implementation	**Timeframe**
Main recommendations	
Use Pillar 2 capital requirements to handle bank-specific risk profiles to mitigate concentration risk, including large holdings of debt and equity securities.	Immediate
Encourage banks to build capital buffers, especially those with capital shortfalls in the stress tests, for example, through restrictions on dividend distribution.	Immediate
Ensure the accuracy and consistency of information to ensure the reliability of analyses.	Immediate
Conduct a cash-flow analysis to assess banks' liquidity risk on a regular basis, considering varied degrees of stress in both local and foreign currencies.	Immediate
Continue vigilant risk monitoring given existing vulnerabilities in the corporate and household sectors.	Immediate
Implement limits on debt to income and debt service to income for mortgage lending.	Near-term
Validate the results produced by participating banks in the annual bottom-up stress testing exercise, in part to ensure banks' risk management capacity.	Near-term
Adopt an integrated approach to assess the financial-sovereign linkages.	Near-term
Other recommendations	
Review the corporate insolvency regime to ensure efficient debt restructuring and recovery processes.	Near-term
Require banks to assess the sensitivity of borrowers' debt servicing capacity to macrofinancial shocks.	Near-term
Develop the solvency-liquidity contagion module in the bank stress testing framework as planned.	Medium-term
Enhance the stress testing framework through the improvement in handling of overseas operations and estimation of credit loss based on default probability and loss given default.	Medium-term

INTRODUCTION

A. Financial System Landscape

1. The Brazilian financial system is dominated by banks and investment funds. While total assets of financial institutions have grown to nearly 200 percent of GDP, the structure of the financial system has changed little over the past decade (Appendix Table 1). The banking sector, controlled by three private and three public banks, still accounts for almost half of financial institutions' total assets. Assets under management of investment funds represent 33 percent of financial institutions' total assets. The pension fund and insurance sectors account for 13 and 8 percent of financial institutions' total assets, respectively. Shadow banking, including only investment funds that perform credit intermediation and maturity transformation, is small.[2] Bank-led financial conglomerates, which control around 85 percent of financial institutions' total assets, carry out a variety of businesses, such as investment banking, securities brokerage, asset management and insurance, through their subsidiaries.

2. Financial markets primarily feature short-term assets and derivatives instruments. The size of financial markets has grown to about 210 percent of GDP. Brazil's history of macrofinancial instability and high inflation has driven investors towards short-term floating-rate or indexed securities, with the latter mainly linked to inflation or exchange rate. In the money market, with the size of 28 percent of GDP, most instruments are indexed to overnight secured (Selic) or unsecured (CDI) interest rates. The corporate bond market is small, with outstanding corporate debt securities of 11 percent of GDP. Meanwhile, government debt securities amount to 52 percent of GDP. Liquidity is mostly concentrated in the short-end market, making longer-term instruments prone to market volatility. The stock market is similarly small, with market capitalization of 39 percent of GDP. Derivatives markets are relatively large, with outstanding contracts amounting to 81 percent of GDP. They play an important role in shifting risks from risk-averse retail investors to institutional investors. Foreign exchange derivatives are heavily traded in Brazil, as regulatory constraints limit nonbanks' participation in the spot foreign exchange market.

3. The public sector continues to play a dominant role in the financial sector. Public banks provide 55 percent of bank credit. Earmarked credit, which are bank loans with lower interest rates that follow a government-specified allocation, and subsidized credits have led to inefficiencies and credit market segmentation.[3] Government debt securities are the centerpiece of the fixed-income market and are the single most important asset class held by investment funds, pension funds and

[2] While shadow banking based on the Financial Stability Board's broad definition, which includes all investment funds, reaches around 54 percent of GDP, the BCB's estimate is 7 percent of GDP based on a narrower definition that includes only investment funds performing credit, maturity and liquidity transformation. See the BCB's Financial Stability Report (April 2015).

[3] The government is setting rules for credit earmarking, subsidies, tax exemptions, remuneration of funding originated in special funds, and interest rates for longer-tenure credit (typically below market rates).

insurance companies.[4] Banks hold 10 percent of their assets in government bonds and additional 16 percent in reverse repos collateralized with government bonds. Moreover, the government accounts for a large share of all banks' capital due to deferred tax credits. Similarly, investment funds hold 50 percent of their assets in government bonds and additional 25 percent in reserve repos collateralized with government bonds. Therefore, intra-system interconnectedness is reinforced by common exposures, namely claims on the government, with abovementioned reverse repo transactions making banks and investment funds interconnected.

B. Macrofinancial Environment

4. Brazil experienced a deep and prolonged recession during 2014–16 (Figure 1). Triggered by large macroeconomic imbalances and a loss of confidence, the recession was exacerbated by deteriorating terms of trade due to the fall of commodity prices, tightening financial conditions driven by the expectation of U.S. monetary policy normalization, and a domestic political crisis that ultimately led to the impeachment of President Rousseff and corruption scandal at the state-owned oil company Petrobras. As a result, investment and private consumption declined sharply. Furthermore, a sharp realignment of regulated prices in 2015 and subsequent monetary policy tightening dampened activity. Brazil also lost its investment grade in 2015, but ample international reserves, strong FDI flows and exchange rate flexibility provided important buffers throughout. The recession lasted 11 quarters, with a cumulative output contraction by around 8 percent. Meanwhile, the unemployment rate doubled to 14 percent.

5. The economy has turned the corner, but economic growth is expected to remain subdued. Markets have responded positively to the new government's reform promises since mid-2016, bolstering asset prices and overall confidence. Many of factors that earlier hampered activity (e.g. failing terms of trade and tightening financial conditions) have normalized, and, in some cases improved. The economy exited the recession in 2017Q1. Medium-term real GDP growth is projected to reach 2 percent by 2019, but the forecast assumes that a sufficiently strong set of fiscal measures—most notably social security reform—is put in place to ensure fiscal sustainability.

6. The corporate and household sectors have become more vulnerable. Leverage, profitability and liquidity of the corporate sector have all deteriorated on the back of the recession. Despite recent improvements, leverage is still high. Foreign exchange risk is small since the large part of foreign-currency debt is hedged.[5] Households have high debt servicing obligations relative to income at 22 percent, among the highest in the world, reflecting high interest rates. Moreover, the prevalence of short-duration loans makes households particularly vulnerable to a rise in interest rates. High unemployment and weak real earnings as a result of the weak economy continue to weigh on household financial strength.

[4] The share of Brazilian government debt securities held by investment funds and pension funds has increased (to about half of the Brazilian public debt) since the start of the recession.

[5] Hedging could be through financial derivatives, export receipts, overseas assets, and support from nonresident parents.

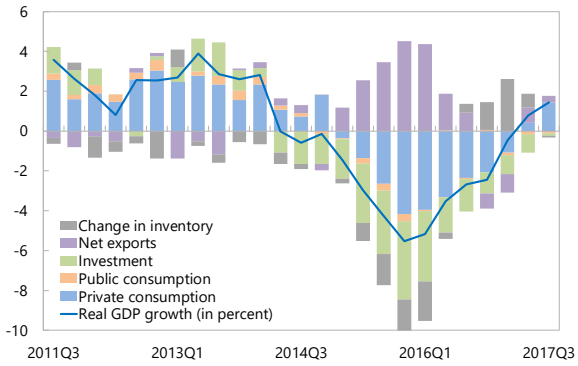
7. Despite the severe recession, the banking sector has remained resilient. The banking sector has continued to be well-capitalized, profitable, and liquid. Profitability has been supported by prudent lending standards, high interest margins and robust fee income, despite record loan losses. Strong profits and deleveraging have ensured that banks' capitalization remains above regulatory requirements. However, public banks have lower capital ratios than private counterparts. External funding exposures are low (around 10 percent of total funding) and net foreign exchange positions are small.

8. There are signs that credit intermediation has started to recover following the large contraction during the recession. The aggressive monetary easing that started at end-2016 have had its effects. Financial conditions have eased, surveys showed more favorable lending terms through 2017, and lending-to-funding spreads have fallen by 380 basis points (as of January 2018) since end-2016. Overall bank lending still contracted in 2017, mainly due to the continued decline in lending to corporates. Lending to households, which has been expanding during the recession thanks to earmarked credit, saw an accelerating growth to 5.6 percent in 2017.

Figure 1. Brazil: Macrofinancial Developments

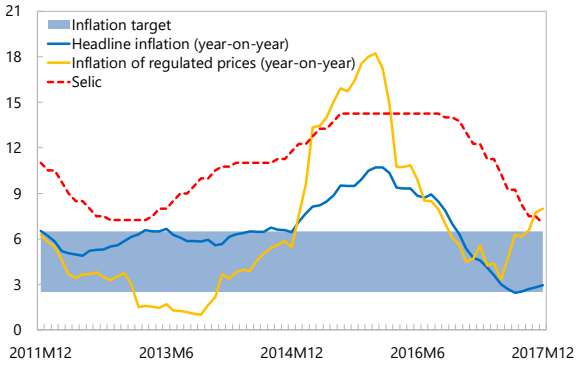
Brazil experienced a deep and prolonged recession, …

Contribution to Real GDP Growth, 2011-2017
(In percentage points; year-on-year)



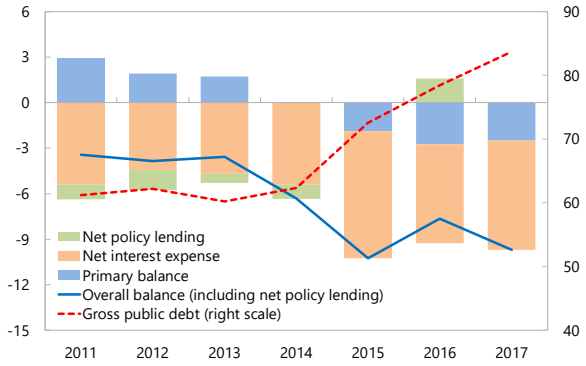
Falling inflation on the back of waning effects of regulated price adjustments in 2015 paves a way for recent cuts in the policy interest rate.

Inflation and Monetary Policy, 2007-17
(In percent)



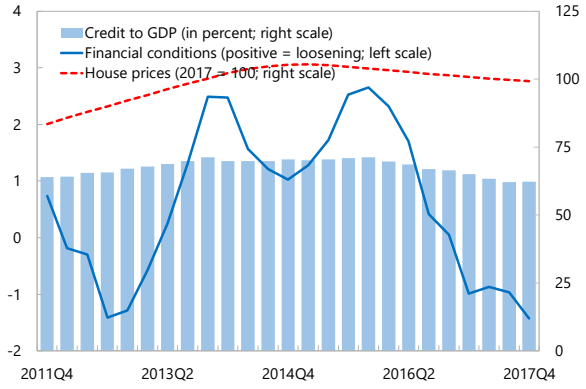
… pushing public debt on an unsustainable path.

Fiscal Balance and Pubic Debt, 2011-2017
(In percent of GDP)



Financial conditions are loosening, while credit-to-GDP and house prices continue are still declining.

Financial Conditions, Credit and House Prices, 2007-17



Sources: BIS, Credit-to-GDP Gap data; CEIC; Haver Analytics; and IMF staff estimates.

9. The performance of the nonbank financial sector remains solid, but the sector faces challenging times as interest rates fall. Assets under management of investment funds have grown steadily, led by fixed-income funds, the dominant investment vehicle in the industry. While the growth of insurance premiums has fallen, the sector's profitability and other key credit metric have all improved, mainly reflecting higher investment returns supported by higher interest rates. Pension funds have also enjoyed a steady growth as tax benefits support growing contributions. However, some pension schemes, especially of state-owned enterprises, have experienced poor performance of investment portfolios given losses on equity investment. As interest rates approach historical lows, the outlook for the nonbank sector will become more challenging, as lower returns will affect investment income and a search for yield may increase risk-taking.

C. A Bird's-Eye View on Systemic Risk

10. Market data suggested that systemic risk as of 2017Q3 was low. Figure 2 shows a set of systemic risk indicators based on market data for 14 financial institutions.[6,7] The probability that several financial institutions experience simultaneously, despite on a rising trend since early 2016, was still at about a half of the level prevailing during the stress episode in 2015. Meanwhile, the expected loss in the event of distress remained at a historically low level. These findings, which should be interpreted with caution given that market information contains noises, suggested that the likelihood of financial institutions experiencing significant stress was small, and systemic risk—the risk of disruptions to the provision of financial services that is caused by an impairment of all or parts of the financial system—was low in 2017.

11. Large banks were the main drivers of systemic risk but some appeared to play a stabilizing role in periods of stress. The systemic importance of the four-listed domestic systemically important banks (D-SIBs) is illustrated by their potential to generate stronger cascade effects (i.e., the ability to bring other institutions under distress) than other banks and nonbanks in absolute terms.[8] The central clearing party (CCP) operator also appeared to be systemically important given its crucial role in financial market infrastructures. However, the contribution to systemic risk of most of these D-SIBs was smaller than their size, suggesting that they tended to mitigate rather than amplify shocks at time of stress. Market data also suggested that systemic risk arising from interconnectedness was largely concentrated among the four listed D-SIBs. The probability that other D-SIBs would become distressed given that one D-SIB became distressed was relatively high.

[6] Based on the "Surveillance of Systemic Risk and Interconnectedness" approach. See Segoviano and Goodhart (IMF WP/09/4) and Technical Note on Systemic Risk and Interconnectedness Analysis, 2016 United Kingdom FSAP (IMF Country Report No. 16/164).

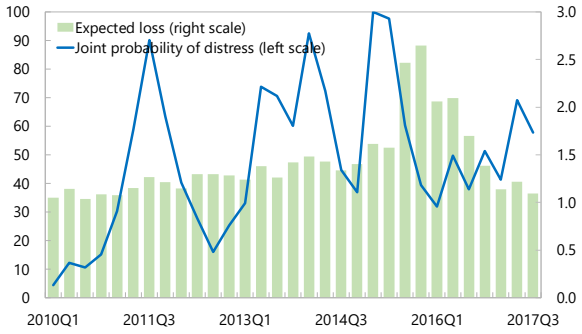
[7] The sample included Banco do Brasil, Itaú, Bradesco, Santander Brasil, Banrisul, Banco do Nordeste do Brasil, Pan, Banestes, and ABC (banks); Porto Seguro and Sul America (insurance companies); Cielo and Bradespar (other nonbanks); and B3 (CCP operator).

[8] Five banks are designated as D-SIBs. They are Banco do Brasil, Banco Itaú, Caixa Econômica Federal, Bradesco, and Santander Brasil.

Figure 2. Brazil: A Bird's-Eye View on Systemic Risk[1]

As of 2017Q3, systemic risk was lower than the stress episode in 2015.

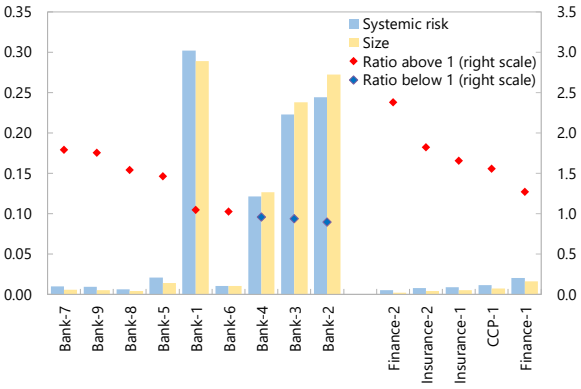
Joint Probability of Distress and Expected Loss, 2010-17



Joint probability that all institutions become distressed (2015Q1 = 100)
Expected loss at the 99th–percentile tail risk (in percent of total assets)

Large banks appeared to act as shock stabilizers.

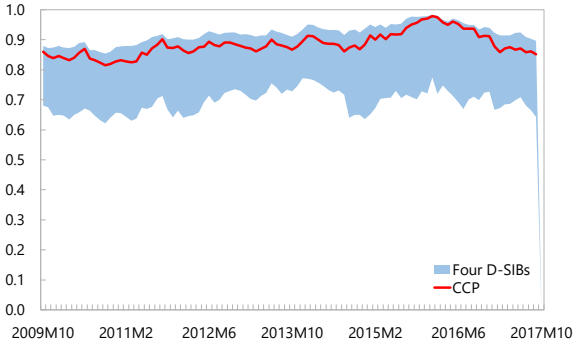
Marginal Contribution to Systemic Risk, September 2017 [2]



Distress of D-SIBs will likely create distress at other institutions. So will the CCP operator.

Cascade Effects, 2009-17

The probability that at least another institution becomes distressed given that a particular institution became distressed



Systemic risk arising from interconnectedness is largely concentrated among the four listed D-SIBs.

Pairwise Conditional Probability of Distress, September 2017

The probability that the institution in the row becomes distressed given the institution in the column became distressed

	Bank-1	Bank-2	Bank-3	Bank-4	Bank-5	Bank-6	Bank-7	Bank-8	Bank-9	CCP-1	Finance-1	Finance-2	Insurance-1	Insurance-2
Bank-1		0.5	0.5	0.2	0.2	0.0	0.1	0.1	0.3	0.4	0.2	0.1	0.2	0.1
Bank-2	0.3		0.5	0.2	0.2	0.0	0.1	0.1	0.2	0.3	0.1	0.1	0.2	0.1
Bank-3	0.3	0.6		0.2	0.2	0.0	0.1	0.1	0.3	0.4	0.1	0.1	0.2	0.1
Bank-4	0.2	0.3	0.3		0.2	0.0	0.1	0.1	0.2	0.3	0.1	0.1	0.2	0.2
Bank-5	0.2	0.3	0.3	0.2		0.0	0.1	0.1	0.2	0.3	0.1	0.2	0.1	0.1
Bank-6	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bank-7	0.1	0.2	0.1	0.1	0.1	0.0		0.1	0.1	0.2	0.1	0.1	0.1	0.1
Bank-8	0.1	0.1	0.1	0.1	0.1	0.0	0.0		0.1	0.1	0.0	0.1	0.0	0.0
Bank-9	0.2	0.3	0.2	0.1	0.2	0.0	0.1	0.1		0.3	0.1	0.1	0.1	0.1
CCP-1	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.1	0.2		0.1	0.1	0.1	0.1
Finance-1	0.1	0.2	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.2		0.1	0.1	0.1
Finance-2	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.2	0.2	0.4	0.2		0.2	0.1
Insurance-1	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.2	0.1	0.0		0.2
Insurance-2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.2	

Sources: Bloomberg; Moody's KMV; and IMF staff estimates.

1/ The analysis is based on the "Surveillance of Systemic Risk and Interconnectedness" approach. See Segoviano and Goodhart (IMF WP/09/4) and Technical Note on Systemic Risk and Interconnectedness Analysis, 2016 United Kingdom FSAP (IMF Country Report No. 16/164). The sample includes 9 banks, 2 insurance companies, 2 finance companies, and 1 CCP operator.

2/ Blue bars represent marginal contribution to systemic risk, and yellow bars show relative size. When the ratio of Sharpley value to relative size above (below) 1, the institution is considered to be a shock amplifier (stabilizer).

D. Scope of the Financial Stability Analysis in the FSAP

12. The FSAP took a comprehensive approach to assess financial stability risks, focusing on the two largest financial sectors—banks and investment funds. The analysis included assessing the resilience of banks against macrofinancial shocks, analyzing the financial soundness of corporates and households, examining potential vulnerabilities stemming from investment funds,

and looking into the interconnectedness of the financial system. The exercise undertaken by the FSAP team comprised the following modules:[9]

- **Bank solvency stress tests.** The FSAP team conducted a top-down bank solvency stress test based on the balance sheet approach for Brazil's 12 largest banks, which account for 90 percent of banking sector assets, using supervisory data provided by the authorities. In parallel, the Banco Central do Brasil (BCB) carried out a top-down bank solvency stress test, using the same sample of banks, but relied on its own methodology. All tests used the same baseline (October 2017 WEO projections) and adverse scenarios (see the next section). In addition, a variety of sensitivity tests was conducted by the FSAP team.

- **Bank liquidity stress tests.** The FSAP team, together with the BCB, performed a top-down bank liquidity stress testing exercise for the 12 largest banks (same as in the bank solvency stress tests), using supervisory data. The tests comprise three modules: (i) Liquidity Coverage Ratio (LCR)-based test, (ii) Net Stable Funding Ratio (NSFR)-based test, and (iii) cash flow analysis. The LCR-based and NSFR-based tests were conducted based on regulatory and stressed parameters, while the cash-flow analysis considered liquidity for domestic and foreign currencies separately. In addition, the FSAP team analyzed the BCB's internal short-term liquidity indicator (IL) for a larger set of banks.

- **Bank contagion analysis.** The FSAP team conducted an interbank network analysis covering the 12 largest banks (same as in the bank solvency and liquidity stress tests), using supervisory data. In addition to a typical standalone exercise, the analysis was performed as part of the FSAP bank solvency stress tests to gauge the additional impact on banks' capital due to credit loss associated with exposures to the defaulting banks.

- **Corporate sector analysis.** The FSAP team analyzed firm-level balance sheets of listed and non-listed companies, using publicly available data. The analysis adopted the debt-at-risk approach that identifies financially weak companies based on financial metrics such as debt servicing capacity (i.e., based on interest coverage ratio (ICR)) and assess the amount of "debt at risk", which is belonged to such companies.

- **Household sector analysis.** The BCB carried out household-level balance sheets based on the debt-at-risk approach, using credit registry data. The exercise identified financially weak households based on financial metrics such as debt service to income and debt to income.

- **Analysis of potential vulnerabilities stemming from investment funds.** The FSAP team evaluated the consequence of large-scale asset sales by investment funds due to a tail-event redemption shock for government bond market liquidity, using IMF methodology and

[9] The overall exercise is conducted with close cooperation with the authorities, and some parts of the exercise are performed by the authorities. The FSAP mission is given access to necessary information, including supervisory data, to carry out the analysis.

supervisory data. The exercise covered open-end money market funds, bond funds and mixed funds, which account for 78 percent of the industry's total net assets (TNA).

- **Interconnectedness and spillover analysis.** The FSAP team analyzed financial interlinkages among different sectors (subsectors within the financial system and nonfinancial sectors) in Brazil, using flow-of-funds data. In addition, cross-border linkages between Brazil and other countries were examined using market data.

13. The remainder of this technical note is structured as follows. Section II presents key macrofinancial risks and the scenarios underpinning financial stability analysis. Sections III, IV and V cover bank solvency stress tests, bank liquidity stress tests and bank contagion analysis. Sections VI and VII discuss corporate and household sector analyses, respectively. Section VIII analyzes vulnerabilities stemming from investment funds, while Section IX assesses interconnectedness of the financial system and the associated spillover risk.

MACROFINANCIAL RISKS UNDERPINNING THE FINANCIAL STABILITY ANALYSIS

A. Overview of Key Macrofinancial Risks

14. Brazil is still facing significant downside risks that are driven by both domestic and external factors (Table 2). Political instability and spillovers from the corruption investigation are major sources of risk that could threaten the reform agenda and the recovery. The main policy risk is that the reforms necessary to maintain the constitutional expenditure ceiling are diluted or delayed, prompting adverse market reaction and additional fiscal measures. The main external risks are tighter or more volatile global financial conditions associated with the unwinding of the unconventional monetary policy, the retreat from cross-border integration, and a significant slowdown in China.

Table 2. Brazil: Risk Assessment Matrix (RAM)		
Source of risks	**Likelihood**	**Impact**
Weak domestic economic growth due to loss of confidence This risk could materialize due to: • Failure to pass reforms necessary to maintain the constitutional expenditure ceiling • Uncertainty surrounding the outcome of the 2018 presidential elections and associated policy uncertainty • Broadening of the corruption scandal, including in the financial sector • Effects of the retreat from cross-border integration	**High**	**High** Weakened confidence and prolonged uncertainty induce a sizeable output contraction and a capital flows reversal, leading to: • Increase in funding costs across the board, with impacts on banks' net interest income and liquidity squeeze for corporates • Impaired debt servicing capacity of corporates and households, raising banks' nonperforming loans • Losses on holding of government bonds for banks, and redemptions at investment funds • Reduced bank lending to the economy, adversely affecting growth and public finance
Tighter and more volatile global financial conditions This risk could materialize due to: • Disruptive adjustments following the U.S. monetary policy normalization and the QE tapering in the euro area • Corrections of overstretched asset valuations, in part supported by high leverage	**High**	**Medium** Decompression of risk premiums prompts a worldwide decline in asset prices, leading to: • Tightening of liquidity conditions and increase in funding costs, especially for entities that rely on external funding • Losses on holding of government bonds and other securities • Weaker economic activity, contributing to deterioration in banks' asset quality
Significant China slowdown and its spillovers This risk could materialize due to: • Efforts to rein in financial sector risks expose vulnerabilities of indebted entities and reduce growth • Overly ambitious growth targets further increase financial imbalances, with an abrupt adjustment	**Medium**	**Medium** Negative spillovers from China weaken growth, in part through falling commodity prices, leading to: • Growing vulnerabilities in the commodity-related sector • Reduction in exports and investment, with knock-on effects on banks' asset quality

B. Macrofinancial Scenarios Underpinning the Financial Stability Analysis

15. The financial stability analysis was conducted broadly based on two macrofinancial scenarios (Figure 3). One is the baseline, which is based on the October 2017 WEO projections. The baseline envisages a moderate recovery, with real GDP growth reaching 2 percent during 2019–20. Interest rates are expected to be on a downward trend, resulting in some compression in net interest margins. Credit will grow at around 8 percent annually during 2018–20. Another is an adverse scenario, which was designed based on key macrofinancial risks outlined in the RAM. The Global Macrofinancial Model (GFM), which is a structural macroeconometric model of the world economy, was used to simulate the adverse scenario.[10] See Appendix I for complete details on the scenario design. These two scenarios were used for the bank solvency stress tests, although they provided some guidance for haircuts of high-quality liquid assets (HQLA) for the bank liquidity stress tests and for shocks considered in the analysis of corporate and household sectors.

16. In the adverse scenario, Brazil would experience a severe recession underpinned by a sudden stop of capital inflows. While domestic factors, namely the loss of confidence, are the main driving forces, the adverse scenario would also take place in a challenging global environment. Real GDP would fall 11.8 percent below the baseline by 2018, with its 3-year cumulative growth 2 standard deviation (based on real GDP growth in the past 30 years) below the baseline, broadly in line with recent FSAPs. Notwithstanding the precarious public finance position, the adverse scenario does not consider a government default; though, it features a large spike in government bond yields.

17. A recession in the adverse scenario would result in a worsening of financial conditions that might affect the financial system. Financial conditions would tighten reflecting a large depreciation, collapsing stock prices, and spiking bond yields. Corporate and household balance sheets would weaken due to rising funding costs and falling income, with unhedged foreign-currency borrowers seeing a sharp rise in the debt burden. Banks could face large credit and market losses given their borrowers' impaired repayment capacity and their holding of government bonds, which are sizeable for some banks. Liquidity risk could also materialize, with banks facing deposit funding outflows and investment funds enduring redemptions in the face of increased market volatility. Bond yields could further increase due to asset sales by banks and investment funds to meet their liquidity need. Tightening of financial conditions could be amplified by intra-system linkages, while constrained bank lending capacity could further exacerbate the recession.

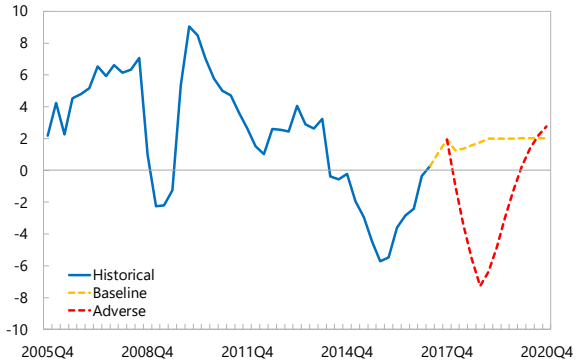
[10] This estimated panel dynamic stochastic general equilibrium model features a range of nominal and real rigidities, extensive macrofinancial linkages with both bank and capital market based financial intermediation, and diverse spillover transmission channels. For more details, see Vitek (2017), "Policy, Risk and Spillover and Analysis in the World Economy: A Panel Dynamic Stochastic General Equilibrium Approach", IMF WP/17/89.

Figure 3. Brazil: Key Macrofinancial Variables in The Baseline and Adverse Scenarios

In the adverse scenario, Brazil would experience a double-dip recession.

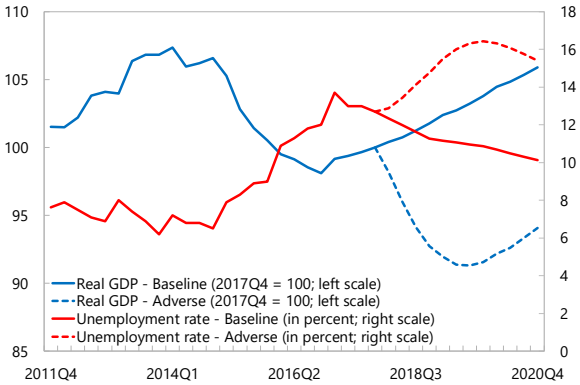
Real GDP Growth, 2005-20

(In percent; year-on-year)



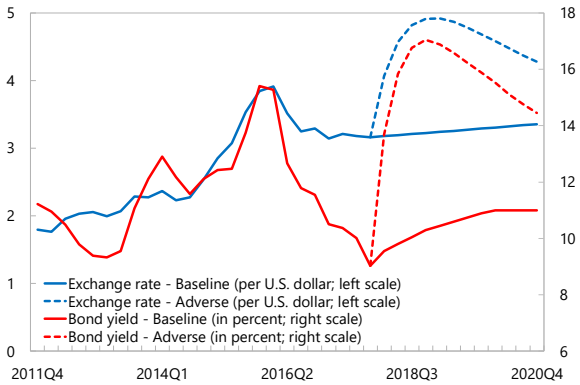
Output would fall by about 9 percent from the end-2017 level, coupled with rising unemployment.

Real GDP and Unemployment, 2011-20



Brazil would face a sudden stop of capital inflows, resulting in a large exchange rate depreciation and bond yield spikes.

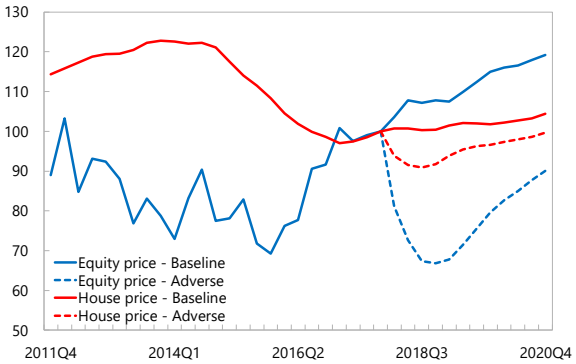
Exchange Rate and 10-year Government Bond Yield, 2011-20



Equity and house prices would also decline.

Equity and House Prices, 2011-20

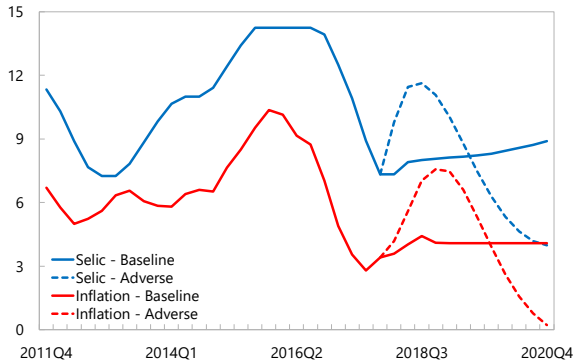
(2017Q4 = 100)



Monetary policy would be tightened initially to contain inflationary pressures.

Policy Interest Rate and Inflation, 2011-20

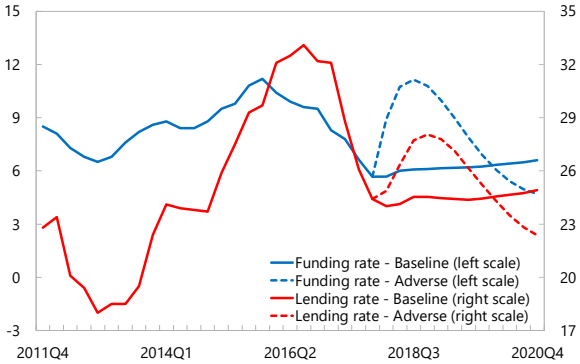
(In percent)



Banks would face a relatively large increase in funding costs, reducing their net interest margins.

Bank Funding and Lending Rates, 2011-20

(In percent)



Sources: Haver Analytics; IMF staff estimates.

BANK SOLVENCY STRESS TESTS

A. Overview

18. The bank solvency stress testing exercise comprised both scenario and sensitivity analyses based on data as of end-2017Q3. The scenario analysis assessed banks' solvency over the period of three years, i.e. during 2017Q4–2020Q4, while the sensitivity analysis assessed the impact of single risk factors—such as exchange rate risk, interest rate risk, concentration risk, as well as some other aspects of market risk—on the existing capital buffers. For the scenario analysis, the FSAP top-down exercise was conducted based on the methodology prescribed below. The sensitivity analysis was only carried out by the FSAP team. Appendix II presents the stress testing matrix (STeM), with the methodology being described in greater details in a following subsection.

B. Recent Banking Sector Performance

19. Brazilians banks' capitalization has improved since late 2015 and is broadly in line with their peers. The common equity tier-1 (CET1) capital ratio for the banking sector was 12.7 percent at end-2017Q2, up from 11.1 percent about two years ago, thanks to continued strong profitability even in the aftermath of a severe recession (Figure 4). The banking sector as a whole comfortably meets the capital regulatory requirements, with buffers of about 6.3 percent of risk-weighted assets, as of 2017Q3.[11] Public banks as a whole had a lower level of capitalization than the banking sector (Table 3). Capitalization of Brazilian banks is broadly in line with their international peers (Figure 5). While about three-quarters of capital are in the form of CET1 capital, deferred tax assets (DTAs) account for almost 30 percent of CET1 capital.

20. Profitability remains strong despite being on a declining trend for many years. Brazilian banks have enjoyed decent profitability even in the aftermath of the severe recession, with the system-wide return on assets of 1.3 percent as of 2017Q3. Their profitability still compares well with international peers. The strong profitability has been supported by large net interest income that has been more than enough to cover the increase in impairment cost in recent years. On average, public banks are less profitable than their private counterparts. Notwithstanding some recent recovery in 2017 on the back of improving macrofinancial conditions, profitability has been on a downward trajectory over the past decade due to reduced net interest income.

21. Asset quality had deteriorated in the aftermath of the severe recession, with banks still facing large impairment cost. For the banking sector as a whole, nonperforming loans (NPLs) have declined to 3.7 percent of total loans at end-2017Q3, down by 0.3 percentage point from its peak a year ago, following the increase from the pre-recession level at 2.9 percent at end-2013. However, the NPL ratio may understate the full amount of problem loans. As of 2017Q2, the figure would

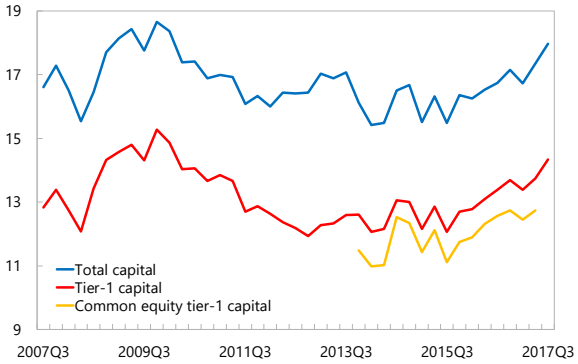
[11] The buffers are calculated based on T1 capital, which is the most binding.

increase to 5 percent (from 3.7 percent) if restructured loans are included, and to 8.1 percent if restructured loans and loans in the "E" to "H" categories are included.[12] Moreover, banks have actively written off bad loans due to the regulatory requirements. Impairment cost has increased to 4.2 percent of total assets, up from 2.6 percent prior to the economic downturn. Within the banking sector, private banks and D-SIBs have higher NPL ratios and large impairment costs. The provisioning coverage at 160 percent is more than enough to cover existing NPLs.

Figure 4. Brazil: Banking Financial Soundness Indicators

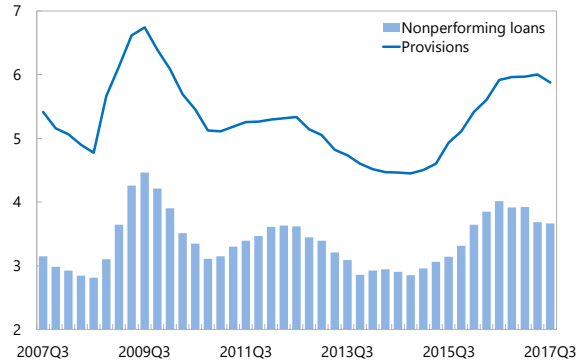
Banks' capitalization has improved since late 2015.

Capitalization, 2007-17
(In percent of risk-weighted assets)



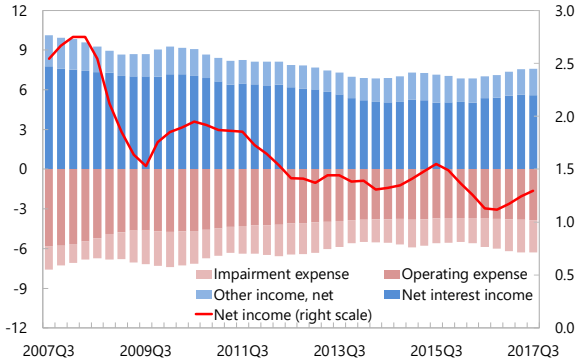
Nonperforming loans has stabilized following a large increase in the aftermath of the recession, with a strong provisioning coverage.

Nonperforming Loans and Provisions, 2007-17
(In percent of total loans)



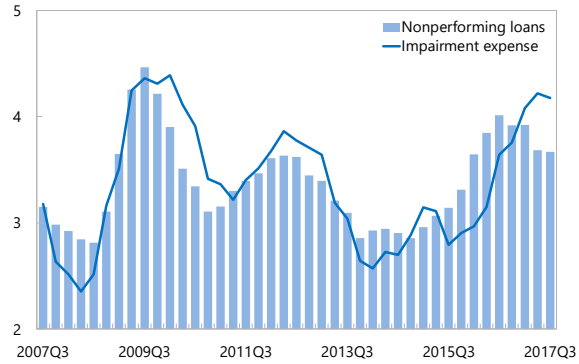
Profitability has declined for many years due to reduced net interest income.

Net Income and Its Componenets, 2007-17
(In percent of total assets)



Impairment cost remains large, following the dynamics of nonperforming loans with some lag.

Nonperforming Loans and Impairment Expense, 2007-17
(In percent of total loans)



Sources: Banco Central do Brasil; IMF, Financial Soundness Indicators database; and IMF staff calculations.

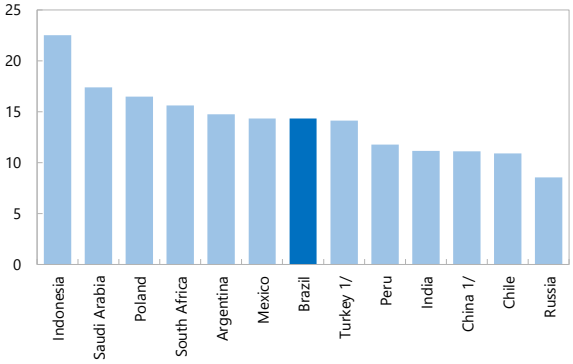
[12] According to Brazil's regulatory framework, loans are classified into 9 categories including: "AA", "A", "B", "C", "D", "E", "F", "G" and "H". Provisioning requirements vary based on loan categories.

Figure 5. Brazil: Selected Emerging Market Economies: Banking Financial Soundness Indicators

Brazilian banks' capitalization is similar to their peers, …

Tier-1 Capital Ratio, 2017Q3

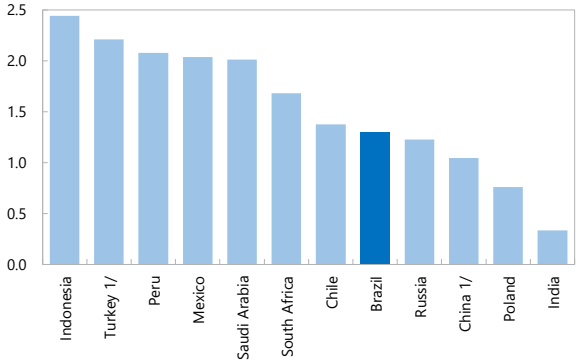
Tier-1 capital in percent of risk-weighed assets



Supported by still strong profitability ….

Return on Assets, 2017Q3

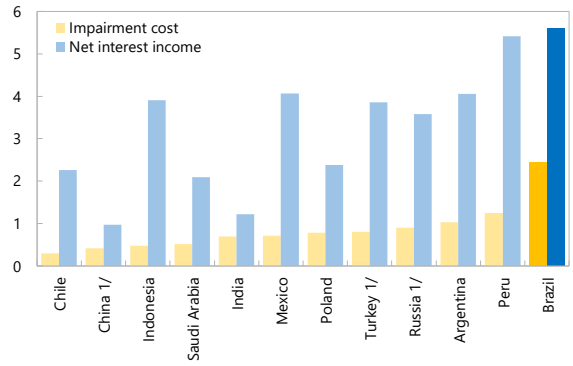
Net income in percent of total assets



Despite the relatively high impairment cost thanks to the large net interest rate margin.

Impairment Cost and Net Interest Income, 2017Q3

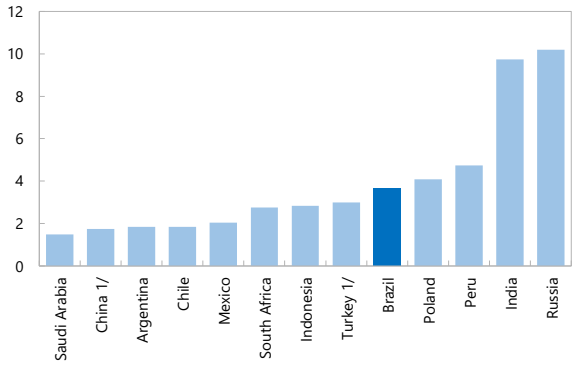
(In percent of total assets; annualized)



Nonperforming loans are not excessively high in Brazil as banks actively write off bad loans.

Nonperforming Loans Ratio, 2017Q3

Nonperforming loans in percent of total loans



Sources: IMF, Financial Soundness Indicators database; and IMF staff calculations.

1/ As of 2017Q2 for China and Turkey. As of 2016 for Russia.

Table 3. Brazil: Banking Financial Soundness Indicators

	Total	Public	Private	Foreign	D-SIBs
Capitalization and leverage					
Total capital to risk-weighted assets	18.0	17.3	18.5	18.1	17.8
Tier-1 capital to total risk-weighted assets	14.3	11.7	15.3	16.7	13.7
Total equity to total assets	10.0	5.3	13.4	12.9	9.0
Asset quality					
Nonperforming loans to total loans	3.7	3.2	4.4	3.4	3.9
Provisions to total loans	5.9	4.7	7.5	6.0	6.5
Impairment expense to total assets	-2.4	-2.1	-2.7	-2.5	-2.6
Profitability					
Return on assets	1.3	0.8	1.8	1.3	1.3
Return on equity	12.4	11.2	14.2	9.8	13.2

Sources: Banco Central do Brasil; and IMF staff calculations.

C. IMF Top-down Stress Tests: Methodology

22. The solvency stress tests follow a balance sheet approach broadly in line with Brazil's regulatory framework. The solvency stress tests apply the Basel III capital standard per the national framework; all banks still use the standardized approach for credit risk[13] Despite the concern about the quality of capital given the sizeable amount of DTAs in light of some concerns about Brazil's public debt sustainability and the lengthy timeframe for the government to release deferred tax credits (DTCs), the FSAP did not make any initial adjustment to the starting position.[14] However, the FSAP team assessed the sensitivity of banks' solvency position in response to a deduction of all existing DTAs from CET1 capital and the downgrading of performing problem loans.[15] Furthermore, the FSAP team deviated from the regulatory framework by estimating unrealized gain/loss associated with holding of debt securities in both available-for-sale (AFS) and held-to-maturity (HTM) accounts.

23. The balance sheet approach requires projections of key items in banks' balance sheets and income statements to project regulatory capital. The solvency stress tests essentially assess whether banks have adequate capital buffers (from existing capital and forthcoming pre-impairment net income) to absorb potential credit and market losses as a result of deteriorating macrofinancial conditions. Appendix III outlines how these key items were projected, based on either simplified approximation or more sophisticated modeling. The stress testing exercise focused on-balance sheet items—particularly, loan portfolios (49 percent of total assets) and securities holding (20 percent of total assets).[16] For the scenario analysis, key balance sheet and income statement items, including capital, are estimated on the annual frequency (i.e., 2018, 2019, and 2020).

24. The tests are based on a quasi-static balance sheet assumption. In particular, growth of gross exposures, such as total gross loans and gross holding of debt securities, is assumed to be identical to the overall credit growth prescribed in the macrofinancial scenarios, and the balance sheet composition is assumed to remain constant. In addition, banks are assumed to be able to build capital buffers only through retained earnings. Banks would not be able to raise new capital, and any tier-2 capital instruments that are maturing would not be renewed. Banks are allowed to pay dividends if they record a positive net income after taxes and do not need additional capital,

[13] The phase-in of deductions from CET1 capital would be completed at the beginning of 2018. The exercise assumed that the deduction on ineligible DTAs takes place in 2017Q4 to facilitate the comparison of results over the stress testing horizon.

[14] The BCBS's Regulatory Consistency Assessment Program (2013) viewed that the provision in Law 12838, passed in July 2013), which allows banks to convert DTAs relating to loan loss provisions into a tax credit when the bank reports a loss, is liquidated or becomes bankrupt, is equivalent to the situation described in the related BCBS's Frequently Asked Question (FAQ).

[15] The deduction of all existing DTAs is largely motivated by the concern about the public debt sustainability, deviating from the Basel III standards that allow DTAs to be included in CET1 capital (up to 10 percent).

[16] Other important items are cash in vault and lending to the central bank (13 percent of total assets), and other investment and credit claims (12 percent of total assets), and tax assets and nonfinancial assets (6 percent of total assets).

with the dividend payout rate similar to the 2016 level. Given the evolution of total assets and equity, total liabilities would need to be adjusted accordingly, with banks expected to raise additional funding, as needed, at the same prevailing funding costs.

25. The tests allow banks to use forthcoming pre-impairment income as loss-absorbing buffers. Pre-impairment (net) income comprises three main components—net interest income, other (net) income, and operating expense. The estimation of net interest income accounts for changes in balance sheet size and interest rates, as well as existing NPLs.[17] More specifically, banks would not receive interest income from new NPLs arising during the stress testing horizon, while they may have larger interest expenses due to a larger amount of funding (required to bridge the gap between total assets and equity). Average interest rates for lending activity, non-lending activity and funding are estimated based on fixed-effects panel regressions that feature macrofinancial conditions (i.e., real GDP growth, system-wide bank lending and funding rates, and EMBI spread) as explanatory variables. The estimation of other (net) income and operating expense accounts for changes in balance sheet size; furthermore, fee income could be influenced by macrofinancial conditions (i.e., real GDP growth, Selic and equity price).[18] The exercise also assumes zero non-operating net income and no extraordinary items.

26. The tests assess banks' resilience to credit and market risks based on common equity CET1, tier-1 (T1) and total capital ratios, as well as leverage ratio (Table 4). For the adverse scenario, the hurdle rates are the combination of the Basel minimum (4.5, 6 and 8 percent for CET1, T1 and total capital ratios) and the applicable capital surcharges for D-SIBs.[19] For the baseline scenario, the hurdle rates also include the phased-in capital conservation buffer, with the countercyclical capital buffer (CCB) being set at zero throughout the stress testing horizon. In addition to the capital ratios, the leverage ratio is considered.

[17] The exercise assumes that banks' behavior of recording interest income, including existing NPLs, does not change.

[18] Fee income is the only component of other income that exhibits a meaningful relationship with macrofinancial conditions. Other income components (i.e., trading income, investment income, and other operating income) and operating expense were assumed to be the same as their historical levels relative to total assets.

[19] A development bank, which is the fifth largest bank in Brazil, is not designated as a D-SIBs. In the case that it was to be considered a D-SIB in the stress testing exercise, the results remain the same given the bank's ample capital buffers.

Table 4. Brazil: Hurdle Rates of the Bank Solvency Stress Tests

	2017	2018	2019	2020
Capital ratios (in percent of risk-weighted assets)				
Minimum level				
CET1 capital	4.5	4.5	4.5	4.5
T1 capital	6.0	6.0	6.0	6.0
Total capital	8.0	8.0	8.0	8.0
Additional requirements for both baseline and adverse scenarios				
Capital surcharges for D-SIBs	1.0	1.0	1.0	1.0
Additional requirements for the baseline scenario				
Capital conservation buffer	1.25	1.875	2.5	2.5
Leverage ratio (in percent of total exposures)				
Leverage ratio (T1 capital)	3.0	3.0	3.0	3.0

27. The tests assess credit risk of all important types of exposures. The exercise captures credit loss associated with loan portfolios, securities holding and other credit claims. The FSAP team employed a suite of satellite credit risk models to project the amount of provisions for credit loss associated with lending and non-lending activities. The FSAP team also adopted the economic approach to the valuation of securities holding in the HTM account.

- **Provisioning for credit loss.** Given banks' prevalent practice of writing off NPLs, the credit risk models aim at estimating the amount of provisions directly. Three main approaches were explored. The reported results are based on estimating lending impairment and other impairment separately, with the former element being projected using a model based on macrofinancial indicators and the latter element according to the 2017Q1-Q3 level. Alternative approaches consider (i) estimating total impairment or (ii) using estimated problem loans to derive the amount of provisions.

- **Exposures in the HTM account.** The regulatory framework treats sovereign exposures differently based on how banks are holding them, even though they are all the same from an economic point of view. In the spirit of the economic concept, all exposures (including sovereign exposures) in the HTM account are treated in the same way as those in the AFS account. Potential credit loss is thus captured by unrealized gain/loss based on the market value.

28. The tests assess market risk stemming from existing open positions in banks' balance sheets and valuation adjustments of banks' holding of debt and equity securities. As market risk related to the re-pricing of adjustable deposit and lending rates is captured through the estimation of pre-impairment income, the exercise estimates market loss/gain driven by fluctuations in the exchange rate, bond yields, and commodity and equity prices. The financial positions (e.g. the net open foreign exchange position and the holding of securities) are adjusted in line with balance sheet growth. The impact of changes in bond yields is estimated based on exposures by types of interest rate risk (e.g. fixed-rate, flexible-rate or inflation-linked) and maturity buckets. The yield

curves (one for each interest rate type) are derived based on changes in short-term and long-term interest rates, as well as changes in inflation rate in the case of inflation-linked debt securities.[20] The exercise considers net exposures that incorporate future positions. The exercise did not consider the impact of interest rate movements on other financial derivatives (e.g. interest rate swaps).

29. The tests assume that the change in risk-weighted assets primarily reflects the size of total assets. Risk-weighted assets would increase proportionately with the balance sheet size. In addition, risk-weighted assets for foreign-currency exposures would be adjusted to reflect changes in the amount of exposures in Brazilian reais (as the currency moves).

30. The tests compute the amount of income tax based on pre-tax net income to simplify the complication related to DTAs. In Brazil, provisions for loan loss are not tax deductible. Income tax would, in principle, be applied to the sum of pre-impairment income and other impairment cost (excluding provisions for loan loss), with the tax rate of 45 percent.[21] However, banks are entitled to receive DTCs from their provisions for loan loss. Effectively, in each period, 45 percent of provisions for loan loss would be added to CET1 capital in the form of DTCs, while CET1 capital could be deducted as banks monetize some DTAs after the final settlement of NPLs. To avoid the need to model the evolution of DTCs, the exercise follows a typical accounting structure (i.e., income taxes based on pre-tax net income) since the impact on capital would be neutral as illustrated by a stylized example (Table 5).[22] The change in banks' capital is thus simply driven by net income after taxes, dividend payouts, and unrealized gain/loss associated with holding of debt securities in both AFS and HTM accounts; the exercise does not consider other components of accumulated other comprehensive income (AOCI).[23]

Table 5. Brazil: Stylized Impact on Capital Given the Existence of DTCs

	Brazilian tax rule	Typical accounting
Pre-impairment income	200	200
Provisions for loan loss	-100	-100
Taxes (at the rate of 45 percent)	-90	-45
Net income after taxes	10	55
New DTCs	45	0
Impact on capital	55	55

31. The stress testing exercise does not consider second-round effects, but captures the contagion effects owing to interbank cross-exposures. Specifically, the exercise does not consider (i) deleveraging prompted by weakened banks' balance sheets and (ii) impact on the real

[20] The value of inflation-linked debt securities would be affected by the change in real yields rather than nominal yields. The real yields are estimated based on both prevailing inflation and long-term historical inflation.

[21] For large banks, the tax rate is likely to be 45 percent, comprising statutory corporate income tax (15 percent), surtax on income in excess of 0.24 million Brazilian real, and social contribution tax (20 percent).

[22] The impact on capital would be identical in both cases if banks retain their earnings for the same amount.

[23] For some banks, pension schemes for their employees could have a significant impact on AOCI.

economy arising from more limited credit growth, with additional adverse effects on NPLs. However, the scenario analysis is extended to assess additional credit loss related to interbank cross-exposures, incorporating the interaction between banks' solvency and contagion effects via the interbank network. At the end of each year during the stress testing horizon, additional credit loss from failure of other banks is calculated, and the level of capital after the contagion analysis would be the starting point for banks' solvency in the subsequent period for the solvency stress tests.

D. IMF Top-down Stress Tests: Results

32. This subsection discusses the stress test results conducted by the FSAP mission. Given the importance of net interest income and credit loss for the bank solvency stress tests, this subsection first presents the projection of these two items based on satellite models, and then discusses the results of the scenario analysis and the sensitivity analysis, respectively.

Projection of Average Interest Rates by Satellite Net Interest Income Models

33. The FSAP team estimated average interest rates for lending activity, non-lending activity and funding, using the fixed-effects panel regression approach. The purpose is to examine how bank-level interest rates could be influenced by system-wide lending and funding rates, overall financial conditions, which are represented by Selic and EMBI spread, and macroeconomic outcome such as real GDP growth. The estimation was based on bank-level quarterly information on average interest rates for the period of 2000Q1–2017Q3.

34. The interest margin would be compressed significantly during the early phase of the adverse scenario (Figure 6). The compression is largely driven by the sharp increase in the funding cost. The interest rate margin would subsequently widen as banks earn at a higher rate from lending and non-lending activities. Banks would also enjoy a lower funding cost thanks to the monetary policy accommodation required to support the economy. In the baseline, the interest rate margin would decline marginally over the stress testing horizon, reflecting loosening financial conditions.[24]

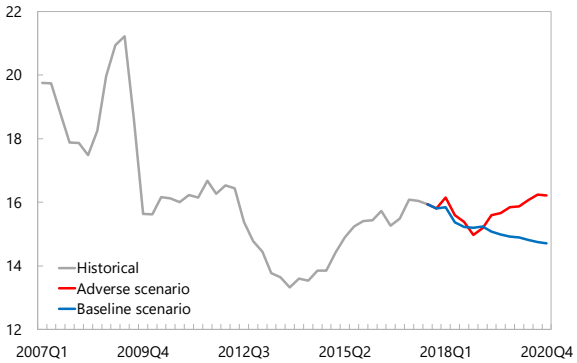
[24] In reality, the interest rate margin could be much more compressed given recent monetary policy loosening that is not envisaged in the baseline scenario analyzed in this stress testing exercise.

Figure 6. Brazil: Estimated Average Interest Rates for Bank Solvency Stress Tests

In the adverse scenario, the interest rate on lending would eventually increase on the back of the rise in the system-wide lending rate.

Average Interest Rate on Lending Activity, 2007-20

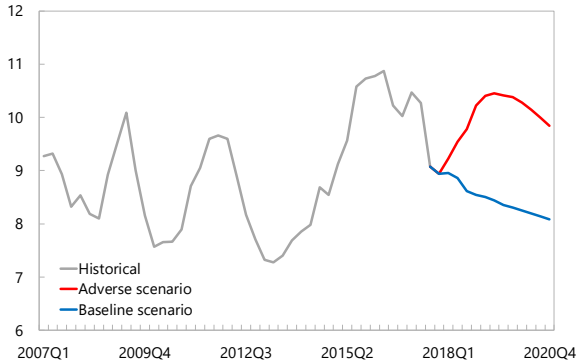
(In percent of total loans)



The interest rate on non-lending would increase in tandem with growing EMBI spread.

Average Interest Rate on Non-lending Activity, 2007-20

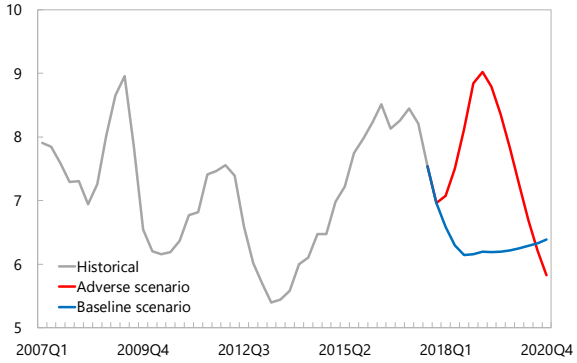
(In percent of non-lending financial assets)



Meanwhile, the interest rate on funding would increase sharply due to the rise in the system-wide funding rate.

Average Interest Rate on Funding, 2007-20

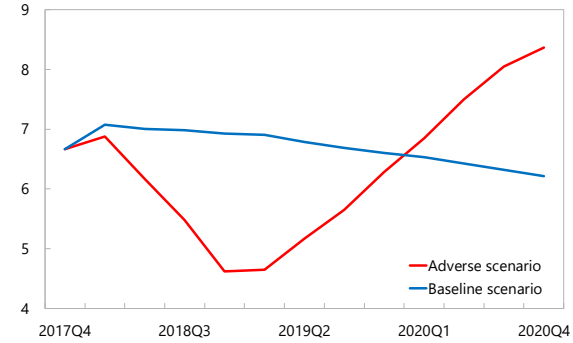
(In percent of total funding)



As a result, the interest margin would be compressed during the early phase of the adverse scenario.

Average Interest Margin, 2007-20

(In percentage points; difference between interest rate on earning assets (from lending and non-lending activities) and interest rate on funding)



Sources: Banco Central do Brasil; and IMF staff estimates.

Projection of Credit Loss by Satellite Credit Risk Models

35. The FSAP team estimated a suite of satellite credit risk models, using the fixed-effects panel regression technique. The FSAP team considered three broad approaches to estimate impairment cost, using bank-level quarterly information on total and lending impairment costs for the period of 2000Q1–2017Q3 and problem loans in total and by portfolios (e.g. currency type and economic sector) for the period of 20004Q1–2017Q3.[25]

- **The first approach** (which was used to present the results). It rests on estimating lending impairment and other impairment separately. The former is estimated based on a regression model with real GDP growth and EMBI spread as explanatory variables, while the latter follows the 2017Q1–Q3 level.

[25] Problem loans include NPLs and other loans in the "E" to "H" categories.

- **The second approach.** Alternatively, total impairment cost is estimated based on a regression model.

- **The third approach.** It relies on using estimated problem loans based on a regression model to derive the amount of provisions; the relationship between lending impairment cost and outstanding problem loans is also estimated by a regression model. Under the third approach, problem loans could be estimated in a total amount, as well as by loan portfolios (which could be aggregated in varied combinations). It is noteworthy that estimating impairment cost from the change in NPLs would be extremely challenging given banks' prevalent practice of writing off NPLs; in other words, the increase in outstanding NPLs would represent a fraction of newly defaulted exposures.

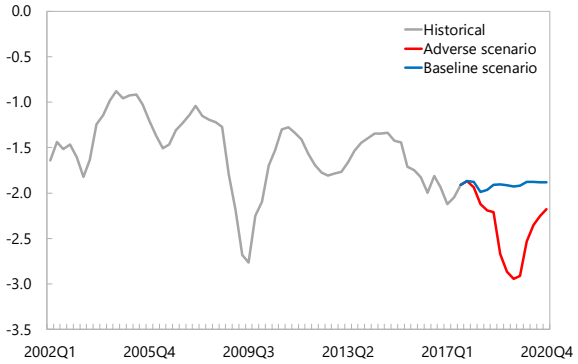
36. Lending impairment cost relative to total loans would increase to 5.3 percent in the adverse scenario (Figure 7). Lending impairment would peak in 2019, though still lower than the level after the global financial crisis (6.2 percent of total loans). The increase in lending impairment cost would largely underpin the increase in total impairment cost, which would reach 2.9 percent of total assets, a higher level than what was prevailing during the last recession. Intuitively, this could reflect a weaker starting position, i.e. corporate and household balance sheets are currently more vulnerable to deteriorating macrofinancial conditions than prior to the last recession (see additional analysis on corporate and household sectors in Sections VI and VII). Total impairment cost is projected to remain broadly stable relative to total assets in the baseline, reflecting a relatively weak macroeconomic outlook. Over the stress testing horizon, total impairment cost would be cumulatively larger in the adverse scenario by about 1.6 percent of total assets than in the baseline.

37. The dynamics of total impairment cost estimated under different approaches broadly look similar. Overall, banks' asset quality is mainly influenced by macroeconomic outcome (i.e., real GDP growth or unemployment), EMBI spread (which probably serves as the best proxy for credit risk in Brazil), and system-wide lending interest rate. Other macrofinancial indicators do not generally influence impairment cost, as well as problem loans either in total or by portfolios. See Appendix III for the detail on the regression specification of satellite credit risk models. In comparison to the first and second approaches, the third approach, which relies estimated problem loans, yields a smaller amount of total impairment cost in the adverse scenario.

Figure 7. Brazil: Estimated Impairment Cost for Bank Solvency Stress Tests

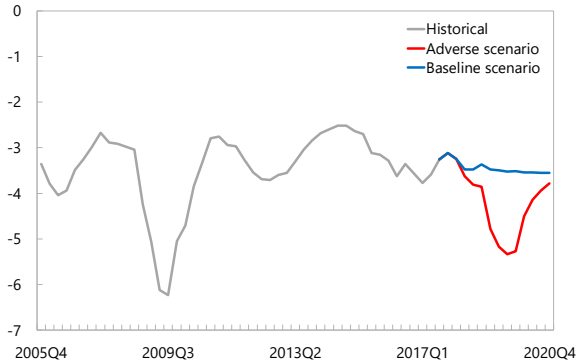
In the adverse scenario, total impairment cost could rise sharply on the back of higher lending impairment.

Total Impairment Cost, 2002-20
(In percent of total assets)



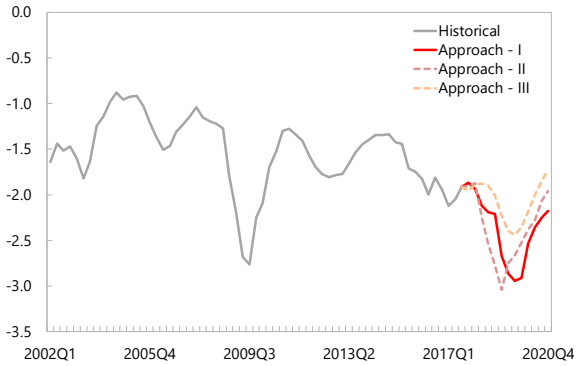
Though, lending impairment would still be smaller than during the global financial crisis.

Lending Impairment Cost, 2005-20
(In percent of total loans)



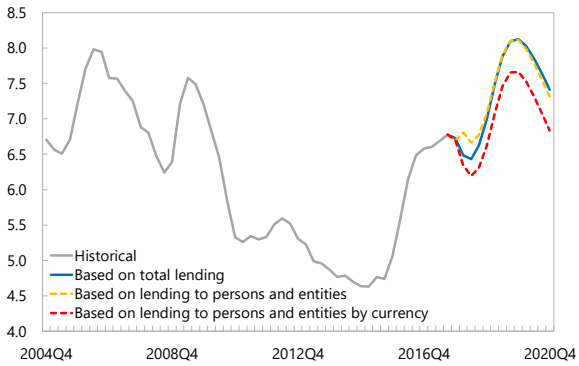
All three estimated total impairment costs share the same dynamics, though the magnitude more benign under the third approach.

Total Impairment Cost in the Adverse Scenario, 2002-20
(In percent of total assets)



Different aggregation of estimated problem loans yields broadly similar dynamics of problem loans.

Total Problem Loans in the Adverse Scenario, 2004-20
(In percent of total loans)



Source: Banco Central do Brasil; IMF staff estimates.

Benchmark Results of the Scenario Analysis

38. In the baseline, banks' solvency condition appears to be overall strong, although the capital ratios would be on a declining trend. For the sample of the 12 largest banks, the CET1 capital ratio would fall from 13.2 percent at end-2017Q3 to 11.4 percent at end-2020 (Figure 8). Besides the phase-in of deductions from CET1 capital (-0.2 percentage points), the reduction could be largely attributed to the dividend payout (-2.1 percentage points) and the growth of balance sheet (-2.7 percentage points). Over the same period, banks would be able to generate net income that boosts capitalization by 3.4 percentage points, reflecting moderating profitability on the back of slightly falling net interest income and persistently large impairment cost. One public D-SIB's capitalization would fall below the hurdle rates, with the additional capitalization need of R$6 billion (0.1 percent of GDP). This bank, despite not making any loss, could struggle to meet regulatory capital requirements under the assumption of no new equity issuance, as its profitability is too low to support the growing balance sheet.

39. Banks appear to be broadly resilient to severe macrofinancial shocks in the adverse scenario. The CET1 capital ratio of the 12 largest banks would decline by 4.7 percentage points to 8.5 percent at end-2020. These banks collectively would make aggregated loss and incur unrealized loss associated with holding of debt securities that bring down the CET1 capital ratio by 0.2 and 1.4 percentage points, respectively. The reduction is also driven by the dividend payout (1.1 percentage points) and the growth of balance sheet (1.8 percentage points). Other noteworthy features are:

- **Banks' losses would be largely driven by reduced net interest income and substantial credit loss.** Banks would experience negative net income after taxes in 2018 and 2019 before returning to be profit-making again in 2020. Relative to the baseline, net interest income would fall by 21 percent and credit loss would increase by 23 percent. The compressed net interest margin on the back of the sharp increase in funding costs underpins the decline in net interest income. Credit loss alone is roughly equal to pre-impairment income (both about 11.2 percent of risk-weighted assets). Other income and operating expense would be little changed relative to the baseline.

- **Banks would also face significant market loss particularly in 2018.** Over the stress testing horizon, market loss (including unrealized loss associated with holding of debt securities) would amount to 1.5 percent of risk-weighted assets. However, banks would face market loss of 3.6 percent of risk-weighted assets in 2018 before the subsequent improvement in market conditions that would help reduce the original loss.[26]

- **Three banks' capitalization would fall below the hurdle rates at end-2020.** Another bank would also fail to meet the hurdle rates at some point but would manage to recover by the end of the stress testing horizon. These four banks would require additional capital of R$46 billion (0.7 percent of GDP), nearly all of which is for two public banks.

Additional Results of the Scenario Analysis

40. Th results are sensitive to the stress tests' treatment of DTAs and problem loans. To assess the sensitivity of the results to the deduction of all existing DTAs from CET1 capital and the downgrading of performing problem loans, the FSAP team ran additional tests.

- **Deduction of all existing DTAs from CET1 capital.** About 30 percent of CET1 capital are in the form of DTAs.[27] In a very extreme scenario, these DTAs may not be used to absorb losses given the weak public finance situation. A test assumes that all existing DTAs (including DTCs) are deducted from CET1 capital. This adjustment would immediately reduce the CET1 capital ratio

[26] If debt securities in the HTM account are not affected by market movements, market loss would amount to 3.1 and 0.9 percent of risk-weighted assets in 2018 and over the stress testing horizon, respectively. The CET1 capital ratio would instead be at 8.9 percent at end-2020.

[27] DTCs that are eligible for CET1 capital account for 85 percent of these DTAs. The remaining are DTAs that are allowed to be included in CET1 capital up to a certain limit.

by 3.1 percentage points.[28] The CET1 capital ratio would then fall to 5.8 percent at end-2020 in the adverse scenario, compared with 8.5 percent in the case of no adjustments (Table 6).

- **Downgrading of performing problem loans.** Given the existence of restructured and renegotiated loans, a test considers downgrading all performing problem loans to the "E" category.[29] This adjustment would immediately reduce the CET1 capital ratio by 0.2 percentage points. With more restrictions on dividend distribution, the CET1 capital ratio at end-2020 would be at 8.3 percent (slightly higher than 7.8 percent with no adjustments) in the adverse scenario.

- **Combined shocks.** The combined impact of both adjustments would immediately reduce the CET1 capital ratio by 3.3 percentage points. In the adverse scenario, the CET1 capital ratio would fall to 5.5 percent at end-2020. Seven banks would fail to meet the hurdle rates at some point, but one bank would manage to recover by the end of the stress testing horizon. The additional capitalization need would amount to R$136 billion (2 percent of GDP), about three quarters of which is for public banks.

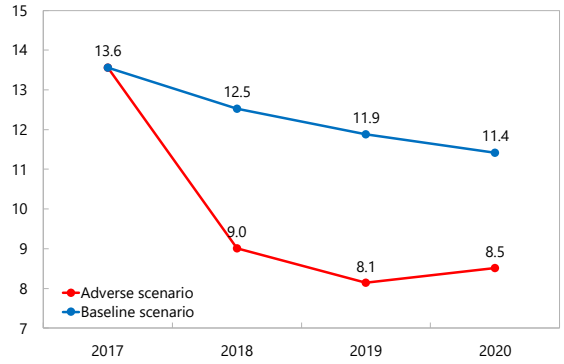
[28] This calculation also assumes the risk weight for all these DTAs is 2.5.

[29] Based on the regulatory framework, loans are classified into nine categories. The "E" category is considered to be the best class among NPLs.

Figure 8. Brazil: Bank Solvency Stress Test Results

The CET1 capital ratio is projected to fall in both baseline and adverse scenarios.

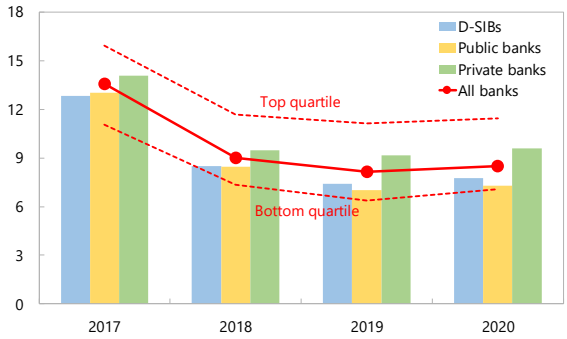
Common Equity Tier-1 Capital Ratio, 2017-20
(In percent of risk-weighted assets)



In the baseline, credit loss continues to be relatively large, driving the decline in the CET1 capital ratio in light of balance sheet growth and unchanged dividend policy.

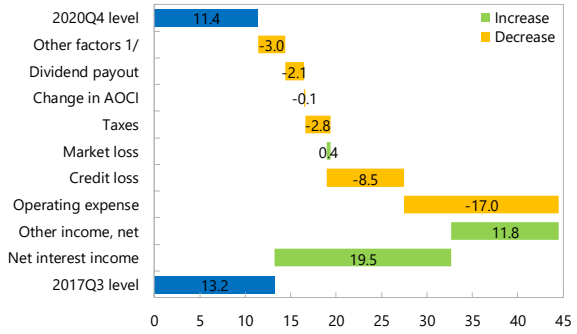
Capitalization of public banks is weaker than private banks.

Common Equity Tier-1 Capital Ratio in the Adverse Scenario, 2017-20
(In percent of risk-weighted assets)



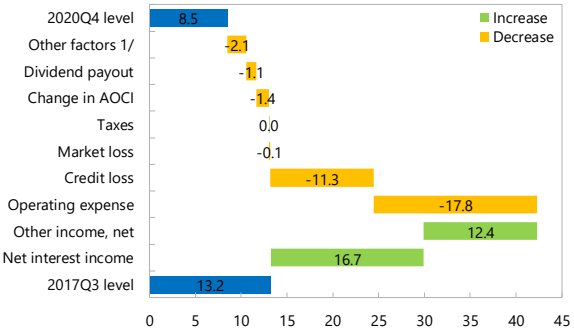
In the adverse scenario, banks would face reduced net interest income, greater credit loss and larger change in AOCI relative to the baseline, …

Dynamics of Common Equity Tier-1 Capital Ratio in the Baseline Scenario, 2017Q4-20Q4
(In percent of 2020 risk-weighted assets)



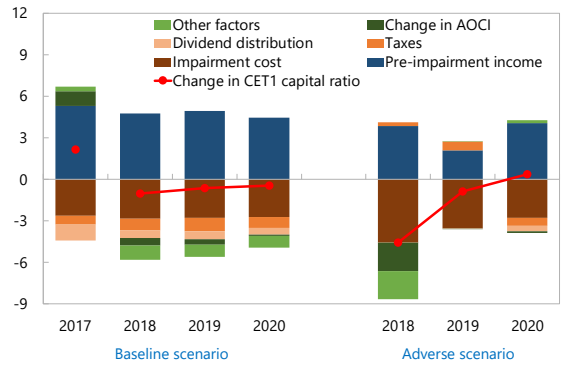
… with the negative impact largely concentrating in 2018. In addition to substantial credit loss, material market loss manifests in both change in AOCI and …

Dynamics of Common Equity Tier-1 Capital Ratio in the Adverse Scenario, 2017Q4-20Q4
(In percent of 2020 risk-weighted assets)

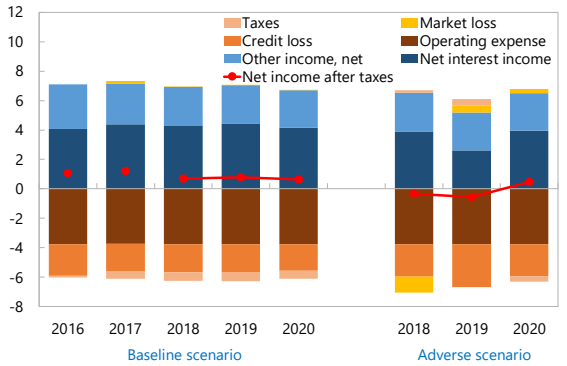


… loss in the trading account.

Contribution to Common Equity Tier-1 Capital, 2017-20
(In percent of risk-weighted assets)



Net Income, 2016-20
(In percent of total assets)



Source: IMF staff estimates.

1/ Other factors largely capture changes in risk-weighted assets, and also include effects of the phase-in of deductions from CET1 capital.

Table 6. Brazil: Bank Solvency Stress Test Results – Scenario Analysis

		CET1 capital ratio (in percent)				Banks not meeting the hurdle			Amount of capital shortfalls	
						Number		Share of assets		
		2017	2018	2019	2020	Total	End-2020	(in percent)	Billion R$	Percent of GDP
Baseline scenario	Benchmark (no adjustments)	13.6	12.5	11.9	11.4	1	1	20	6	0.1
	With adjustments	10.4	9.7	9.5	9.5	6	5	63	45	0.6
	Derecognition of DTAs	10.6	9.9	9.7	9.7	6	3	63	37	0.4
	Downgrading of problem loans	13.3	12.4	11.7	11.3	1	1	20	10	0.1
	With interbank contagion	13.6	12.5	11.9	11.4	1	1	20	6	0.1
Adverse scenario	Benchmark (no adjustments)	13.6	9.0	8.1	8.5	4	3	24	46	0.7
	With adjustments	10.4	5.9	5.0	5.5	7	6	65	136	2.0
	Derecognition of DTAs	10.6	6.1	5.2	5.8	7	6	65	126	1.9
	Downgrading of problem loans	13.3	8.8	7.9	8.3	4	3	24	53	0.8
	With interbank contagion	13.6	8.5	6.7	7.1	6	5	43	81	1.2

Source: IMF staff estimates.

41. Owing to interbank cross-exposures, banks would face additional non-negligible loss in the adverse scenario. The integrated exercise of bank solvency stress tests and interbank network analysis assesses the additional impact of interbank contagion on banks' solvency.[30] In the adverse scenario, when credit loss due to interbank cross-exposures are incorporated based on the same parameters used in the standalone exercise (see the Bank Contagion section below), the CET1 capital ratio would fall to 7.1 percent at end-2020, with additional loss amounting to R$68 billion (1.5 percent of risk-weighted assets). Six banks' capitalization would fall below the hurdle rates at some point, resulting in additional capitalization need of R$81 billion (1.2 percent of GDP). Hence, interbank contagion would make other two banks fail to meet the hurdle rates.

42. Banks could come under significant stress given the strong banking-sovereign linkages if the Brazilian government default is considered in the adverse scenario. Although the adverse scenario does not consider a government default, the stress testing exercise could still provide some insight. In the case that the default event materializes, the ultimate impact on banks' solvency would depend on the outcome of debt restructuring, i.e. the greater the debt relief, the larger the loss incurred by banks. When the default becomes a likely event, government bond yields will increase sharply. Given banks' substantial holding of government debt securities, a spike in bond yields (the adverse scenario features an increase by 700 basis points) could result in a significant market loss of R$90 billion (2.3 percent of risk-weighted assets), about two-thirds of which are unrealized losses. The loss could be R$34 larger if flexible-rate government debt securities are subject to a similar haircut (16 percent).[31] Furthermore, the government would not be able to provide needed support to the banking sector (i.e., recapitalize banks and guarantee banks' liabilities). As a result, banks may not be able to use DTAs to absorb loss as needed, implying much larger capital shortfalls (see Paragraph 49). As public banks, which account for a lion share of credit

[30] The exercise only considers the credit loss channel. The trigger for a bank to default is set at the minimum regulatory capital requirements. It is worth mentioning that the results are not sensitive to the trigger threshold. In particular, the additional credit loss would be the same if the trigger is instead set at the half of the minimum regulatory capital requirements, although the default would instead spread over 2018 and 2019 rather than concentrate in 2018 only.

[31] This haircut could be interpreted as the loss related to debt restructuring following a government default.

to nonfinancial sectors, appear relatively less resilient, the government's inability to support weak public banks would have a significant impact on economic activity.

Results of the Sensitivity Analysis

43. The sensitivity analysis considers four types of risk—concentration risk, market risk, exchange rate risk, and interest rate risk. The sensitivity analysis assesses the impact of single-risk factors individually with the magnitude broadly in line with those in the scenario analysis. The exercise captures the following transmission channels of these risks:

- **Concentration risk:** The impact involves credit loss generated by the default of large borrowers from an individual bank as well as the banking sector. Loans to five largest borrowers of individual banks account for 3.6 percent of banking sector assets, while loans to five largest system-wide borrowers account for 2.9 percent of banking sector assets.

- **Market risk:** The impact only considers market loss related to movements in bond yields, equity prices, exchange rates, and commodity prices. The impact related to banks' holding of debt securities only covers net exposures (including future positions) in the trading account. For other risk factors, the impact is assessed based on gross holding of equity securities, net open foreign exchange positions and net exposures of commodities in the entire balance sheet.

- **Exchange rate risk:** The impact includes credit loss associated with foreign-currency lending (i.e., credit risk induced by exchange rate movements), market loss due to existing net open positions, and additional risk-weight assets related to foreign-currency exposures.

- **Interest rate risk:** The impact encompasses market loss due to fluctuations in bond yields, change in net interest income following the adjustment of interest rates, and credit loss due to changes in borrowers' debt servicing capacity.

44. Concentration risk and market risk seem significant. The default of very largest borrowers of individual banks and of the system could have a sizeable impact on capital, especially at public banks. The CET1 capital ratio could fall by 5.3 percentage points following the default of the five largest borrowers of individual banks (Table 7).[32] Besides their holding of Brazilian government debt securities, banks' lending to the same large system-wide borrowers provides another source of large common exposures. The default of five largest system-wide borrowers could reduce the CET1 capital ratio by 4.3 percentage points. The fact that state-owned enterprises are among the largest borrowers of public banks could amplify contagion through the bank-sovereign linkages. Furthermore, banks are generally exposed to market loss particularly stemming from movements of bond yields, while two banks are particularly exposed to changes in equity prices. The

[32] For assessing concentration risk, the exercise assumes loss given default of 100 percent and individual banks' average risk weight for credit risk.

sensitivity analysis considers only market loss through income statement (i.e. related to the trading account), not unrealized loss through AOCI. Banks would suffer a reduction in the CET1 capital ratio by 1.1 percentage points if bond yields increase by 700 basis points,[33] and a reduction by 1.2 percentage points if equity prices fall by 50 percent. Market losses associated with net open foreign exchange positions and net exposures of commodities are very limited.

45. Banks could face a sizeable impact on capital following large exchange rate depreciation. Despite banks' small net open foreign exchange positions, the CET1 capital ratio would decline by 1.8 percentage points. The impact would largely arise from additional credit loss (potentially associated by unhedged borrowers) induced by currency depreciation and increased risk-weighted assets (as value in reais of foreign-currency exposures increases).

46. Interest rate risk largely arises from banks' substantial holding of debt securities, and the downward trend of interest rates could impact profitability. The impact on banks' solvency could amount to 3.5 percentage points of risk-weighted assets following a spike in bond yields by 700 basis points. The reduction in the CET1 capital ratio could mainly be attributed to unrealized loss associated with the AFS account (54 percent) and market loss through income statement (31 percent). Unrealized loss associated with the HTM account would be relatively limited. In addition, banks will likely experience reduced profitability in the environment of lower interest rates. For instance, a decline in Selic by 200 basis points (this has actually happened since 2017Q3 but does not feature in the baseline scenario) would reduce net interest income by 0.5 percent of risk-weighted assets.[34] With some benefit from reduced credit loss, the impact on net income would be 0.4 percent of risk-weighted assets. Public banks appear more vulnerable to falling interest rates than private banks given that the reduction in their net interest income would likely be larger.

47. An application of a positive risk weight for sovereign exposures may not have a significant impact on capital, and additional capital buffers would likely fall short of potential losses incurred by banks. A hypothetical exercise considers an application of a 0.2 risk weight for exposures to the Brazilian government. This would reduce the CET1 capital by 0.5 percentage points. Under the assumption that banks will rebuild their capital buffers to maintain the same level of capital ratios, such additional capital buffers would be fairly small (i.e., 0.5 percent of risk-weight assets) in comparison to potential losses arising from a sharp increase in bond yields. Using the same assumption about the yield curve (see Footnote 24), these additional capital buffers would only be adequate to cover losses related to the holding of Brazilian government debt securities in an event that bond yields increase by about 250 basis points.

[33] The exercise assumes that the nominal yield curve has a parallel upward shift and the real nominal yield curve is also affected the increase in near-term inflation by 4.5 percentage points and in long-term inflation by about 2 percentage points.

[34] The impact is estimated based on simple satellite models that project average interest rates and lending impairment cost based on the dynamics of Selic.

Table 7. Brazil: Bank Solvency Stress Test Results—Sensitivity Analysis

Impact on the CET1 capital ratio (in percentage points)

	All	D-SIBs	Public	Private
Concentration risk				
Default of individual bank's largest borrowers				
The largest borrower	-1.8	-1.5	-2.9	-0.9
Three largest borrowers	-3.9	-3.1	-6.4	-1.8
Five largest borrowers	-5.3	-4.1	-8.7	-2.4
Ten largest borrowers	-7.7	-5.9	-12.6	-3.5
Default of banking system's largest borrowers				
The largest borrower	-1.6	-1.3	-2.8	-0.5
Five largest borrowers	-4.3	-3.3	-8.0	-1.0
Ten largest borrowers	-6.2	-5.0	-11.7	-1.7
Twenty-five largest borrowers	-9.4	-7.4	-17.1	-3.0
Market risk (market loss only)				
Bond yield spike by 700 basis points	-1.0	-1.1	0.0	-1.9
Equity price decline by 50 percent	-1.2	-0.3	-2.0	-0.5
Exchange rate depreciation by 50 percent	0.1	0.0	0.2	0.0
Commodity price decline by 50 percent	0.0	0.0	0.0	0.0
Exchange rate risk				
Exchange rate depreciation by 50 percent	-1.8	-2.0	-1.5	-2.2
Due to open position	0.1	0.0	0.2	0.0
Due to risk-weighted assets	-0.8	-0.7	-0.6	-1.0
Due to depreciation-induced credit loss	-1.1	-1.4	-1.0	-1.2
Interest rate risk				
Bond yield spike by 700 basis points	-3.4	-3.6	-2.7	-4.0
Market loss for the trading account	-1.0	-1.1	0.0	-1.9
Unrealized loss associated with AFS securities	-1.8	-1.9	-1.8	-1.8
Unrealized loss associated with HTM securities	-0.5	-0.6	-0.8	-0.2
Selic increase by 350 basis points	0.6	0.5	0.9	0.4
Related to interest income	1.0	0.9	1.2	0.8
Related to credit loss	-0.4	-0.5	-0.4	-0.4
Selic decrease by 200 basis points	-0.4	-0.3	-0.5	-0.3
Related to interest income	-0.5	-0.5	-0.6	-0.4
Related to credit loss	0.1	0.1	0.1	0.1
Asset quality				
Downgrading of problem loans to "E" category				
Total loans	-0.2	-0.3	-0.4	-0.1
Renegotiated loans	-0.2	-0.2	-0.3	-0.1
Restructured loans	-0.2	-0.2	-0.3	-0.1
Quality and quantity of capital				
Derecognition of existing deferred tax assets	-3.1	-3.6	-2.8	-3.3
Assume risk weight of 0.2 for sovereign exposures	-0.5	-0.5	-0.5	-0.6

Source: IMF staff estimates.

E. Top-down Stress Tests by the Authorities

48. The BCB conducted bank solvency stress tests using its own methodology that has been recently upgraded. Its stress testing framework is based on the balance sheet approach that involves projections of credit growth, average interest rates for lending activity, non-lending activity and funding, other income and operating expense components, credit loss derived from the dynamics of provisions, and market loss based on marking-to-market. Balance sheet growth is only driven by growth of credit portfolios, with other asset items remaining constant. Unrealized loss/gain associated with holding of debt securities in the AFS account is also included in market loss. The impact on capital accounts for evolution of prudential filters and risk-weighted assets. For the latter, the market risk component is estimated relatively precisely per the regulatory framework.

49. The results of stress tests conducted by the BCB looked more favorable than the IMF tests, with an upward trend in the CET1 capital ratio in both baseline and adverse scenarios (Figure 9). Differences in the results arise because of both methodological approaches and modeling techniques.

- **In the baseline scenario,** the CET1 capital ratio would increase to 15.4 percent at end-2020, in contrast to the downward trend in the IMF test. The higher CET1 capital ratio estimated in the BCB test largely arises from no dividend payout (2.1 percentage points), lower credit loss (1.9 percentage points), and taxes (1.9 percentage points). The BCB test also envisages smaller balance sheet expansion and lower pre-impairment income. Two banks would fail to meet the hurdle, resulting in capital shortfalls of R$12 billion.

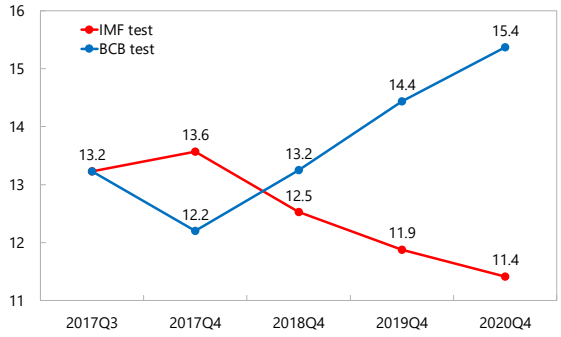
- **In the adverse scenario,** the CET1 capital ratio would eventually improve to 13.5 percent by end-2020, opposite to a sharp decline projected by the FSAP team. The higher CET1 capital ratio in the BCB test largely stems from lower credit loss (3.8 percentage points), lower market loss (1.3 percentage points; 0.4 percentage points due to different treatment of debt securities in the HTM account), and no dividend payout (1.1 percentage points). The BCB test expects a smaller impact from increased risk-weighted assets and a lower level of pre-impairment income. Two banks would fail to meet the hurdle, one of which would suffer a significant increase in market risk. Capital shortfalls would amount to R$15 billion.

Figure 9. Brazil: Comparison of Results of Bank Solvency Stress Tests Conducted by the FSAP Team and the BCB

In the baseline, the BCB test showed an upward trend in the CET1 capital ratio, …

Common Equity Tier-1 Capital Ratio in the Baseline Scenario, 2017-20

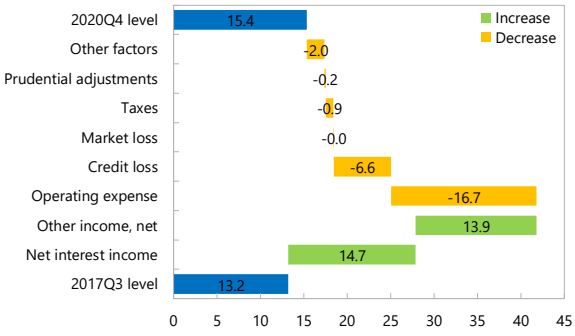
(In percent of risk-weighted assets)



… partly due to lower credit loss and taxes relative to the IMF test, as well as no dividend payouts.

Dynamics of Common Equity Tier-1 Capital Ratio in the Baseline Scenario, 2017Q4-20Q4

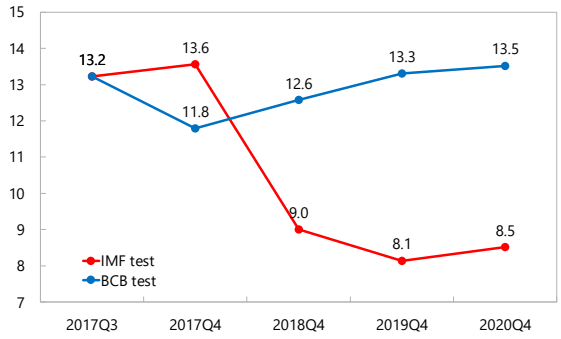
(In percent of 2020 risk-weighted assets)



In the adverse scenario, the BCB test also showed a moderate increase in the CET1 capital ratio, …

Common Equity Tier-1 Capital Ratio in the Adverse Scenario, 2017-20

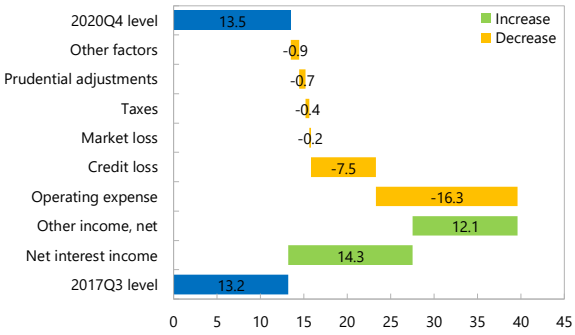
(In percent of risk-weighted assets)



… mainly supported by more benign credit and market losses.

Dynamics of Common Equity Tier-1 Capital Ratio in the Adverse Scenario, 2017Q4-20Q4

(In percent of 2020 risk-weighted assets)



Source: IMF staff estimates.

F. Assessment of the BCB's Solvency Stress Testing Framework

50. The BCB has strengthened its top-down solvency stress testing framework in the past years and stress tests have become an integrated part of its policymaking. The top-down stress test results have served as input into the discussion at its Financial Stability Committee and the supervisory process of individual banks. The BCB has also published the results in its biannual Financial Stability Report. The current framework represents a significant upgrade, including a new module to estimate pre-impairment income and a new approach to estimate credit loss based on the dynamics of provisions.[35] The upgraded framework can be used to conduct stress tests with a

[35] Previously, the stress testing framework only covered credit loss and market loss. The estimation of credit loss was based on the dynamics of NPLs without accounting for substantial loan write-offs by banks, resulting in an underestimation of credit loss.

longer horizon beyond the 18-months period. The BCB has utilized various data sources that enable it to carry out stress tests on a timely basis (monthly information with two-months lag).[36]

51. The current stress testing framework has a number of notable strengths but could benefit from further enhancements to ensure the reliability of stress test results. Its strengths lie on its granular approach to handle market risk related to debt securities holding and net foreign exchange positions, to estimate the market risk component of risk-weighted assets, and to account for Brazil-specific tax and prudential treatments. However, there are areas that are warranted for a closer review.

- **Balance sheet growth.** The framework assumes that balance sheet growth is only driven by growth of credit portfolios, which is in turn estimated based on macrofinancial conditions. However, it would be useful to ensure that aggregated bank-level credit projections are consistent with overall credit growth in macrofinancial scenarios. Other exposures should also be adjusted in line with macrofinancial conditions.

- **Overseas operations.** The framework does not differentiate between domestic and overseas operations. Given that some Brazilian banks have relatively large overseas operations, the current approach, albeit more conservative given more severe shocks assumed in Brazil, could provide misleading results. Estimating net interest income and credit loss of key overseas subsidiaries would constitute a major improvement.

- **Net interest income.** The framework estimates net interest income, which comprises three components—earnings from credit portfolios, earnings from securities holding, and funding costs. Average interest rates in each component is solely linked to Selic. Given the importance of net interest income, this module should be reviewed to ensure more sensible projections in light to particularly low estimated net interest income in outer years in the BCB stress tests.

- **Credit loss.** The framework estimates credit loss based on three portfolios—residential mortgage, retail consumer and corporate. For the residential mortgage portfolio, the framework assumes a default when home equity becomes negative and determines impairment costs based on associated losses. For the other two portfolios, the framework estimates impairment costs based on the dynamics of provisions projected based on macrofinancial conditions and accounting for the recent pattern of loan recovery and write-offs. Nevertheless, the framework could improve its estimation of credit loss by projecting default probability and loss given default.[37]

- **Market loss.** The framework takes a granular approach to estimate market loss associated with debt securities holding by interest rate types and maturity buckets and net foreign exchange

[36] The data come from supervisory reports, which provide information on accounting, capital structure, and market risk exposures, and other sources such as credit registry (used for satellite credit risk models), payment systems (interbank exposures), and trading repositories.

[37] Default probability could be proxied by newly recognized NPLs and/or outstanding NPLs adjusted for loan recovery and write-offs. Loss given defaulted could be estimated based on provisioning practices.

positions by currencies. It would be important to capture market loss associated with equity securities holding given that existing large exposures at some banks.

- **Capitalization.** The framework replicates the regulatory approach to estimate the market risk component of risk-weighted assets while maintaining the constant risk weight intensity for the credit risk component. However, the market risk component appeared to be calculated once at the beginning of the stress testing horizon based on the BCB stress test results, potentially overestimating risk-weighted assets in outer years as market conditions change. The calculation of capital also accounts for Brazil-specific tax and prudential treatments (particularly, related to DTAs).[38]

52. The stress tests should be conducted based on macrofinancial scenarios that reflect the BCB's view of the baseline and the relevant financial stability risks in adverse scenarios. The BCB regularly conducts stress tests based on three scenarios—baseline (using Consensus Economics forecasts), adverse (targeting real GDP growth at the 5th-percentile) and structural break (targeting all macrofinancial indicators at the 5th-percentile). The design of adverse and structural break scenarios is based on the Bayesian vector auto regression (VAR) model featuring key macrofinancial variables. In the upcoming annual bottom-up stress testing exercise, the BCB plans to use scenarios consistent with its own macro view.[39] This approach should also be applied to its regular top-down stress tests to ensure the consistency across policy spectra.

53. The BCB plans to further enhance its stress testing framework, including the development of a solvency-liquidity contagion module. The near-term plan also includes expanding satellite credit risk models to exploit more granularity than the current three portfolios and estimating all income components at the bank level for the largest banks. The plan to develop the solvency-liquidity contagion module will enable the BCB to better capture interactions between solvency and liquidity situations that banks face.

54. The BCB initiated an annual bottom-up stress testing exercise in 2017, with a focus on ensuring that the entire process works smoothly. Essentially, the exercise was to request banks subject to the Internal Capital Adequacy Assessment Process (ICAAP) to use common macrofinancial scenarios provided by the BCB to run stress tests. Building on the early success, the BCB plans to validate the results produced by participating banks in the upcoming exercise. Given that a preliminary review revealed that some results in the 2017 exercise did not look plausible and coherent, the validation of results would be important.

[38] The amount of CET1 capital is adjusted to reflect the cap on ineligible DTAs (at 15 percent of CET1 capital).

[39] An interdepartmental committee has been set up to design scenarios for the upcoming annual bottom-up stress testing exercise, with the use of the Economics Department macrofinancial model.

G. Policy Recommendations

55. The use of Pillar 2 capital requirements could help mitigate identified risks, supporting the need to build additional capital buffers at some banks. Given concentration risk, including large holdings of debt and equity securities, capital add-ons based on individual banks' risk profiles should be considered. The BCB is rightly taking steps in this direction. The supervisory process, including grading of banks' financial soundness, already covers the abovementioned risks and takes stress testing results into account. Furthermore, banks that would experience capital shortfalls in the stress tests should be encouraged to build capital buffers, for example, through the restriction on dividend distribution, to improve their resilience to macrofinancial shocks.

56. The BCB's stress testing framework is generally sound and could benefit from further enhancements. The recent upgrade in the framework led to a significant improvement, but its performance should be reviewed to ensure that all modules generate sensible results. The framework could also improve its handling of overseas operations and estimation of credit loss based on default probability and loss given default. The BCB also rightly plans to develop its solvency-liquidity contagion module to better capture potential risk amplification. Given that the BCB is using various data sources, the accuracy and consistency of information is key to ensure the reliability of analyses. Lastly, it would be important to validate the results produced by banks to reap the full benefit of the annual bottom-up stress testing exercise, including the improvement in banks' risk management capacity.

BANK LIQUIDITY STRESS TESTS

A. Overview

57. The liquidity stress tests comprised LCR-based tests, NSFR-based tests, and a cash-flows analysis. The liquidity stress testing exercise assesses banks' ability to manage potential funding outflows during the period of significant financial stress. The tests were conducted jointly by the FSAP mission and the BCB. The first test was based on the LCR, which measures bank's ability to meet its liquidity needs in a 30-day stress scenario by using a stock of unencumbered high-quality liquid assets (HQLA). The results from the LCR exercise were then compared to the ones from the BCB's IL ratio. The second test was based on the NSFR, which provides a useful complementary view of banks' funding profile in relation to the composition of their assets and off-balance sheet activities at a one-year horizon. The third test is a cash-flow-based analysis by maturity buckets. It allows for a more granular analysis of bank's liquidity buffers taking into account cash flows generated by different assets and liabilities with different maturities ranging from 1 day to more than six months. The cash-flow based analysis, LCR-based test and NSFR- based tests were carried out using supervisory data as of 2017Q3, covering the 12 largest banks—consisting of 11 largest commercial banks (of which five are D-SIBs and four are publicly-owned) and one (Brazil's largest) publicly-owned development bank—similar to the solvency stress tests. The BCB's IL ratio was also computed for other small and medium sized banks (132 banks). The NSFR-based tests were

performed in all currencies together (both domestic and foreign), while the LCR-based tests and cash-flow analysis analyzed liquidity risks in local currency and foreign currency separately.

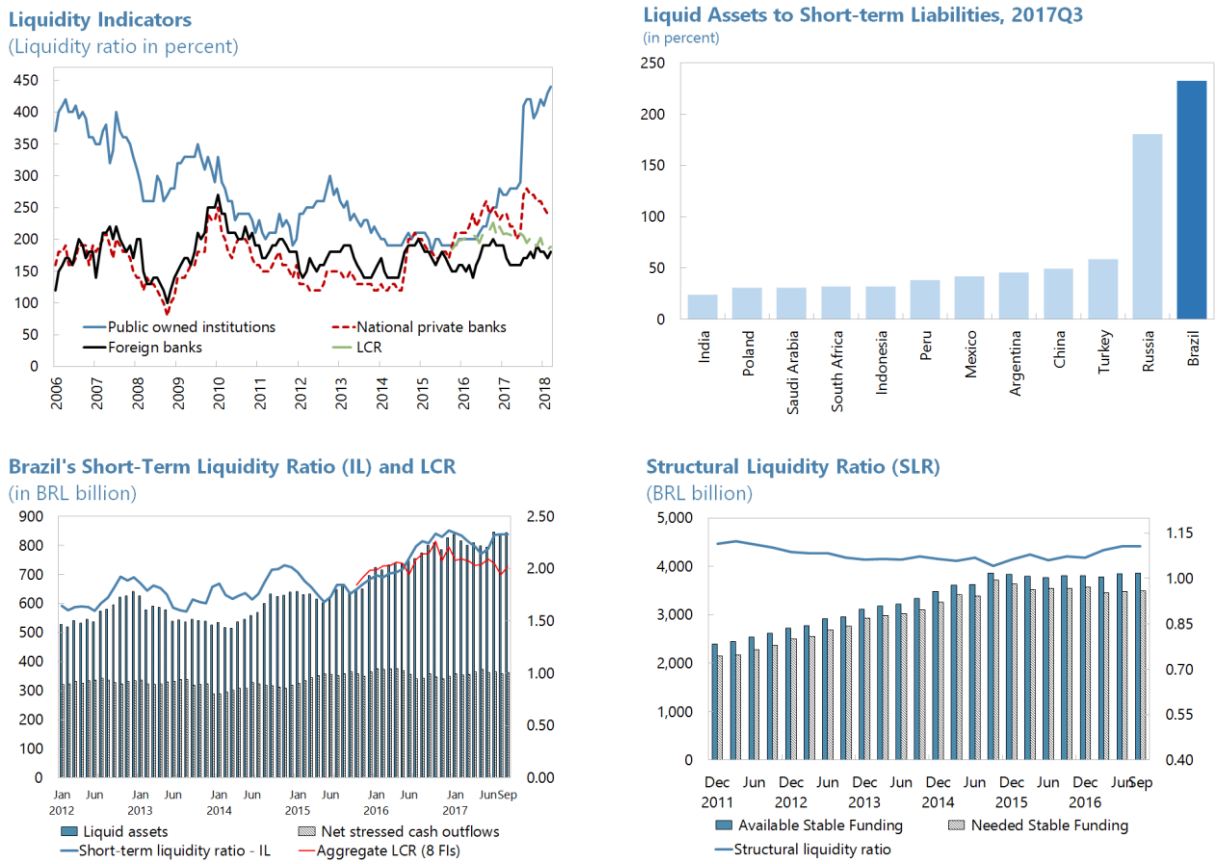
B. Current Liquidity Conditions and Banks' Liquidity Profiles

58. Liquidity risk was low despite the large recession (Figure 9). During the recession banks increased holdings of liquid assets in a period of low credit demand. Brazilian banks' have one of the highest liquid assets to short-term liabilities ratio amongst its peers. The BCB's IL ratios have remained comfortably above the internal monitoring warning level despite the recession, and system-wide LCR has been above 100 percent since end-2015. Same holds true for liquidity risk in the longer term, as shown by the BCB's Long-Term Structural Liquidity Ratio, which do not suggest large maturity transformation at the aggregate level.

59. High quality liquid assets are largely composed of government securities. Almost all of LCR's HQLA is composed of Level 1 assets (99 percent), with government securities holding a very large share (70 percent for all 12 banks and 66 percent excluding the development bank, where the latter holds only government securities as level 1 assets which constitutes 95 percent of its total HQLA), followed by reserves (23 percent) and cash (4 percent). Foreign currency-denominated assets are not a significant part of HQLA and overall Level 2 assets are almost zero. Moreover, more than seventy-five percent of the secured lending portfolios constitute reverse repos secured by government securities.

60. More than sixty percent of commercial banks' funding comes from wholesale sources (Figure 10). Forty percent of wholesale funding for the 11 largest commercial banks comes from short-term overnight repo funding secured by government securities (constituting 25 percent of total commercial bank funding), and the remaining 60 percent comes from longer-term unsecured wholesale sources. It is important to note that banks act as intermediaries to channel liquidity between investment funds and the BCB by entering the repos of government bonds with the former and the reserve repos with the latter, as the BCB sterilizes Brazil's structural liquidity surplus (around 25 percent of GDP) via Open Market Operations (OMOs). Retail deposits comprise around a quarter of total funding. On the other hand, Brazil's largest development bank obtains almost all of its funding from unsecured long-term wholesale funding in the form of borrowing (maturity beyond six months) from the Brazilian government.

Figure 10. Brazil: Liquidity Conditions[1,2]



Sources: IMF, Financial Soundness Indicators database; BCB and IMF staff calculations.

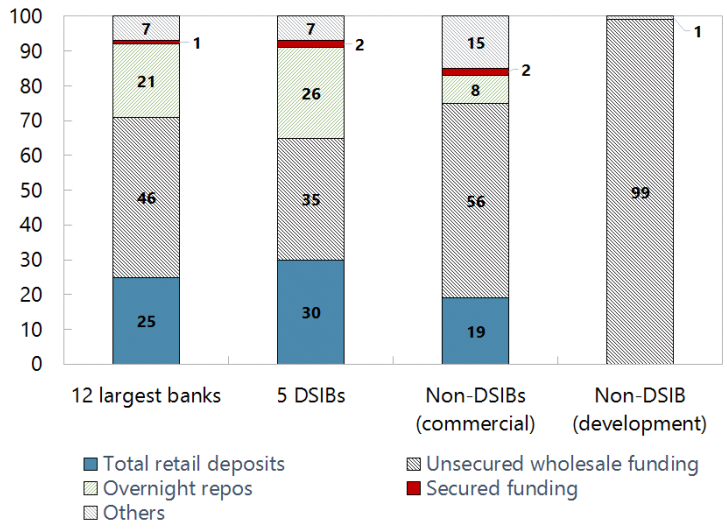
[1] Brazil's Short-term Liquidity Ratio (IL) measures whether banks have enough liquid assets to cover their short-term (1 month) cash-flow needs in a simulated stress scenario, defined and calibrated by the BCB (since 2002).

[2] Brazil's Structural Liquidity Ratio (SLR) is a metrics based on the NSFR methodology, which measures banks' ability to obtain stable funding sources to finance their long-term activities (on-year horizon).

61. Funding structure differs across the development bank, D-SIBs and non-SIB commercial banks. The share of short-term funding, in domestic and foreign currencies, is larger for D-SIBs in comparison to the non-SIBs. Close to 60 percent of D-SIBs' overnight funding comes from repos backed by government securities versus 25 percent for non-SIBs. Moreover, the development bank has a unique funding structure as it holds mainly long-term assets backed by long-term liabilities.

62. The reliance on offshore funding remains low. Foreign funding accounts for 8 percent of total funding for the 12 largest banks, of which 65 percent comes from issuance of securities in foreign currency, 15 percent from other unsecured wholesale funding (from time deposits of nonfinancial corporates, nonresident parents and other banks), followed by 9 percent from retail time deposits and secured borrowing. On the assets side, loans to clients, banks and other financial institutions (both performing and nonperforming) account for 86 percent of total foreign-currency (FX) assets. The overseas exposures are concentrated at D-SIBs, accounting for 90 percent of total FX loan portfolio of the banking system, and 83 percent of the total foreign funding.

Figure 11. Brazil: Funding Structure of Brazil's Banking System



Source: Authorities.

C. LCR-Based Stress Tests

63. The LCR-based tests were conducted in line with the national implementation of the Basel III regulatory framework. The LCR-based tests assess banks' ability to manage potential liquidity pressures for a period of 30 days. Currently, Brazilian banks with total assets above R$100 billion (encompassing eight conglomerates that account for 77 percent of Brazil's total banking system assets) are required to maintain an LCR above 80 percent, which will increase to 100 percent in January 2019.[40] The BCB also monitors the LCR by currency and by jurisdiction for these banks.[41] To ensure proper diversification of banks' HQLA, there are limits on the amount of central bank reserves that can be included in the stock of HQLA. This is more conservative than the Basel standards, which permit central bank reserves to be included in Level 1 HQLA to the extent that the central bank policies allow them to be drawn down in times of stress.[42] A sum of three components determines the amount of reserves that form HQLA: (a) excess reserves; (b) the automatic releases of required reserves due to deposit outflow; and (c) remaining required reserves up to 15 percent of the stock of Level 1 HQLA.

[40] The LCR is self-declared: it's calculated on a daily basis by banks and sent to BCB on a monthly basis by the means of the Report on Liquidity Risk. Calculation accuracy is assessed by the on-site supervision.

[41] In 2017, the Basel Committee on Banking Supervision (BCBS)'s Regulatory Consistency Assessment Program assessed that Brazil is complied with the Basel III LCR standards.

[42] Brazilian banks may draw down all central bank reserves, including, but not only, in times of stress, with only a limited financial penalty for not fulfilling a reserve requirement at the end of the day (and without any penalty for intraday use).

64. To assess the short-term resilience of banks to an abrupt withdrawal of funding, the LCR-based stress tests, in addition to regulatory parameters, included a scenario that is more severe than those prescribed by the Basel III (Appendix IV, Table IV.1). The LCR-based liquidity stress tests covered two scenarios:

- *A Baseline scenario* which is based on a standard LCR applying the regulatory parameters set out by the Brazilian LCR requirement. Based on supervisory data, the overall LCR and the LCRs by significant currencies for the eight largest commercial banks (subject to the LCR requirement) were analyzed.

- *An Adverse scenario* which is broadly consistent with the solvency stress tests, and with the historical funding shocks faced by Brazilian banks for retail and nonfinancial wholesale funding. The assumption of government bond yields in the adverse scenario largely underpins the calibration of the haircut rates. The run-off rates for deposits were calibrated based on historical bank-level behavior during 2007–17, and differentiated by types (sight, savings and term deposits in both reais and FX) and by counterparties involved (natural individuals, small and medium-sized enterprises (SMEs), nonfinancial legal entities other than SMEs).[43] See Appendix IV for complete details on the calibration of the scenarios.

65. In the LCR-based tests, banks can counterbalance negative funding gaps by using their cash holdings, reserves, and standard lending facilities of the BCB. In the tests, banks were allowed to cover negative balances of cash inflows relative to cash outflows by obtaining additional liquidity from markets or through BCB's lending facilities. The use of unencumbered HQLA is subject to certain haircuts that reflect the decline in asset prices during financial stress and/or haircuts required by the BCB. As noted above, based on the BCB's regulatory rule, the stock of required reserves, that could be used to cover net cash outflows, was adjusted to increase in line with higher run-offs on deposits in the adverse scenario. In line with the Basel III standards, the possibility to access BCB's emergency liquidity assistance (ELA) was not taken into account.

66. Our sample of 12 banks are grouped into 4 categories to get a deeper understanding of short-term liquidity in the banking system. These are liquidity for: (i) the 12 largest commercial and development banks in the solvency stress test; (ii) the largest 10 commercial banks;[44] where the latter are further decomposed into (iii) the 5 D-SIBs; and (iv) the 5 largest non-SIBs.

[43] The adverse scenario uses historical data to calibrate the run-off parameters of retail deposits, operational deposits and funding from nonfinancial corporates, sovereigns, central banks, international organizations, public entities. The run-off parameters for deposits from SME are more conservative than historical data. Other parameters are obtained by means of an additional markup over the regulatory scenario.

[44] The two banks not being included have ample liquidity in the short run under both regulatory and adverse scenarios. They both have a large counterbalancing capacity in comparison to their net cash outflows in the short run (LCR comfortably above 1000 percent). This is because of their unique funding structure, as they hold mainly long-term assets backed by long-term liabilities. The combined total cash outflow of the two banks constitutes less than 1 percent and about 2 percent of the total outflows and inflows, respectively (in both the baseline and adverse scenario), whereas their HQLA constitutes 22 percent of the total HQLA. Hence, including these two banks inflates the liquidity at the aggregate level, which masks the actual underlying liquidity in the remaining banking system.

67. Results based on the standard (baseline) LCR show that Brazilian banks have ample liquidity buffers (Table 8, Figures 12 left panel). The aggregate LCR is 203 percent for 10 largest commercial banks and 248 percent for all 12 banks as of September 2017. Under this standard scenario, each bank has the LCR above the current regulatory requirement at 80 percent, and even above the 100 percent hurdle rate, which will be binding in 2019. This strength can be explained by the large stable retail deposit base, large holdings of government securities and reverse repos on the assets side, as well as the large share of secured funding collateralized by government securities on the liabilities side, which are not subject to any haircuts in the baseline scenario.

68. However, one D-SIB would face some short-term liquidity pressures if facing more severe shocks in the adverse scenario. Under this adverse scenario, banks lose between 10 and 30 percent of their retail and small business deposits, including sight and term deposits, in a month. Moreover, banks would experience a reduction in their unsecured and secured wholesale funding by 71 and 10 percent, respectively. Finally, a haircut of 9.35 percent, consistent with the spike in government bond yields and inflation assumption in the solvency tests, is applied to the entire portfolio of government securities.[45] One D-SIB (out of 10 banks) would see its LCR below the regulatory requirement at 80 percent, though with a small liquidity shortfall of R$31 billion (equivalent of less than 1 percent of the bank's assets and less than 1 percent of GDP). Another D-SIB would set its LCR slightly above 100 percent. The aggregate LCR would fall to 122 percent and 145 percent for the 10 and 12 banks, respectively. For the D-SIB with liquidity shortfalls, the use of all required reserves in HQLA would not be sufficient to bring the LCR above 100 percent; liquidity support through ELA would be required to cover the remaining gap.

Table 8. Brazil: Summary of the LCR-Based Stress Test Results

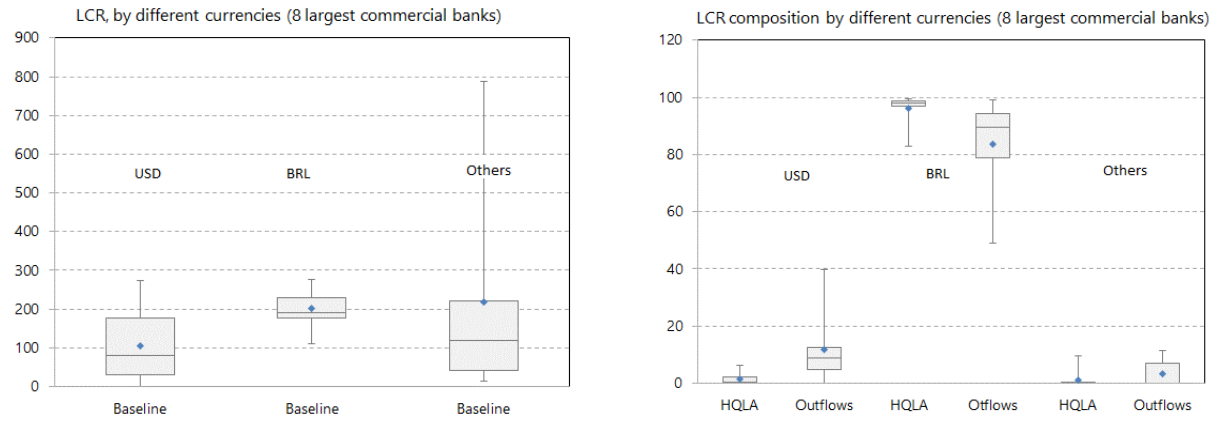
	Baseline				Adverse			
	12 largest banks	10 largest commercial banks			12 largest banks	10 largest commercial banks		
		All	DSIBs	Non-DSIBs		All	DSIBs	Non-DSIBs
Aggregate LCR	248	203	200	231	145	122	120	144
No. of banks LCR<100	0	0	0	0	1	1	1	0
No. of banks LCR<80	0	0	0	0	1	1	1	0
Liquidity shortfall								
BRL billion	0	0	0	0	30.6	30.6	30.6	0
% of GDP	0	0	0	0	0.5	0.5	0.5	0
% of banks' assets in sample	0	0	0	0	0.4	0.5	0.53	0
No. of banks use RR	0	0	0	0	1	1	1	0
No. of banks use ELA	0	0	0	0	1	1	1	0

Source: BCB; and IMF staff calculations.

[45] The haircut takes into account both: (i) the average market loss on the entire government securities portfolio from a spike in bond yield by 700 bps; and (ii) BCB's haircut on standard lending facilities. The former is calculated as an average loss on holdings of the entire government bond portfolio, across the 12 banks in our sample, which consists of different types and maturities, ranging from Selic-indexed bonds facing no market loss to fixed-rate bonds with maturity greater than 5 years facing 49 percent market loss in its value.

69. Moreover, the (baseline) LCR in U.S. dollar (USD) is below 35 percent for three out of eight largest commercial banks (Figure 11).[46] The share of net cash outflow in USD constitutes more than 13 percent of total cash outflow for these three banks.[47] This is because Brazilian banks do not hold sufficient FX HQLA that could be used to counterbalance negative FX-denominated net cash outflows. However, FX liquidity shortfalls are small and equivalent to less than 1 percent of foreign reserves (R$9.3 billion); overall LCRs for these three banks are well above 100 percent.

Figure 12. Brazil: The Regulatory LCR Test by Currency[1]



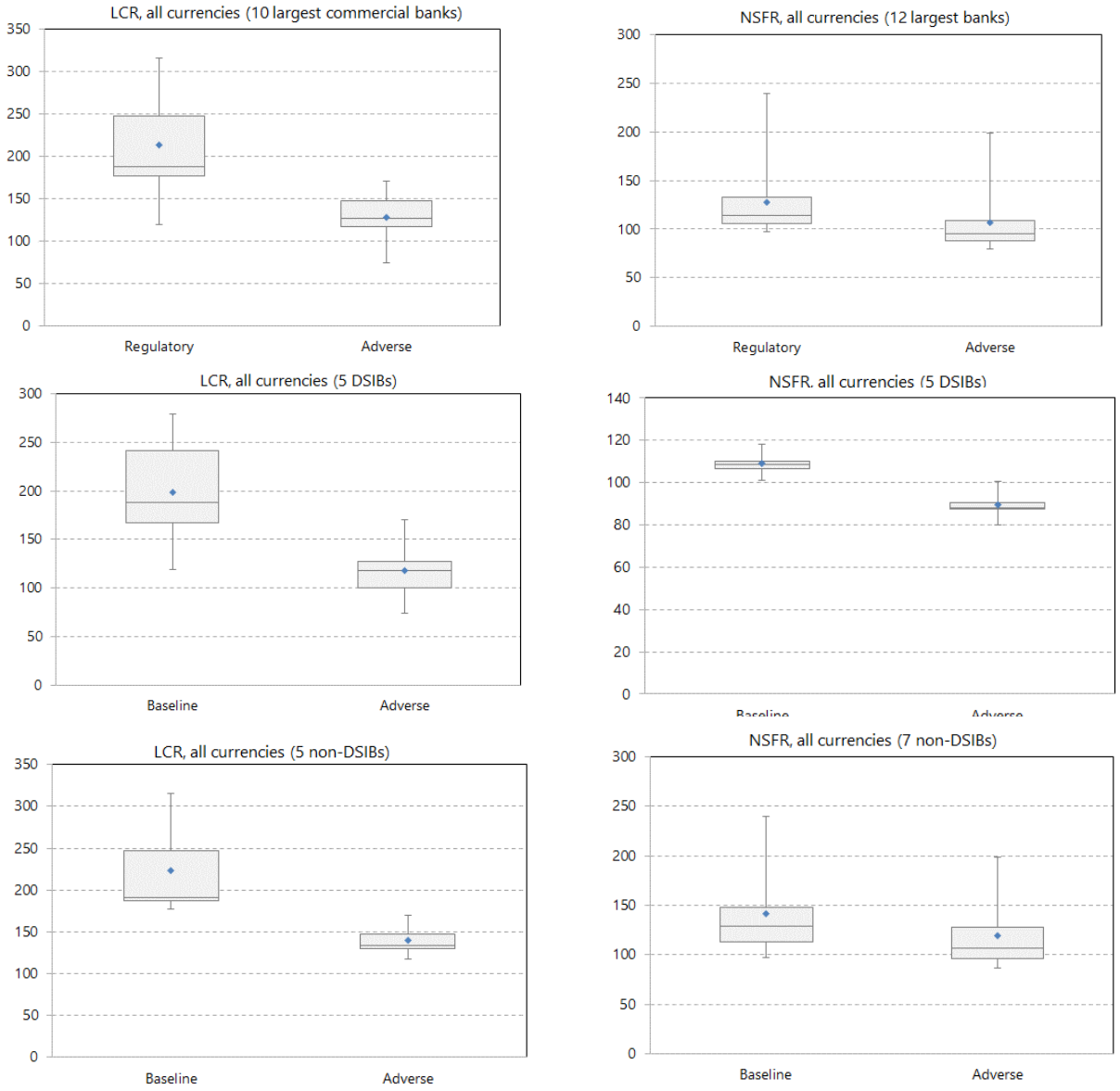
Source: IMF staff estimates.

[1]The box spans the interquartile range (ends of the box are the upper and lower quartiles), median is marked by a vertical line, and the whiskers are the two lines outside the box that extend to the highest and lowest observations. The blue dot is the mean.

[46] LCR in foreign currency is required as a monitoring tool.

[47] Foreign funding constitutes 12 percent of total funding maturing within 30 days for one of these banks and less than 3 percent for the remaining two banks.

Figure 13. Brazil: The LCR and NSFR Tests[1]



[1]The box spans the interquartile range (ends of the box are the upper and lower quartiles), median is marked by a vertical line, and the whiskers are the two lines outside the box that extend to the highest and lowest observations. The blue dot is the mean.

70. Results from the baseline scenario in the LCR-based tests were compared to the BCB's IL ratio. The IL ratio measures whether banks have enough liquid assets to cover their short-term (1 month) cash-flow needs in a historical stress scenario, defined and calibrated by the BCB (since 2002). The IL ratio is computed based on granular data and is a complementary risk measure to the LCR. Table 2 in Appendix IV presents the key differences between the two methodologies.

Table 9. Brazil: Short-Run Liquidity Results: Brazil's IL Versus Regulatory LCR

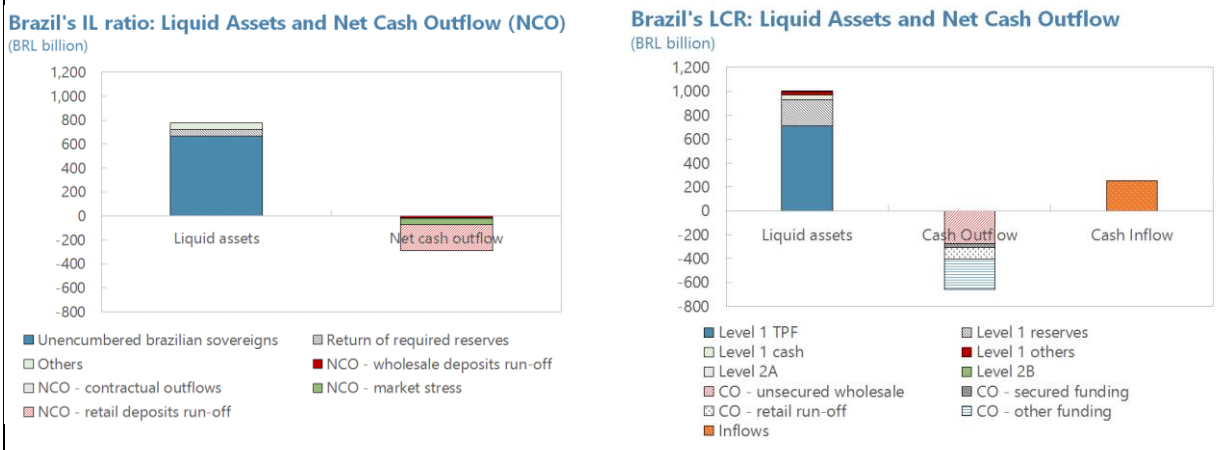
	IL							LCR (baseline)		
(in BRL billion)	All banks	12 largest banks	10 largest banks 1/	DSIBs	Small & micro	Medium	Large	12 largest banks	10 largest banks 1/	DSIBs
Total Number of Banks	135	12	10	5	123	6	6	12	10	5
Banks with No Liquidity Shortfall	116	12	10	5	104	0	0	12	10	5
Banks with Liquidity Shortfall	19	0	0	0	19	0	0	0	0	0
Net Cash Outflows	325	291	280	241	78	41	250	404	403	366
Value of Liquid Assets 2/	895	802	608	522	191	120	682	1002	816	731
Aggregate Coverage Ratio (IL)	275	275	217	217	245	289	273	248	203	200

1/ This excludes Brazil's development bank

2/ In case of IL, this is before haircuts whereas in the case of LCR it is the value of assets after haircuts.

Source: BCB; and IMF staff calculations.

Figure 14. Brazil: Short-Run Liquidity Results: Brazil's IL and LCR[1,2]



Source: BCB; and IMF staff calculations.

[1]NCO stands for net cash outflow and CO stands for cash outflow.

[2]The denominator in the IL ratio is a sum of retail deposits run-off, wholesale deposits run-off, market stress and net contractual outflows.

71. While the LCR ratio is less than the IL on an aggregate level, this does not always hold true at the individual bank level (Table 9). Results suggest that, in September 2017, the aggregate IL was 271 percent for the 10 largest commercial banks and 275 percent for all 12 banks, which is higher than the baseline LCR ratio, thus resulting in a larger liquidity buffer. Based on the IL ratio, 19 small and micro banks would face liquidity shortfalls within a 30-day horizon, mainly driven by large outflows of wholesale and retail deposits. These banks would face a liquidity shortfall of

R$10 billion.[48] On an aggregate level, the IL is more conservative in its coverage of liquid assets, mainly reserves, in the numerator. However, the net cash outflow in the LCR is larger than in the IL owing to two factors: a) the assumptions on wholesale deposits run-off which are not as strict in the latter, particularly for DSIBs; and b) run-off on retail deposits and net contractual outflows, which are based on observed historical outflows (in the last 100 days), which are not as severe (see Figure 13).

D. NSFR-Based Stress Tests

72. The NSFR-based tests assessed the maturity mismatch, utilizing the BCB's Structural Liquidity Ratio (ILE) developed based on the NSFR methodology. For the assessment of the liquidity risk over a longer horizon, the NSFR-based tests were conducted using supervisory data that uses the BCB's internal definitions for available stable funding for calculating the SLR.[49] While banks are not yet required to meet the NSFR—it will be effective from October 2018 onwards—the tests provide a useful complementary view of banks' funding profile in relation to the composition of their assets and off-balance sheet activities at a one-year horizon. The exercise was carried based on regulatory and stress parameters (Appendix IV, Table 3).

73. Two scenarios consistent with the ones in the LCR-based tests were considered: (i) a *baseline scenario*, which assumes regulatory parameters; and (ii) an *adverse scenario* consistent with the adverse scenario used in the LCR-based tests and bank solvency stress tests. The latter scenario is to assess banks' capacity to maintain stable funding in a stressed macrofinancial setup under the assumption that banks continue their credit operations.[50]

74. Results based on the baseline NSFR do not suggest large maturity transformation at the aggregate level (Table 10, Figure 12 right panel). Under the NSFR methodology, available stable funding for the twelve largest banks amounts to R$4,027 billion in September 2017 and the required stable funding to R$3,486 billion, resulting in an aggregate NSFR of 116 percent, comfortably above the minimum requirement of 100 percent. This mainly reflects the high regulatory capital and high reserve requirements of Brazilian banks. Nevertheless, at an individual level, two non-SIB private banks would experience a small stable funding gap (with individual NSFRs just slightly below 100 percent).

[48] These banks have other sources of funding such as liquidity lines with their shareholders or with nonresident parents/affiliates and secondary credit market. These alternative funding sources are not categorized as liquid assets by the BCB methodology.

[49] Since 2015, the BCB has monitored the ILE ratio, which is a metrics based on the NSFR methodology. The supervisory data is based on BCB's internal definitions for retail/non-retail and stable/less stable deposits, in which only part of the Brazilian regulatory framework is replicated.

[50] Compared to the baseline, the parameters of the adverse scenario in the NSFR were adjusted: (i) using the haircuts and the one-year cumulative run-off rates in the cash-flow-based liquidity analysis (discussed below) for the categories that are directly comparable between the two tests; or by (ii) 10 percentage points, for other categories.

Table 10. Brazil: Summary of the NSFR-Based Stress Test Results

	Baseline			Adverse		
	12 largest banks			12 largest banks		
	All	DSIBs	Non-DSIBs	All	DSIBs	Non-DSIBs
Agg. NSFR	116	111	138	98	91	127
No. of banks NSFR<100	2	0	2	6	4	2
Stable funding gap						
BRL billion	1.0	0.0	1.0	289	277.0	11.5
% of banks' assets in sample	0.0	0.0	0.1	4.8	5.8	0.9
% of GDP	0.02	0.00	0.02	4.61	4.43	0.18

Source: BCB and IMF calculations.

75. In the adverse scenario, however, six banks would not be able to maintain a stable funding profile in relation to the current composition of their assets and off-balance sheet activities within one year. In such an event, the aggregate NSFR would fall to 95 percent, translating into a stable funding gap of R$288 billion (equivalent to 4.6 percent of GDP and 4.7 percent of banks' assets). The NSFR of the 5 D-SIBs would fall to 91 percent (four out of five seeing their NSFRs in the range of 80-91 percent), with a stable funding gap of R$227 billion. This is because of the reliance on redeemable deposits—particularly less stable retail deposits—which were assumed to face a cumulative outflow of 35 percent within one year.

E. Cash-Flow Analysis

76. The cash-flow analysis was based on seven maturity buckets to capture the comprehensive time structure of banks' cash inflows and outflows. The cash-flow analysis was conducted for different time horizons, from 1 day to a period up of 6 months, in both local and foreign currencies, where the latter is largely denominated in USD (close to 90 percent). The maturity ladder was composed of the following time buckets: overnight, 2 days to 1 week, 1 week to 2 weeks, 2 weeks to 1 month, 1 month to 3 months, 3 months to 6 months, and over 6 months.

77. The cash-flow analysis assessed banks' resilience to liquidity risk based on the net cash balances following funding outflows. In the exercise, banks would have liquidity shortfalls if they experience a negative net cash balance after fully utilizing their counterbalancing capacity. The net cash balance consists of the existing cash position, the counterbalancing capacity (i.e., the ability to obtain additional liquidity), and the amount of net funding inflows. Only when banks had no eligible collateral to access the standard facilities, banks could also obtain ELA under more stringent conditions and/or authorities could waiver reserve requirement.[51] It must be noted, that only

[51] At the banking system level, eligible assets for BCB's ELA (after haircuts) make up 5 percent of total assets and 20 percent of counterbalancing capacity. There are no asset class delimitations in the current framework for the eligible collateral for ELA. In the exercise, ELA only considered loans with maturity beyond 6 months to avoid double-counting with the credit inflows.

government bonds are accepted as collateral for standard BCB lending facilities. On the other hand, eligible collateral for BCB's ELA is composed of eligible loans provided by banks. While these loans are traded between financial institutions, they do not have a structured secondary market (such as sovereigns or stocks), and hence subject to more stringent haircuts. The pass-fail criterion in the test is defined by the need for a waiver on required reserves and/or the use of ELA: a bank that needs ELA and/or use required reserves to continue operating would fail. In these cases, the results of both scenarios—with and without access to ELA and/or with and without waiver on required reserves—are reported.[52] It must be noted, however, that historically, ELA has not been used for more than 20 years, due to, among other things, the existence of relatively easier access to open-bank assistance from the FGC (Credit Guarantee Fund; see Technical Note on crisis management). The policy framework for providing ELA to banks is currently under review.

78. The cash-flow analysis was conducted based on the following assumptions. The exercise considered a scenario that is broadly consistent with the adverse scenario in the LCR-based tests outlined above. The run-off rates for the cash-flow analysis are kept consistent with the LCR-based tests (for shorter maturities) and the NSFR-based tests (for longer maturities) where the pace of deposit outflows was assumed to slow down as the time horizon increases (Appendix IV, Table IV.4). This exercise is based on the going concern assumption: banks' actions do not compromise banking relations with important borrowers and cause no significant business disruptions. The exchange rate assumption is critical for converting the net cash balance in foreign currencies into reais, while the government bond yields and inflation assumption largely underpins the calibration of the haircuts.[53] Liquid assets eligible as central bank collateral (government securities only) are subject to a haircut depending on the type and maturity of bond, ranging from Selic-indexed bonds facing no market loss to fixed-rate bonds with maturity greater than 5 years facing 49 percent market loss in its value.[54]

79. The cash-flow analysis identified three banks that would face liquidity shortfalls within the 180-day horizon (Table 11). In the event of a cumulative group-wide deposit outflows of 21 percent in one month and 25 percent in six months**,** one D-SIB would face a liquidity shortfall within a 30-day period, and two additional non D-SIBs would have insufficient liquidity for a 180-day horizon. If banks draw down on required reserves (before access to ELA), all abovementioned banks would be able to remain liquid for a 180-day horizon.[55] If banks maintain reserve requirement instead, access to ELA from the BCB is not sufficient to help these banks confront withdrawals of funding. The analysis confirms the findings of the LCR-based tests that the same D-SIB would face

[52] In order to inject liquidity in the banking system during the 2008 global financial crisis, the BCB lowered the reserve requirement on time deposits for the entire banking system, which led to the reduction of required reserves from just over BRL 250 million in October 2008 to about BRL 180 billion (approximately, a 30 percent release).

[53] Banks are assumed to keep a static hedging structure.

[54] The LFTs (Selic indexed bonds) are notional indexed zero-coupon bonds, indexed by the Selic rate. In such a case, either the discount rate and the indexation rate are the same, making the LFT insensitive to movements in interest rates. Hence, their MtM values does not change due to yield curve fluctuations.

[55] The historical and the planned sequence of assistance of banks in a liquidity risk event is to use reserves first, then followed by ELA, if required.

short-term liquidity problems in the adverse scenario if required reserves are not included in HQLA. Five banks could face liquidity problems for longer than 6 months, which is consistent with the findings of the NSFR-based tests that six banks will not meet the NSFR at 100 percent.

Table 11. Brazil: Cash-flow Stress Test Result in Domestic Currency

A. Banks Maintain Required Reserves

Number of Banks (out of 12) with Liquidity Shortfall in Domestic Currency						
Before use of ELA and/or RR						
	Time period					
	1d	1-7d	1-2w	2w-1m	1-3m	3-6m
Total	1	1	1	1	2	3
DSIBs	1	1	1	1	0	1
Others	0	0	0	0	2	2
After use of ELA						
	Time period					
	1d	1-7d	1-2w	2w-1m	1-3m	3-6m
Total	0	0	1	1	0	3
DSIBs	0	0	1	1	0	1
Others	0	0	0	0	0	2

B. Banks Drawdown Required Reserves

Number of Banks (out of 12) with Liquidity Shortfall in Domestic Currency						
Before use of RR and/or ELA						
	Time period					
	1d	1-7d	1-2w	2w-1m	1-3m	3-6m
Total	1	1	1	1	2	3
DSIBs	1	1	1	1	0	1
Others	0	0	0	0	2	2
After use of RR						
	Time period					
	1d	1-7d	1-2w	2w-1m	1-3m	3-6m
Total	0	0	0	0	0	0
DSIBs	0	0	0	0	0	0
Others	0	0	0	0	0	0

Source: IMF staff calculations.

80. Seven banks would deplete all their FX liquidity buffers within six months (Table 12). Four D-SIBs and three other banks would face a FX liquidity shortfall in the magnitude of R$52 billion after sale of securities within 180 days in the adverse scenario (about 4.3 percent of

foreign reserves).[56] This is because banks thus do not hold sufficient FX assets that could be used to counterbalance negative FX net cash outflows.[57]

Table 12. Brazil: Cash-flow Stress Test Result in Foreign Currency

Number of Banks (out of 12) with Liquidity Shortfall in FX						
Before use of ELA and/or RR						
	Time period					
	1d	1-7d	1-2w	2w-1m	1-3m	3-6m
Total	2	2	2	1	4	7
DSIBs	1	1	0	0	3	4
Others	1	1	2	1	1	3
After use of ELA						
	Time period					
	1d	1-7d	1-2w	2w-1m	1-3m	3-6m
Total	2	2	2	1	4	7
DSIBs	1	1	0	0	3	4
Others	1	1	2	1	1	3
After use of ELA & release of RR						
	Time period					
	1d	1-7d	1-2w	2w-1m	1-3m	3-6m
Total	2	2	2	1	4	7
DSIBs	1	1	0	0	3	4
Others	1	1	2	1	1	3

Source: IMF staff calculations.

F. Reputational Crisis Scenario

81. The LCR-based tests were also used to analyze Brazilian banks' ability to withstand a reputational crisis scenario. Two scenarios tailored to stresses based on historical reputational events faced by Brazilian banks were considered (see Technical Note on crisis management for details):

- A *localized reputational crisis scenario* where the run-off rates were calibrated to match the volatility of funding during recent historical reputational events. The run-off rates on unsecured wholesale funding and less stable retail deposits are higher than those in the adverse scenario, while the run-off on secured funding are lower and the run-off on stable retail deposits are

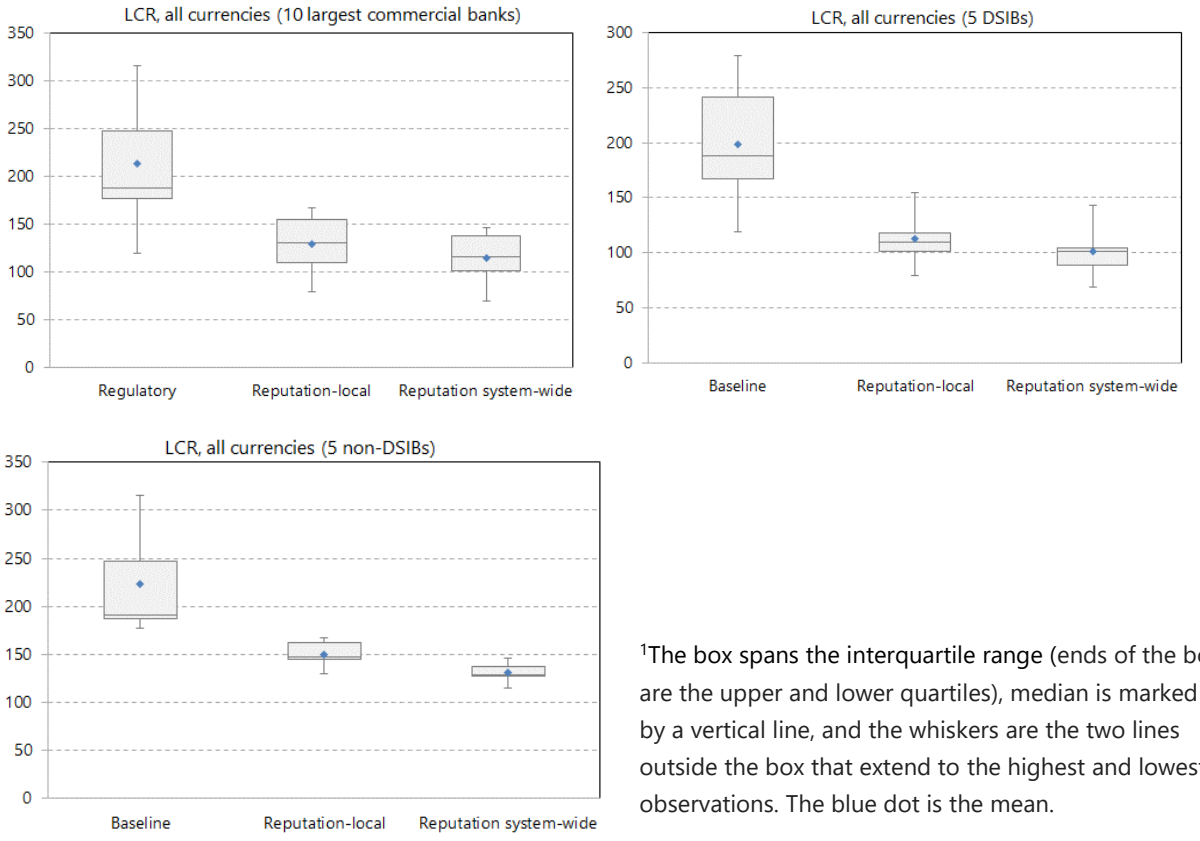
[56] Foreign currency deposits are obtained through the Report on Liquidity Risk that contains the details of LCR calculation. The report segregates the exposures by customer type and insurance coverage, but does not differentiate in types of deposits, nor the specific time bucket within one month. These exposures were thus considered in more conservative categories. BCB does not have information regarding cash-flows of deposits in subsidiaries above 1 month.

[57] Brazilian banks obtain external funding, through the issuance of securities and access to credit line abroad, which is transferred to local operations and applied in assets denominated in reais (free-purpose funding).

marginally lower.[58] Since the assumption is a localized event, Basel III regulatory haircuts were applied.

- A *system-wide reputational crisis scenario* which is a hypothetical (and unlikely) exercise that aims at capturing the possibility of a broader loss of confidence in major Brazilian banks, leading to system-wide reputational concerns and resulting in fire sales that imply higher haircuts.

Figure 15. Brazil: LCR in Reputational Crisis[1]



[1]The box spans the interquartile range (ends of the box are the upper and lower quartiles), median is marked by a vertical line, and the whiskers are the two lines outside the box that extend to the highest and lowest observations. The blue dot is the mean.

82. Banks appear broadly resilient to a localized reputational shock, but two D-SIBs would face liquidity shortfalls in the system-wide reputational crisis event (Figure 15). The aggregate LCR would fall to 119 percent for the 10 largest commercial banks (and to 142 percent for all 12 banks) in the localized reputational crisis scenario. One D-SIB would fall below the regulatory LCR hurdle rate of 80 percent, though with a small liquidity shortfall of R$25 billion (less than 0.5 percent of banks' assets). However, counting all required reserves in the HQLA would still not be sufficient to cover the liquidity gap in this bank (the same bank as the one in the adverse scenario in the LCR-based tests and cash-flow analysis). In the event of fire sales under a system-wide reputational crisis

[58] The run-off on drawdown on committed credit/liquidity facilities is also lower since the assumption is a localized reputational event.

event, two D-SIBs would experience liquidity shortfalls of R$56 billion (3.2 percent of failing banks' assets), where one of them would need ELA (after using all required reserves) to cover their liquidity gap. The aggregate LCR would fall to 107 percent for the 10 largest commercial banks (and to 127 percent for all 12 banks).

83. The BCB's internal study on reputational risk estimates a lower liquidity shortfall. Comparing the IMF's LCR-based results in the localized reputational crisis scenario with the BCB's internal tests showed the same two banks that would face a liquidity shortfall in such a scenario. However, the BCB estimated a considerably lower liquidity shortfall for these banks, where these differences were driven by both a higher value of liquid assets and a lower value of net cash outflow.

G. Policy Recommendations

84. The liquidity stress test results confirm the strong liquidity buffers of Brazilian banks, but liquidity risk may arise in some parts of the banking system in extreme scenarios. Although the three types of tests are not fully comparable—the cash-flow analysis captures all cash inflows and outflows, the LCR-based test and NSFR-based test while accounting for some cash inflows focuses on cash outflows based on overall liquidity with no currency differentiation up to 30 days and one-year horizon respectively—they highlight that some large banks may need to draw down on require reserves and/or obtain ELA in severe financial stress situations. Nevertheless, total liquidity shortfalls appear to be manageable in the reach of BCB's capacity, including available foreign reserves. The main challenge is how to strengthen BCB's liquidity provision framework, including ELA (see Technical Note on Crisis Management).

85. The BCB's liquidity monitoring tools have been advanced in recent years; however, their stress testing methodology should be further enhanced going forward:

- **Perform liquidity stress tests using the structure of cash flows at various horizons.** The authorities should adopt a maturity ladder exercise by including features of the FSAP cash-flow analysis, and considering varied degrees of stress in both local and foreign currencies.
- **NSFR:** In addition to the SLR, which is a proxy NSFR measure, the authorities' efforts to implement the NSFR requirements on a consolidated basis later in 2018 are welcome.

86. The authorities should ensure consistency across different sources of data. The BCB uses multiple sets of data for liquidity monitoring purposes, from daily Trade Repository granular data to monthly financial statements and specific risk reports. Although definitions and scope of these different datasets may not be exactly the same, the data submitted by individual banks to the BCB through the Report on Liquidity Risk that contains the details of the LCR calculation should be aligned with the data from Trade Repository and other sources used to calculate the proxy NSFR and BCB's IL ratio. This will help assess the calculation and reporting accuracy of data by banks, as well as ensure consistency and comparability across different liquidity tests.

BANK CONTAGION ANALYSIS

A. Interbank Network

87. The risk of contagion within the banking system is assessed using a network model (Espinosa-Vega and Solé, 2010). The analysis is based on supervisory data that provide details of bilateral interbank gross exposures among the 12 largest banks in Brazil as of 2017Q3. Bilateral exposures include interbank deposits, term deposits, derivates, repos/reverse repos, and any other securities issues by banks (including both on- and off-balance sheet items). The data also have the information on each of the 12 bank's exposures to other Brazilian banks (the total exposures to the remaining 123 banks) as well as the breakdown between secured and unsecured exposures.[59] The exercise comprises both stand-alone analysis and integrated analysis with bank solvency stress tests.

- **Stand-alone interbank network analysis.** This analysis includes direct contagion arising from a stand-alone solvency event, whereby default of a bank triggers direct credit losses in other banks, and subsequent fire sales caused by funding shocks (see Appendix V for the detailed methodology). It assumes the hypothetical default of each bank, one at a time, on all its interbank obligations, and assesses the impact on other banks. A bank is assumed to default when the bank's CET1 ratio drops below 4.5 percent of risk-weighted assets, which is the regulatory requirement.[60] If the default of any given bank on its interbank obligations leads to the default of another bank in the system, a subsequent round is calculated to assess the impact of the second bank's default on all other banks, and so on (i.e. "cascade effects"). The recovery rates of interbank claims, in the baseline, are assumed to be 50 percent—so the creditor bank will suffer a loss equivalent to 50 percent of its exposure to the defaulted bank, which is the loss given default parameter (LGD).[61] Regarding funding shocks, in addition to the direct loss of capital, a bank needs to replace a fraction (50 percent) of the funding lost due to the default. It does so by selling other assets at heavy discounts in the market (assuming a 50 percent haircut on the assets being sold), and these fire sales cause further losses of capital. The main advantage of this approach is that we can directly identify the sources of spillovers and estimate the impact of spillovers on the system. The caveat is that contagion happens instantaneously, and it assumes that there is no time for banks to take measures to mitigate the negative effects of spillovers in between each round of contagion.[62]

[59] The data in the matrix does not include a breakdown of the interbank exposures with and amongst each of the small 123 banks individually, and only as a group.

[60] While there are no automatic thresholds or indicators for triggering bank resolution in Brazil, the objective is to resolve a bank when there is still positive equity.

[61] The analysis assumes a 90 percent recovery rate for secured interbank lending, and a zero-recovery rate for unsecured lending, resulting in an overall LDG on the total interbank exposure of 50 percent based on the weighted average.

[62] We exclude the possibility of institutions raising new capital, and assume that the loss induced by a funding shortfall is absorbed by bank's capital.

- **Solvency-interbank contagion interaction.** To incorporate potential contagion effects into the solvency stress tests, direct credit losses associated with interbank exposure would also affect banks' capital based on the interbank network analysis. The exercise is conducted sequentially in each year during the stress horizon. More specifically, after the impact of adverse macrofinancial developments on banks' capital is estimated in a year based on the solvency stress test, the impact of default events of (possibly multiple) banks is added on top of the solvency results to calculate the post-contagion capital position, which would serve as the starting position for the solvency stress tests in the following year. Note that this combined analysis does not consider the funding loss channel.[63] The main advantage of this approach is that we can capture additional credit losses related to interbank cross-exposures within the solvency tests. The caveat is that we assume that the matrix of bilateral exposures does not change throughout the stress horizon. The results of this integrated analysis were presented together with the bank solvency stress tests above.

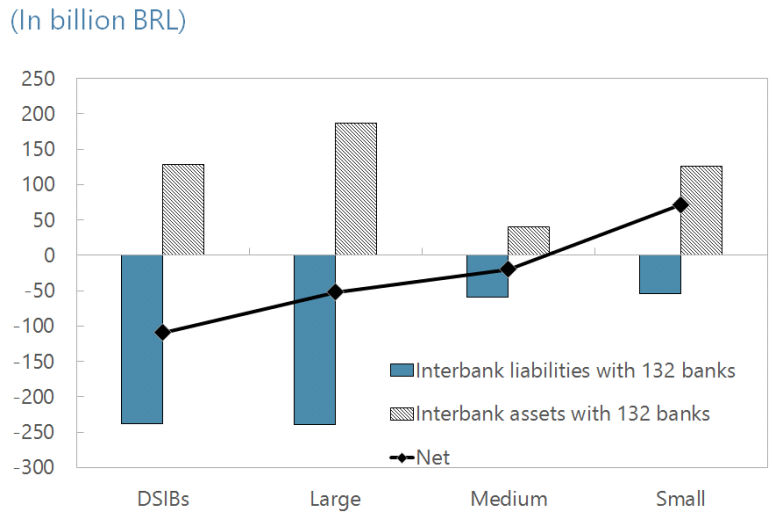
88. The six large banks combined are net borrowers in the interbank market, while smaller banks are net lenders (Figure 15). The large banks have the highest interbank assets relative to their CET1 capital, followed by the small banks. By September 2017, about 42 percent of the banking system in terms of assets are net borrowers. Interbank exposures among 12 largest banks are not found to be large (2.4 percent of banking system assets and 2.8 percent of GDP). However, this constitutes only half of their interbank exposures, where the remaining half comes from their interbank exposures to the 123 small and micro banks. On an average, 67 percent of the interbank exposures are secured, almost all of which are overnight repos collateralized by government securities.

89. The stand-alone analysis reveals that contagion risks stemming from interbank exposures are very limited. In six simulations where each of the large banks defaulted, only one large bank (bank 1) triggered the default of one medium-sized bank (bank 9).[64] With the threshold at 4.5 percent of the CET1 ratio, the hypothetical default of two of the large banks (bank 5 and bank 1) individually would reduce system-wide total capital by around 11 and 10 percent, respectively (Figure 16). The index of vulnerability, which is the percentage point of average capital loss due to the default of all other institutions, would be 18 percent at most (in bank 9).

[63] This is because of the methodology used and since funding loss channel is indirectly being captured in the solvency stress tests.

[64] Banks 1–6 are the large banks and banks 7–12 are the medium-sized banks.

Figure 16. Brazil: Interbank Assets and Liabilities



Sources: Authorities.

90. To evaluate the sensitivity of the result to parameter assumptions, the same simulation exercise is repeated with different LGD and funding replacement parameters:

- Figure 17 compares the results of simulations with different LGD parameters. With increasing magnitude of the credit shock, the large banks 1, 2, 3 and 5 become increasingly contagious (Figure 17, left panels): if the LGD rate is assumed to be 100 percent (as opposed to 50 percent in the baseline) large bank 5 failure would impair 25.5 percent of the other banks' capital, and large bank 1 failure would impair 12 percent of the other banks' capital. In the former case, large bank 1's capital would be completely wiped out, and default of bank 1 would completely impair medium-sized bank 9's capital in both cases.

- Medium-sized bank 9's vulnerability greatly depends on the LGD rate (Figure 17, right panels). If the interbank LGD rate is moderate, bank 9 would not be affected as much—the average impairment of bank 9's capital is only 2.6 percent in case LGD is 0 percent (i.e. funding shock only). If the LGD rate is high, bank 9 would be greatly affected—the average impairment of bank 9's capital is 32 percent in case LGD is 100 percent. Similar results hold for large banks 1 and 3.[65]

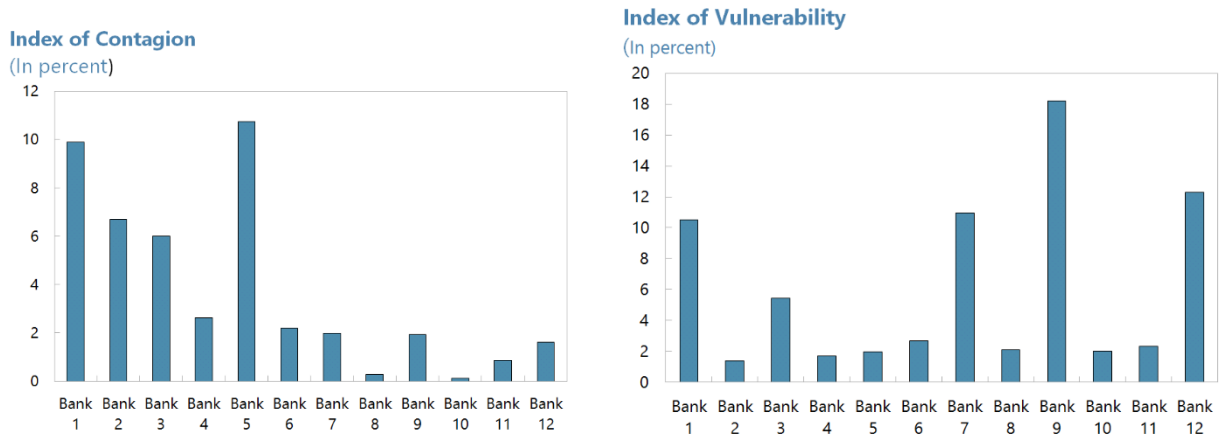
- Figure 18 compares the results of simulations with different funding replacement parameters. With an increasing magnitude of the funding shock, the contagiousness of bank 1 increases substantially from 3 percent under the assumption of 0 percent funding replacement to 17 percent. The vulnerability of medium-sized bank 12 is very sensitive to the magnitude of the funding shock. On the other hand, failing medium-sized bank 9 is vulnerable even when the

[65] It must be noted, however, that a LDG of 100 percent is too extreme given that 60 percent of the exposures on an average are secured.

funding stress is moderate—under 0 percent funding replacement, bank 9 would suffer 16 percent capital loss (as opposed to 18 percent in the baseline).

- All of these sensitivity results reflect the fact that the vulnerability in Brazil's domestic interbank linkages amongst the 12 largest banks arises from both large exposures for some banks to particular banks in the system (especially, the exposures of bank 9 against bank 1, and bank 1 against bank 5), and from the funding side for some other banks.

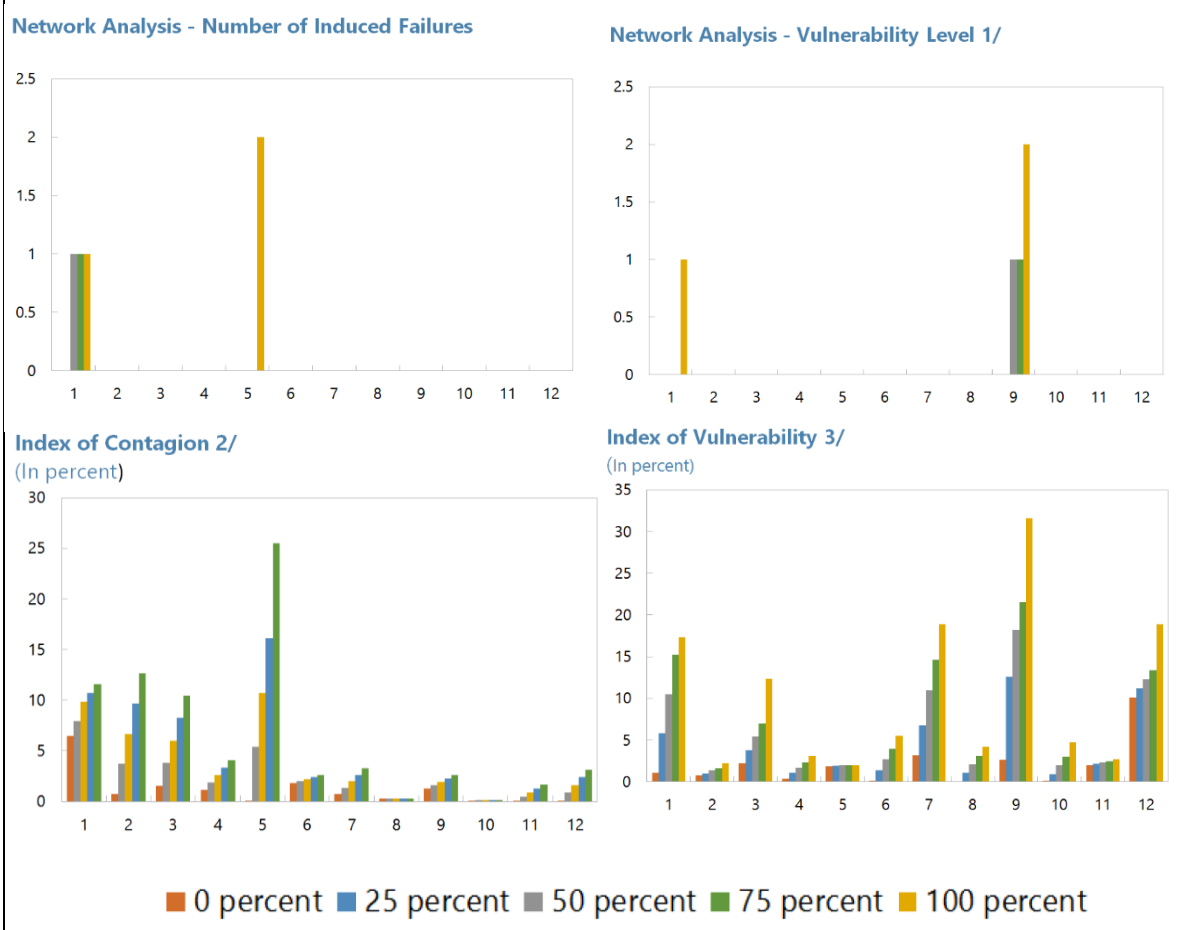
Figure 17. Brazil: Interbank Exposures[1]



Sources: BCB and IMF staff calculation.
[1] Index of contagion is the percent of total capital losses in the system due to the failure of each bank, while index of vulnerability shows the average of capital losses of each bank due to the failure of all other banks.

91. The default of small and micro banks would not cause a failure of any other Brazilian bank (Figure 19). The hypothetical default of all small and micro banks simultaneously (which constitutes an 18 percent fall in the system's CET1) could, on average, reduce the capital of the rest of the banks by 23 percent through interbank exposures in the baseline. However, the 12 largest banks' vulnerability to the failure of the small and micro banks greatly depends on the LGD rate. If the LGD rate is high, these banks will be greatly affected—the average impairment of bank capital is 36 percent in case LGD is 75 percent; and would eventually induce default of 3 medium-sized banks. As a group the small and micro banks have a low index of vulnerability, however, at an individual bank level this might not hold (could not be tested owing to data constraints).

Figure 18. Brazil: Result of the Simulation Study of 12 Largest Brazilian Banks: Sensitivity to the LGD Assumption



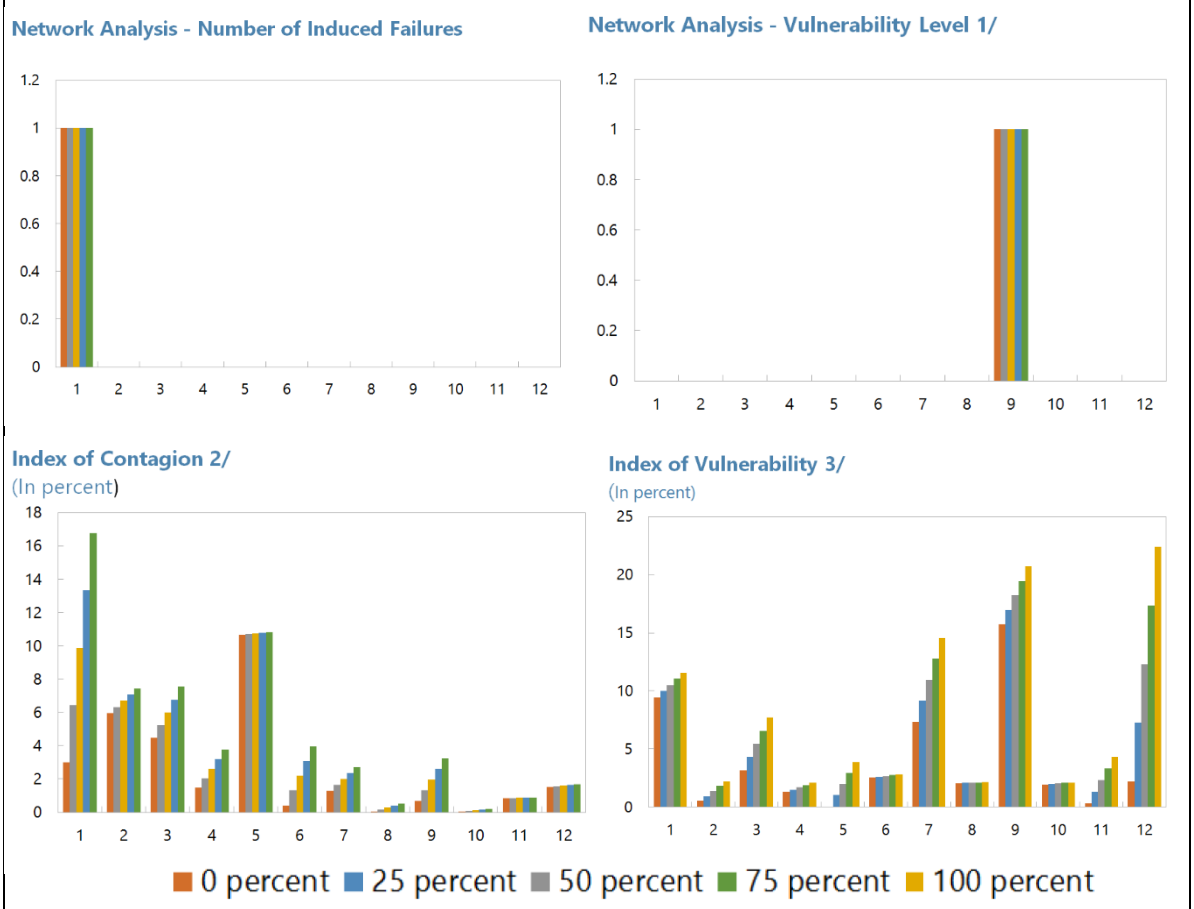
Sources: BCB and IMF Staff calculations

1/ Number of simulations in which each bank fails.

2/ Total capital impairment in other banks due to the failure of each bank (percentage of the original total capital in other banks).

3/ Average capital impairment of each bank due to the failure of other banks (percentage of the original capital in the bank).

Figure 19. Brazil: Result of the Simulation Study of 12 Largest Brazilian Banks: Sensitivity to the Funding Replacement Assumption



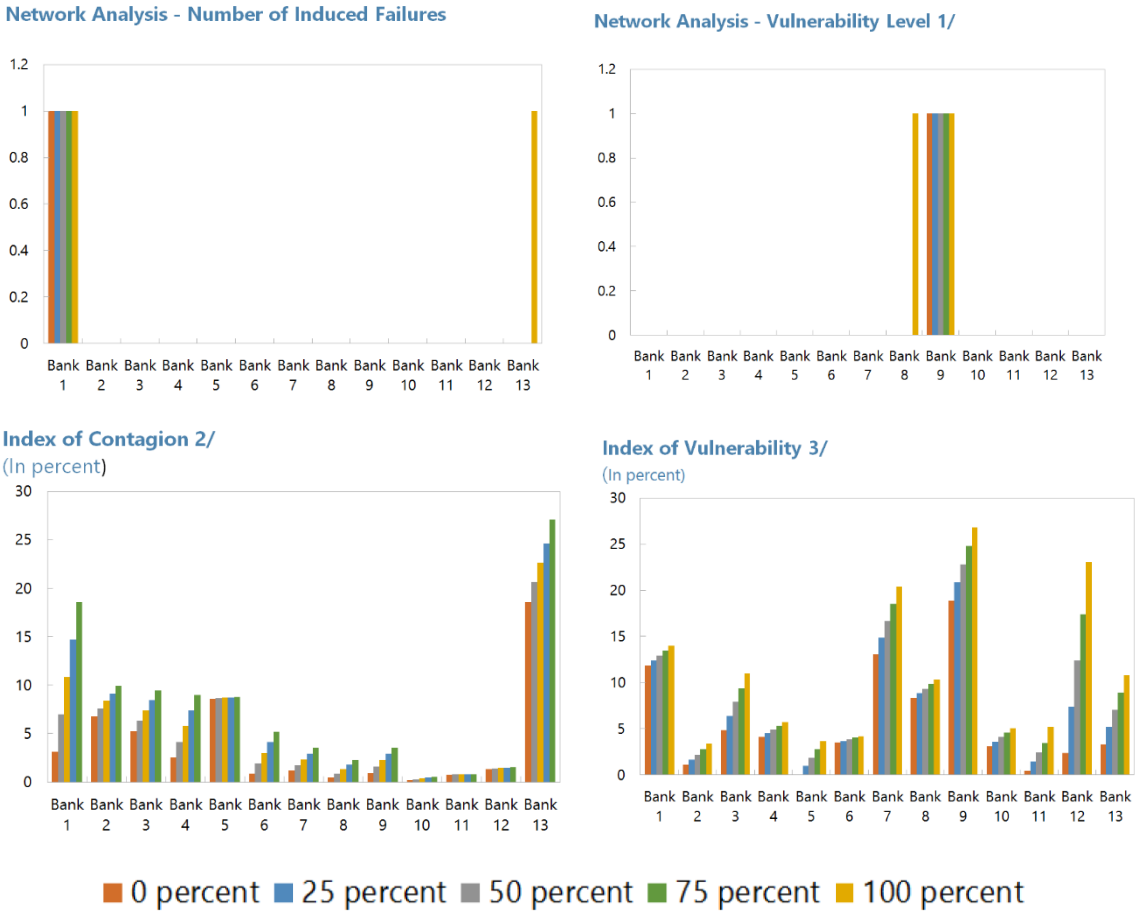
Sources: BCB and IMF Staff calculations

1/ Number of simulations in which each bank fails.

2/ Total capital impairment in other banks due to the failure of each bank (percentage of the original total capital in other banks).

3/ Average capital impairment of each bank due to the failure of other banks (percentage of the original capital in the bank).

Figure 20. Brazil: Result of the Simulation Study of 135 Brazilian Banks: Sensitivity to the Funding Replacement Assumption



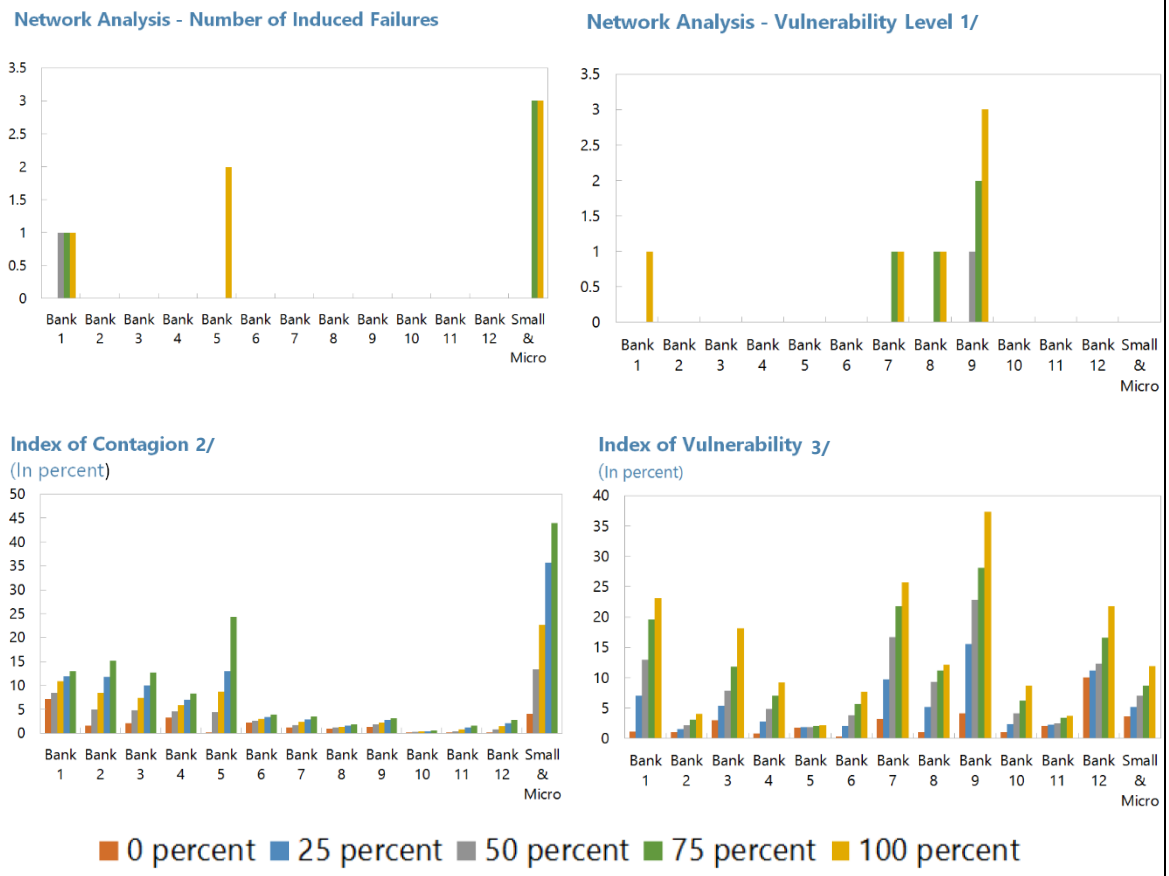
Sources: BCB and IMF Staff calculations

1/ Number of simulations in which each bank fails.

2/ Total capital impairment in other banks due to the failure of each bank (percentage of the original total capital in other banks).

3/ Average capital impairment of each bank due to the failure of other banks (percentage of the original capital in the bank).

Figure 21. Brazil: Result of the Simulation Study of 135 Brazilian Banks: Sensitivity to the LGD Assumptions



Sources: BCB and IMF Staff calculations

1/ Number of simulations in which each bank fails.

2/ Total capital impairment in other banks due to the failure of each bank (percentage of the original total capital in other banks).

3/ Average capital impairment of each bank due to the failure of other banks (percentage of the original capital in the bank).

CORPORATE SECTOR ANALYSIS

A. Overview

92. The corporate sector shows moderate signs of recovery from the recession, but vulnerabilities linger among financially weak firms that constitute a large fraction of the sector. Low profitability remained a challenge especially for firms in the energy sector where their return on equity fell below the interest rates in 2017Q3. About two-thirds of firms in the services sector faced difficulty in servicing their debt solely relying on operating income, while at the same time firms in this sector were highly leveraged. Macro-financial shock could substantially raise debt at risk in the corporate sector. While corporates with international activities utilize a reasonable degree of financial and operational hedges against their FX exposures, profitability and interest rate shocks could double the amount of debt at risk under the downturn scenario, especially in manufacturing and energy sectors. The authorities should closely and continually monitor trends in the corporate sector and enhance the insolvency regime.

B. Recent Developments

93. To examine the financial soundness of Brazilian non-financial corporates (NFCs), disaggregated financial statements of listed and un-listed firms were used from Capital IQ database. The analysis examined corporate profitability, corporate leverage, corporate debt servicing capacity and the share of short-term debt from 2005 to 2017Q3.

94. The corporate profitability continued its declining trend during the recession, but has recently started to improve. The corporate sector; profitability was on declining trend since 2009. However, it reversed course until 2015, after median ROE dropped to about 5percent. Profitability has improved since then with Median ROE rates reaching 8.5 percent in 2017Q3. Compared with the Selic rate, however, 2/3 of all firms were unable to produce comparable returns on equity.

95. The corporate debt servicing capacity has remained lower than pre-recession levels. Median ICR has been slightly increasing as of recession (from 1.5 to 2) but it is significantly below pre-recession ICR of 3. Furthermore, 40 percent of firms in 2017Q3 could not generate sufficient EBITDA to cover interest expenses. Accounting for interest income through financial positions of corporates, 21 percent of firms in 2017Q3 failed to earn sufficiently to cover net interest expenses.

96. Corporate leverage of Brazilian firms deteriorated over a decade ending in 2015, but has recently started to recover. The median share of total corporate debt relative to equity almost doubled from 2006 to 2015 reaching 0.8. Corporates deleveraged during the past economic recession and shifted the composition of their liabilities towards equity financing resulting in reduced median leverage of 0.7 in 2017Q3. However, 1/3 of all firms remained highly leveraged with total debt exceeding twice equity.

97. The maturity composition of corporate debt has been relatively stable since 2010 with a mild decline in recent years. Short-term borrowing accounted for 8percent of total debt in 2005,

which arrived at a maximum of 12percent in 2013 and has gone down to about 9percent in 2017Q3. Nonetheless, a large fraction of firms relies on short-term borrowing, which exposes them to roll-over risk. 1/3 of firms used short-term debt that exceeded 35percent of their total debt. The debt position of these firms makes them susceptible to fluctuations in the money market and their business operations could be disrupted if they temporarily lose access to short-term funds.

C. Vulnerability Assessment by Sector

98. Major sectors of Brazilian corporates include energy, manufacturing, consumer and services. Firms in the materials and industrials sectors were bundled under the manufacturing sector. Firms in utilities and energy sectors were classified under the energy sector. Consumer staples and consumer discretionary firms composed the consumer sector. Telecommunication services, information technology, healthcare and real estate sectors composed the services sector.

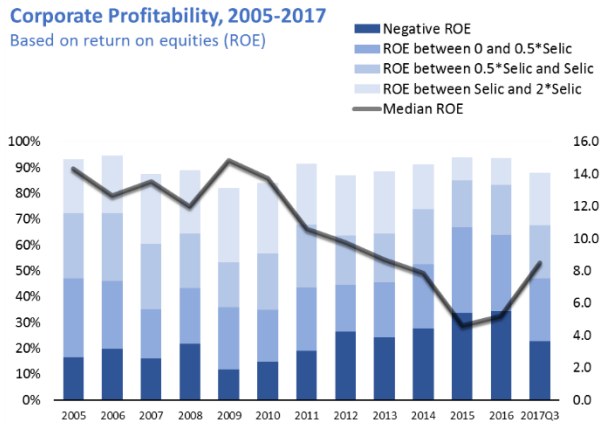
99. Vulnerabilities of industry sectors were analyzed based on the debt-at-risk approach. Figure 2 shows the distribution of debt at risk for corporate profitability, leverage. For debt servicing capacity vulnerabilities were analyzed using both debt at risk concept and sensitivity analysis with respect to macrofinancial shocks (see next section).

- ***Manufacturing companies yielded best profitability while firms in the services sector performed worst among other sectors.*** Debt at risk based on ROE falling below the Selic rate exceeded 80percent for services companies, which was less than 50percent for manufacturing companies. Furthermore, the services sector had a substantial fraction of negative ROE that accounts for more than half of the debt in this sector. While negative ROE is less of concern for energy companies, there was still a large fraction of firms with low positive returns.

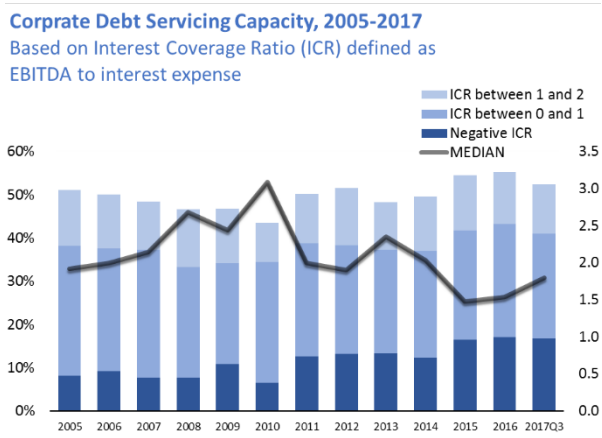
- ***Similarly, the services industry had the lowest capacity to service debt while firms in the energy sector exhibited highest capacity among industry sectors.*** Low profitability in the services sector was likely to be responsible for the low debt servicing capacity in this sector. More than 2/3 of all debt in this sector belong to ICR falling below 1.5. The debt at risk by this threshold was only 10percent for companies in the energy sector.

Figure 22. Brazil: Corporate Financial Soundness

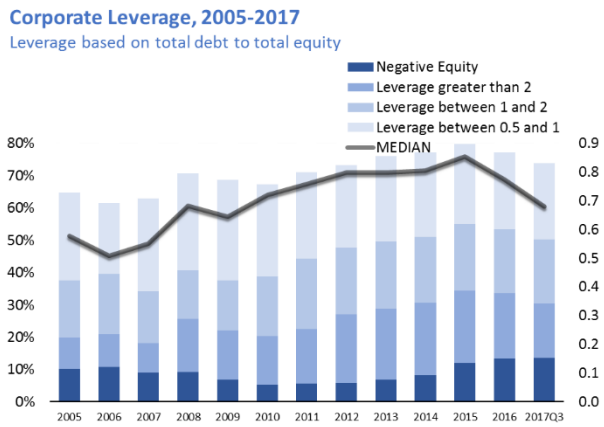
While corporate profitability has been recovering since last recession, 2/3 of firms failed to generate return on equity as high as the Selic rate …



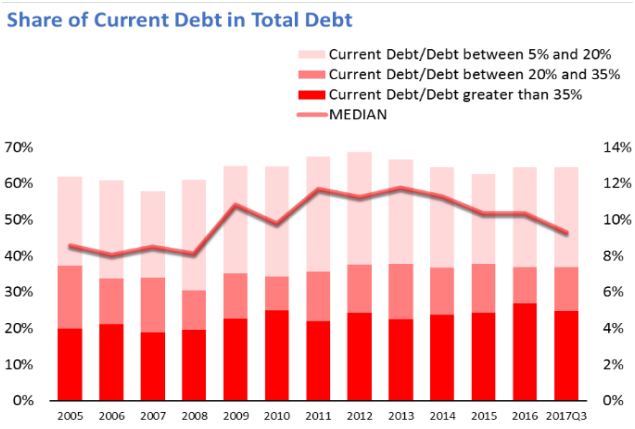
… and 40 percent of firms could not service their debt relying only on operating income.



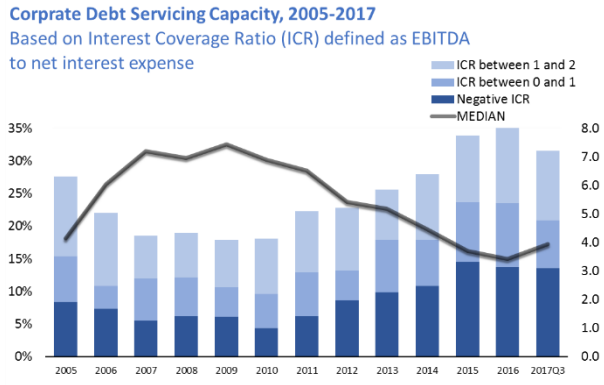
Corporates continued to deleverage in 2017, while financially weak firms with negative equity or debt exceeding twice equity constituted 1/3 of all firms.



While short-term debt accounts for a small fraction in general, 30percent of firms used more than 1/3 of their total debt in short-term debt, hence exposed to rollover risk.



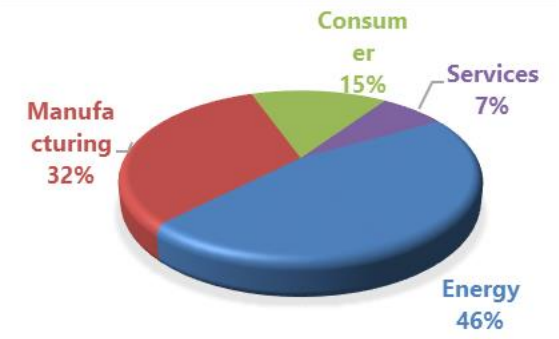
1/5 of firms were unable to cover net interest expenses relying on earnings.



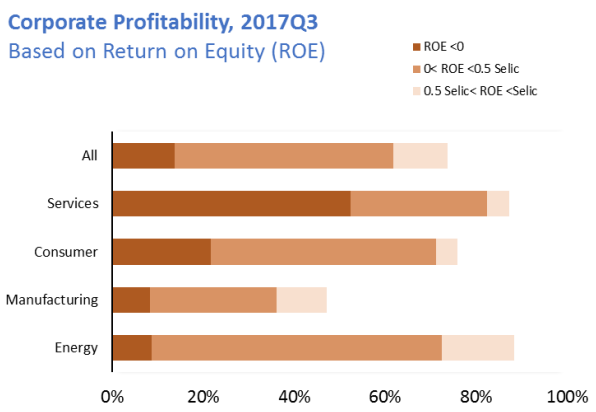
Source: Capital IQ and IMF staff calculations

Figure 23. Brazil: Vulnerabilities in Corporate Sector

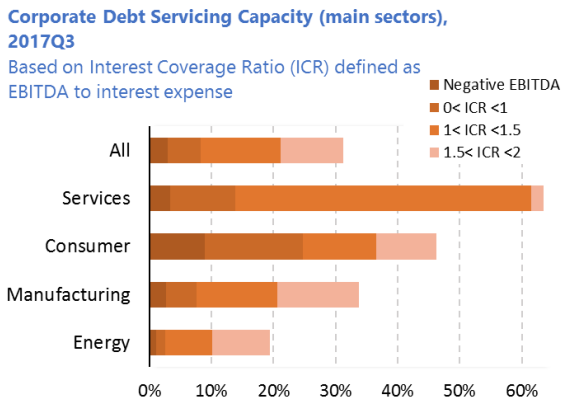
The energy and manufacturing sectors held the largest fraction of all debt in the corporate sector



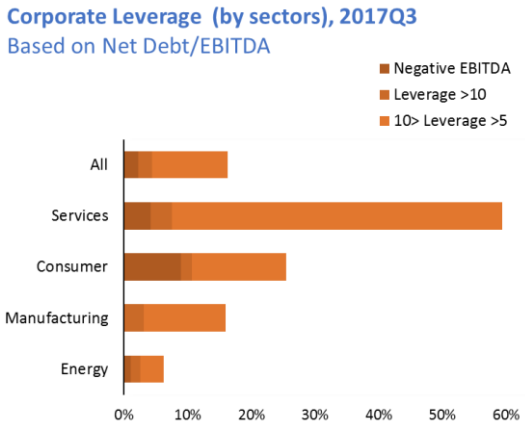
Low corporate profitability was salient particularly among services companies.



… and many companies in the services sector are still facing difficulties to service their debt



… yet more than half of firms the services sector were highly leveraged.



Source: Capital IQ and IMF calculations.

100. Corporate leverage was highest among services and lowest in the energy sector. Based on net debt to EBITDA, more than half of the debt in the services sector had a leverage ratio exceeding 5. The corresponding debt at risk for the energy sector was 5percent.

D. Sensitivity Analysis

101. Brazilian companies are vulnerable to deterioration of macrofinancial conditions. The impact on the debt servicing capacity by four macro-financial shocks, consistent with the bank solvency adverse scenario, were examined i) 8percent increase in the market interest rate, ii)

43percent spike in foreign exchange rate, iii) 10percent drop in profitability of businesses and iv) the downturn scenario that incorporates all shocks occurring simultaneously.

102. Debt servicing capacity of companies was susceptible to the interest rate shock. The increase in debt burden is partially hedged by interest bearing assets held by companies. Therefore, ICR after interest rate shock was specified as

$$ICR = \frac{EBITDA}{Interest\ Expense + \mathbf{\Delta R}\ (\text{Current Debt} - \text{Short Term Investment})}$$

Interest rate shock almost doubles the share of total debt with ICR less than 1. The shock adds an additional 6percent to already 8percent debt at risk as seen in Figure 3.

103. Firms appear to be well-hedged against FX shocks using natural and financial hedging. FX shock is modeled as

$$ICR = \frac{EBITDA}{Interest\ Expense\left(1 + \mathbf{FX\ shock}\ (share\ of\ external\ debt)(1 - hedging)\right)}$$

where hedging includes both financial and natural hedges. The data for FX hedge was confidential and the calculations were conducted by BCB staff for this part. Two scenarios for hedging were considered. The inclusive approach incorporated all operational and financial hedges. The conservative approach only included financial hedges. Operational hedges defined by BCB staff included three types of risk mitigators that are discussed in Box 1. In response to a 43percent FX shock, debt at risk would increase by 4 and 2 percentage points, respectively. Given that this is not considered as a material change compared to the effect of other shocks, firms appear to be well-hedged against FX shocks.

104. Profitability shock has the largest impact among other shocks on financially weak firms. Profitability shock affects ICR as following

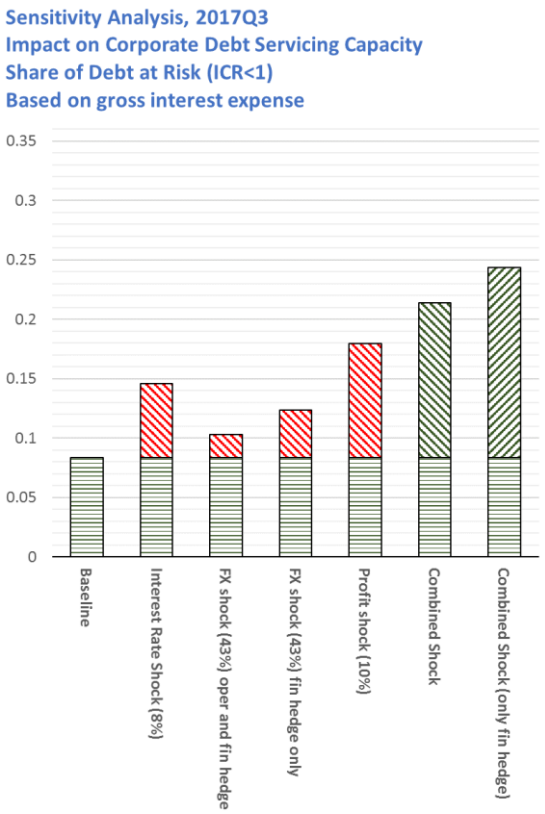
$$ICR = \frac{EBITDA(1 - \mathbf{profitability\ shock})}{Interest\ Expense}$$

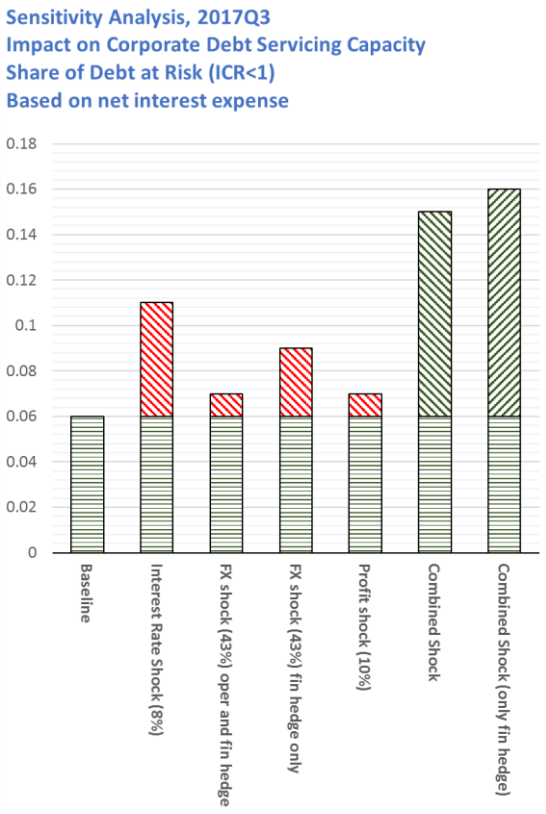
A 10percent profitability shock would significantly impact firms' ability to service their debt and result in increasing debt at risk by 14 percentage points (more than 2.5 times). This result implies that the corporate sector is highly vulnerable to reduced profitability if faced with another downturn.

105. Using BCB's alternative measure for ICR, the impact of profitability shock is lessened, but the results for other shocks remains the same. BCB uses net interest expenses in calculation of ICR, which accounts for the interest income that corporate achieve by holding interest bearing

securities, which acts like a hedge against interest risk. Figure 23 reports the results of sensitivity analysis for ICR based on gross and net interest expenses.

Figure 24. Brazil: Sensitivity Analysis of Debt Servicing Capacity in the Corporate Sector





Source: Capital IQ, BCB and IMF staff calculations

Box 1. Brazil: Operational Hedging in Brazilian Corporate Sector

In evaluating hedging schedules of firms, BCB defines risk mitigators that result in partially or fully hedging FX risk of firms with FX exposure beyond financial hedges.

Exporters

By definition, a company is classified as exporter (hence considered a full natural hedge by BCB) if its debt linked to export revenues exceed half of its total debt. Two concerns may arise with this approach. First, the company's export revenues could be used to cover import costs (e.g. raw material or energy costs) in the operation, shrinking the debt coverage of export revenues against FX obligations. As an alternative, net exports could provide a better measure of this type of operational hedging.

Assets overseas

A company's value of assets oversees is considered to hedge FX debt. The value of assets overseas comoves with FX rate, giving them hedging property. In this regard, it is also important to evaluate the effective liquidity value of these assets to assess their hedging value. In particular, physical assets, e.g. PPE, are hard to sell in short notice unless at a fire-sale value, therefore providing little liquidity against loan service obligations. While an accurate evaluation of effective liquidity value of foreign assets of a company may be difficult, a rough measure of liquid versus illiquid components of foreign assets could substantially sharpen the analysis.

Parent company

A company with an international parent company is considered to be fully hedged. The underlying assumption is that a subsidiary of a foreign parent company would be under the parent's coverage in case of financial difficulty. The implicit assumption is the strength of the business of the parent company. To examine this, the rating of the company could be evaluated and factored in the hedging capacity assigned to the firm.

Updating the formula for evaluating FX shock

Taking the above points into consideration, the updated ICR formula incorporating FX shock should have the following expression for hedging (or 1 if the expression is larger than 1 implying a full hedge)

(Net Export ratio)+(effective liq value of foreign assets)+1[high-rated foreign parent]+(fin hedge)

where *1[high-rated foreign parent]* takes 1 if the rating of the parent is high (e.g. above Baa) and 0 otherwise.

HOUSEHOLD SECTOR ANALYSIS

A. Overview

106. This section assesses financial strength of the household sector. It first reviews the recent trend of household financial soundness, and then discusses the household-level balance sheet analysis based on the deb-at-risk approach. The debt-at-risk analysis assesses the amount of so-called "debt at risk", which is debt that is belonged to financially distressed borrowers. The metrics for financial distress are typically based on debt service to income and debt to income. The household-level balance sheet analysis was conducted by BCB staff, using credit registry data as of end-2017Q3 based on the methodology agreed with the FSAP team.

B. Recent Development

107. Household debt has declined early 2015, as households have strengthened their balance sheet in the aftermath of the recession (Figure 23). As of November 2017, the level of household debt relative to disposable income has fallen to 41¼ percent, down from its peak at 46½ percent in April 2015. The slowdown in banks' lending to households, though still growing at a positive rate and more strongly than banks' overall lending, has underpinned recent household deleveraging. Mortgage borrowing now accounts for about 45 percent of total household debt, a marked increase from 14 percent a decade ago. It is worth mentioning that the loan-to-value (LTV) requirement has become tighter over the same period, with only a small fraction of mortgages featuring high LTV ratios. Among the 12 largest banks, the higher share of mortgage lending (14 percentage points since end-2012) is largely matched by the lower share of non-payroll-deducted secured lending and unsecured consumer credit (8 and 7 percentage points, respectively). Meanwhile, the share of payroll-deducted lending has increased by 3 percentage points.

108. Banks' lending to households has weathered the deterioration in macrofinancial conditions during the recession quite well. In the run up to the recession, banks had been reducing nonperforming loans (NPL). For lending to households, the NPL ratio increased from 3.6 percent in June 2015 to 4.3 percent in January 2016, before embarking on a downward trend. The increase in NPLs for lending to households was more muted than the increase in NPLs for overall lending, although the NPL ratio for the former has been historically higher. As of December 2017, the NPL ratio for lending to households was at 3.5 percent, slightly higher than the NPL ratio for overall lending (3.2 percent). The shares of loans written-off for lending to households and for overall lending were similar at almost 4 percent as of June 2017; their upward trends will likely continue given that the dynamics of loans written-off lags the dynamics of NPLs by about a year. The resilient performance of banks' lending to households during the recession could be attributed

to banks' active portfolio management (including debt restructuring) and their relatively prudent lending practices in recent years.[66]

109. However, household financial strength remains fragile. Households are exposed to a liquidity squeeze given their large debt servicing obligations. Financial distress could arise when income falls or interest rates increase, especially given that flexible-rate loans account for 43 percent of bank lending to households.[67] While their indebtedness relative to income does not appear excessive, households need to spend about 20 percent of their income on principal and interest payments. The level of debt servicing payments has remained at an elevated level since 2012. In 2017, about half of debt servicing payments were to cover interest charges. Furthermore, high unemployment and weak real earnings continue to weigh on household balance sheets, despite the progress on deleveraging in the aftermath of the recession.[68] Since 2016, banks have been more active to restructure loans—especially those related to real estate financing. As a result, the share of loans with 90 days past due and restructured loans has not yet declined as of June 2017.

[66] According to the BCB's analysis, the negative impact of unemployment on loan delinquency was low during the last recession relative to the historical benchmark. The main driver was that loan portfolios associated with unemployed borrowers are more concentrated among secured lending such as mortgage lending and vehicle financing.

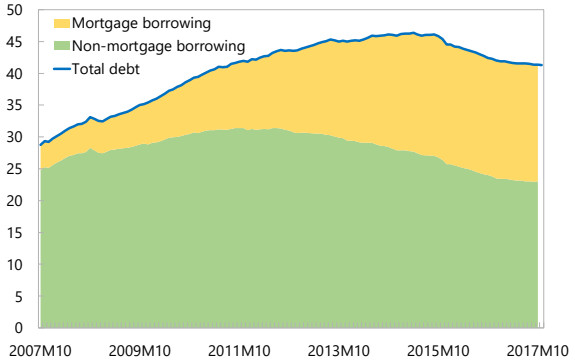
[67] The impact of rising interest rates would likely be limited initially given that the flexible rate component of almost all flexible-rate loans is based on the reference rate (Taxa Referencial), which is set by the BCB and currently at a historical low level.

[68] It is noteworthy that high unemployment may not raise financial stability concerns as much as one would typically expect. About 40 percent of debt at risk features payroll-deducted loans and the unemployed could be active outside the formal sectors.

Figure 25. Brazil: Household Financial Soundness

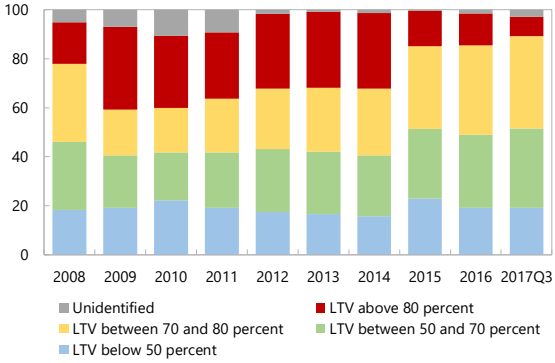
Household debt relative to disposable income has fallen.

Household Debt, 2007-17
(In percent of disposable income)



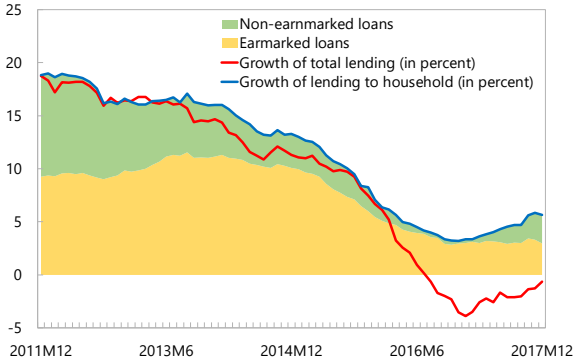
Despite a growing share of mortgage borrowing, LTV has become more strictive.

Loan-to-Value (LTV) at Origination, 2008-17
(In percent of new mortgage lending)



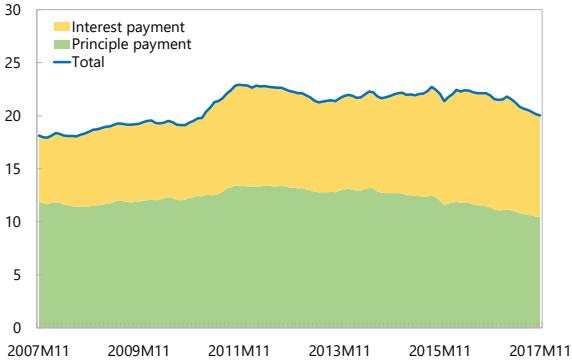
Growth of lending to households has moderated, with earmarked loans underpinning the recent increase.

Contribution to Lending to Households, 2011-17
(In percentage points; based on year-on-year lending growth)



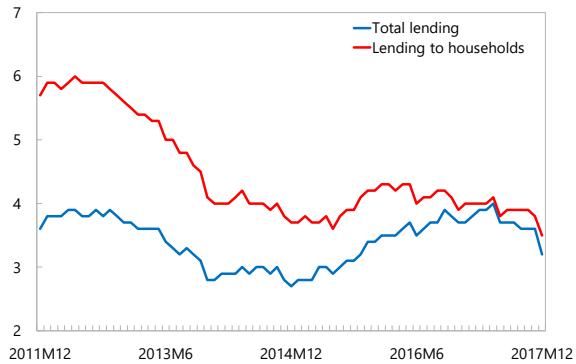
Debt servicing obligation is particularly large, due to sizeable interest payments.

Household Debt Servicing Obligation, 2007-17
(In percent of disposable income)



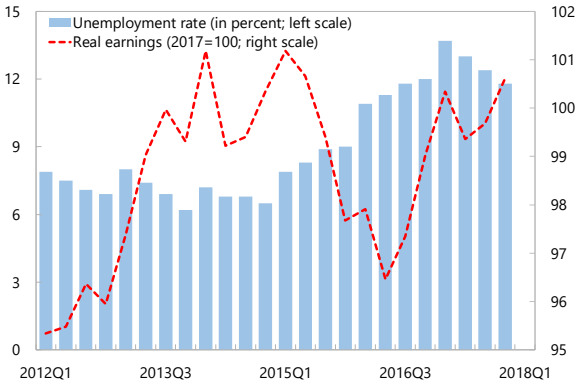
Banks did not see a sharp deterioration in asset quality for their lending to households during the last recession.

Nonperforming Loans, 2011-17
(In percent of total loans)



However, household financial strength remains fragile, given high unemployment and weak earnings.

Unemployment and Earnings, 2012-17



Sources: Banco Central do Brasil; Haver Analytics; and IMF staff calculations.

C. Household-Level Balance Sheet Analysis

110. The debt-at-risk analysis assesses the vulnerability of household balance sheets over time and the resilience to adverse macrofinancial shocks. Households are considered to be financially weak if their debt service to income above 40 percent and/or their debt to income above 3,[69] and debt that is belonged to financially distressed borrowers is considered to be at risk. Furthermore, debt at risk could be decomposed into those covered by assets (only housing assets that serve as collaterals of mortgage loans are considered in this exercise) and those not covered by assets. In addition to examining the recent trend, the exercise assesses the impact of negative macrofinancial shocks on the magnitude of financially weak households and debt at risk in the sensitivity and scenario analysis.

111. Households' financial weakness largely stems from their high debt servicing obligations (Figure 24). As of 2017Q3, the share of households with debt service to income above 40 percent was 20.2 percent, while the share of households with debt to income above 3 was 3.6 percent. Based on the combined metrics, the share of financially weak households was 2.9 percent, and the corresponding share of debt at risk was 22.5 percent. A sizable portion of debt at risk was covered by assets, limiting potential losses that could be incurred by banks in the case that households default. The share of debt at risk not covered at assets stood at 2.9 percent.

112. Based on the household-level information, the weaknesses of household balance sheets have not worsened dramatically since 2013. This finding is consistent with the NPL ratio for lending to households had increased marginally during the recession. Based on the combined metrics (debt service to income above 40 percent and debt to income above 3), the share of financially weak households has edged up by 0.3 percentage points since 2013. Over the same period, the share of debt at risk has increased from 18.1 percent to 22.5 percent, while the share of debt at risk not covered by assets has been on a declining trend.[70] Notwithstanding the deteriorating trend, balance sheets of financially weak households have been quite robust in the face of severely adverse macrofinancial conditions. That's said, more households have become on a brink of being financially distressed as illustrated by the analysis below.

113. Certain households appear to be more exposed to financial distress. Low-income households (with earnings up to minimum wage; representing about 20 percent of households) and retirees, as well as unsecured, multiple-loans, and mortgage borrowers are more exposed to a liquidity squeeze given their large debt servicing obligations.[71] The amount of their corresponding debt at risk not covered by assets is relatively large, except for mortgage borrowers whose

[69] There are the common thresholds used in recent FSAPs.

[70] The declining trend of debt at risk not covered by assets is influenced by the fact that mortgage borrowing accounts for an increasing share of total household borrowing. The exercise only considers housing assets that serve as collaterals of mortgage loans.

[71] Unsecured borrowers are those who have at least one unsecured loans, where secured loans include mortgage vehicle-financing, and payroll-secured loans. Multiple-loans borrowers are those who have more than one loans for the same borrowing category.

borrowings are collateralized by housing assets. When the combined metrics are considered (debt service to income above 40 percent and debt to income above 3), balance sheets of relatively low-income households (with earning between 1 and 3 times minimum wage; representing about 50 percent of households) and employees, as well as multiple-loans and mortgage borrowers appear relatively weak. Meanwhile, low-income households (with earnings up to minimum wage) are associated with the highest share of debt at risk not covered by assets.

114. Households appear vulnerable to adverse macrofinancial developments. Such negative shocks as declining income, rising interest rates and falling house price could have a discernable impact on household balance sheets.[72] These single-factor shocks could individually drive the share of financially weak households and the corresponding share of debt at risk to the level surpassing the post-2013 peaks, regardless of the financial metric used to determine household financial weaknesses (debt service to income and/or debt to income). This sensitivity analysis thus suggests that the increase in NPLs for lending to households could be substantial should the economy suffers from deteriorating macrofinancial conditions, broadly supporting the view that household financial strength remains fragile.

115. The scenario analysis confirms that the deterioration of household balance sheets could be significant, though the magnitude of banks' credit loss potentially manageable (Table 13). The analysis envisages an adverse scenario that features declining income by 8 percent, rising interest rates by 250 basis points, and falling house price by 10 percent. Based on the combined financial metrics (debt service to income above 40 percent and debt to income above 3), the share of financially weak households could increase from 2.9 percent to 3.9 percent, while the corresponding share of debt at risk could rise sharply to 27.7 percent. Nevertheless, the share of debt at risk not covered by assets would increase to 3.7 percent, still below the previous peak at 4.8 percent, thanks to the larger amount of housing assets that households have pledged to secure loans. As a result, the credit loss that banks may incur could be relatively limited, although the ultimate outcome would rest on the ability to execute collaterals efficiently.

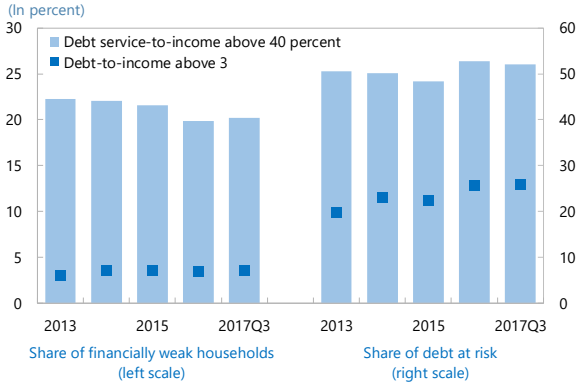
[72] The impact of rising interest rates is only relevant for borrowing with flexible interest rates.

Figure 26. Brazil: Vulnerabilities of Household Balance Sheets

Household financial weaknesses stem from large debt servicing obligations.

Financially Weak Households and Debt at Risk, 2013-17

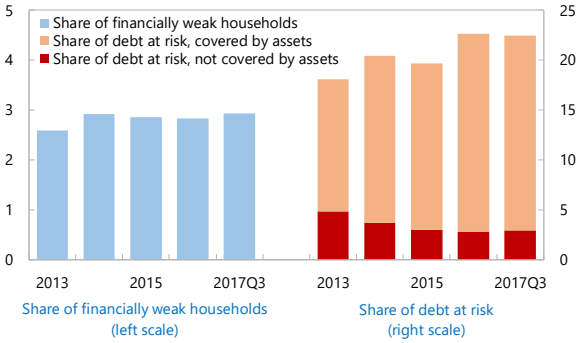
(In percent)



The share of debt at risk has increased, but financial stability implications are limited given that a growing portion is covered by assets.

Financially Weak Households and Debt at Risk, 2013-17

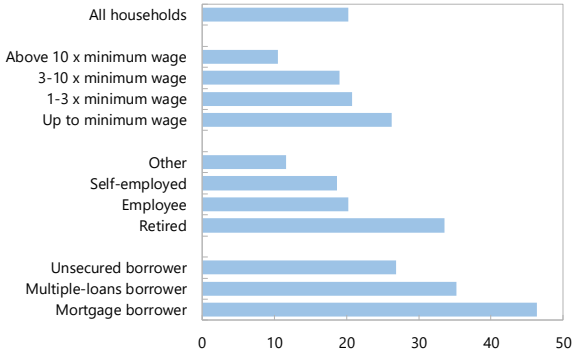
(In percent; based on households with both debt service-to-income above 40 percent and debt-to-income above 3)



Given their debt servicing obligations, low-income households, retirees, and unsecured, multiple-loans and mortgage borrowers are exposed to a liquidity squeeze.

Share of Financially Weak Household, 2017Q3

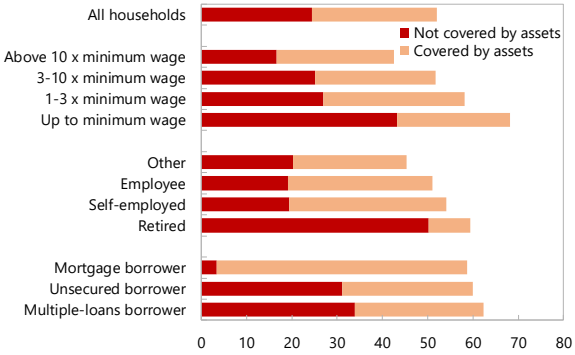
(In percent; based on households with debt service-to-income above 40 percent)



The share of debt at risk not covered by assets belonged to these groups of households, except mortgage borrowers, is relatively high.

Share of Debt at Risk, 2017Q3

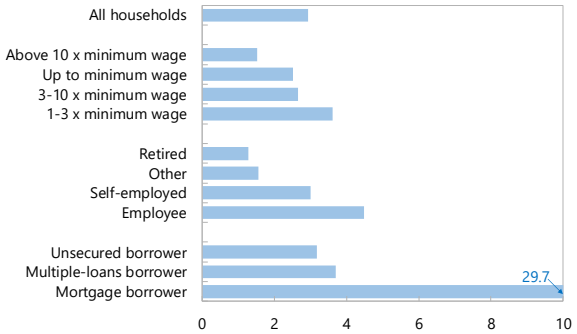
(In percent; based on households with debt service-to-income above 40 percent)



With indebtedness also being taken into consideration, low-income households, employees, and multiple-loans and mortgage borrowers appear financially weak.

Share of Financially Weak Household, 2017Q3

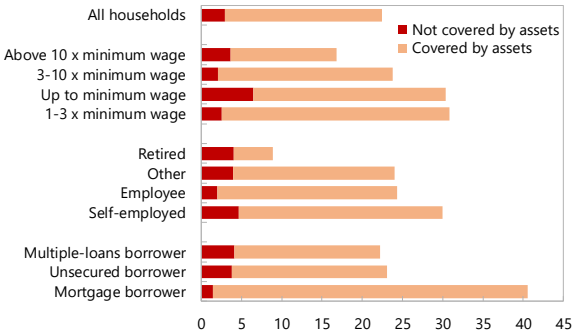
(In percent; based on households with both debt service-to-income above 40 percent and debt-to-income above 3)



The share of debt at risk not covered by assets is the highest for low-income households.

Share of Debt at Risk, 2017Q3

(In percent; based on households with both debt service-to-income above 40 percent and debt-to-income above 3)



Sources: Banco Central do Brasil; and IMF staff calculations.

Table 13. Brazil: Sensitivity and Scenario Analysis of Household Debt at Risk

	Debt service-to-income above 40 percent			Debt-to-income above 3			Debt service-to-income above 40 percent and debt-to-income above 3		
	Share of financially weak households	Share of debt at risk	Share of debt at risk not covered by assets	Share of financially weak households	Share of debt at risk	Share of debt at risk not covered by assets	Share of financially weak households	Share of debt at risk	Share of debt at risk not covered by assets
Latest (as of 2017Q3)	20.2	52.1	24.5	3.6	25.8	3.4	2.9	22.5	2.9
Highest level since 2013	22.3	52.7	29.5	3.6	25.8	5.2	2.9	22.6	4.8
Sensitivity analysis									
Declining income by 5 percent	21.5	54.7	25.6	3.9	27.7	3.6	3.2	24.4	3.2
Declining income by 10 percent	23.0	57.4	26.7	4.3	29.7	4.0	3.6	26.5	3.5
Rising interest rates by 250 basis points	21.9	58.4	25.4	...	...	...	3.4	24.6	2.9
Rising interest rates by 500 basis points	23.4	63.4	26.2	...	...	...	3.6	25.3	2.9
Falling house price by 10 percent	...	...	25.0	...	...	3.6	...	...	3.2
Falling house price by 20 percent	...	...	25.9	...	...	4.3	...	...	3.8
Scenario analysis									
Declining income by 8 percent, rising interest rates by 250 basis points, and falling house price by 10 percent	24.1	62.4	27.7	4.1	28.9	4.2	3.9	27.7	3.7

Sources: Banco Central do Brasil; and IMF staff calculations.

D. Policy Recommendations

116. The BCB should consider implementing limits on debt to income and debt service to income to contain a buildup of systemic risk in the mortgage lending segment. The debt-at-risk analysis suggested that the share of mortgage borrowers who were relatively indebted and had large debt servicing obligations was at 30 percent. In addition, banks' lending to households has been increasingly geared towards mortgage lending. While credit growth remains limited, it would be useful to consider putting these macroprudential measures in place now to contain a buildup of systemic risk when the credit cycle upturn starts. In addition, the BCB should require banks to assess the sensitivity of borrowers' debt servicing capacity to macrofinancial shocks such as rising interest rates.

ANALYSIS OF POTENTIAL IMPACT ON SOVEREIGN BOND MARKET STEMMING FROM INVESTMENT FUNDS

A. Introduction

117. The focus of the analysis of investment funds was on testing the resilience of government bonds' market to liquidity shocks in the investment fund industry but in the absence of action by the BCB and the National Treasury. The main objective of the analysis of investment funds was to evaluate the consequences of large-scale asset sales by investment funds due to a hypothetical, tail-event redemption shock for government bonds' market liquidity. The focus was not on testing the resilience of individual funds but on assessing whether, in aggregate,

the activity the funds undertake if hit by a liquidity shock (large redemptions) can contribute to price changes of government bonds, which comprised the largest asset holding on investment funds.

118. The analysis was motivated by the size of investment funds and their large holdings of government securities. First, using historical observations, three approaches were used to calibrate redemption shocks. Next, the size of first-round asset sales to meet redemption under waterfall and pro rate asset sales were evaluated for each calibration approach and associated price effects in the government securities' market were quantified. Finally, a regression model was estimated to assess second-round redemptions due to decreased market returns implied by first-round asset sales.

119. The analysis followed and extended the liquidity analysis undertaken in recent FSAP of the U.S., Ireland, Sweden and Luxembourg. While previous FSAPs considered the effects of investment funds on market liquidity and the price effects, this was the first time the price effects were estimated and analyzed in greater depth building on the recent work by Baranova and others (2017), currently used at the Bank of England for assessing the resilience of corporate bonds' market in the presence of bond dealers facing balance-sheet limitations. The analysis contributed further by using three calibration approaches that took fund heterogeneity into considerations.

120. The analysis was not intended to account for general equilibrium implications and subject to important caveats. The analysis did not assume any reactionary role of the Central Bank and the Treasury. While the analysis followed simple techniques for analyzing price effects of large-scale asset sales there were limitations in providing a full picture of various forces that could have primary impact on the market for government bonds such as the role of monetary policy, the unwinding of repurchase agreements with the Central Bank, reverse auctions by the Treasury, the role of banks.

B. Data, Methodology, and Results

121. The investment fund industry is dominated by '555-funds', including fixed income funds, multimarket funds and equity funds. The data provided by BCB and CVM covered the whole universe of 555-funds. The dataset contained historical information for fund flows, NAV, returns, composition of funds' asset holdings, and fund families and subfamilies. September 2017 data was used for asset composition.

122. Open-ended funds accounted for about 78 percent of total TNA of the entire investment fund industry by the end of September 2017. To identify funds potentially subject to redemption shocks, the following categories were excluded from the entire sample of funds: (i) closed-ended funds, (ii) funds who had pension funds as their dominant investor, (iii) funds with non-deposit institutions as their investor and (iv) funds with redemption notice date exceeding a week. The rest of the sample representing runnable funds accounted for 52 percent of funds in frequency and 78 percent of total TNA in the investment fund industry.

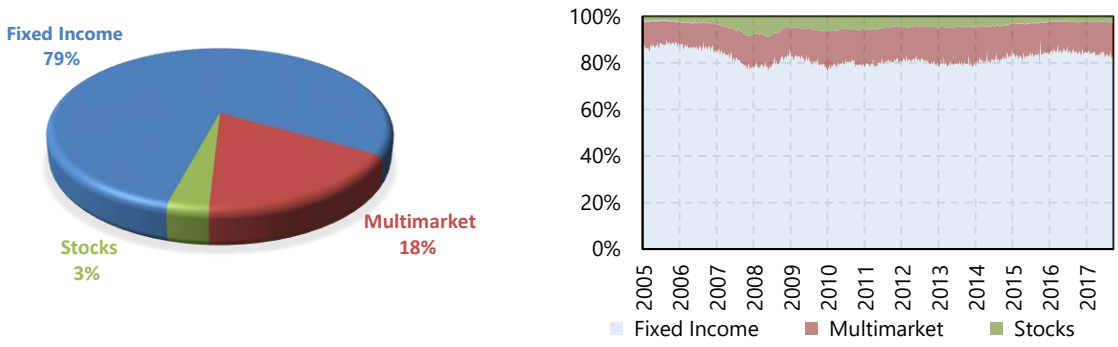
Table 14. Brazil: Exclusion of Funds from the Sample

type	Frequency		TNA (R$ trillion)	
	Count	Fraction (in percent)	Count	Fraction (in percent)
Closed-ended	2,280	30.0	0.284	7.7
Pension fund Investor	799	10.5	0.408	11.0
Non-Deposit Investor	14	0.2	0.063	1.7
Long Redemption Notice	527	6.9	0.063	1.7
Open-ended	**3,976**	**52.3**	**2.893**	**77.9**
Total	*7,596*		*3.711*	

Source: BCB data and IMF staff calculations

123. Among open-ended funds, fixed-income family historically attracted the largest share of investment accounting on average for 82 percent of total TNA, followed by multimarket family (13 percent), stocks family (4 percent) and foreign investment (<1 percent).[73] As Figure 14 exhibits, the TNA share of fixed-income funds remained stable over time, with some fluctuations around particular time periods (e.g. around 2008, 2010 and 2014). Nonetheless, fixed-income funds continued to be the largest share of total TNA of the industry.

Figure 27. Brazil: Share of TNA of Open-Ended Funds (By Fund Families)

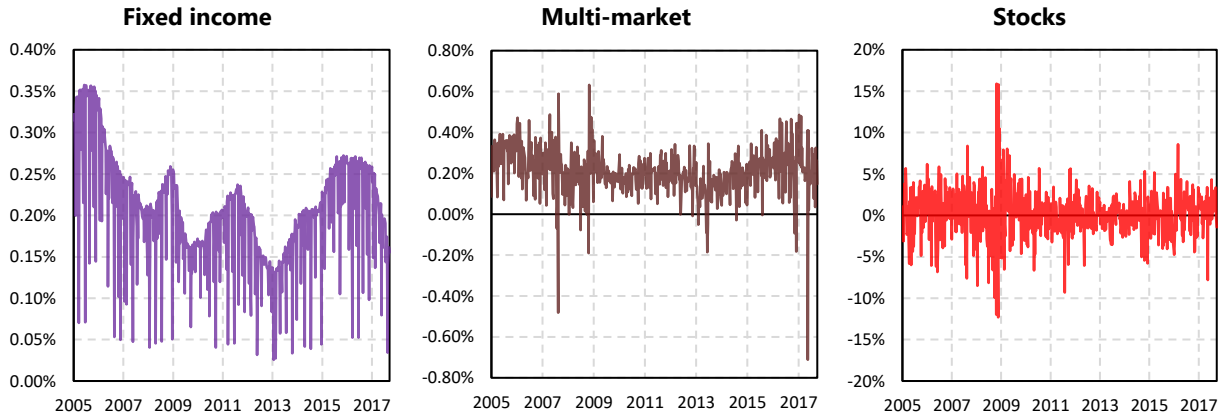


Source: BCB data and IMF staff calculations.

124. The return paths of fund families reflect differences in their investment strategy. Figure 27 displays median returns of funds in different families. Fixed-income fund families closely traced the government bond rate and offered relatively stable positive returns. Multimarket funds had a more volatile time-path compared to fixed income funds with the advantage of sometimes offering higher returns. Investors in the stocks fund family experienced the most volatile returns among fund families.

[73] Because of the tiny share of foreign investment funds (0.5 percent of total TNA), for brevity we do not report results for these funds.

Figure 28. Brazil: Median Weekly Returns (By Fund Family)



Source: BCB data and IMF staff calculations.

125. In addition to exclusion of funds with shares redeemable only after a week and not subject to the redemption risk the following data cleaning was done to ensure the dataset consistency for analysis. The authorities instructed that data for net asset value (NAV) is more precise and comprehensive than TNA in the dataset and therefore more appropriate for the purposes of calculating redemption rates. The analysis therefore used NAV rather than TNA. Furthermore, the following data cleaning steps were taken to ensure data consistency.

- **Imputed missing values of NAV:** NAV entries were sporadically missing (0.14 percent of the sample[74]) in the dataset most probably due to data entry mistakes. Since weekly observations are at high frequency, missing NAVs were imputed assuming an affine relationship.[75]

- **Missing data for flows and returns were substituted with zero.** This treatment was instructed by authorities.

- **Excluded observations with high margin of error:** The dataset included daily returns and flows and end-of-week NAV values. Evolution of daily NAV should satisfy the following equality[76]

$$NAV_t = NAV_{t-1} + Flow_t + Return_{t-1,t}$$

[74] The sample contained 2.7 million weekly observations.

[75] For instance, if NAV entries of weeks t to t+k-1 were missing, the following formula would be used to fill in those missing entries $NAV_{t+i} = NAV_{t-1} + \frac{i+1}{k+1}(NAV_{t+k} - NAV_{t-1})$ for i between 0 to k-1.

[76] In growth term, the relationship takes the following intuitive form:

$$\frac{NAV_t - NAV_{t-1}}{NAV_{t-1}} = \frac{Flow_t}{NAV_{t-1}} + return_{t-1,t}$$

implying the growth rate of NAV is attributed to the net flow rate and rate of return on holdings.

Comparing implied end-of-week NAV values using the above equality and available NAV values yields a margin of error that reflects poor data quality. Observations with a margin of error exceeding 5 percent (accounting for 0.4 percent of the sample) were removed.

- **Ensured NAV and the total sum of assets match.** First, NAV values that fell below the total sum of assets were overridden by the total sum of assets (16 percent of observations). For the rest of the sample, a new variable entitled "other assets" was defined that accounted for the difference between NAV and the total sum of assets.

Calibration of Redemption Shocks

126. Calibration of redemption shocks was based on three approaches.

- **Calibration based on fund-homogeneity assumption.** The fund-homogeneity based calibration considered the first percentile of distribution of flow rates[77] of all fund-week observations in each fund family (Figure 28) and therefore assumed a common size of redemption shock impacting each fund regardless of their differences (hence labeled *homogenous*). One advantage of this fund-homogeneity approach is that it tests for potentially stressful situations that funds may not have experienced in the past. However, since differences among funds are not considered, the size of the shock could be too large for certain funds.

- **Calibration based on fund heterogeneity assumption.** The fund heterogeneity-based calibration assumed that each individual fund experienced outflow equivalent to the 1st percentile of its own historical flow rates and therefore assumed different sizes of redemption shocks impacting each fund (hence labeled *heterogenous*). It was assumed that such fund-specific extreme shocks take place simultaneously. While this approach is more realistic in terms of the size of the shock, it does not allow for testing redemptions shocks beyond what has been historically observed.

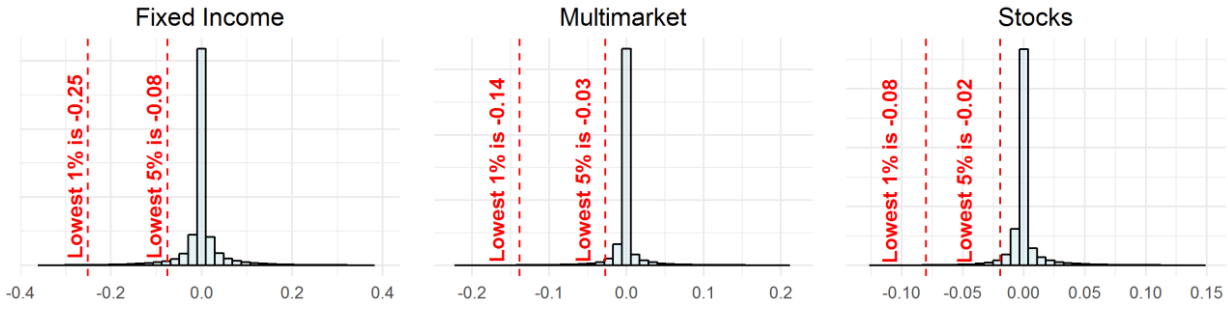
- **Calibration based on fund-family flows.** The fund-family calibration considered the 1st percentile of combined outflow of all funds within a fund family. This approach assumed that inflows and outflows net out within a fund family (transferred across funds).

127. Based on fund-homogeneity calibration, the lowest 1 percent redemption rates were 25 percent, 14 percent and 8 percent for fixed-income, multi-market and stocks families, respectively. Historical distribution of redemption rates displays a well-behaved symmetric distribution around zero net flow for all fund families. This ranking is in the opposite order of return volatilities of in each family but consistent with the relative size of investment, suggesting that investors in fixed-income funds value (and exercise) liquidity of their investment while seeking a

[77] Flow rate is defined as the ratio of sum of flows during week relative to NAV at the beginning of the week. See previous footnote.

more stable return patterns. Accordingly, fixed-income funds are exposed to redemption shocks when investors' aggregate demand for liquidity rises.[78]

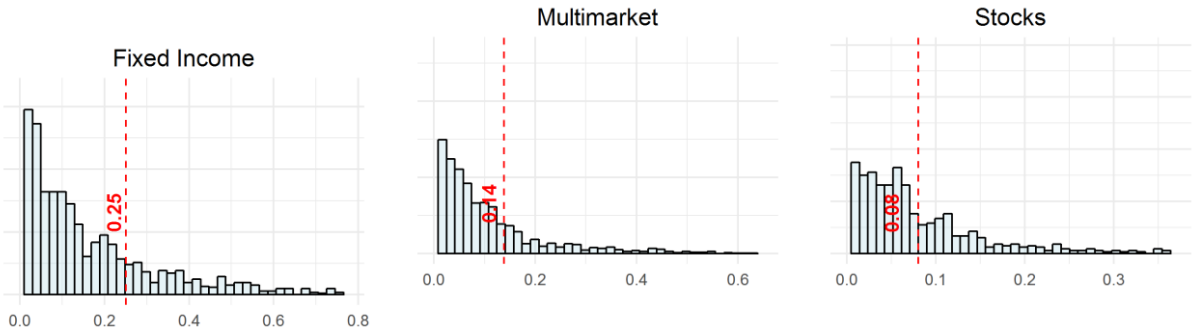
Figure 29. Brazil: Historical distribution of flow rates (by fund family)



Source: BCB data and IMF staff calculations

128. Based on fund-heterogeneity calibration, a distribution of redemption shocks was generated for each fund family. The distribution of the 1st percentile of fund-specific redemption rates is displayed in Figure 28. To enable comparison with fund-homogeneity approach, the fixed calibrated redemption rate achieved by fund-homogeneity approach is also displayed in Figure 29. The distributions are right skewed indicating a large concentration of funds that did not observe large redemptions in their lifetime as of the last week of September 2017. As a result, the fund-homogeneity approach implied substantially larger outflows compared to the fund-heterogeneity approach corresponding to 80th, 80th and 70th percentiles in their respective heterogenous redemption distributions.

Figure 30. Brazil: Historical Distribution of Redemption Rates Per Individual Fund (By Fund Family)



The dashed red line shows redemption rates based on fund-homogeneity calibration.

Source: BCB data and IMF staff calculations

[78] One drawback of this approach is that same funds could appear the tail of distribution hence decreasing the representativeness of the lower tail for the entire distribution.

129. Based on fund-family flow calibration, the lowest 1 percent redemption rates were 1.9 percent, 2.2 percent and 1 percent for fixed-income, multi-market and stocks families, respectively. The worst combined outflow rates were 2.9 percent (Aug 1, 2014), 4.2 percent (March 18, 2005) and 3.3 percent (August 17, 2007) in the fixed-income, multi-market and stocks families.

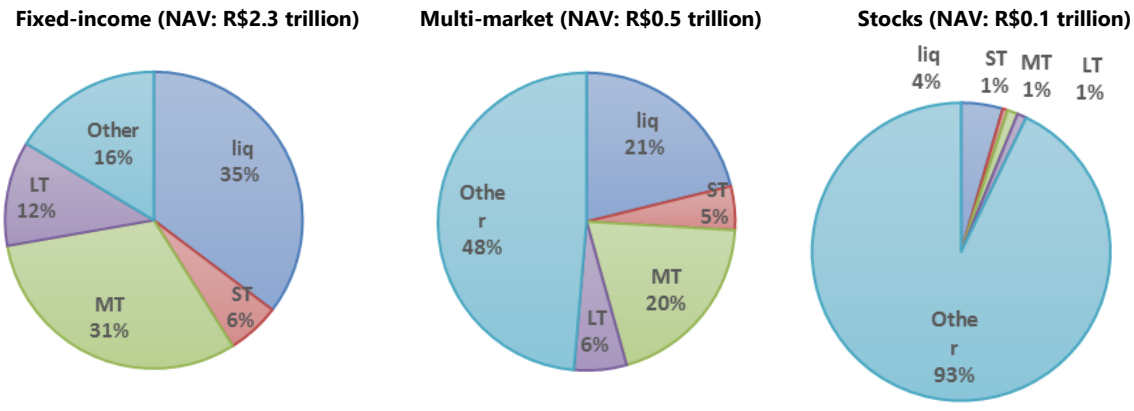
Asset Sales

130. Given the redemption shock and the composition of asset holdings of investment funds, the analysis evaluated the implied total value of assets to be sold under two schedules while assuming:

- **Waterfall approach.** In waterfall approach, a fund was assumed to satisfy redemptions by using its most liquid assets in a hierarchical manner. Mutual funds were assumed to rank-order assets held by their liquidity characteristics, as captured by the LCR haircut hierarchy, selling assets to meet redemptions in descending order of liquidity. Specifically, the assets are assumed to be sold in the following order: i) cash, ii) reverse repo, iii) bank deposits, iv) sovereign bonds, v) short-term government bonds, vi) medium-term government bonds, vii) long-term government bonds, viii) Index of Bovespa (stocks), ix) stocks offshore, x) derivatives, and xi) NFC debt. This approach was used as a benchmark.

- **Pro-rata approach.** In pro-rata selling of assets, assets were sold to meet the redemptions by making sure that the structure of assets is intact. As a result, redemptions were met by liquidating a common fraction of all assets held by each fund.

Figure 31. Brazil: Portfolio (By Fund Family)



liq: Liquidity including cash, reverse repo, deposits, offshore soverign bonds; ST: short-term gov bonds (<1 yr), MT: Medium-term gov bonds (1yr to 5yr), LT: Long-term gov bonds (>5 yr)

Source: BCB data and IMF staff calculations

Table 15. Brazil: Asset Composition (Panel A) and Asset Sales (Panel B) (R$ Billion)

a. Portfolio

	Fixed Income	Multimarket	Stocks	Total
Cash Liquidity	812	105	4	**922**
Short-term Bonds	131	24	1	**156**
Medium-term Bonds	713	97	1	**811**
Long-term Bonds	261	28	1	**290**
Other Assets	375	210	88	**673**
NAV (total)	**2292**	**464**	**95**	**2852**

b. Sales

		Waterfall Sales				Pro Rata Sales			
		Fixed Income	Multi-market	Stocks	Total	Fixed Income	Multi-market	Stocks	Total
fund homogeneity	**Cash Liquidity**	394	39	3	**437**	204	14.5	0.3	**219.0**
	Short-term Bonds	48	5	0	**53**	33.0	3.3	0.0	**36.4**
	Medium-term Bonds	116	10	1	**127**	178.9	13.4	0.1	**192.6**
	Long-term Bonds	12	2	0	**14**	65.6	3.8	0.1	**69.5**
	Other Assets	5	9	3	**17**	94.0	29.0	7.1	**130.3**
	Total	**575**	**64**	**8**	648	**575.3**	**64.1**	**7.6**	647.7
fund heterogeneity	**Cash Liquidity**	179.6	33.0	2.2	**215.2**	111.6	14.0	0.2	**126.0**
	Short-term Bonds	11.7	1.4	0.2	**13.3**	12.0	1.7	0.0	**13.8**
	Medium-term Bonds	13.7	3.9	0.3	**17.9**	48.6	8.4	0.1	**57.2**
	Long-term Bonds	2.2	0.6	0.1	**2.9**	14.8	2.0	0.0	**16.9**
	Other Assets	1.9	4.8	1.7	**8.4**	22.2	17.5	4.1	**43.9**
	Total	**209.1**	**43.7**	**4.4**	257.7	**209.1**	**43.7**	**4.4**	257.7
fund family	**Cash Liquidity**	60.5	14.2	1.7	**76.6**	23.8	4.4	0.1	**28.4**
	Short-term Bonds	2.9	1.3	0.2	**4.4**	3.9	1.0	0.0	**4.9**
	Medium-term Bonds	2.8	1.9	0.2	**5.0**	20.9	4.1	0.0	**25.1**
	Long-term Bonds	0.7	0.4	0.0	**1.1**	7.7	1.2	0.0	**8.9**
	Other Assets	0.2	1.8	0.9	**3.0**	11.0	8.8	2.9	**22.8**
	Total	**67.2**	**19.5**	**3.1**	90.1	**67.2**	**19.5**	**3.1**	90.1

Panel a shows aggregate asset composition of fund families in September 2017. Panel b shows three calibration approaches and two asset sale schedules used to evaluate asset sales to meet redemptions.

Source: BCB data and IMF staff calculations

131. Investment funds would sell R$194 billion, R$34 billion and R$10 billion of government bonds to meet redemptions under the fund-homogeneity, fund-heterogeneity and fund-family calibration approaches if asset sales follow waterfall schedule (Table 15). Altogether, funds would need to liquidate a total value of R$648 billion, R$258 billion and R$90 billion to meet redemptions under fund-homogeneity, fund-heterogeneity and fund-family calibration approaches. Cash liquidity position[79] of funds would be sufficient to cover 67 percent, 83 percent and 85 percent of total value of redemptions under fund-homogeneity, fund-heterogeneity and fund-family calibration approaches.

132. If investment funds follow pro rata schedule for asset sales, a larger sale of government bonds would be required to meet redemptions, i.e. R$298 billion, R$88 billion and R$39 billion. To ensure their portfolio composition remains intact, pro rata schedule forces funds to more aggressively sell their assets. In this case, they could only use their cash liquidity position against 34 percent, 49 percent and 32 percent of the total funds required to meet redemptions under fund-homogeneity, fund-heterogeneity and fund-family calibration approaches.

133. While aggregated liquidity position of funds industry is sufficient to absorb redemption shocks, individual differences force funds with insufficient cash position to sell assets. Aggregate liquidity position of investment funds (R$ 922 billion) exceeded the total amount of redemptions under any of the calibration approaches. However, differences in individual cash liquidity positions forced funds with shortage of cash to sell government bonds to meet redemptions. NAV at risk[80] was 52 percent, 21 percent and 20 percent under fund-homogeneity, fund-heterogeneity and fund-family calibration approaches. Therefore, while at the aggregate level, the investment fund industry appeared to hold sufficient liquidity, a systemic shock would lead to asset sales due to asset holding heterogeneities among investment funds.

134. Relative to historical market turnover, the scales of government bond sales by investment funds is significant under the benchmark calibration but insignificant under alternative calibration. Table 16 compares the size of asset sales under different schedules for different government bond type with the historical turnover in their markets.[81] Under the benchmark calibration with waterfall sales, asset sales are at the higher end of the distribution at about 60th percentile and short-term NTN-B about its maximum. Pro rata sales result in more extreme sales of less liquid assets (above 80th percentile). While benchmark calibration yields large scales of asset sales relative to historical market turnover, alternative calibration implies an insignificant size of

[79] Cash liquidity position refers to the sum of cash, reverse repo, deposits and offshore sovereign bonds holdings of funds. Reverse repo constitutes the largest portion of cash liquidity position. While government bonds would in general be included in the liquidity position, they have been considered separately since the purpose of the analysis is to assess price effects arising from their sales.

[80] NAV at risk reflects the sum of NAV of funds with insufficient cash liquidity position relative to aggregate NAV of all funds.

[81] Coverable government bonds, i.e. LFT, and bonds that funds were lightly invested in are excluded from Table 16.

government bond sales (with the exception of NTN-B bonds). Therefore, results are sensitive to the choice of redemption schedule.

Table 16. Brazil: Comparison of the Scale of Government Bond Sales by Investment Funds Relative to Weekly Turnover (R$ Billion)

Bond type	Maturity bucket	Waterfall			Pro rata		
		(1)	(2)	(3)	(1)	(2)	(3)
LTN	Short-term	22 (58th)	15 (35th)	3 (0th)	5 (1st)	0 (0th)	2 (0th)
NTN-B	Short-term	10 (98th)	4 (85th)	4 (88th)	1 (33rd)	2 (57th)	0 (21st)
LTN	Medium-term	29 (63rd)	50 (99th)	0 (0th)	9 (4th)	0 (0th)	6 (2nd)
NTN-B	Medium-term	20 (63rd)	26 (81st)	3 (0th)	7 (9th)	0 (0th)	4 (1st)
NTN-B	Long-term	12 (55th)	22 (89th)	2 (12th)	6 (31st)	0 (1st)	3 (18th)

Numbers in praranthesis represent the percentile of asset sale in the distribution of weekly market turover of the asset. (1), (2) and (3) correspond to fund-homogeneity, fund-heterogeneity and fund-family calibrations.

Source: BCB data and IMF staff calculations

Assessing Market Liquidity of Government Securities

135. Price sensitivity of government bond due to selling pressures from investment funds was assessed using the Amihud illiquidity measure. The Amihud measure uses historical turnover and price changes of government securities. The Amihud illiquidity measure was evaluated for each government security's type and maturity as the equally weighted average of the weekly ratio of absolute return of the security to its weekly market turnover over the period of a year. Specifically,

$$A = \frac{1}{T}\sum_{t=1}^{T}\frac{|R_t|}{V_t}$$

where the length of time is denoted by T (one year), asset return readings at each period (week) t is denoted by R_t and the trading volume at that period is V_t. While the Amihud measure over a year was used in the benchmark analysis, extreme historical Amihud measure were used as well to assess the price effects under distressed market conditions. The first-round price effect of asset sales was given by multiplying the Amihud illiquidity measure by the size of assets sold following the tail redemption event.

136. Different calibration approaches lead to various degrees of price effects. Table 17 reports price effects under 2017 (top panel) and 2015 (bottom panel) market conditions for the three calibration approaches. Figure 30 compares price changes relative to median to historical distributions.[82]

[82] It is assumed that the price effect due to asset sales by investment funds lower the price further from its historical median value. percentiles reported are based on the net effect, so that no effect would correspond to 50th percentile.

137. Asset sales based on fund-homogeneity, fund-heterogeneity and fund-family calibrations on average would lead to 62, 21 and 8 basis points drop in government bonds under waterfall asset sales and 2017 market conditions. The effects would be sharper if more severe market conditions of 2015 were to materialize.[83] Under 2015 conditions, average relative drop in government bond prices would be 99, 28 and 11 basis points under fund-homogeneity, fund-heterogeneity and fund-family calibrations assuming waterfall sales.

138. Asset sales under waterfall schedule could significantly raise short-term government rates. Asset sales based on fund-homogeneity, fund-heterogeneity and fund-family calibrations could lower NTN-B yields down from their median by 186 basis points, 88 basis points and 36 basis points under 2017 market conditions, corresponding to low percentiles therefore indicating large price effects. Price effects on short-term government bonds under pro rata sales would be smaller because unlike waterfall sales short-term bonds would not be prioritized relative to less liquid assets to be used for meeting liquidity pressures.

139. Asset sales depress medium-term government bonds by 29, 2 and 1 basis points on average based on fund-homogeneity, fund-heterogeneity and fund-family calibrations under the 2017 market liquidity conditions.

Table 17. Brazil: Price Effects from Sale of Government Bonds by Funds to Meet Redemptions

a. Based on 2017 market conditions

Bond (maturity)	Amihd	Waterfall			Pro rata		
		(1)	(2)	(3)	(1)	(2)	(3)
LTN (ST)	0.008	18 (5th)	3 (35th)	0 (50th)	12 (10th)	5 (27th)	2 (41th)
NTN-B (ST)	0.177	186 (0th)	88 (0th)	36 (0th)	82 (0th)	19 (5th)	12 (15th)
LTN (MT)	0.011	32 (16th)	1 (48th)	0 (50th)	55 (8th)	10 (37th)	7 (41th)
NTN-B (MT)	0.013	26 (23th)	4 (44th)	1 (48th)	35 (16th)	10 (36th)	5 (42th)
NTN-B (LT)	0.043	52 (28th)	10 (46th)	4 (48th)	99 (19th)	27 (40th)	13 (45th)

b. Based on 2015 market conditions

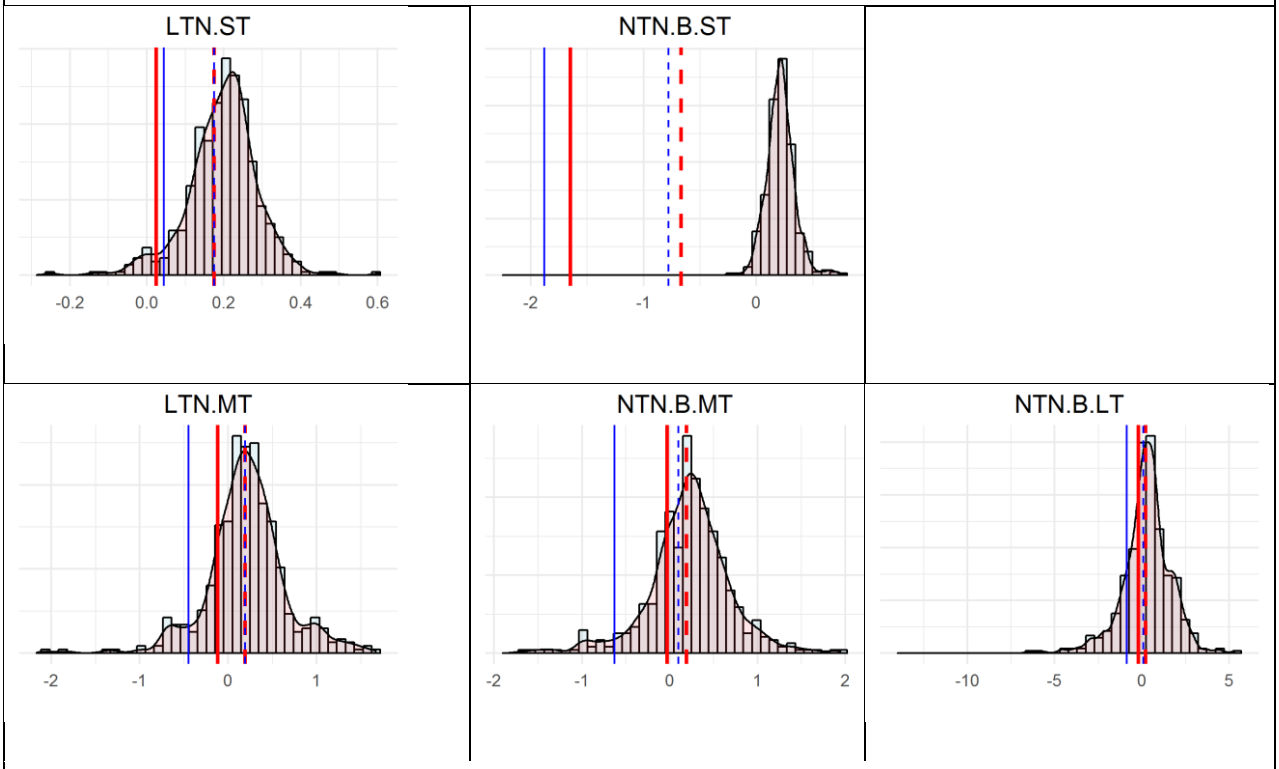
Bond (maturity)	Amihd	Waterfall			Pro rata		
		(1)	(2)	(3)	(1)	(2)	(3)
LTN (ST)	0.007	16 (6th)	3 (35th)	0 (50th)	11 (11th)	4 (31th)	1 (44th)
NTN-B (ST)	0.199	209 (0th)	99 (0th)	40 (0th)	92 (0th)	22 (3th)	13 (13th)
LTN (MT)	0.022	65 (7th)	1 (48th)	1 (48th)	110 (1th)	20 (26th)	14 (32th)
NTN-B (MT)	0.042	86 (4th)	13 (34th)	3 (45th)	113 (3th)	32 (17th)	17 (32th)
NTN-B (LT)	0.097	118 (15th)	23 (41th)	9 (47th)	223 (6th)	62 (27th)	29 (38th)

The left number under each asset sale schedule shows the amount of sales in R$ billion and the right number in percent shows the percentile in historical distribution of weekly trading volume relative to the median historical price changes. (1), (2) and (3) correspond to fund-homogeneity, fund-heterogeneity and fund-family calibrations. ST: Short-Term, MT: Medium-Term, LT: Long-Term

Source: BCB data and IMF staff calculations

[83] Brazil lost its investment grade in September 2015, which caused large volatility in government bonds market.

Figure 32. Brazil: Historical Distribution of Weekly Price Changes of Government Bonds (by Type and Maturity, in percent)



Note: Red color lines show price changes relative to median resulting from asset sales under 2017 market conditions and blue refers to 2015 market conditions. Solid lines indicate fund-homogeneity calibration and dashed-line indicates fund-heterogeneity calibration. Fund-family calibrations are not shown in the chart due to overlap.
Sources: BCB, CVM

Sensitivity of Redemptions to Fund Returns

140. The sensitivity of investors to fund returns was assessed by modeling the behavior of investor redemptions due changes in weekly returns and controlling for fund size and fund family fixed effects. The following regression model was estimated

$$F_{i,t} = \beta_i + \beta_1 R_{i,t-1} + \beta_2 R_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t}$$

where β_i captures fund-specific fixed effects, $F_{i,t}$ denotes fund flows to fund i, $R_{i,t-1}$ and $R_{i,t}$ denote weekly returns of fund i in the previous and current periods, $X_{i,t}$ captures control variables that we currently include year fixed effect to capture general changes in the macroeconomic environment and fund family fixed effects to reflect family specific trends. $\varepsilon_{i,t}$ is the error term of the regression. The second-round of redemptions were calculated using estimated elasticities of fund flows to fund returns. In turn, the Amihud measure was used to evaluate the price effect resulting from the second-round asset sales.

141. Regression model estimated for modeling investor behavior implies insignificant sensitivity of investors to changes in returns. We model the redemption flow rate in terms of current returns, lagged returns, year fixed effect and fund family fixed effect using weekly observations. Estimated regression model, reported in Table 18, shows insignificant effects on flow behavior arising from changes in returns when controlling for lagged returns and fund size (NAV) and including year and family fixed effects. The economically weak relationship between fund flow rates and returns suggests that investors are insensitive to short-term return fluctuations. The low elasticity of redemptions to Brazilian fund returns implies the second-round effect is insignificant in the Brazilian investment fund industry.

Table 18. Brazil: Regression Estimate Modeling Investor Redemption Behavior in Terms of Returns

	Dependent Variable: Flow Rate			
Coefficients:	**Estimate**	**Std. error**	**t-value**	**Pr(>|t|)**
(Intercept)	0.0051***	0.0005	7.664	0.000
Lag RETURN	0.0000	0.0002	0.01	0.990
RETURN	0.0011	0.0048	0.22	0.825
Year fixed effect	Yes			
Fund family fixed effect	Yes			
Adjusted R^2 = 0.07 percent				

INTERCONNECTEDNESS ANALYSIS

A. Overview

142. The interconnectedness analysis examined financial linkages among different sectors in Brazil and cross-border spillovers. The FSAP team analyzed financial linkages within the financial system and those between financial institutions and nonfinancial sectors, using flow-of-funds data. In addition, the FSAP team used market data to analyze cross-border spillovers between Brazil and major countries.

B. Cross-Sectoral Linkages

143. This section analyzes financial interlinkages among institutional sectors in Brazil using financial accounts (flow-of-funds data). This analysis is based on a non-consolidated dataset as of end 2016 from a BCB-IBGE joint project[84] for all resident institutional sectors and subsectors, as

[84] The FSAP team is very grateful for the support of the BCB statistics department, and IBGE in earlier exchanges, in providing the data, methodological information and relevant clarifications. BCB uses stocks and flows of financial accounts while IBGE matches the data using flows from the sectoral production accounts. See https://ww2.ibge.gov.br/english/estatistica/economia/contasnacionais/2014/default.shtm for additional

(continued)

defined by national accounting methodology (SNA 2008). The dataset is used to analyze financial interconnectedness by financial instruments within and between institutional sectors, including the rest of the world. The analysis includes ten institutional sectors comprising main aggregated non-financial sectors and disaggregated financial subsectors. In particular, the non-financial institutional sectors include: Government (GOV), Non-financial Corporations (NFC), Households and Non-profit Institutions Serving Households (HH) and the Rest of the World (ROW). The financial sector comprises the following subsectors: Central Bank of Brazil (BCB), Other Deposit-taking Institutions (BNK), Insurers and Pension Funds (INSPF), Other Financial Institutions (FIN), Monetary Investment Funds (IFM), comprise most of the 555-funds families[85], and Non-Monetary Investment Funds (IFNM), which include non-555 funds and remaining 555-funds such as fixed income-foreign debt funds and stocks funds. The 10 broad financial instruments categories aggregate a total of 22 financial instruments (Table 19). This classification broadly follows that of the ECB's "Financing and investment dynamics" statistics[86].

144. Households and the rest of the world are the biggest net lenders whereas non-financial corporations and the government are the largest net borrowers (Table 20). Banks, and investment funds, as the largest financial sectors, and NFC, the largest non-financial sector and the government, are both large holders and issuers of financial instruments[87].

methodological references. The dataset was obtained from several common sources of other datasets used at BCB for financial stability monitoring, including trade repositories or compulsory reporting to supervisory authorities such as CVM or BCB. This dataset has lower frequency due to methodological conventions and other operational capacity challenges and constraints, but it stands out as the only dataset that includes all sectors and all financial instruments. For instance, BCB use high frequency data to monitor individually supervised banks and other financial institutions (the database used in the multilayer interbank network analysis) across all financial instruments and also but separately securities transactions reported in TR among banking and non-banking financial institutions, including investment funds. This means that there is complete coverage of instruments but not for entities in the former and partial coverage in instruments but broader one of entities in the latter.

[85] 555-funds are funds governed by CVM's Instruction 555/14 and broadly include fixed income, foreign exchange, multimarket and stocks funds. Non-555 funds include private equity funds, asset backed securities funds and non-standard asset backed securities funds, ETF and real estate funds.

[86] Available for reference at https://www.euro-area-statistics.org/financing-and-investment-dynamics.

[87] Note that total assets and total liabilities by sector are in network analysis jargon out-strength and in-strength centrality measures, respectively and they inform about centrality of each sector in the network. See Appendix X for explanations of terms and interpretation of network analysis terms used in the analysis presented in this section.

Table 19. Brazil: Financial Accounts by Financial Instruments in 2016 Q4

BCB Code	Financial Instrument	Total Assets/Liabilities BRL Million	% Share	FSAP Category
AF1	Monetary gold and SDRs	32,210	0.1	
AF11	Monetary gold	8,180	0.0	Omitted
AF12	SDRs	24,031	0.1	
AF2	Currency and deposits	7,256,700	16.8	1
AF21	Currency	232,147	0.5	
AF22	Transferable deposits	1,732,247	4.0	
AF221	Interbank deposits	279,849	0.6	
AF229	Other transferable deposits	1,452,398	3.4	
AF29	Other deposits	5,292,307	12.3	
AF3	Debt securities	8,604,486	20.0	
	In domestic currency	7,182,288	16.7	
AF311	Short-term securities	972,995	2.3	2
AF321	Long-term securities	6,209,293	14.4	3
	In domestic currency	1,422,198	3.3	
AF312	Short-term securities	26,660	0.1	2
AF322	Long-term securities	1,395,538	3.2	3
AF4	Loans	6,335,062	14.7	
AF41	Short-term	1,173,943	2.7	4
AF42	Long-term	5,161,119	12.0	5
AF5	Equity and investment funds shares/units	15,001,190	34.8	
AF51	Equity	9,633,247	22.4	6
AF511	Listed shares	2,535,528	5.9	
AF512	Unlisted shares	7,097,719	16.5	
AF52	Investment funds shares/units	5,367,943	12.5	7
AF521	Money market funds shares/units	4,826,577	11.2	
AF522	Non-MMF investment funds shares/units	541,366	1.3	
AF6	Insurance, pension and standardized guarantee schemes	1,560,140	3.6	8
AF61	Technical reserves in non-life insurance	133,211	0.3	
AF62	Life insurance and annuity entitlements	662,286	1.5	
AF63	Pension entitlements	764,643	1.8	
AF71	Financial Derivatives	477,434	1.1	9
AF8	Other accounts receivable/ payable	3,817,121	8.9	10
AF81	Trade credits and advances	1,706,723	4.0	
AF89	Other accounts receivable/ payable, excluding trade credits and advances	2,110,399	4.9	
	Total	**43,084,344**	**100.0**	

Note: This table aggregates assets/liabilities across all institutional sectors. Monetary gold and SDRs are presented only for illustration but are not included in the analysis. Shares are highlighted using a color scale, where the largest is red and lowest is green.
Source: BCB.

Table 20. Brazil: Financial Accounts by Institutional Sector in 2016 Q4

	Total assets		Total liabilities		Net
	BRL Million	% share	BRL Million	% share	Financing/Investment
BCB	2,969,017	7.7	2,928,889	7.6	40,128
BNK	8,358,636	21.6	8,943,456	23.1	-584,819
INSPF	1,930,291	5.0	1,848,216	4.8	82,075
FIN	3,296,252	8.5	3,269,111	8.4	27,141
IFM	4,942,426	12.7	4,924,068	12.7	18,358
IFNM	526,429	1.4	572,767	1.5	-46,337
GOV	3,876,539	10.0	6,167,831	15.9	-2,291,292
NFC	6,235,561	16.1	9,383,692	24.2	-3,148,131
HH	6,238,167	16.1	2,353,143	6.1	3,885,024
ROW	4,678,815	12.1	2,660,962	6.9	2,017,853

Note: This table sums across rows (assets) and columns (liabilities) across institutional sectors. The color scales highlight large shares and large net financing needs in red. The data excludes Monetary gold and SDRs. Sectors acronyms: Central Bank of Brazil (BCB), Other Deposit-taking Institutions (BNK), Insurers and Pension Funds (INSPF), Other Financial Institutions (FIN), Monetary Investment Funds (IFM), Non-Monetary Investment Funds (IFNM), Government (GOV), Non-financial Corporations (NFC), Households and Non-profit Institutions Serving Households (HH) and the Rest of the World (ROW).
Source: IMF staff estimates and BCB.

145. The structure of cross-sectoral exposures is dominated by equity, cash and currency deposits, repos collateralized with government securities, debt securities, mainly long-term government securities, highlighting the nexus between sovereign and the financial sector (Figure 30). These three instruments amount for nearly 60 percent of the total. Equity instruments, mainly issued by NFC are nearly a quarter of total issued instruments. Long-term securities, predominantly issued by the government, ranked second with 18 percent. Currency and deposits, comprising deposits at banks and repos, rank third with almost 17 percent and include as main participants the government, BCB, banks and investment funds.

146. Interconnectedness in the Brazilian economy is underpinned by the role of government. The government plays a central role in the network mainly due to its role in public banks and state-owned firms, the importance of repos collateralized by government securities as the main instrument for conducting monetary policy and carrying out interbank transactions and the fact that government securities represent the main liquid financial instrument in Brazil.

147. Banks are the most interconnected sector by size of exposures and their presence across all financial instruments (layers). Non-financial corporates and households represent banks' largest borrowers (by taking bank loans) and lenders (by holding bank deposits and bank securities). Investment funds represent large source of bank funding, mostly via repo operations and to a smaller extent investment funds' holdings of bank deposits and bank securities. The government provides a large share of funding to public banks in the form of [equity or deposits?]. The large reciprocal link between banks and the BCB reflects monetary policy operations via repos collateralized with government securities.

148. Investment fund industry has strong links to banks and pension and insurance sectors. Investment funds mostly attracts funds from institutional investors such as pension funds and insurance companies. Retail investors such as corporates and households represent around 20 percent of investment funds' funding. Investment funds mainly invest in government securities and repos with (parent) banks as the main counterparties. By centrality measures such as hub scores or multiplex centrality (Appendix VI), this sector plays not only an important role in large markets but also in connecting other sectors and also layers. This means that shocks to their main financial instruments could potentially propagate through important layers of the system and hit many other sectors.

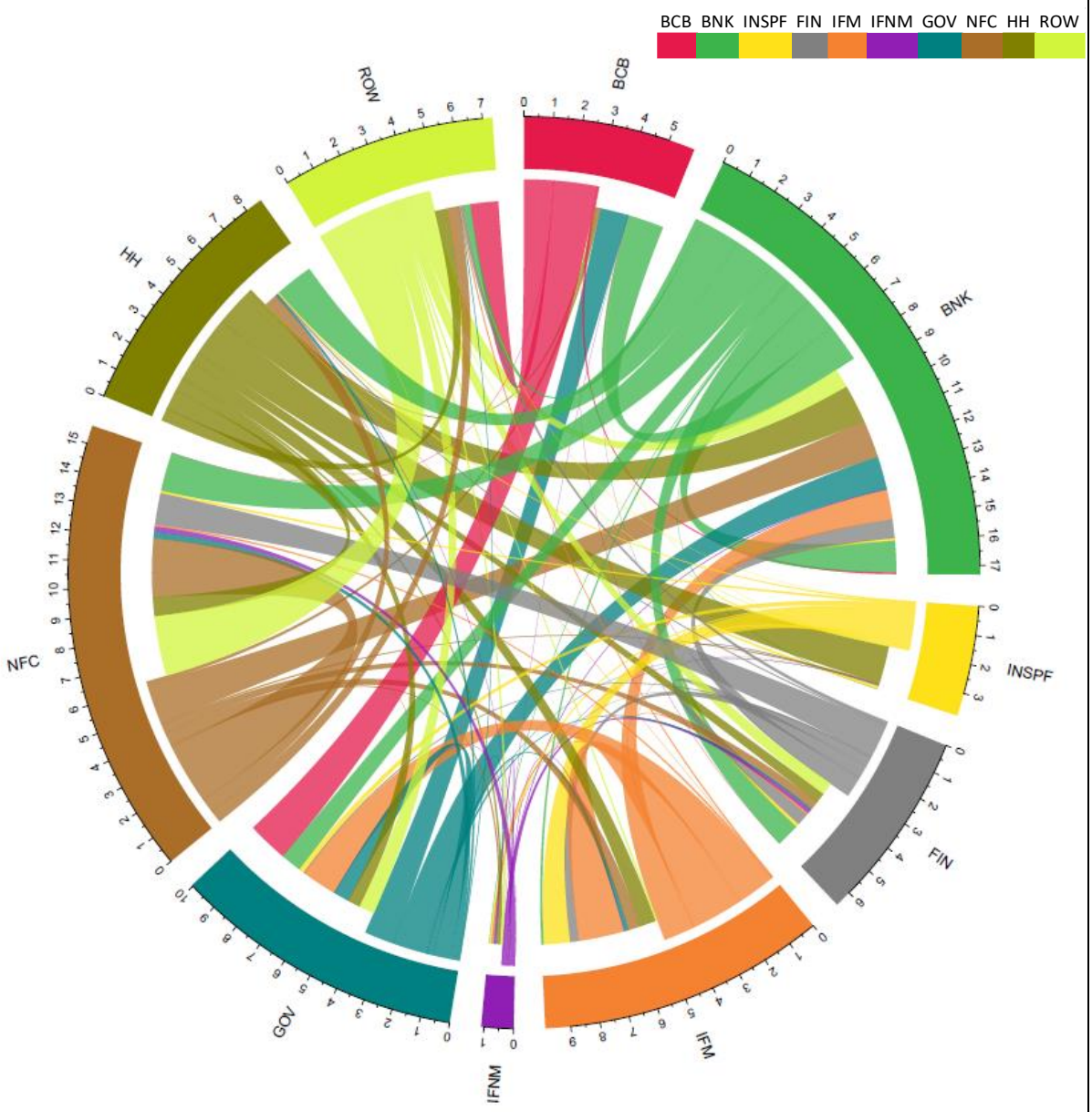
149. Pension funds and insurance companies mainly channel funds from households to investment funds. Around 85 percent of pension funds' and insurance companies' funding comes from households. Almost 60 percent of their assets is invested in investment funds' share and additional 10 percent in government securities.

150. Non-financial corporate sector has large bilateral exposures, mainly with the rest of the world, banks and within the non-financial corporate sector. The non-financial corporate sector-bank links are to a large extent reciprocal- banks lend and provide trade credit to the corporates while corporates hold banks securities and bank deposits. The rest of the world is an important source of corporates' funding, almost 30 percent of total funding (by holding firms' equity and proving long-term loans). Non-financial corporations have a very important role as central node in the network by number and size of exposures as well as for their position connecting layers and other sectors (Appendix VI). This sector has either large or the largest participation in several layers as holder and issuer of financial instruments, including securities, loans, equity and trade credit. Firms also rank high as a hub, which highlights its role as shock propagator. This result justifies active BCB work using payment systems and other supervisory data (Silva et al, 2017 and October 2017 Financial Stability Report) to shed light on other important transmission channels in addition to interbank markets and more importantly across financial layers.

151. Households stand out by their large holdings of pensions and insurance products, investment funds' shares and bank deposits. While the deposits of banks are roughly mirrored by borrowing from banks, the holdings of pensions and insurance products held by households explain their large net investment position.

152. Intra-sector exposures are important for corporates, investment funds and banks. This means that important channels of transmission across-sectors can also produce feedback effects within sectors. Non-financial corporates hold large amounts of equity and other receivables from other NFCs. Investment funds show strong intra-sectoral exposures in their own products. Interconnectedness among banks takes place mainly through interbank deposits and repo transactions.

Figure 33. Brazil: Cross-Sector Network in 2016 Q4

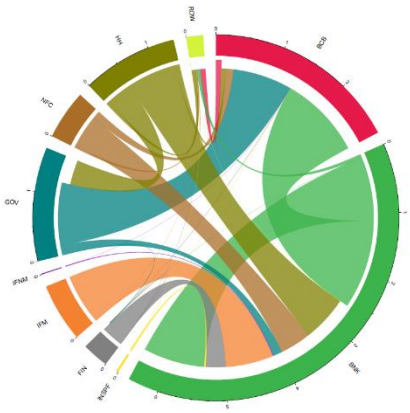


Note: The chord diagram shows ten institutional sectors (the nodes) arranged along the circle. The sector's segment size is the sum of its total assets and liabilities, it is denominated in trillions of BRL and has graduation accordingly. Each sector has its own color. Arc connections represent holdings of financial instruments (non-consolidated assets) are drawn closer to the sector labels while issuance of financial instruments (non-consolidated liabilities) are shown closer to the circle center in the colors of the holder. As data is non-consolidated, intra-sectoral exposures can be easily identified.

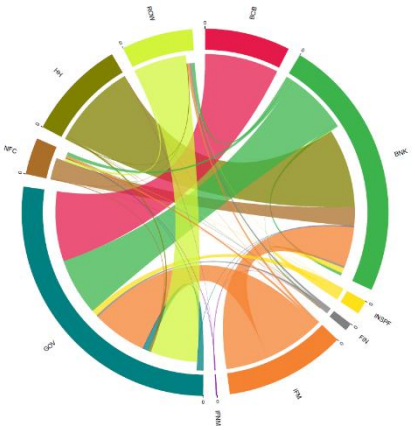
Source: IMF staff estimates and BCB.

Figure 34. Brazil: Selected Cross-Sector Subnetworks in 2016 Q4

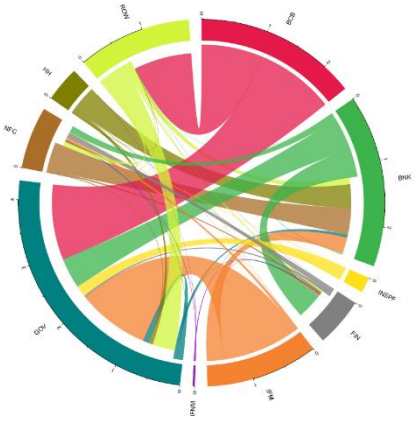
Currency and deposits



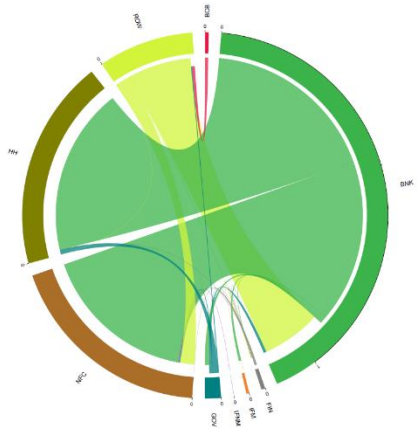
Short-term securities



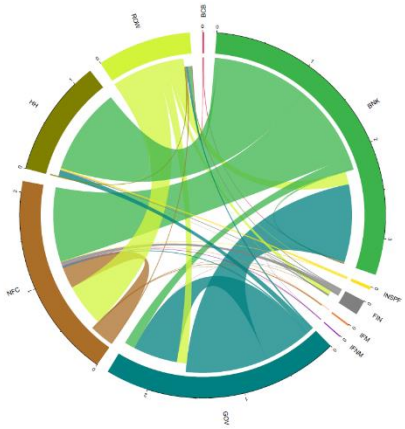
Long-term securities



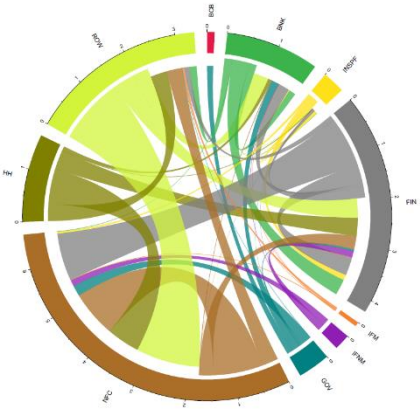
Short-term loans



Long-term loans



Equity

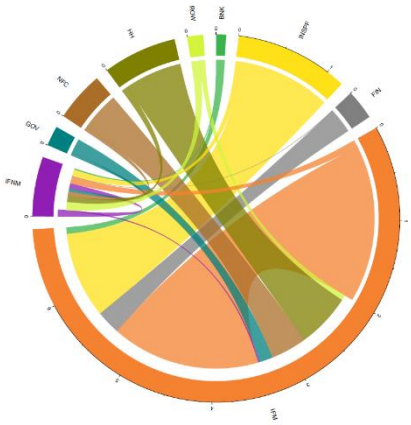


Source: IMF staff estimates and BCB.

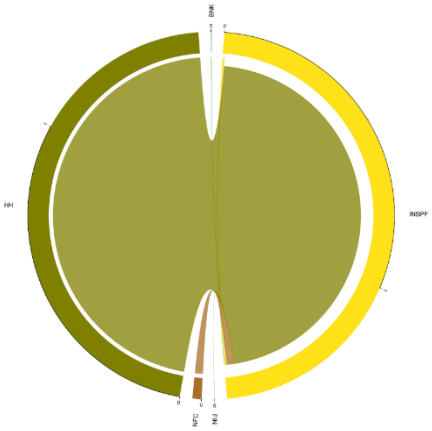
BCB BNK INSPF FIN IFM IFNM GOV NFC HH ROW

Figure 34. Brazil: Selected Cross-Sector Subnetworks in 2016 Q4 (concluded)

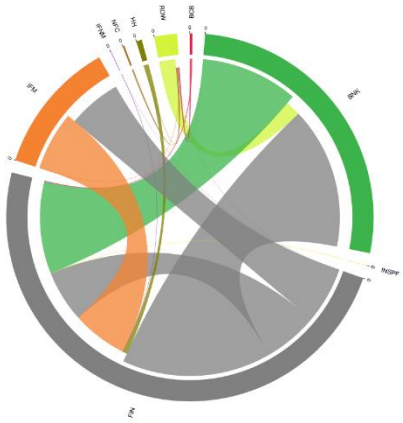
Investment funds shares/units



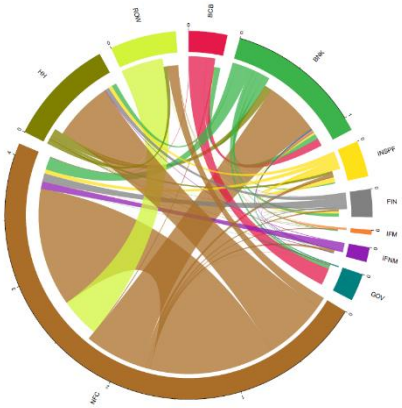
Insurance, pension and standardized guarantee schemes



Financial derivatives



Other accounts receivable/payable



Source: IMF staff estimates and BCB.

BCB BNK INSPF FIN IFM IFNM GOV NFC HH ROW

C. Cross-Border Spillovers Based on Market Data

153. This section analyzes cross-border linkages between Brazil and its 16 most relevant neighbors from a financial stability perspective. The methodology is based on Diebold and Yilmaz (2014, 2015) and recent extensions in Demirer et al. (2017). The method relies on variance decompositions of marked based variables in VAR models with adjustments to deal with large datasets and parametrization. The method produces weighted, directed and generally complete networks as well as measures of connectedness among returns and return volatilities. The method produces pairwise and total directional connectedness measures and each country's relative contribution to connectedness. This approach allows identifying and understanding connectedness between Brazil and relevant countries across different financial markets and potential channels of cross-border financial vulnerabilities. Returns and volatility connectedness are informative of financial stress episodes[88].

154. The analysis uses daily market information on stock, sovereign CDS and exchange rates. The application to stock indices, sovereign CDS and FX returns is undertaken to explore different channels of financial vulnerabilities for Brazil. A VAR model is estimated using daily returns of stock price indices (total market and banking sector indices), sovereign CDS and dollar FX rates. An additional exercise uses bank stock return volatilities of 86 large banks headquartered in the countries in the sample, including three largest private Brazilian banks and one public bank. The application to individual banks uses daily range-based volatility estimates and provides a consistency check to the results applied to total market and bank sector indices.[89] This approach requires high, low, opening and closing prices of each bank each day. The sample covers 2007Q4 and 2017Q3 and the country list includes Brazil's most important trade partners-- the most relevant Latin American economies; main financial centers; and other peer countries[90].

155. The method uses high-dimensional generalized variance decompositions with a chosen 10-day forecast obtained from a VAR model of daily returns and range volatilities.[91] The VAR model is estimated using three lags and an elastic net shrinking and selection procedure,

[88] Diebold and Yilmaz (2014) focused first on volatility connectedness of single stocks because it is asymmetric, which points out to stress episodes when it is high and normal times when it is low. Subsequent methodological extensions focus on returns connectedness due to data specificities and provide complementary information as they comove tightly with volatility connectedness during financial stress and economic recessions.

[89] See Demirel et al (2017) for details of the approach. Garman and Klass (1980) formula was used for most banks. Only Argentine and a pair of Chilean banks' volatilities where estimated using high and low prices and Parkinson (1980) formula due to data availability.

[90] This set of countries is routinely monitored by BCB's International Economy Division. The list of countries comprises Argentina, Chile, China, Colombia, France, Germany, India, Indonesia, Japan, Mexico, Russia, South Africa, Spain, Turkey, United Kingdom and the United States. See Appendix X for details on the sample in each market and the number of banks in the stock return volatility application.

[91] A VAR lag length, forecast horizon and rolling-window sizes were chosen using applications described in Diebold and Yilmaz (2015) and available at http://financialconnectedness.org. Range volatility is an estimator of latent volatility using intraday information, including high, low, close and opening prices.

combining LASSO and Ridge estimators (Demirer et al., 2017).[92] The shrinkage methods are introduced to handle large datasets and ease parametrization challenges. The variance decomposition needs to be invariant to ordering and therefore uses a generalized Koop-Pesaran-Potter- Shin identification framework. Due to different trading hours across time zones, returns are computed as the average of two days following standard applications in the literature and FSAP applications.

156. Connectedness measures include pairwise directional and system-wide measures. The method produces pairwise contributions to volatility on a given country/bank due to shocks in another country/bank. The "from" directional spillover denotes the extent to which the system explains the total expected variation of a country/bank. (inward spillover). The "to" directional spillover denotes contributions of individual country/bank to the rest of the system (outward spillover). Figure 32 shows the pairwise directional connectedness from countries in columns to the countries in rows. This is a result of a static analysis covering the full sample in each market. The figure is presented as a heatmap to emphasize the direction and strength of variance shares. The main diagonal was placed next to the heatmap as a column to highlight cross-border connectedness in the matrix while emphasizing the large share of variation due to domestic factors.

157. The results of the analysis point to relevant regional spillovers between Brazil and its main regional partners in stock and CDS markets and between Brazil and other large and financially integrated emerging economies in FX markets. Brazil is also exposed to shocks from advanced economies across markets such as the U.S. or euro area countries, which means that cross-market spillovers can take place from shocks to these economies or can be transmitted directly from one or some of them, i.e. the U.S., in more than one market at the same time.

158. There is a clear regional clustering pattern for stock market indices, especially for sovereign CDS. Regional clustering is stronger for sovereign credit risk spillovers as the country shares are less uniformly distributed[93].

159. In addition, the U.S. is a source of shocks in stock markets to most countries in the sample and may work as a channel of transmission of shocks generated in more remote regions. For a large number of countries in the sample, the U.S. is a direct, large source of potential shocks. To the extent that this makes the U.S. a global factor as a central node, shocks in other countries are likely to be spread with delay through the U.S. In network terms, the U.S. plays the role of main hub connecting regions.

[92] The FSAP team is grateful to TengTeng Xu for sharing the R code that was adapted to this application. In practice, LASSO shrinkage is not relevant for country level applications because of the relatively small number of countries in the list compared to the times series length. For the analysis of individual banks, some shrinkage takes place and penalizes large geographic distance.

[93] As the heatmaps are sorted by regions, the square areas right along the main diagonal tend to show larger average values while off-diagonal regions show lower values. This means that the larger inward and outward spillovers have a strong geographical nature that also creates important feedback effects

160. Brazil's stock market's and sovereign credit risk inward and outward spillovers are likely to spread mainly within Latin America and to come from the U.S., but also from advanced European countries directly in stock markets. Brazil shows very tight inward and outward spillover connections to its neighborhood in CDS markets and to a lesser extent to other large emerging markets, i.e. BRICs and MINTs[94] economies.

161. The outward spillover matrices do not differ significantly when applied to the total stock market index or to the bank stock indices. This may reflect that the financial sector plays an important role in country indices but mainly that international spillovers may not significantly differentiate between sectors and their idiosyncrasies, creating implicitly intersectoral contagion.

162. The spillovers in FX markets show a different structure, with less geographical clustering. The distribution of volatility spillovers is more concentrated among fewer countries and do not show a clear geographical clustering. In fact, Brazil is more closely linked to other large and financially integrated emerging economies such as Mexico, South Africa or Turkey, where spillovers are mutual, than it is to Argentina or Chile. This points out to channels of spillovers due to financial integration (IMF, 2016). Brazil is also subject to shocks from the euro area and the U.K. Finally, Brazil shocks matter to its vicinity significantly as a result of its weight in the region, becoming a net transmitter of shocks in FX markets.

163. The individual bank network has a strong geographical clustering, in line with findings for the country stock market applications (Table 20). Geographical clustering takes place, in line with findings in the literature, within countries and between countries, forming tightly connected regions.

164. The four large Brazilian banks in the sample also show strong clustering among themselves, but they are prone to shocks from U.S. banks. For each Brazilian bank, volatility shocks originated by the other Brazilian banks are large and range between 63.4 to 88.1 percent for Itaú and Santander, respectively. The second main source of volatility shocks comes from the U.S. and it is larger for banks where the domestic shocks are relatively smaller. For instance, domestic shocks to Santander sum up to 88.1 percent and US shocks are around 6 percent, whereas domestic shocks for Itaú are 63.4 while US shocks are significantly larger (24.4 percent). As U.S. banks are relatively remote from shocks from abroad with exception of other large European banks, spillovers from third countries to Brazil are not sizable. Brazilian banks do however not produce significant volatility spillovers, so reciprocity is limited. Some residual shocks come from Spain or France.

[94] Includes Brazil, Russia, India, South Africa, Mexico, Indonesia, Nigeria and Turkey.

Figure 35. Brazil: Diebold-Yilmaz Outward Spillover Matrices

Total stock market Index

		BRA	ARG	CHI	COL	MEX	CHN	IND	IDN	RUS	ZAF	TUR	FRA	DEU	ESP	GBR	JPN	USA
BRA	0.190		0.056	0.065	0.040	0.095	0.006	0.024	0.016	0.059	0.048	0.033	0.069	0.067	0.053	0.075	0.010	0.091
ARG	0.267	0.081		0.049	0.035	0.072	0.004	0.017	0.015	0.042	0.035	0.027	0.067	0.066	0.055	0.068	0.011	0.089
CHI	0.243	0.089	0.044		0.043	0.092	0.004	0.025	0.019	0.039	0.045	0.028	0.063	0.062	0.042	0.067	0.006	0.089
COL	0.270	0.075	0.043	0.061		0.081	0.005	0.025	0.016	0.044	0.040	0.027	0.059	0.055	0.046	0.070	0.011	0.072
MEX	0.206	0.091	0.046	0.069	0.038		0.004	0.027	0.016	0.048	0.049	0.028	0.067	0.070	0.049	0.069	0.010	0.113
CHN	0.564	0.035	0.020	0.023	0.019	0.032		0.041	0.028	0.023	0.021	0.017	0.032	0.031	0.022	0.033	0.023	0.034
IND	0.251	0.060	0.025	0.047	0.030	0.080	0.011		0.040	0.046	0.044	0.037	0.061	0.066	0.047	0.064	0.015	0.077
IDN	0.268	0.072	0.040	0.051	0.034	0.076	0.011	0.055		0.049	0.045	0.035	0.049	0.047	0.037	0.052	0.015	0.064
RUS	0.210	0.082	0.039	0.042	0.035	0.073	0.004	0.031	0.021		0.065	0.045	0.069	0.071	0.046	0.076	0.017	0.071
ZAF	0.195	0.074	0.035	0.053	0.033	0.086	0.004	0.030	0.023	0.064		0.040	0.073	0.073	0.051	0.080	0.011	0.074
TUR	0.261	0.064	0.031	0.041	0.030	0.058	0.003	0.031	0.022	0.061	0.053		0.070	0.071	0.058	0.073	0.009	0.065
FRA	0.143	0.059	0.039	0.044	0.027	0.065	0.003	0.024	0.012	0.045	0.046	0.033		0.126	0.108	0.117	0.014	0.094
DEU	0.154	0.057	0.038	0.044	0.025	0.066	0.003	0.026	0.011	0.047	0.046	0.034	0.131		0.097	0.111	0.013	0.096
ESP	0.179	0.056	0.040	0.037	0.027	0.059	0.002	0.022	0.011	0.037	0.040	0.035	0.135	0.116		0.106	0.014	0.085
GBR	0.145	0.065	0.040	0.048	0.033	0.071	0.003	0.026	0.012	0.048	0.050	0.033	0.116	0.108	0.085		0.013	0.101
JPN	0.174	0.057	0.040	0.042	0.029	0.071	0.008	0.031	0.019	0.046	0.036	0.027	0.084	0.085	0.067	0.080		0.102
USA	0.184	0.077	0.053	0.059	0.030	0.102	0.003	0.024	0.010	0.043	0.035	0.029	0.089	0.092	0.068	0.091	0.012	

Banks stock Index

		BRA	ARG	CHI	COL	MEX	CHN	IND	IDN	RUS	ZAF	TUR	FRA	DEU	ESP	GBR	JPN	USA
BRA	0.334		0.031	0.062	0.047	0.070	0.019	0.029	0.014	0.030	0.038	0.036	0.050	0.040	0.062	0.065	0.009	0.065
ARG	0.463	0.051		0.031	0.034	0.038	0.011	0.016	0.013	0.026	0.019	0.032	0.057	0.040	0.062	0.052	0.008	0.046
CHI	0.360	0.083	0.027		0.048	0.058	0.011	0.032	0.013	0.027	0.039	0.034	0.046	0.043	0.050	0.058	0.008	0.063
COL	0.365	0.079	0.028	0.056		0.049	0.018	0.026	0.022	0.032	0.032	0.031	0.046	0.036	0.054	0.061	0.018	0.047
MEX	0.350	0.087	0.030	0.051	0.037		0.012	0.021	0.016	0.036	0.031	0.030	0.053	0.043	0.054	0.064	0.007	0.076
CHN	0.376	0.062	0.028	0.024	0.031	0.038		0.050	0.040	0.042	0.031	0.031	0.049	0.037	0.048	0.061	0.024	0.029
IND	0.347	0.070	0.021	0.040	0.029	0.046	0.034		0.037	0.027	0.031	0.040	0.047	0.035	0.051	0.062	0.016	0.068
IDN	0.386	0.063	0.027	0.036	0.044	0.044	0.039	0.056		0.034	0.026	0.034	0.041	0.030	0.043	0.045	0.018	0.031
RUS	0.373	0.054	0.019	0.030	0.034	0.040	0.022	0.023	0.016		0.041	0.048	0.061	0.049	0.057	0.071	0.024	0.038
ZAF	0.374	0.062	0.018	0.048	0.031	0.041	0.015	0.023	0.018	0.039		0.050	0.055	0.030	0.061	0.067	0.010	0.059
TUR	0.370	0.060	0.025	0.036	0.033	0.036	0.014	0.031	0.018	0.045	0.050		0.060	0.044	0.063	0.066	0.010	0.039
FRA	0.221	0.042	0.030	0.027	0.025	0.035	0.013	0.018	0.010	0.032	0.029	0.033		0.108	0.154	0.136	0.013	0.074
DEU	0.272	0.043	0.024	0.032	0.025	0.037	0.009	0.022	0.007	0.032	0.021	0.032	0.130		0.116	0.114	0.014	0.070
ESP	0.229	0.052	0.031	0.030	0.028	0.035	0.013	0.021	0.010	0.031	0.033	0.037	0.153	0.097		0.119	0.016	0.065
GBR	0.215	0.055	0.026	0.034	0.032	0.043	0.017	0.025	0.010	0.037	0.034	0.036	0.128	0.089	0.111		0.017	0.092
JPN	0.297	0.053	0.026	0.027	0.038	0.037	0.024	0.026	0.016	0.042	0.020	0.027	0.068	0.059	0.079	0.085		0.076
USA	0.346	0.065	0.032	0.043	0.025	0.059	0.006	0.020	0.004	0.021	0.026	0.027	0.083	0.063	0.073	0.100	0.008	

Source: IMF Staff estimates, BIS and Thomson Reuters Datastream.
Note. The heatmap shows pairwise directional connectedness from countries in columns to the countries in rows. The elements in the main diagonal, corresponding to domestic spillovers, are placed in the first column outside the heatmap to emphasize the cross/border variance shares given that each country's own share tends to be large. Large values are shown in red, low values in green.

Figure 35. Brazil: Diebold-Yilmaz Outward Spillover Matrices (concluded)

Sovereign CDS

		BRA	ARG	CHI	COL	MEX	CHN	IND	IDN	RUS	ZAF	TUR	FRA	DEU	ESP	GBR	JPN	USA
BRA	0.297			0.115	0.169	0.165	0.025		0.019	0.027	0.079	0.072	0.009	0.005	0.012	0.006	0.000	
ARG																		
CHI	0.264	0.102			0.162	0.147	0.032		0.024	0.028	0.085	0.082	0.022	0.011	0.026	0.014	0.001	
COL	0.228	0.130		0.140		0.169	0.028		0.024	0.035	0.089	0.085	0.020	0.013	0.025	0.015	0.000	
MEX	0.240	0.134		0.134	0.177		0.029		0.024	0.029	0.084	0.084	0.018	0.010	0.023	0.013	0.001	
CHN	0.286	0.056		0.075	0.084	0.086			0.117	0.030	0.071	0.076	0.027	0.024	0.035	0.017	0.016	
IND																		
IDN	0.306	0.063		0.077	0.088	0.090	0.126			0.025	0.075	0.077	0.017	0.015	0.022	0.010	0.009	
RUS	0.453	0.047		0.054	0.076	0.062	0.030		0.020		0.088	0.092	0.019	0.013	0.029	0.014	0.001	
ZAF	0.252	0.077		0.087	0.107	0.098	0.039		0.036	0.052		0.152	0.024	0.016	0.038	0.021	0.001	
TUR	0.254	0.064		0.081	0.098	0.092	0.043		0.039	0.056	0.153		0.032	0.019	0.048	0.020	0.001	
FRA	0.424	0.014		0.037	0.038	0.034	0.019		0.006	0.020	0.043	0.057		0.111	0.136	0.060	0.002	
DEU	0.496	0.010		0.022	0.029	0.024	0.019		0.009	0.016	0.033	0.040	0.124		0.092	0.080	0.006	
ESP	0.391	0.017		0.039	0.043	0.039	0.022		0.012	0.028	0.060	0.076	0.120	0.080		0.069	0.005	
GBR	0.517	0.011		0.028	0.034	0.029	0.015		0.007	0.018	0.043	0.041	0.072	0.088	0.093		0.004	
JPN	0.882	0.002		0.004	0.003	0.003	0.043		0.023	0.003	0.006	0.005	0.003	0.011	0.007	0.005		
USA																		

US dollar exchange rates

		BRA	ARG	CHI	COL	MEX	CHN	IND	IDN	RUS	ZAF	TUR	FRA	DEU	ESP	GBR	JPN	USA
BRA	0.368		0.001	0.005	0.009	0.151	0.006	0.051	0.031	0.045	0.128	0.116	0.042			0.043	0.004	
ARG	0.991	0.002		0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.000	0.000			0.001	0.002	
CHI	0.387	0.082	0.000		0.040	0.096	0.010	0.056	0.031	0.046	0.091	0.070	0.050			0.041	0.001	
COL	0.429	0.085	0.001	0.042		0.090	0.006	0.039	0.030	0.072	0.076	0.067	0.032			0.029	0.002	
MEX	0.347	0.143	0.000	0.007	0.008		0.007	0.063	0.030	0.047	0.140	0.114	0.042			0.041	0.009	
CHN	0.758	0.013	0.001	0.002	0.001	0.016		0.027	0.022	0.016	0.026	0.020	0.047			0.040	0.012	
IND	0.451	0.062	0.000	0.002	0.002	0.082	0.016		0.050	0.047	0.093	0.094	0.058			0.042	0.002	
IDN	0.562	0.048	0.000	0.001	0.004	0.049	0.016	0.063		0.044	0.069	0.065	0.039			0.039	0.001	
RUS	0.516	0.063	0.000	0.003	0.012	0.070	0.011	0.053	0.040		0.078	0.062	0.050			0.040	0.002	
ZAF	0.313	0.109	0.000	0.006	0.005	0.126	0.010	0.064	0.038	0.047		0.151	0.071			0.059	0.001	
TUR	0.334	0.106	0.000	0.002	0.005	0.110	0.009	0.069	0.038	0.040	0.161		0.066			0.055	0.004	
FRA	0.409	0.046	0.000	0.003	0.003	0.050	0.025	0.052	0.028	0.040	0.092	0.081				0.151	0.019	
DEU																		
ESP																		
GBR	0.443	0.051	0.000	0.001	0.001	0.053	0.023	0.042	0.031	0.034	0.083	0.074	0.164				0.000	
JPN	0.885	0.010	0.001	0.000	0.000	0.023	0.014	0.004	0.002	0.004	0.003	0.012	0.042			0.000		
USA																		

Source: IMF Staff estimates, BIS and Thomson Reuters Datastream.
The heatmap shows pairwise directional connectedness from countries in columns to the countries in rows. The elements in the main diagonal are placed in the first column outside the heatmap to emphasize the cross/border variance shares given that each country's own share tends to be large. Large values are shown in red, low values in green. For sovereign CDS, Argentina, India and USA have been omitted due to lack of data. For US dollar exchange rates, data for Germany and Spain have been omitted for redundancy and the euro area is represented by France.

Figure 36. Brazil: Summary Diebold-Yilmaz Outward Spillover Matrices for Individual Banks

		BR01	BR02	BR03	BR04	BRA	ARG	CHI	CHN	COL	FRA	DEU	IND	IDN	MEX	RUS	ZAF	ESP	TUR	GBR	USA
BR01	**Banco do Brasil**	0.523	0.130	0.170	0.006	**0.829**	0.005	0.001	0.001	0.000	0.018	0.003	0.006	0.005	0.001	0.001	0.002	0.022	0.003	0.002	0.092
BR02	**Itaú Unibanco**	0.097	0.397	0.136	0.004	**0.634**	0.010	0.001	0.002	0.001	0.029	0.003	0.021	0.001	0.006	0.000	0.013	0.021	0.002	0.003	0.244
BR03	**Bradesco**	0.145	0.149	0.466	0.004	**0.764**	0.016	0.001	0.002	0.000	0.025	0.002	0.014	0.001	0.012	0.000	0.020	0.025	0.001	0.002	0.108
BR04	**Banco Santander**	0.009	0.007	0.007	0.857	**0.881**	0.002	0.002	0.006	0.001	0.002	0.003	0.029	0.002	0.001	0.000	0.003	0.003	0.004	0.002	0.060

Source: IMF Staff estimates, BIS and Thomson Reuters Datastream.
The heatmap shows pairwise directional connectedness from countries in columns (sum of banks in each country) to the four large Brazilian banks. The BRA column aggregates all domestic spillovers while the other countries connections are highlighted by row using a heatmap color scale, where larger shocks are in red and smaller in green.

Appendix Table 1. Brazil: Banking Financial Soundness Indicators

	2007				2012				2017			
	Number of Institutions	Financial sector assets			Number of Institutions	Financial sector assets			Number of Institutions	Financial sector assets		
		R$ billion	Percent of total	Percent of GDP		R$ billion	Percent of total	Percent of GDP		R$ billion	Percent of total	Percent of GDP
Depository institutions	1,673	2,520.7	60.6	92.7	1,478	5,877.9	68.7	122.1	1,137	8,080.6	63.6	123.2
Multiple and commercial banks 1/	119	2,245.7	53.9	82.6	123	4,982.3	58.2	103.5	118	6,887.1	54.2	105.0
o/w, by size 2/:												
Large banks	3	931.0	22.4	34.2	4	3,439.7	40.2	71.4	6	5,762.9	45.3	87.8
Medium banks	9	960.7	23.1	35.3	6	969.6	11.3	20.1	5	434.3	3.4	6.6
Small banks	36	294.5	7.1	10.8	29	460.0	5.4	9.6	31	552.6	4.3	8.4
Mirco banks	71	59.5	1.4	2.2	84	113.0	1.3	2.3	76	137.3	1.1	2.1
o/w, by ownership:												
Federal government-owned banks	6	633.3	15.2	23.3	4	1,775.0	20.7	36.9	3	2,683.2	21.1	40.9
State government-owned banks	6	83.0	2.0	3.1	5	75.0	0.9	1.6	5	122.1	1.0	1.9
Private banks, domestically-controlled	59	978.4	23.5	36.0	58	2,213.0	25.8	46.0	53	2,930.7	23.1	44.7
Private banks, foreign-control	48	551.0	13.2	20.3	56	918.8	10.7	19.1	57	1,151.0	9.1	17.5
Development banks	3	205.5	4.9	7.6	4	708.1	8.3	14.7	4	893.2	7.0	13.6
Savings banks	0	0.0	0.0	0.0	0	0.0	0.0	0.0			0.0	0.0
Savings and loans associations	2	2.1	0.1	0.1	2	4.6	0.1	0.1	1	7.3	0.1	0.1
Credit unions	1,441	38.1	0.9	1.4	1,250	103.5	1.2	2.1	920	199.3	1.6	3.0
Investment banks	10	22.7	0.5	0.8	10	65.2	0.8	1.4	10	62.5	0.5	1.0
Consumer finance companies	35	4.7	0.1	0.2	40	13.2	0.2	0.3	42	30.1	0.2	0.5
Real estate credit companies	17	1.8	0.0	0.1	13	1.4	0.0	0.0	6	0.8	0.0	0.0
Micro-financing institutions	46	0.1	0.0	0.0	36	0.1	0.0	0.0	36	0.3	0.0	0.0
Non-depository financial institutions	484	18.9	0.5	0.7	394	25.9	0.3	0.5	303	41.4	0.3	0.6
Development agencies	12	3.7	0.1	0.1	16	8.0	0.1	0.2	14	10.6	0.1	0.2
Leasing companies	3	1.0	0.0	0.0	3	1.9	0.0	0.0	6	2.5	0.0	0.0
Securities brokerage companies	69	5.9	0.1	0.2	57	5.4	0.1	0.1	36	9.4	0.1	0.1
Exchange brokerage companies	45	0.1	0.0	0.0	52	0.2	0.0	0.0	55	0.4	0.0	0.0
Security Distribution companies	70	3.2	0.1	0.1	67	1.4	0.0	0.0	50	1.5	0.0	0.0
Consortium managers	285	5.0	0.1	0.2	199	9.0	0.1	0.2	142	17.0	0.1	0.3
Insurance companies	150	207.3	5.0	7.6	156	517.0	6.0	10.7	151	1,037.0	8.2	15.8
o/w open pension funds	29	89.5	2.2	3.3	33	288.2	3.4	6.0	27	728.5	5.7	11.1
Life (long-term)	38	100.7	2.4	3.7	34	248.5	2.9	5.2	28	488.8	3.8	7.5
Nonlife (general)	97	73.9	1.8	2.7	96	142.8	1.7	3.0	92	210.2	1.7	3.2
Life and non-life	15	32.7	0.8	1.2	13	109.5	1.3	2.3	15	309.2	2.4	4.7
Reinsurance	n.a	n.a	n.a	n.a	13	16.2	0.2	0.3	16	28.8	0.2	0.4
Pension fund management companies	401	547.2	13.1	20.1	360	1,042.8	12.2	21.7	334	1,699.0	13.4	25.9
Closed Pension fund companies	372	457.7	11.0	16.8	327	678.6	7.9	14.1	307	837.2	6.6	12.8
Pension funds' states and municipalities 3/	n.a	n.a	n.a	n.a	n.a	76.0	0.9	1.6	n.a	133.3	1.0	2.0
Open pension funds with insurance firms	29	89.5	2.2	3.3	33	288.2	3.4	6.0	27	728.5	5.7	11.1
Investment and asset managers 4/	87	1,160.0	27.9	42.6	93	2,268.0	26.5	47.1	107	4,174.5	32.8	63.6
o/w closed pension funds		68.9	1.7	2.5		408.9	4.8	8.5		544.1	4.3	8.3
o/w pension funds' states and municipalities		n.a	n.a	n.a		64.0	0.7	1.3		118.3	0.9	1.8
o/w insurance companies		104.1	2.5	3.8		321.5	3.8	6.7		787.6	6.2	12.0
o/w depository institutions		26.9	0.6	1.0		48.7	0.6	1.0		68.4	0.5	1.0
o/w non-depository financial institutions		2.0	0.0	0.1		38.9	0.5	0.8		76.4	0.6	1.2
Total financial sector 5/		4,162.8		153.0		8,561.5		177.8		12,709.1		193.7
Money and capital markets 6/												
Money market		443.0	10.6	16.3		886.0	10.3	18.4		1,830.0	14.4	27.9
Government bond market		1,224.9	29.4	45.0		1,916.7	22.4	39.8		3,435.5	27.0	52.4
Corporate bond market		223.0	5.4	8.2		507.6	5.9	10.5		747.9	5.9	11.4
Equity market		1,765.0	42.4	64.9		2,000.6	23.4	41.6		2,575.9	20.3	39.3
Derivatives market 7/		1,728.7	38.8	63.5		3,703.3	38.1	76.9		5,340.6	35.5	81.4
Memorandum items:												
Insurance firms ex- open pension funds		117.8	2.8	4.3		228.8	2.7	4.8		308.6	2.4	4.7
Invest funds ex- closed pension and insurance		987.0	23.7	36.3		1,473.6	17.2	30.6		2,724.5	21.4	41.5
Nominal GDP		2,720.3	65.3			4,814.8	56.2			6,559.9	51.6	

Sources: B3; Brazil Financial and Capital Markets Association (ANBIMA); Brazilian authorities; and IMF staff calculations.

1/ *Caixa* is classified as a multiple bank (not savings bank) as this best describes its activities from an economic perspective.

2/ Exposure to GDP ratio according to CMN Resolution 4553/2017. Exposure is an indicator of balance and off-balance assets, which is defined by Circular 3748/2015.

3/ Funds under the supervision of SPPS (Secretariat of Social Security Policies). Preliminary data indicate that by 2017 there were about 2,000 funds.

4/ Assets refers to assets under management.

5/ Aggregation may overstate the total size in due to some double-counting.

6/ This aggregation reduces double counting of investment funds with closed and open pensions, insurance companies and depository /non-depositary institutions.

7/ Amount outstanding unless otherwise noted.

Appendix I. Characterization of Baseline and Adverse Scenarios

1. The baseline and adverse scenarios are characterized by a set of global and domestic, macro and financial variables (Table 1). Global indicators include global real GDP growth, U.S. interest rates and commodity prices. Domestic indicators include real GDP growth, nominal GDP growth, inflation rate, unemployment rate, interest rates, exchange rate, equity price, house price, EMBI spread, and bank credit growth.

Table 1. Brazil: List of Key Macro and Financial Variables

Variable	Source for the baseline	Additional note
Global indicators		
Energy commodity price	WEO global assumptions	Include crude oil, natural gas, and coal
Non-energy commodity price	WEO global assumptions	Include food and beverages, and industrial inputs (agricultural materials and metals)
Domestic indicators		
Real GDP	WEO projections	
Nominal GDP	WEO projections	
Inflation rate	WEO projections	Consumer price
Unemployment rate	WEO projections	
Exchange rate	WEO projections	
Equity price	FSAP estimates	
House price	FSAP estimates	BIS property price index
Policy interest rate	WEO projections	Selic
Long-term government bond yield	WEO projections	10-year government bond yield
Bank funding rate	FSAP estimates	
Bank lending rate	FSAP estimates	
EMBI spread	FSAP estimates	
Bank credit	FSAP estimates	

2. Macro and financial variables for the baseline scenario were either obtained readily from WEO projections or projected using variables available from WEO projections. The baseline scenario is based on the October 2017 WEO projections. However, some of the macro and financial variables are not part of the WEO projections produced by the IMF country team; as a result, these variables were projected by the FSAP team.

- **Variables that are part of WEO projections.** These variables were projected by either the IMF's Research Department (i.e., global WEO assumptions) or the country team. It is noteworthy that the WEO projection horizon on the quarterly basis is typically up to 2 years. Hence, quarterly figures for outer years were interpolated based on the (average) annual figure available from WEO projections.

- **Variables that are not part of WEO projections.** A set of simple regression models are employed to obtain the projection of these variables. Specific details are presented in Table 2.

Table 2. Brazil: Estimation Methods for Selected Variables in the Baseline

Variable	Estimation Method
Bank funding rate	The projection of bank funding rate is based on the change in the estimated bank funding rate: $Bank\ funding\ rate_t = 2.3 + 0.6\ Selic_t$.
Bank lending rate	The projection of bank lending rate is based on the change in the estimated bank lending rate: $Bank\ lending\ rate_t = 15.3 + 0.9\ Selic_t - 0.5\ Real\ GDP\ growth_{t-2}$.
Real equity price	The projection of real equity price is based on the estimated real equity price growth: $Real\ equity\ price\ growth_t = -4.0 + 1.7\ Real\ GDP\ growth_t - 1.3\ \Delta Selic_t - 9.3\ \Delta EMBI\ spread_t$. The projection is being smoothed to remove some volatility.
Real house price	The projection of real house price is based on the estimated real house price growth: $Real\ house\ price\ growth_t = -3.5 + 0.7\ \Delta Real\ house\ price\ growth_{t-4} + 0.9\ Real\ GDP\ growth_t - 1.8\ \Delta Selic_t$. The projection is being smoothed to remove some volatility.
EMBI spread	The projection of EMBI spread is based on the estimated change in EMBI spread: $\Delta EMBI\ spread_t = -0.4 + 0.1\ Exchange\ rate\ depreciation_t$. The estimated EMBI spread is subject to the historical minimum level.
Credit to GDP	The projection of credit to GDP is based on the estimated change in credit to GDP: $\Delta Credit/GDP_t = 2.0 + 0.2\ Real\ GDP\ growth_{t-1} + 0.2\ Real\ house\ price\ growth_{t-4}$. The projection is being smoothed to remove some volatility.

3. The adverse scenario was simulated using the GFM to capture key domestic and external macrofinancial risks faced by Brazil. The GFM provides a simulation as deviations from the baseline. Combining the simulated scenario from the GFM with the baseline scenario described above yields the complete adverse scenario.

4. The adverse scenario features a double-dip recession with a sudden stop of capital flows driven by negative macrofinancial shocks. The adverse scenario is largely triggered by domestic developments, namely the loss of confidence, but also takes place in the challenging global environment, as described in the RAM. The simulation of the adverse scenario was subject to certain policy constraints.[1]

5. At the global level, the adverse scenario envisages tighter and more volatile global financial conditions and a significant slowdown in China. The normalization of U.S. monetary policy and the tapering of quantitative easing (QE) in the euro area would raise interest rates, decompress risk premiums, and strengthen the U.S. dollar and the euro vis-à-vis other currencies.

[1] Conventional monetary policy responds endogenously with nominal policy interest rate cuts subject to effective zero lower bound constraints worldwide, while no additional unconventional monetary policy responses are envisaged. For the purpose of the stress testing exercise, automatic relaxation of regulatory capital requirements is assumed in Brazil is assumed so that the simulation abstracts from any increase in banks' lending interest rate in response to deterioration in banks' capital position (relative to the regulatory requirement).

Disruptive market adjustments could occur on the back of policy surprises. An abrupt repricing of risks could also occur in light of some overstretched asset valuations that have been partly supported by high leverage in the low interest rate environment. In addition, China could face significant financial stress and an economic slowdown due to the existing financial imbalances after years of rapid credit growth, leverage buildup, and an expansion of shadow banking activity. Efforts to rein in financial sector risks expose vulnerabilities of indebted entities, leading to an abrupt adjustment with significant adverse effects on economic activity. More specifically, these global layers were modelled as follows.

- **Asset price corrections would occur globally, prompting some credit cycle downturns.** The disruptive market adjustments are accompanied by the decline in house prices and equity prices across countries, with varying degrees depending on the level of asset price overvaluation and excessive leverage (Layer 1, Table 3). There is also flight to quality where safe-haven economies see a compression in the term premium on long-term bonds while other financially open economies face rising long-term bond yields. These market corrections also trigger persistent credit cycles downturns, with effects captured by increasing default rates (Layer 2, Table 3).

- **China would experience significant financial stress and growth slowdown.** Financial stress is manifested by a respective decline real house price and real equity price by 12.5 and 25 percent, a surge in capital outflows that depreciate the Chinese renminbi by 12.5 percent in real terms against the U.S. dollar, and a decompression of risk premiums that raises the short-term money market spread and the long-term government bond yield by 150 and 75 basis points, respectively (Layer 3, Table 3). Financial stress also has a significant negative impact on economic activity, particularly through investment.

- **Economic risk-taking would be suppressed globally due to increased uncertainty.** The domestic demand falls, driving a decline in private consumption, residential investment and business investment by 1, 4 and 4 percent, respectively, across all countries (Layer 4, Table 3). Global output is further impacted by negative spillovers through the trade channel.

- **The Brazilian economy would face inward spillovers through the trade and financial channels.** In addition to the immediate impact of asset price corrections, credit cycle downturn, and weakening consumption and investment, Brazil would embrace negative spillover effects through financial market volatility (due to asset price co-movements), worsening terms of trade (due to falling commodity prices), and lower export demand (due to moderating global economic growth).

6. At the domestic level, the adverse scenario envisages a loss in confidence that causes a sizeable output contraction and a sudden stop of capital flows. Key risk factors involve both political and policy aspects. The failure to pass an adequate social security and other reforms necessary to secure fiscal sustainability, the uncertainty surrounding the outcome of the 2018 presidential elections and associated policy uncertainty, and the broadening of the corruption scandal could severely undermine confidence, resulting in a sudden stop of capital flows, a credit cycle downturn, and a significant growth slowdown, as illustrated by the following domestic layers:

- **A sudden stop of capital flows takes place amidst of domestic financial market turmoil and a credit cycle downturn.** The sudden stop creates massive pressures on the Brazilian real, with depreciation of 50 percent against the U.S. dollar in real terms. While a spike in the government bond yield reflects concerns about the fiscal sustainability and higher inflationary expectations following large exchange rate depreciation, the sudden stop also affects the money market, the stock market, and the housing market. In particular, the long-term government bond yield increases by 700 basis points, the short-term money market spread (relative to the policy rate) edges up 50 basis points, the real equity price declines by 30 percent, and the real house price falls by 7.5 percent (Layer 5, Table 3). The financial market turmoil creates financial stress, with a significant negative impact on economic activity, particularly through investment. In addition to market losses, banks face credit losses as output contracts and unemployment rises, raising lending interest rates (Layer 6, Table 3). As a result, credit supply is constrained, with negative spillovers to the real sector.

- **A loss of confidence weakens private consumption, residential investment and business investment.** Financial stress also has negative effects on corporate and household balance sheets, including liquidity squeeze, with knock-on effects on economic activity. All these effects cause a decline in private consumption, residential investment and business investment by 4, 16, and 16 percent, respectively (Layer 7, Table 3).

Table 3. Brazil: Description of Shocks for the Adverse Scenario

Description	Magnitude at Peak
Layer 1: Asset price corrections globally, 2018	
House price; Housing risk premium shocks	-2,-4,-6 percent
Equity price; Equity risk premium shocks	-9,-12,-15 percent
Term premium; Duration risk premium shocks	
Safe havens	-25 basis points
Other financially open economies	+50 basis points
Layer 2: Credit cycle downturn globally, 2018-20	
Mortgage loan default rate; Mortgage loan default shocks	+0.1,+0.2,+0.3 percentage point
Corporate loan default rate; Corporate loan default shocks	+0.3,+0.4,+0.5 percentage point
Layer 3: Financial stress and growth slowdown in China, 2018	
Real house price; Housing risk premium shocks	-12.5 percent
Real equity price; Equity risk premium shocks	-25 percent
Money market interest rate spread; Credit risk premium shocks	+150 basis points
Long-term government bond yield; Duration risk premium shocks	+75 basis points
Real bilateral exchange rate; Current risk premium shocks	+12.5 percent

Table 3. Brazil: Description of Shocks for the Adverse Scenario (concluded)

Description	Magnitude at Peak
Layer 4: Suppressed economic risk taking globally, 2018-20	
Private consumption; Consumption demand shocks	-0.5 percent
Residential investment; Residential investment demand shocks	-2 percent
Business investment; Business investment demand shocks	-2 percent
Layer 5: Sudden stop of capital flows in Brazil, 2018-19	
Real house price; Housing risk premium shocks	-7.5 percent
Real equity price; Equity risk premium shocks	-30 percent
Money market interest rate spread; Credit risk premium shocks	+50 basis points
Long-term government bond yield; Duration risk premium shocks	+700 basis points
Real bilateral exchange rate; Current risk premium shocks	+50 percent
Layer 6: Credit risk materialization in Brazil, 2018-20	
Mortgage loan default rate; Mortgage loan default shocks	+1 percentage point
Corporate loan default rate; Corporate loan default shocks	+4 percentage points
Layer 7: Weak domestic demand in Brazil, 2018-20	
Private consumption; Consumption demand shocks	-4 percent
Residential investment; Residential investment demand shocks	-16 percent
Business investment; Business investment demand shocks	-16 percent

7. In the adverse scenario, Brazil would experience a severe recession that would result in significant financial stress. Real GDP falls 11.8 percent below the baseline by 2018. Appendix Table I.4 shows key macro and financial variables in both baseline and adverse scenarios, with following key features.

- **The economy thus enters another recession,** with negative real GDP growth for 2018 and 2019 (-4.3 and -3.9 percent, respectively). Despite output contraction, CPI-based inflation accelerates during 2018-19 due to large exchange rate depreciation before moderating in 2019 as the impact of economic slack kicks in. The unemployment rate rises above 16 percent, the highest level ever.

- **Financial stress manifests in all key markets.** The exchange rate depreciates more than 50 percent, reaching 4.8 real per U.S. dollar on average in 2019, as capital flows out of the country. The bond and stock markets get hit severely, with the share price falling by almost 50 percent in and the government bond yield increases by 800 basis points by end-2018. House price also declines by about 7 percent.

- **Monetary policy is being tightened in the initial phase before being loosened subsequently.** Selic is raised to 11 percent on average in 2018, mainly to contain inflationary pressures stemming from sharp exchange rate depreciation. Accommodative monetary policy follows given the large negative output gap, with Selic being reduced to 8.1 and 4.5 percent on average in 2019 and 2020, respectively.

- **The spread between bank funding rate and bank lending rate is compressed.** While both bank funding and lending rates broadly move with the policy rate, the spread is reduced given the larger increase on the funding side. Banks also adjust lending rates in response to the rise in the expected cost of credit risk, with the spread between bank lending rate and policy rate reaching 19 percentage points.

- **Banks' credit supply becomes more constrained during 2018-19.** Bank credit remains essentially flat in 2018 and contracts by 2.6 percent in 2019. Bank credit growth turns positive in 2020, broadly in line with the economic recovery.

Table 4. Brazil: Key Macro and Financial Variables in the Baseline and Adverse Scenarios

(In percent; unless indicated otherwise)

	Baseline scenario					Adverse scenario		
	2016	2017	2018	2019	2020	2018	2019	2020
Real GDP growth	-3.6	0.7	1.5	2.0	2.0	-4.3	-3.9	1.6
Inflation rate	8.7	3.7	4.0	4.1	4.1	6.1	5.8	1.3
Unemployment rate	11.5	13.1	11.8	11.0	10.4	13.8	16.1	15.9
Exchange rate (real per U.S. dollar)	3.5	3.2	3.2	3.3	3.3	4.6	4.8	4.4
Equity price (2016=100)	100	118	127	132	140	86	88	103
House price (2016=100)	100	97	99	101	102	91	94	97
Selic	14.2	9.9	7.8	8.2	8.7	11.0	8.1	4.5
Long-term government bond yield	12.8	10.0	9.9	10.7	11.0	15.8	16.4	15.0
Bank funding rate	9.9	7.1	6.0	6.2	6.5	10.4	8.4	5.3
Bank lending rate	32.5	27.9	24.3	24.4	24.7	26.7	26.6	23.2
EMBI spread	3.6	2.7	2.4	2.1	1.8	5.0	4.9	4.0
Bank credit growth	-2.7	4.6	7.9	7.9	8.4	0.1	-2.6	5.9

Appendix II. Stress Testing Matrix (STeM)

Banking Sector: Solvency Risk			
Domain		Assumptions	
		Top-down by the authorities	Top-down by FSAP team
1. Institutional perimeter	Institutions included	• 12 largest banks	• 12 largest banks
	Market share	• 90 percent of banking system assets	• 90 percent of banking system assets
	Data and baseline date	• Supervisory data (balance sheet and income statement) • Data as of September 2017 • Consolidated data of prudential conglomerate	
2. Channels of risk propagation	Methodology	• Balance sheet approach • BCB methodology	• Balance sheet approach • IMF methodology
	Satellite models for macrofinancial linkages	• Satellite models to estimate pre-impairment income (by various components) and credit loss based on macrofinancial variables • Market loss is estimated based on detailed market exposure information that also includes derivative positions and yield curves	• Satellite models to estimate pre-impairment income (by various components) and credit loss based on macrofinancial variables • Market loss is estimated based on detailed market exposure information that also includes derivative positions and yield curves • No accrued interest income on nonperforming loans
	Stress test horizon	• 3 years (2017Q4–2020Q4)	
3. Tail shocks	Scenario analysis	• Two macrofinancial scenarios, agreed with the authorities • Each scenario describes key domestic variables (real GDP growth, inflation rate, unemployment rate, exchange rate, equity price, house price, interest rates, and credit growth), and global variables (real GDP growth, U.S. interest rates, and commodity prices) • Baseline scenario based on the October 2017 WEO projections • Adverse scenario featuring a severe double-dip recession together with a sudden stop to capital inflows; domestically, loss of confidence acting as a prominent factor and financial stress amplified by contagion due to intra-system linkages; externally, a challenging global environment owing to tight and more volatile global financial conditions and significant China slowdown • Under the adverse scenario, the Brazilian economy would contract for two years during 2018-19, with a cumulative decline in real GDP growth of 2 standard deviation over the 3-year horizon	

Domain		Assumptions	
		Top-down by the authorities	Top-down by FSAP team
	Sensitivity analysis	• N/A	• Single-risk factors include concentration risk, exchange rate risk, interest rate risk, and other market risk
4. Risks and buffers	Risks/factors assessed (how each element is derived, assumptions)	• Credit loss capturing all on-balance sheet loan portfolios; overseas exposures sharing the same credit risk as domestic exposures • Market loss based on valuation adjustments of banks' holding of debt securities and existing net open foreign exchange positions	• Credit loss capturing all on-balance sheet loan portfolios; overseas exposures not being modeled explicitly • Market loss based on valuation adjustments of banks' holding of debt and equity securities and existing net open foreign exchange positions • Loss due to interbank cross-exposures • Net interest rate income affected by compressed margins due to relatively higher funding costs
	Behavioral adjustments	• Quasi-static balance sheet assumption, with balance sheet growth driven by projected bank-level credit growth based on macrofinancial conditions • Banks can only accumulate capital through retained earnings; maturing capital instruments would not be renewed • No dividend payouts	• Quasi-static balance sheet assumption, with balance sheet growth identical to overall credit growth assumption and balance sheet composition remaining constant through the stress testing horizon • Banks can only accumulate capital through retained earnings; maturing capital instruments would not be renewed • Banks can pay dividends only if they record a positive post-tax net income and do not need additional capital
5. Regulatory and market-based standards and parameters	Calibration of risk parameters	• Point-in-time credit risk proxies • Marking-to-market for assessing market risk	
	Regulatory/accounting and market-based standards	• National regulatory framework based on Basel III, with all banks under the standardized approach • Hurdle rates based on minimum capital requirements (CET1, T1 and total capital) and applicable surcharges for D-SIBs; for the baseline scenario, hurdle rates also including prevailing conservation capital buffer	

Domain		Assumptions	
		Top-down by the authorities	Top-down by FSAP team
6. Reporting format for results	Output presentation	• System-wide capital shortfalls • Number of banks that fail to meet the hurdle and their assets share in the banking sector	

BANKING SECTOR: LIQUIDITY RISK		
Domain		Assumptions
		Top-down by the authorities and FSAP team jointly
1. Institutional perimeter	Institutions included	• Cash-flow analysis: 12 largest banks • LCR test: 12 largest banks (including the 8 banks currently subjected to the requirement) • NSFR test: 12 largest banks
	Market share	• 90 percent of banking sector assets
	Data and baseline date	• Supervisory data • Data as of September 2017 • Scope of consolidation: perimeter of individual banks
2. Channels of risk propagation	Methodology	• The FSAP liquidity stress testing exercise comprise three types of tests: (i) Cash-flow analysis using maturity buckets; (ii) LCR test; and (iii) NSFR test
3. Risks and buffers	Risks	• Funding liquidity risk (short-term liquidity outflows) • Market liquidity shock (asset price shocks and fire-sales)
	Buffers	• The counterbalancing capacity in all types of tests includes liquidity obtained from markets through asset sales (subject to certain haircuts) and from BCB's standing facilities. • Expected cash inflows are also included.

Domain		Assumptions
		Top-down by the authorities and FSAP team jointly
4. Tail shocks	Size of the shock	• The haircuts are calibrated consistent with the increase in government bond yields in the solvency stress test. • The run-off rates are calibrated to reflect scenarios of system-wide deposit runs and dry-up of wholesale funding. Parameters are chosen to match volatility of deposits and reputational risk events.
5. Regulatory standards and parameters	Calibration of risk parameters	• Regulatory: haircuts and run-off rates based on regulatory LCR/NSFR parameters. • Stressed: more severe haircuts similar to the adverse scenario in the solvency stress tests and larger run-off rates to reflect more severe episodes of market and funding risks based on historical events.
	Regulatory standards	• For the LCR and NSFR tests, the hurdle is set to 100 percent. • For the cash-flow analysis, the hurdle is to have a non-negative cash balance.
6. Reporting format for results	Output presentation	• Number of banks that fail to meet the hurdle and their assets share in the banking sector • Bank-level survival period in days, number of banks that can still meet their obligations.

BANKING SECTOR: CONTAGION RISK		
Domain		Assumptions
		Top-down by FSAP team
1. Institutional perimeter	Institutions included	• 12 largest banks
	Market share	• 90 percent of banking sector assets
	Data and baseline date	• Supervisory data • Data as of September 2017
2. Channels of risk propagation	Methodology	• Interbank network analysis based on Espinosa-Vega and Solé (2010)
3. Risks and buffers	Risks	• Credit and funding losses related to interbank cross-exposures as a result of some bank defaults
	Buffers	• Banks' own capital

Domain		Assumptions
		Top-down by FSAP team
4. Tail shocks	Size of the shock	• Default threshold: banks would default if their CET1 capital ratios fall below 4.5 percent (regulatory minimum) • For the standalone exercise, each individual bank is assumed to default at the time • For the extended solvency stress testing exercise, the starting point is based on the solvency stress test results in the same period
5. Reporting format for results	Output presentation	• System-wide capital shortfall, bank-level capital shortfall • Number of banks that become undercapitalized • Evolution and direction of spillovers

INTERCONNECTEDNESS ANALYSIS		
Domain		Assumptions
		Top-down by FSAP team
Cross-sectoral linkages	Data and methodology	• Approach: "Flow-of-funds" type of data collected BCB for the disaggregation of ten institutional sectors in the System of National Accounts of Brazil: non-financial corporations, government, financial sector, families and NPISH, rest of the world, BCB, other deposit-taking institutions, insurers and pension funds, other financial institutions, monetary investment funds and non-monetary investment funds. Financial instruments include deposits, debt securities, derivatives, equity and credit. • Sample: quarterly data between 2015Q1 and 2016Q4. • Methodology: Dees, Henry and Martin (eds) (2017), Castrén and Rancan (2014) and e Silva (2016).
Cross-border spillovers	Data and methodology	• Approach: Examine spillover risks between Brazil and the main relevant countries from a financial stability perspective across equity and FX markets and across sovereign CDS and bond/EMBI spreads. • Sample: Weekly observations between 2007Q4 and 2017Q4 in each series for Argentina, Brazil, Chile, China, Colombia, France, Germany, India, Indonesia, Japan, Mexico, Russia, South Africa, Spain, Turkey, United Kingdom and the United States. • Methodology: Demirer, Diebold, Liu and Yilmaz (2016) and Diebold and Yilmaz (2015).

Appendix III. Detail on Balance Sheet and Income Statement Projections for the Bank Solvency Stress Tests

Overview of the Balance Sheet Approach

Item	Estimation details
Balance sheet	
Exposures	Growth of gross exposures by types, such as total gross loans and gross holding of debt securities, identical to overall credit growth, with the balance sheet composition unchanged[1] Total assets not affected by exchange rate movements[2]
Net interest income	
Net interest income	Combination of interest income and interest expense
Interest income	Sum of interest income from lending activity and other activities
Interest income from lending activity	Amount of loans (adjusted for balance sheet growth and existing NPLs) multiplied by estimated interest rate for lending activity Bank-level interest rate for lending activity estimated using a panel regression model, including its lag, real GDP growth, system-wide lending rate, and EMBI spread Also accounting for interest rate adjustments within the period
Interest income from other activities	Amount of other claims (adjusted for balance sheet growth) multiplied by estimated interest rate for non-lending activity Bank-level interest rate for non-lending activity estimated using a panel regression model, including its lag, and EMBI spread Also accounting for interest rate adjustments within the period
Interest expense	Amount of funding (adjusted for balance sheet growth and accounting for potential additional required funding[3]) multiplied by estimated interest rate for funding Bank-level interest rate for funding estimated using a panel regression model, including its lag, and system-wide funding rate Also accounting for interest rate adjustments within the period
Pre-impairment income, other items	
Trading income[4]	Total assets (adjusted for balance sheet growth) multiplied by average trading income (relative to total assets) Average trading income based on the historical benchmark during 2007-17

[1] Essentially, all maturing financial assets will be renewed.

[2] In principle, total assets would be affected by exchange rate movements. To keep the framework simple and consistent, the valuation effect would be applied to risk-weighted assets directly.

[3] Additional required funding is equal to the gap between total assets and equity.

[4] Trading income in this stress testing framework should be interpreted as an "pre-impairment" item, which does not include realized market gain/loss as this will be treated as part of impairment.

Item	Estimation details
Fee income	Total assets (adjusted for balance sheet growth) multiplied by estimated fee income (relative to total assets) Bank-level fee income estimated using a panel regression model, including its lag, real GDP growth, Selic and equity price movement
Investment income (e.g. through method of equity)	Total assets (adjusted for balance sheet growth) multiplied by average investment income (relative to total assets) Average investment income based on the 2017Q1-Q3 level
Other operating income	Total assets (adjusted for balance sheet growth) multiplied by average other operating income (relative to total assets) Average other operating income based on the 2017Q1-Q3 level
Operating expense	Total assets (adjusted for balance sheet growth) multiplied by average operating expense (relative to total assets) Average operating expense based on the 2017Q1-Q3 level
Impairment cost	
Impairment cost	Combination of credit loss and market loss
Credit loss	Three approaches: *First approach: based on lending impairment and other impairment* Lending impairment cost (relative to total loans) estimated using a panel regression model, including its lag, real GDP growth, and change in EMBI spread Other impairment cost based on the 2017Q1-Q3 level *Second approach: based on credit loss due to total impairment* Total impairment cost (relative to total assets) estimated using a panel regression model, including its lag, real GDP growth, and change in EMBI spread *Third approach: based on nonperforming loans (NPLs)* Total NPL ratio estimated using a panel regression model, including its lag, real GDP growth, and change in system-wide lending rate Estimated NPL ratio then translated into lending impairment cost Total impairment cost derived from sum of lending impairment and other impairment, the latter based on the 2017Q1-Q3 level
Market loss	Marking-to-market related to (i) bond yield movements for holding of debt securities in the trading account, (ii) equity price movements for holding of equity securities, (iii) exchange rate movements for the net open foreign-exchange position, and (iv) commodity price movements for the net open commodity position
Net income and its effect on capital	
Net income before taxes	Sum of pre-impairment income and impairment cost Pre-impairment income derived from sum of net interest income, all other operating income, and operating expense
Taxes	Income tax based on the applicable tax rate at 45 percent Tax credit allowed up to the amount of credit loss

Item	Estimation details
Net income after taxes	Sum of net income before taxes and taxes
Dividend payout	Based on the 2016 level for positive net income and zero otherwise, subject to restrictions on dividend distribution
Profits attributed to capital	Sum of net income after taxes and dividend payout
Capital	
Capital	Affected by retained profits, and unrealized gain/loss associated with the available-for-sale (AFS) and HTM accounts
Risk-weighted assets	Adjusted for balance sheet growth, and exchange rate movements (for foreign-currency exposures)
Total exposures	Adjusted for balance sheet growth, and exchange rate movements (for foreign-currency exposures)

Regression Specification of Satellite Pre-Impairment Income Models

1. The satellite interest rate models estimate average interest rates for lending activity, non-lending activity and funding. Net interest income comprises three components—interest income from lending activity, interest income from non-lending activity, and interest expense. Each component is influenced by the volume and the interest rate; the latter was estimated by the satellite models using the fixed-effects panel regression technique as showed in Table 1. These dependent variables are average interest rates for lending activity ('InterestRate_Lending_A'), for non-lending activity ('InterestRate_NonLending_A'), and for interest rate on funding ('InterestRate_Funding_A'); all are based on the average over four quarters. Explanatory variables include Selic, lending rate, funding rate, and EMBI spread (all annual average), as well as real GDP growth (year-on-year). Real GDP growth appears to be a driving factor for average interest rate for lending activity, suggesting that banks could charge higher rates in the face of strong demand for loans. The notation 'L' denotes a "lagged" term. The main stress test results reported in this technical note are based on Model L.1, Model NL.1 and Model F.1.

Table 1. Brazil: Regression Specifications for Satellite Interest Rate Models

	InterestRate_Lending_A		InterestRate_NonLending_A			InterestRate_Funding_A	
	Model L.1	Model L.2	Model NL.1	Model NL.2	Model NL.3	Model III.1	Model III.2
Selic_Y		0.3055*		0.5294***	0.0714		0.3652***
		(0.1513)		(0.0874)	(0.1162)		(0.0529)
LendingRate_Y	0.1776*						
	(0.0897)						
FundingRate_Y						0.6082***	
						(0.1058)	
EMBI_Y	0.6517***	0.5256**	0.8438***		0.7935***		
	(0.1682)	(0.2232)	(0.1582)		(0.2064)		
L.RealGDP_Y	0.2730***	0.2291***					
	(0.0607)	(0.0674)					
L4.InterestRate_Lending_A	0.3729***	0.3243***					
	(0.0672)	(0.0434)					
L4.InterestRate_NonLending_A			0.1786**	0.2028***	0.1595**		
			(0.0674)	(0.0533)	(0.0583)		
L4.InterestRate_Funding_A						0.0940**	0.0860**
						(0.0312)	(0.0294)
Constant	4.2982	6.2997***	5.5474***	1.4618*	4.9931***	1.3254	2.6798***
	(2.9306)	(1.8788)	(0.2989)	(0.7597)	(1.0511)	(1.0660)	(0.7556)
Number of observations	756	756	756	756	756	756	756
Number of banks	12	12	12	12	12	12	12
Adjusted R-squared	0.56	0.57	0.55	0.41	0.55	0.31	0.32

Note: *** denotes p-value < 0.01; ** denotes p-value < 0.05; and * denotes p-value < 0.1. The figures in parenthesis are robust standard errors.

2. For other income and operating expense, the satellite models could be estimated meaningfully only for fee income and trading income. The dependent variables are fee income to total assets ('FeeIncome_A') and trading income to total assets ('TradingIncome_A') over the period of four quarters. The models, which were estimated based on the fixed-effects panel regression technique, considered a set of explanatory variables such as real GDP growth, change in exchange rate, and change in equity price (all year-on-year), as well as Selic and long-term bond (both annual average). Appendix Table III.2 presents the regression specifications of the satellite models. At the end, the main stress test results reported in this technical note are based on the Model FI.1 for fee income. Trading income was instead estimated based on the historical benchmark during 2007-17 as trading gain/loss could be nullified over time to provide a "pre-impairment" figure.

Table 2. Brazil: Regression Specifications for Satellite Models for Fee Income and Trading Income

	FeeIncome_A			TradingIncome_A		
	Model FI.1	Model FI.2	Model FI.3	Mdeol TI.1	Mdeol TI.2	Mdeol TI.3
L.RealGDP_Y	0.0121	0.0257	0.0076	-0.0540**	-0.0406*	-0.1754***
	(0.0168)	(0.0190)	(0.0184)	(0.0200)	(0.0202)	(0.0441)
L.Selic_Y	0.0194*	0.0288***				
	(0.0093)	(0.0083)				
L.EquityPrice_Y	0.0047**		0.0058***			0.0185**
	(0.0016)		(0.0014)			(0.0075)
L.ExchangeRate_Y						-0.0232***
						(0.0062)
L.BondYield_YD					-0.0299	
					(0.0362)	
L4.FeeIncome_A	0.7110***	0.7112***	0.7072***			
	(0.0360)	(0.0398)	(0.0378)			
L4.TradingIncome_A				0.2485**	0.0513	0.2599***
				(0.0821)	(0.0333)	(0.0765)
Constant	0.3919**	0.2750	0.6703***	0.1633**	0.1813***	0.3300***
	(0.1572)	(0.1584)	(0.0617)	(0.0558)	(0.0236)	(0.1044)
Number of observations	756	756	756	756	408	756
Number of banks	12	12	12	12	12	12
Adjusted R-squared	0.60	0.58	0.59	0.08	0.02	0.20

Note: *** denotes p-value < 0.01; ** denotes p-value < 0.05; and * denotes p-value < 0.1. The figures in parenthesis are robust standard errors.

Regression Specification of Satellite Credit Risk Models

3. The satellite credit risk models were estimated based on three different approaches as discussed in Section III. The dependent variables are lending impairment cost to total loans ('CreditCost_A') and total impairment cost to total assets ('TotalImpairment_A') for the first and second approaches, respectively; both are based on the period of four quarters. For the third approach, the dependent variable is problem loans to total loans ('NPL_Total'). In all specifications, dependent variables were transformed in the logit form. This transformation is particularly important for the third approach, as it ensures that the ratio of problem loans to total loans is bounded between 0 and 1.[1] All models were estimated based on the fixed-effect panel regression technique as showed in Table 3. Explanatory variables include real GDP growth, change in unemployment rate, change in lending rate, and change in EMBI spread, all year-on-year. The main stress test results reported in this technical note are based on Model I.1, while the alternative results are based on Model II.1 and Model III.1.

[1] For the first two approaches, the transformation helps create some non-linearity.

Table 3. Brazil: Regression Specifications for Satellite Credit Risk Models

	logit_CreditCost_A		logit_Impairment_Total_A		logit_NPL_Total	
	Model I.1	Model I.2	Model II.1	Model II.2	Model III.1	Model III.2
L.RealGDP_Y	-0.0214*		-0.0556***		-0.0084***	
	(0.0111)		(0.0124)		(0.0027)	
L.Unemployment_Y		0.0703**		0.0914***		0.0139*
		(0.0296)		(0.0209)		(0.0071)
L.LendingRate_Y					0.0049***	
					(0.0016)	
L.EMBI_Y			0.0282**	0.0347***		
			(0.0093)	(0.0101)		
L2.EMBI_Y		0.0626*				0.0249***
		(0.0342)				(0.0050)
L4.EMBI_Y	0.0974**					
	(0.0369)					
L4.logit_CreditCost_A	0.2541*	0.2576**				
	(0.1155)	(0.1056)				
L4.logit_Impairment_Total_A			0.3874***	0.3774***		
			(0.0819)	(0.0845)		
L.logit_NPL_Total					0.7700***	0.8800***
					(0.1254)	(0.0703)
L2.logit_NPL_Total					0.1358*	
					(0.0727)	
Constant	-2.5600***	-2.5884***	-2.5873***	-2.7358***	-0.2504	-0.4795*
	(0.4122)	(0.3720)	(0.3586)	(0.3853)	(0.1629)	(0.2343)
Number of observations	482	482	643	643	630	642
Number of banks	12	12	12	12	12	12
Adjusted R-squared	0.14	0.11	0.25	0.22	0.79	0.79

Note: *** denotes p-value < 0.01; ** denotes p-value < 0.05; and * denotes p-value < 0.1. The figures in parenthesis are robust standard errors.

4. Under the third approach, the amount of problem loans serves as an input for estimating lending impairment cost. The relationship between lending impairment cost to total loans ('CreditCost_A') and problem loans to total loans ('NPL_Total') was estimated based on the fixed-effects panel regression technique as presented in Appendix Table III.4. Problem loans could be estimated in a total amount (as presented in Appendix Table III.3), as well as by loan portfolios that could then be aggregated. The aggregation could feature a number of combinations, including (i) problem loans of persons and entities, (ii) problem loans of persons and problem loans of entities by currencies, and (iii) problem loans of persons and problem loans of entities by economic sectors;[2] see Appendix Tables III.5, III.6 and III.7. Overall, important explanatory variables for problem loans by portfolios are not much different from those for total problem loans. It is noteworthy that change in house price and change in exchange rate may drive the dynamics of problem loans for the property-

[2] Problem loans by currencies or by economic sectors are based on resident borrowers. The aggregation thus assumes that the share of problem loans of nonresident entities remains constant.

related and other business sectors; meanwhile, change in commodity price does not appear to influence the dynamics of problem loans for the commodity sector.

Table 4. Brazil: Regression Specification for Estimating Lending Impairment Cost Based on Problem Loans

	logit_CreditCost_A					
	NPL_Total	L.NPL_Total	L2.NPL_Total	L3.NPL_Total	L4.NPL_Total	Constant
	0.4569***	0.1411***	-0.0502	0.2664***	-0.5749***	1.5802**
	(0.1173)	(0.0347)	(0.0399)	(0.0766)	(0.0991)	(0.7027)
Number of observations	606					
Number of banks	12					
Adjusted R-squared	0.27					

Note: *** denotes p-value < 0.01; ** denotes p-value < 0.05; and * denotes p-value < 0.1. The figures in parenthesis are robust standard errors.

Table 5. Brazil: Regression Specifications for Estimating Problem Loans of Persons and Entities

	logit_NPL_Persons		logit_NPL_Entities		
	Model P.1	Model P.2	Model E.1	Model E.2	Model E.3
RealGDP_Y	-0.0040*				
	(0.0020)				
L.RealGDP_Y			-0.0135***		
			(0.0015)		
L.Unemployment_Y				0.0257***	0.0297***
				(0.0044)	(0.0052)
L.LendingRate_Y		0.0051**	0.0093***	0.0135***	
		(0.0018)	(0.0027)	(0.0029)	
L.EMBI_Y					0.0314**
					(0.0103)
L.logit_NPL_Persons	0.9664***	0.9529***			
	(0.0115)	(0.0180)			
L.logit_NPL_Entities			0.9065***	0.9042***	0.9080***
			(0.0347)	(0.0342)	(0.0349)
Constant	-0.0846**	-0.1292**	-0.2510**	-0.2824**	-0.2604**
	(0.0297)	(0.0455)	(0.1069)	(0.1061)	(0.1074)
Number of observations	500	540	642	642	642
Number of banks	10	10	12	12	12
Adjusted R-squared	0.92	0.93	0.86	0.86	0.86

Note: *** denotes p-value < 0.01; ** denotes p-value < 0.05; and * denotes p-value < 0.1. The figures in parenthesis are robust standard errors.

Table 6. Brazil: Regression Specifications for Estimating Problem Loans of Entities by Currencies

	Local currency			Foreign currency		
	logit_NPL_E_LC			logit_NPL_E_FC		
	Model E-L.1	Model E-L.2	Model E-L.3	Model E-F.1	Model E-F.2	Model E-F.3
L.RealGDP_Y	-0.0140***			-0.0240**		
	(0.0015)			(0.0097)		
L.Unemployment_Y		0.0301***	0.0350***		0.0362*	
		(0.0041)	(0.0051)		(0.0198)	
L.LendingRate_Y	0.0093***	0.0132***		0.0163**		
	(0.0028)	(0.0030)		(0.0071)		
L.EMBI_Y			0.0237***		0.0832**	
			(0.0064)		(0.0273)	
L.ExchangeRate_Y						0.0058**
						(0.0023)
L.logit_NPL_E_LC	0.9024***	0.8980***	0.8993***			
	(0.0371)	(0.0367)	(0.0377)			
L.logit_NPL_E_FC				0.8040***	0.8158***	0.8198***
				(0.0457)	(0.0461)	(0.0401)
Constant	-0.2576**	-0.2953**	-0.2831**	-0.7542***	-0.7260***	-0.7460***
	(0.1120)	(0.1116)	(0.1140)	(0.1745)	(0.1834)	(0.1679)
Number of observations	642	642	642	565	565	565
Number of banks	12	12	12	12	12	12
Adjusted R-squared	0.85	0.85	0.85	0.68	0.68	0.67

Note: *** denotes p-value < 0.01; ** denotes p-value < 0.05; and * denotes p-value < 0.1. The figures in parenthesis are robust standard errors.

Table 7. Brazil: Regression Specifications for Estimating Problem Loans of Entities by Economic Sectors

	Commodity	Manufacturing		Property-related			Commerce		Other business		
	logit_NPL_E_CD	logit_NPL_E_MF		logit_NPL_E_PP			logit_NPL_E_CC		logit_NPL_E_OB		
	Model CD.1	Model MF.1	Model MF.2	Model PP.1	Model PP.2	Model PP.3	Model CC.1	Model CC.2	Model OB.1	Model OB.2	Model OB.3
L.RealGDP_Y		-0.0240***		-0.0165**			-0.0079***		-0.0222***		
		(0.0068)		(0.0073)			(0.0015)		(0.0058)		
L2.RealGDP_Y	-0.0289**										
	(0.0126)										
L.Unemployment_Y			0.0522***		0.0487***			0.0092**		0.0320***	
			(0.0141)		(0.0114)			(0.0032)		(0.0102)	
L.LendingRate_Y	0.0228**	0.0047*	0.0115***				0.0079***	0.0109***		0.0128**	
	(0.0082)	(0.0025)	(0.0033)				(0.0011)	(0.0012)		(0.0043)	
L.HousePrice_Y						-0.0087***					
						(0.0024)					
L.ExchangeRate											0.1151**
											(0.0398)
L.logit_NPL_E_CD	0.7159***										
	(0.0561)										
L2.logit_NPL_E_CD	0.1210***										
	(0.0371)										
L.logit_NPL_E_MF		0.8180***	0.8120***								
		(0.0645)	(0.0653)								
L.logit_NPL_E_PP				0.8824***	0.8759***	0.8751***					
				(0.0322)	(0.0345)	(0.0305)					
L.logit_NPL_E_CC							0.9343***	0.9354***			
							(0.0209)	(0.0194)			
L.logit_NPL_E_OB									0.8184***	0.8208***	0.8109***
									(0.0904)	(0.0903)	(0.0891)
Constant	-0.5161***	-0.5134**	-0.5736**	-0.2850***	-0.3269***	-0.2952***	-0.1662**	-0.1788**	-0.5433*	-0.5777*	-0.8900**
	(0.0892)	(0.1919)	(0.2046)	(0.0750)	(0.0923)	(0.0841)	(0.0598)	(0.0566)	(0.2906)	(0.2981)	(0.3688)
Number of observations	504	642	642	583	583	583	594	594	638	638	638
Number of banks	10	12	12	11	11	11	11	11	12	12	12
Adjusted R-squared	0.66	0.72	0.72	0.76	0.76	0.76	0.89	0.89	0.74	0.74	0.74

Note: *** denotes p-value < 0.01; ** denotes p-value < 0.05; and * denotes p-value < 0.1. The figures in parenthesis are robust standard errors.

Appendix IV. Calibration of Parameters for Bank Liquidity Stress Tests

1. Funding pressures were captured through specific time profiles of run-off rates for different funding sources. A set of general principles, consistent with international historical experience and empirical studies of depositor and investor behavior in extreme but plausible conditions, guide our choice of run-off rates. *First*, more informed and sophisticated depositors withdraw funding more rapidly than less informed depositors—run-off rates applied to wholesale funding sources are higher than those applied to retail funding sources. *Second*, run-off rates on secured funding sources are lower than those applied on unsecured funding sources. *Third*, under stress, sight deposits and/or deposits protected by deposit insurance are withdrawn at a slower pace than time deposits and/or those uninsured. *Fourth*, regarding the intensity and persistence of the funding liquidity pressures, it is assumed that cash outflows would be protracted—lasting for up to one year. However, run-off rates are assumed to decline over time. The highest rates should correspond to short-term maturity buckets (0–30 days); medium-size rates are applied to intermediate maturity buckets (30–180 days); and the lowest rates correspond to longer-term time buckets (after 180 days). *Fifth*, run-off rates on foreign currency funding is more stringent to reflect the fact that foreign sources of funding are more volatile. More specifically, the run-off rates on insured deposits in foreign currency are higher by 10 percentage points and on uninsured deposits in foreign currency by 30 percentage points.

2. For different assets and maturity buckets, specific roll-off rates were applied to convert maturing loans into cash proceeds. Specifically, 50 percent rates were applied to performing loans to retail and nonfinancial corporate customers, and 100 percent rates to maturing loans to other entities (including financial institutions), non-operational deposits held at other financial institutions and cash flows from debt securities. For secured lending, roll-off rates were kept consistent with the valuation losses resulting from the calibration of the haircuts on the underlying security.

Table 1. Brazil: LCR Liquidity Stress Parameters (in percent)

LCR: Run-off Rates on Cash Outflows

Cash outflows	Run-off Parameters (%)			
			Reputational Crisis	
	Regulatory	Adverse	Localized	System-wide
Retail deposits (i.e., deposits of natural individuals)				
Stable deposits	5	10	9	10
Less stable deposits (total deposits under 1.5MMBRL)	10	20	37	37
Less stable deposits (total deposits above 1.5MM BRL)	20	30	67	67
Unsecured wholesale funding				
Deposits from SMEs				
Stable deposits	5	21	19	21
Less stable deposits	10	30	47	47
Operational deposits (generated by clearing, custody, and cash management activities)				
Fully covered by the deposit insurance scheme	5	16	31	31
Excess - Fully covered by the deposit insurance scheme	20	31	63	63
Not fully covered by the deposit insurance scheme	25	39	78	78
Excess - Not Fully covered by the deposit insurance scheme	40	63	100	100
Excess - Other entities (i.e. not included in NFIs, government, central banks, international organizations)	100	100	100	100
Funding from nonfinancial corporates, sovereigns, central banks, international organizations, public enterprises				
Fully covered by the deposit insurance scheme	20	40	38	40
Not fully covered by the deposit insurance scheme	40	80	77	80
Funding from other legal entities	100	100	100	100
Secured funding				
Transactions with BCB	0	0	0	0
Secured by Level 1 HQLA	0	9	0	9
Secured by Level 2A HQLA	15	23	15	23
Other transactions with Government of Brazil, international organizations, and qualifying public enterprises	25	32	25	32
Secured by residential mortgage backed securities eligible for Level 2B HQLA	25	32	25	32
Secured by other Level 2B HQLA	50	55	50	55
Other funding	100	100	100	100
Additional requirements				
Derivative cash outflows	100	100	100	100
Increased liquidity needs				
Due to potential re-valuation of collaterals	20	52	45	52
Others per the LCR regulation	100	100	100	100
Loss of funding per the LCR regulation	100	100	100	100
Drawdown on committed credit/liquidity facilities				
To retail and SME customers	5	8	5	8
To nonfinancial corporates, sovereigns, central banks, international organizations, and public enterprises				
Credit facilities	10	20	10	20
Liquidity facilities	30	45	30	60
To resident banks	40	60	40	80
To other qualifying financial institutions				
Credit facilities	40	60	40	80
Liquidity facilities	100	100	100	100
To other legal entities	100	100	100	100
Other contractual obligations	100	100	100	100
Other contigent funding obligations				
Related to trade finance	100	100	100	100
Related to guarantees and L/C that are unrelated to trade finance	100	100	100	100
Related to uncommitted credit/liquidity facilities	2	2	2	2
Related to non-contractual obligations where customers' short positions covered by other cutomers' collaterals	50	50	50	50
Related to other non-contractual obligations	100	100	100	100
Credit card settlement (payments to merchants)	100	100	100	100
Other contractural cash outflows (not listed above)	100	100	100	100

Table 1. Brazil: LCR Liquidity Stress Parameters (in percent) (concluded)

LCR: Roll-over Rates on Cash Inflows

Cash inflows	Roll-off Parameters (%)			
			Reputational Crisis Scenario	
	Regulatory	Adverse	Localized	System-wide
Secured lending				
Secured by Level 1 HQLA	0	9	0	9
Secured by Level 2A HQLA	15	23	15	23
Secured by residential mortgage backed securities eligible for Level 2B HQLA	25	32	25	32
Secured by other Level 2B HQLA	50	55	50	55
Margin lending backed by other collaterals	50	50	50	50
Other lending	100	100	100	100
Operations in which the collateral has been reused in REPO transactions	0	0	0	0
Committed facilities	0	0	0	0
Other inflows				
Loan and interest payments				
From retail and SME customers	50	50	50	50
From nonfinancial corporates, sovereigns, international organizations, and public enterprises	50	50	50	50
From BCB	100	100	100	100
From (other) central banks and financial institutions	100	100	100	100
Related to trade finance	100	100	100	100
Credit assignment	100	100	100	100
Earmarket credit (that must be rolled-over)	0	0	0	0
Earmarket credit (excess balances)	100	100	100	100
Maturing securities within 30 days (not included as part of HQLA)	100	100	100	100
Maturing subordinated securities within 30 days (not included as part of HQLA)	75	75	75	75
Non-Operational deposits held at other financial institutions	100	100	100	100
Operational deposits held at other financial institutions	0	0	0	0
Derivative cash inflows	100	100	100	100
Credit Card (payment of bills)	100	100	100	100
Other contractual cash inflows	100	100	100	100

LCR: Haircuts on HQLA

High-quality liquid assets	100-Haircuts (%)			
			Reputational Crisis	
	Regulatory	Adverse	Localized	System-wide
Level 1 assets				
Cash in vault	100	100	100	100
Current placement at BCB				
Required reserves	100	100	100	100
Excess reserves	100	100	100	100
Current placement at other central banks				
Required reserves that can be withdrawn in times of stress (according to host supervisor rules)	100	100	100	100
Excess reserves	100	100	100	100
Qualifying securities issued by BCB	100	100	100	100
Qualifying securities issued by Government of Brazil	100	91	100	91
Other qualifying securities with 0% risk weight	100	91	100	91
Level 2A assets	85	77	85	77
Level 2B assets				
Qualifying residential mortgage backed seucurities with rating at least AA	75	68	75	68
Qualifying corporate debt securities and covered bonds with rating between A+ and BBB-	50	45	50	45
Other qualifying securities	50	45	50	45

Table 2. Brazil: Key Differences Across LCR And Brazil's IL Methodology

Table [x]. Main Differences between LCR and Brazil's IL Methodology		
	LCR	**IL**
Time Horizon	30 days	21 working days
Ratio Formula	LCR = Stock of HQLA / Total net cash outflows Total net cash outflows = Total cash outflows minus min [total cash inflows, 75% of gross outflows]	IL = Stock of HQLA / Total net cash outflows Total net cash outflows = Total cash outflows minus total cash inflows IL metrics does not apply any cap either on level 2 assets or inflows. However Level 2 amount is not relevant when compared with Total HQLA.
Minimum Requirement	Phase in implementation: LCR >= 60% (2015) up to LCR>= 100% (2019)	IL >=100% Not a requirement / monitoring purposes only
Scope of Application	Total assets > R$ 100 billions (8 banks) Domestic and overseas positions and exposures	Individual banks and banking conglomerates (135 banks) Mainly domestic positions and exposures
Data Source	DRL	TR
Cash Inflow	All categories listed in Table [x].	1. Excludes credit inflows due to unavailability of daily data. 2. Excludes cash inflows from 'Other contractual inflows'.
Cash Outflow	All categories listed in Table [x].	Excludes the cash outflow from the following: (a) Operational deposits generated by clearing, custody and cash management activities; (b) Currently undrawn committed credit and liquidity facilities; (c) Other contingent funding liabilities.
HQLA	1. Basel III definitions of Level 1, 2A and 2B assets 2. Reserves are a sum of excess reserves, automatic releases of reserves due to deposit withdrawals, and an additional add on component (remaining reserves up to 15 percent of the stock of Level 1 HQLA).	1. Basel III definitions of Level 1, 2A and 2B assets 2. Reserves include only excess reserves and automatic releases of reserves due to deposit withdrawals. 3. Shares on liquid investment funds added to Level 1 assets. 4. Shares on less liquid investment funds and debt securities issued by financial institutions added to Level 2A assets.
Haircuts	Applied to value of assets in the numerator.	No haircuts to assets in the numerator (except on the financial institutions issuances), instead add losses due to market stress in the denominator.
Run-off on Retail Deposits	Stable and less stable deposits of natural individuals subject to regulatory LCR run-off parameters.	Stable and less stable deposits of natural individuals, SMEs, and non-financial corporates are considered retail. Run-offs based on a sum of 2 components: (1) historical volatility of deposits and (2) run-off factor contingent on type of deposit and/or counterparty involved.
Run-off on Unsecured Wholesale Deposits	Stable/ Unstable deposits of SMEs, non-financial corporates, sovereigns, central banks, financial institutions, investment funds and institutional investors such as pension funds or insurance companies, maturing within 30 days. All subject to regulatory run-off parameters.	Wholesale counterparties include financial institutions, investment funds and institutional investors such as pension funds or insurance companies. A 100% run-off factor is applied on the funding obtained from the three largest wholesale customers with residual maturity above 30 days and subject to early redemption. Whereas the maturing liabilities and inflows within 21 business days are calibrated to be equal to the worst number of daily net cumulative cash flows within 30 days.

Table 3. Brazil: Proxy NSFR Calibration

	Baseline	Adverse
ASF Factor 100percent		
(a) Total regulatory capital	**100percent**	**100percent**
(b) Other capital instruments with effective maturity of one year or more	**100percent**	**100percent**
(c) Liabilities with effective residual maturity of one year or more	**100percent**	**100percent**
ASF Factor 95percent		
Stable non-maturity (demand) deposits and term deposits with residual maturity of less than one year provided by retail and SME customers	**95percent**	**81percent**
ASF Factor 90percent		
Less stable non-maturity (demand) deposits and term deposits with residual maturity of less than one year provided by retail and SME customers	**90percent**	**55percent**
ASF Factor 50percent		
(a) Funding (secured or unsecured) with residual maturity of less than one year provided by non- financial corporate clients	**50percent**	**45percent**
(b) Operational deposits	**50percent**	**45percent**
(c) Funding with residual maturity of less than one year from sovereigns, public sector entities (PSEs), and multilateral and national development banks	**50percent**	**45percent**
(d) Other funding (secured or unsecured) with residual maturity of not less than six less than one year not included in the above categories, including funding provided by banks and financial institutions	**50percent**	**45percent**
ASF Factor 0percent		
(a) All other liabilities and equity categories not included in the above categories, including liabilities without stated maturity	**0percent**	**0percent**
(b) Derivatives payable net of derivatives receivable, if payables are greater than	**0percent**	**0percent**
RSF Factor 0percent		
(a) Coins and banknotes	**0percent**	**0percent**
(b) All central bank reserves (including required and excess reserves)	**0percent**	**0percent**
(c) Unencumbered loans to banks subject to prudential supervision with residual maturity of less than six months	**0percent**	**0percent**
RSF Factor 5percent		
Unencumbered Level 1 assets - excluding coins, banknotes and central bank reserves	**5percent**	**10percent**
RSF Factor 15percent		
Unencumbered Level 2A assets	**15percent**	**23percent**
RSF Factor 50percent		
(a) Unencumbered Level 2B assets	**50percent**	**55percent**
(b) HQLA encumbered for a period of six months or more and less than one year	**50percent**	**55percent**
(c) Loans to banks subject to prudential supervision with residual maturity six months or more and less than one year	**50percent**	**55percent**
(d) Deposits held at other financial institutions for operational purposes	**50percent**	**55percent**
(e) All other assets not included in the above categories, including loans to non-bank institutions, loans to non-financial corporate clients, loans to retail and small business and loans to sovereigns, central banks and PSEs	**50percent**	**55percent**
RSF Factor 65percent		
(a) Unencumbered residential mortgages with a residual maturity of one year or more and with a risk weight of less than or equal to 35percent	**65percent**	**75percent**
(b) Other unencumbered loans not included in the above categories, excluding loans to institutions, with a residual maturity of one year or more and with a risk weight of less equal to 35percent under the *Standardized Approach*	**65percent**	**75percent**
RSF Factor 85percent		
(a) Other unencumbered performing loans with risk weights greater than 35percent *Standardized Approach* and residual maturity of one year or more, excluding loans to institutions	**85percent**	**95percent**
(b) Unencumbered securities that are not in default and do not qualify as HQLA including exchange-traded equities	**85percent**	**95percent**
(c) Physical traded commodities, including gold	**85percent**	**95percent**
RSF Factor 100percent		
(a) All assets encumbered for a period of one year or more	**100percent**	**100percent**
(b) Derivatives receivable net of derivatives payable, if receivables are greater than	**100percent**	**100percent**
(c) All other assets not included in the above categories, including non-performing loans, loans financial institutions with residual maturity of one year or more, non-exchange-traded equities, fixed assets, pension assets, intangibles, deferred tax assets, retained interest, subsidiary interests, and defaulted securities	**100percent**	**100percent**
Off-Balance Sheet Categories		
RSF Factor 5percent		
Irrevocable and conditionally revocable credit and liquidity facilities to any client	**5percent**	**10percent**

Table 4. Brazil: Cash-Flow-Based Calibration
Run-off Rates for the Cash Outflows[1]

Cash-flow Liquidity Stress Test Calibration

	Adverse Scenario (in BRL)							Adverse Scenario (in FX)						
	Within a day	Within a week	Within 2 weeks	Within a month	Within 3 month	Within 6 months	Beyond 6 months	Within a day	Within a week	Within 2 weeks	Within a month	Within 3 month	Within 6 months	Beyond 6 months
Own securities issuance due	100	100	100	100	80	64	51	100	100	100	100	80	64	51
Due secured borrowing														
o/w: Secured by securities issued by BCB or Government of Brazil	9	9	9	9	9	5	2							
o/w: Secured by other securities	55	55	55	55	45	35	17	25	25	25	25	15	5	3
Customer deposits - Natural individuals														
o/w: Insured demand deposits	1	3	5	7	3	2	2							
o/w: Insured saving deposits	1	3	4	6	2	1	1							
o/w: Uninsured sight deposits	2	6	7	12	3	2	2							
o/w: Insured term deposits subject to BCB reserves requirement	35	35	18	18	9	9	9							
o/w: Insured term deposits not subject to BCB reserves requirement	35	35	18	18	9	9	9	45	45	28	28	19	14	9
o/w: Uninsured term deposits	45	45	23	23	11	11	11	75	75	53	53	31	16	11
Customer deposits - Nonfinancial legal entities - Qualifying SMEs														
o/w: Insured demand deposits	3	2	6	12	3	2	2							
o/w: Insured saving deposits	2	4	7	8	2	1	1							
o/w: Uninsured sight deposits	3	6	8	15	3	2	2							
o/w: Insured term deposits subject to BCB reserves requirement	35	35	18	18	18	18	9							
o/w: Insured term deposits not subject to BCB reserves requirement	35	35	18	18	18	18	9	45	45	28	28	28	23	9
o/w: Uninsured term deposits	45	45	23	23	23	23	11	75	75	53	53	53	28	11
Customer deposits - Nonfinancial legal entities - Other entities														
o/w: Insured demand deposits	4	4	10	10	4	2	1							
o/w: Insured saving deposits	4	4	8	10	3	2	1							
o/w: Uninsured sight deposits	6	8	12	15	4	2	1							
o/w: Insured term deposits subject to BCB reserves requirement	40	40	20	20	20	20	10							
o/w: Insured term deposits not subject to BCB reserves requirement	40	40	20	20	20	20	10	45	45	28	28	28	23	9
o/w: Uninsured term deposits	50	50	25	25	25	25	13	75	75	53	53	53	28	11
Other deposits and unsecured borrowing														
o/w: Nonresident parents/affiliates	0	0	0	0	0	0	0	0	0	0	0	0	0	0
o/w: Brazil̃n Government	0	0	0	0	0	0	0							
o/w: Banks	100	100	100	50	50	25	5	100	100	100	50	50	25	5
o/w: Other financial institutions														
o/w: Term deposits subject to BCB reserves requirement	100	100	100	50	50	25	5							
o/w: Other deposits	100	100	100	50	50	25	5							
o/w: Others	100	100	100	100	50	25	5							
Outflows from derivatives transactions														
o/w: Liquidity need due to changes in collateral valuation	100	100	100	100	100	100	100	100	100	100	100	100	100	100
o/w: Others	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Interest expense	100	100	100	100	100	100	100							
Undrawn committed credit/liquidity lines														
o/w: Banks	5	25	20	10	5	5	5							
o/w: Other financial institutions	5	25	20	10	5	5	5							
o/w: Clients	2	2	2	2	2	1	1							
Other contractual outflows														
o/w: Acceptance liabilities	100	100	100	100	100	100	100	100	100	100	100	100	100	100
o/w: Others	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Memo														
Exchange rate (BRL per USD)								4.277	4.562	4.752	4.752	4.562	4.277	4.277

Notes: 1/ A roll-off rate is defined as the *fraction of the asset amount maturing in a given period* that is converted into a cash inflow by the bank. Cash inflows from contingent credit/liquidity lines obtained by the bank, however, are an exception. Once these lines have been approved and contracted, the bank can exercise the option to withdraw liquidity at any time; hence, in this case, a roll-off rates is defined as the *fraction of the initial contracted amount* that is withdrawn by the bank in a given period of time.

Table 5. Brazil: Cash-flow Stress Tests: Asset Price Haircuts (in percent)

	100 - Haircut (%)	
	In BRL Stock	In FX Stock
Cash in vault	100	100
Required reserves	100	100
Excess reserves	100	100
Unencumbered securities		
Securities issued by BCB	100	
Securities issued by Government of Brazil		91
o/w: fixed interest rate < 5 years	91	
o/w: fixed interest rate > 5 years	51	
o/w: inflation linked < 10 years	97	
o/w: inflation linked > 10 years	84	
o/w: selic rate indexation	100	
o/w: others	70	
Other securities issued or guaranteed by sovereigns/central banks/international organizations with 0% risk weight	91	91
Other securities issued or guaranteed by sovereigns/central banks/international organizations with 20% risk weight	77	77
Qualifying corporate debt securities and covered bonds with rating at least AA-	77	
Qualifying residential mortgage backed seucurities with rating at least AA	68	
Qualifying corporate debt securities and covered bonds with rating between A+ and BBB-	45	
Exchange-traded stocks	45	
Other securities	45	
Other eligible collaterals for BCB' emergency liquidity assistance		
Qualifying credit assets (post BCB haircut values)	100	

Table 6. Brazil: Cash-flow Stress Tests: Roll-Off Rates for Items Generating Inflows (in percent)[1]

	Adverse Scenario (in BRL)							Adverse Scenario (in FX)						
	Within a day	Within a week	Within 2 weeks	Within a month	Within 3 month	Within 6 months	Beyond 6 months	Within a day	Within a week	Within 2 weeks	Within a month	Within 3 month	Within 6 months	Beyond 6 months
New own seucirites issuance (already contracted)	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Maturing secured lending	91	91	91	91	91	95	98	91	91	91	91	91	95	98
Maturing loans														
o/w: Banks	100	100	100	100	100	100	100	100	100	100	100	100	100	100
o/w: Other financial institutions	80	80	64	51	41	33	13	80	80	64	51	41	33	13
o/w: Others - Performing	50	50	50	50	30	18	7	50	50	50	50	30	18	7
o/w: Others - Nonperforming	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inflows from derivatives transactions														
o/w: Liquidity receipt due to changes in collateral valuation	100	100	100	100	100	100	100							
o/w: Others	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Interest income	100	100	100	100	100	100	100							
Other contractual inflows														
o/w: Acceptance claims	100	100	100	100	100	100	100							
o/w: Other	100	100	100	100	100	100	100	100	100	100	100	100	100	100

[1] A run-off rate is defined as the *fraction of the liability amount maturing in a period* that is withdrawn by the claim holders. Sight deposits and contingent liabilities (committed credit and liquidity lines) are exceptions, however. Due to the instantaneous maturity of sight deposits, a run-off rate on these deposits is the *fraction of the initial outstanding balance* that is withdrawn in a time period. Credit/liquidity lines can also be withdrawn at any time by clients or other financial institutions once they have been granted by the bank. In the above Table, all run-off rates highlighted in red are defined with respect to the initial outstanding balance.

Appendix V. Detailed Methodology for the Interbank Network Analysis

1. This appendix summarizes the methodology for the interbank network analysis based on Espinosa-Vega and Solé (2010). A simple version of balance sheet identity for a bank i in a network of N banks can be simplified as equation (i),

$$(i) \quad a_i + \sum_{j=1}^{N-1} x_{ji} = k_i + b_i + d_i + \sum_{j=1}^{N-1} x_{ij},$$

where x_{ji} stands for bank i interbank claims on bank j, while a_i, k_i, d_i, and b_i stand for other assets, total capital, deposits, and other short- and long-term borrowing of the bank i, respectively.

For the credit loss channel, let's assume the near-default (failure) of bank h induces credit losses λx_{hi} at another bank i. Then, equation (i) changes to:

$$(ii) \quad a_i + \sum_{j\neq h}^{N-2} x_{ji} + (1-\lambda) * x_{hi} = (k_i - \lambda x_{hi}) + b_i + d_i + \sum_{j=1}^{N-1} x_{ij}.$$

A bank fails if its capitalization falls below a threshold T (in percent of risk-weighted assets), which starts chain reactions to other banks in the banking system. A parameter (loss given default ratio, λ) governs the severity of credit loss.

For the funding loss channel, let's assume the bank i cannot fill a fraction of funding ρx_{ih}, which is obtained from the failed bank h and is forced to sell part of its assets at a discount rate δ. The parameter (loss of funding ratio, ρ) governs the severity of funding loss. These additional effects change equation (ii) to:

$$(iii) \quad a_i + \sum_{j\neq h}^{N-2} x_{ji} + (1-\lambda)x_{hi} - (1+\delta)\rho x_{ih} = (k_i - \lambda x_{hi} - \delta\rho x_{ih}) + b_i + d_i + \sum_{j=1}^{N-1} x_{ij} - \rho x_{ih}$$

Let F_t be the set of failed banks through multiple rounds of contagion. A bank fails the event if:

$(k_i - \sum_{h\in F_t} \lambda x_{hi}) < T * RWA_i$ for the simulation with credit shock and

$(k_i - \sum_{h\in F_t} (\lambda x_{hi} + \delta\rho x_{ih})) < T * RWA_i)$ for the simulation with credit-funding shock.

A simulation continues until there are no more failures of other banks.

There are three parameters that need to be set: loss given default ratio (λ), loss of funding ratio (ρ), and the discount rate (δ). In the benchmark analysis, λ=0.5 for total interbank exposures (approximation based on the weighted share of λ=1 for unsecured exposures and λ=0.1 for secured exposures), ρ=0.5, and δ=0.5.

Appendix VI. Network Analysis Measures and Concepts

1. This appendix reviews a set of key indicators from the network analysis literature that were used in this technical note. More technical definitions and formulae can be found in Boccaletti et al. (2006) and Jackson (2008). This section is only informative and introductory and aims to provide general guidelines for interpretation.

2. A network is a set of elements called nodes (or vertices/points) connected by links (or edges/ties). In a financial context, the links are determined by exposures or flows in a given asset class at a specific time. Given the nature of the relationships, financial networks are weighted, as the links embed intensity in the relationships. They are also directed, as the relationship can go in one direction or in both with the same or different intensities.

3. Two connected nodes are called neighbors or adjacent and the matrix representation of the network is called adjacency matrix. An adjacency matrix is symmetric in undirected networks and asymmetric in directed/weighted networks.

4. It is possible that several nodes are not connected. When all nodes are connected, it is called a complete network. Calculation of some topological properties of the network will be affected by completeness. Therefore, the giant component or largest connected component is used to compute some metrics such as diameter or average path length. The giant component is the connected component that contains the largest fraction of all the nodes in the network. Given that in financial networks there are usually several non-connected nodes, the giant component provides an idea of how would the fully connected network look like to assess transmission mechanisms.

5. It is also possible that some nodes show only one link to the network and they are called leaves. In financial networks, leaf nodes normally drop from the giant component and play a role of either shock originators (source node) or the entities where the shocks are no further transmitted (sink node). They are also associated to stable relationships.

6. Network density describes the portion of the potential links in a network that are actual connections. Low density means few connections are taking place but may also be affected by the proportion of non-connected nodes. Density may also be concentrated in a group of nodes with some similar features. It is therefore important to identify possible sources of density concentration via additional information about the network.

7. Assortativity refers to the tendency of nodes to attach to others that are similar in some way, normally in terms of the number of links (degree). Positive assortativity means that highly connected nodes tend to attach to other highly connected nodes whereas negative assortativity means that low degree nodes tend to attach to highly connected nodes. Together with other measures, it provides information about core-periphery structures in financial networks. It also complements the information of the network density, as positive assortativity may be linked to some clustering in the data.

8. Diameter is more often used for undirected networks and represents the greatest distance between any pair of nodes. To find the diameter of a network, we first find the shortest path between each pair of vertices. The greatest length of any of these paths is the diameter of the network. Directed networks with low reciprocity do not allow computing this metric, therefore a transformation is necessary. Empirical work in financial networks defines a diameter as low if it is between 3 and 8. Diameter is informative about the speed of transmission of information in the network. A fully connected network has a diameter of 1.

9. Average path length is defined as the average number of steps along the shortest paths for all possible pairs of network nodes. It is a measure of the efficiency of information transmission or shock transmission in financial networks. Empirical work in different areas shows different patterns of the distribution of this metrics. In the case of financial networks, average path lengths tend to be low, below 3.

10. Clustering coefficient is a measure of the degree to which nodes in a network tend to cluster together. It takes the average of each node's clustering coefficient. The individual clustering coefficient is calculated using triangles of nodes and their mutual edges. The individual coefficient ranges between 0 and 1 and a higher number means a high degree of attachment in communities. A disconnected node has a 0-clustering coefficient and in directed networks, this coefficient tends to be low due to the different patterns of connections. High clustering, low diameter and low average path length show small-world properties, where nodes tend to be close to each other in a small number of steps.

11. Degree centrality refers to the sum of the number of in-coming and out-going links of a node. A node with higher degree is called more central and means that is highly connected, irrespective of the nature of the links. In- and out-degree make reference to the direction of this links. For weighted networks, in-degree and out-degree become in-strength and out-strength measures.

12. Given a predetermined degree of distance, the average neighbor degree computes the mean degree centrality of all nodes that a one-step distance from a given node. For a degree k=1, the measure is called average nearest neighbor degree.

13. Betweenness centrality is a measure of a node's centrality equal to the number of shortest paths from all nodes to all others that pass through that node. Therefore, a node's betweenness centrality (based on the node's presence in the set of shortest paths) is high not necessarily because it has a high degree (based on the presence of a node in all paths), but because it plays an "intermediary" role in critical paths. It provides additional information about centrality than pure connectivity.

14. PageRank centrality is a variant of Eigenvector Centrality[1] and designed for ranking webpages but also applied in financial networks analysis. PageRank uses links between nodes as a measure of importance. Each node is assigned a score based upon its number of in-coming links or indegree. These links are also weighted depending on the relative score of its originating node. A higher PageRank value denotes more central role in the network.

15. Hub and authority scores are two linked centrality measures for directed networks that highlight relative importance of outgoing and incoming links, respectively. More formally, the hubs score of a node is the sum of the authorities scores of all its successors. Similarly, the authorities score is the sum of the hubs scores of all its predecessors. The sum of all hubs scores is 1 and the sum of all authorities scores is 1. Pagerank is similar to authority score.

16. A core-periphery structure states that core entities serve as hubs between periphery entities that do not interact directly but through the core. In addition, core institutions interact intensely among themselves and become systemically important in the network. Core-periphery structures are common in payment system networks and also in correlation networks. This application uses the definition outlined in Craig and von Peter (2014).

17. Jaccard similarity index (*J*) captures the probability of observing a given connection in a network conditional on observing the same link in another network and it is frequently used in multilayer network analysis. For a given pair of vectors, the index is computed as the quotient between the size of the intersection and size of the union of the two ordered vectors.

18. Cosine similarity index (*C*) is used for directed weighted networks as a proximity. Formally, it measures the cosine of the angle formed by the two vectors by means of a normalized dot product between them. It is also frequently used in multilayer network analysis.

19. The chord diagrams of all financial instruments subnetworks show that a multilayer network approach is highly informative of interconnectedness in the system and channels of transmission of potential shocks with financial stability implications. Each diagram shows the different cross-exposures in a more granular way and allows us to highlight the strongest links, the concentration of cross-exposures among specific sectors in each financial instrument and the relative role in terms of the number and size of links of every sector Table X adds sectoral centrality measures to complement this information with network metrics that allow to quantify and compare the leading centrality roles of sectors across subnetworks.

[1] Eigenvector centrality uses the eigenvector corresponding to the largest eigenvalue of the network represented as an adjacency matrix.

Table 1. Brazil: Centrality Measures by Sector and Financial Instruments in 2016 Q4

		BCB	BNK	INSPF	FIN	IFM	IFNM	GOV	NFC	HH	ROW
Total	In-strength	2,928,889	8,943,456	1,848,216	3,269,111	4,924,068	572,767	6,167,831	9,383,692	2,353,143	2,660,962
	Out-strength	2,969,017	8,358,636	1,930,291	3,296,252	4,942,426	526,429	3,876,539	6,235,561	6,238,167	4,678,815
	Betweeness	0.13	0.75	0.75	0.75	0.13	0.13	0.75	0.75	0.25	0.63
	PageRank	0.09	0.11	0.11	0.11	0.10	0.10	0.11	0.11	0.10	0.09
	Multiplex PageRank	-	-	-	-	-	-	-	-	-	-
	Hub score	0.07	0.11	0.11	0.11	0.10	0.10	0.11	0.11	0.11	0.10
	Authority score	0.09	0.11	0.11	0.11	0.10	0.10	0.11	0.11	0.10	0.09
Currency and deposits	In-strength	2,729,068	3,835,808	0	15,161	0	0	434,486	0	0	242,177
	Out-strength	94,457	2,608,704	28,926	366,140	842,401	13,534	1,208,361	712,380	1,379,755	2,043
	Betweeness	0.33	4.17	0.00	0.67	0.00	0.00	0.50	0.00	0.00	2.33
	PageRank	0.24	0.25	0.02	0.11	0.02	0.02	0.02	0.02	0.02	0.31
	Multiplex PageRank	0.07	0.14	0.06	0.11	0.08	0.06	0.13	0.08	0.21	0.06
	Hub score	0.03	0.13	0.10	0.13	0.09	0.10	0.13	0.13	0.10	0.07
	Authority score	0.25	0.28	0.00	0.20	0.00	0.00	0.03	0.00	0.00	0.24
Short-term securities	In-strength	0	361,568	0	1,654	0	0	593,618	22,992	212	19,610
	Out-strength	169,257	162,369	27,906	13,730	239,497	2,458	15,288	49,657	198,182	121,311
	Betweeness	0.00	2.25	0.00	0.25	0.00	0.00	4.00	2.25	0.25	0.00
	PageRank	0.02	0.22	0.02	0.13	0.02	0.02	0.23	0.22	0.02	0.12
	Multiplex PageRank	0.06	0.14	0.06	0.07	0.25	0.06	0.05	0.06	0.17	0.07
	Hub score	0.03	0.12	0.13	0.09	0.13	0.11	0.08	0.12	0.12	0.10
	Authority score	0.00	0.20	0.00	0.17	0.00	0.00	0.21	0.20	0.07	0.14
Long-term securities	In-strength	0	1,418,510	0	594,471	0	0	4,121,139	398,520	1,125	1,071,067
	Out-strength	2,449,103	1,179,013	231,762	141,213	1,692,328	33,116	167,101	537,306	533,156	640,734
	Betweeness	0.00	0.83	0.00	0.83	0.00	0.00	1.50	0.83	0.50	1.50
	PageRank	0.02	0.20	0.02	0.20	0.02	0.02	0.20	0.20	0.02	0.13
	Multiplex PageRank	0.12	0.14	0.06	0.07	0.24	0.06	0.06	0.08	0.11	0.07
	Hub score	0.04	0.11	0.10	0.11	0.12	0.10	0.10	0.11	0.11	0.10
	Authority score	0.00	0.20	0.00	0.20	0.00	0.00	0.21	0.20	0.07	0.12
Short-term loans	In-strength	111	174,121	0	3,275	6,334	0	11,876	483,275	484,568	10,382
	Out-strength	8,088	925,145	0	5,493	35	144	25,465	83	0	209,490
	Betweeness	0.00	6.33	0.00	18.00	0.00	0.00	10.00	0.33	0.00	12.33
	PageRank	0.04	0.11	0.03	0.28	0.05	0.03	0.11	0.14	0.13	0.09
	Multiplex PageRank	0.31	0.12	0.02	0.02	0.02	0.02	0.06	0.02	0.02	0.39
	Hub score	0.01	0.18	0.10	0.20	0.04	0.09	0.13	0.04	0.00	0.21
	Authority score	0.05	0.12	0.10	0.18	0.04	0.00	0.13	0.18	0.16	0.03
Long-term loans	In-strength	0	1,157,012	2,773	67,469	12,650	1,636	808,267	1,819,621	1,192,914	98,779
	Out-strength	14,308	2,217,727	28,890	85,526	3,750	8,337	1,630,241	294,932	11,310	866,098
	Betweeness	0.00	10.50	0.00	4.00	0.25	0.25	0.00	15.00	0.50	17.50
	PageRank	0.02	0.15	0.04	0.15	0.06	0.04	0.09	0.17	0.14	0.15
	Multiplex PageRank	0.09	0.23	0.02	0.03	0.02	0.02	0.21	0.07	0.03	0.28
	Hub score	0.05	0.15	0.12	0.15	0.06	0.06	0.12	0.09	0.07	0.14
	Authority score	0.00	0.17	0.05	0.14	0.05	0.02	0.11	0.18	0.15	0.13
Equity	In-strength	139,675	1,058,874	170,057	2,285,629	0	0	0	4,897,615	0	1,081,398
	Out-strength	0	712,612	256,228	1,945,971	82,801	302,287	611,826	1,763,239	1,671,737	2,286,546
	Betweeness	0.00	0.25	0.25	0.25	0.00	0.00	0.00	0.25	0.00	0.00
	PageRank	0.02	0.19	0.19	0.19	0.02	0.02	0.02	0.19	0.02	0.15
	Multiplex PageRank	0.04	0.20	0.05	0.07	0.04	0.04	0.12	0.12	0.08	0.24
	Hub score	0.00	0.12	0.12	0.12	0.12	0.10	0.12	0.12	0.12	0.10
	Authority score	0.02	0.20	0.20	0.20	0.00	0.00	0.00	0.20	0.00	0.16
Investment funds shares/units	In-strength	0	0	0	0	4,826,577	541,366	0	0	0	0
	Out-strength	0	103,390	1,191,979	313,501	2,000,068	84,830	208,850	522,860	773,795	168,670
	Betweeness	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	PageRank	0.02	0.02	0.02	0.02	0.43	0.43	0.02	0.02	0.02	0.02
	Multiplex PageRank	0.08	0.09	0.10	0.09	0.11	0.09	0.10	0.11	0.11	0.12
	Hub score	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Authority score	0.10	0.00	0.00	0.00	0.45	0.45	0.00	0.00	0.00	0.00
Insurance, pension and standardized guarantee schemes	In-strength	0	0	1,560,140	0	0	0	0	0	0	0
	Out-strength	0	1,311	7,741	375	0	0	0	26,310	1,524,404	0
	Betweeness	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	PageRank	0.03	0.03	0.77	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	Multiplex PageRank	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.17	0.09
	Hub score	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Authority score	0.10	0.00	0.50	0.00	0.10	0.10	0.10	0.00	0.00	0.10
Financial derivatives	In-strength	0	179,039	0	233,670	60,808	14	0	0	0	3,903
	Out-strength	2,367	105,153	228	281,467	63,797	313	0	1,591	5,174	17,346
	Betweeness	0.00	6.00	0.00	19.50	0.00	0.00	0.00	0.00	0.00	5.50
	PageRank	0.02	0.26	0.02	0.29	0.07	0.07	0.02	0.02	0.02	0.23
	Multiplex PageRank	0.05	0.18	0.03	0.39	0.13	0.03	0.03	0.05	0.05	0.05
	Hub score	0.13	0.13	0.07	0.17	0.13	0.07	0.10	0.06	0.13	0.02
	Authority score	0.00	0.08	0.00	0.35	0.07	0.07	0.10	0.00	0.00	0.32
Other accounts receivable/payable	In-strength	60,035	758,525	115,246	67,783	17,698	29,751	198,444	1,761,669	674,324	133,646
	Out-strength	231,436	343,213	156,631	142,839	17,749	81,411	9,407	2,327,204	140,654	366,577
	Betweeness	0.17	10.31	4.34	1.68	0.14	0.14	0.34	11.03	2.70	1.14
	PageRank	0.06	0.14	0.13	0.09	0.06	0.07	0.12	0.15	0.10	0.09
	Multiplex PageRank	0.04	0.26	0.04	0.15	0.03	0.02	0.02	0.34	0.05	0.06
	Hub score	0.07	0.14	0.11	0.14	0.07	0.08	0.05	0.14	0.12	0.08
	Authority score	0.05	0.13	0.13	0.10	0.07	0.09	0.10	0.12	0.11	0.10

Note: The table presents centrality measures for each sector in each subnetwork and in the total network for 2016Q4. In-strength and out-strength corresponds to total liabilities and total assets, respectively. Multiplex PageRank is the combined version in order to allow sectors to gain centrality if they are not only central but if they are connected to central nodes in other subnetworks. It was computed using a standard 0.85 damping factor. It is not available for the aggregated network. were excluded prior to computing the average in order not to affect the results by extreme values. The largest three values of selected centrality measures are highlighted in red to check consistency across indicators.
Source: IMF staff estimates and BCB.

Appendix VII. Data for Market-based Spillover Analysis

Table 1. Brazil: Diebold-Yilmaz Spillover Analysis Sample and VAR Specifications

Market	Source	Period	Sample
Stock index (Total market)	MSCI	01/02/2008-09/29/2017	17
Stock index (Bank index)	Datastream	01/02/2008-09/29/2017	17
Stock prices (Individual Banks)	Datastream	01/02/2008-09/29/2017	86
Sovereign CDS	Datastream	09/01/2009-09/29/2017	14
FX (US dollar exchange rates)	BIS	01/02/2008-09/29/2017	14

Note. For the dynamic version, the rolling sample windows size is set to 150 for equity indices and bank stock returns and 200 for sovereign CDS and FX series. Number of lags in the VAR is set to 3 and the forecast horizon is 10 for all series. The sample includes all countries for stock indices. For the CDS exercise, Argentina, India and the USA are excluded. For the FX exercise all euro area countries (France, Germany and Spain) are represented in a single series and USA is excluded.

Individual banks included in the sample[1] (ISIN codes in parenthesis):

Brazil: Banco do Brasil (BRBBASACNOR3), Itau Unibanco Holding (BRITUBACNOR4), Banco Bradesco (BRBBDCACNOR1), Banco Santander (BRSANBACNOR8).

Argentina: Gp. Finance Galicia 'B' (ARP495251018), Banco Macro Bansud 'B' (ARBANS010010), BBVA Banco Frances (ARP125991090).

Chile: Banco Santander Chile (CLP1506A1070), Banco de Chile (CLP0939W1081), Banco de Credito E Inversion (CLP321331116), Itau Corpbanca (CL0002262351).

China: ICBC 'A' (CNE000001P37), China Con.Bank 'A' (CNE100000742), Bank of China 'A' (CNE000001N05), Bank of Comms.'A' (CNE1000000S2), Industrial Bank 'A' (CNE000001QZ7), China Citic Bank 'A' (CNE1000000R4), China Merchants Bank 'A' (CNE000001B33), China Minsheng Banking 'A' (CNE0000015Y0), Shai.Pudong Dev.Bk. 'A' (CNE0000011B7), Huaxia Bank 'A' (CNE000001FW7).

Colombia: Bancolombia (COB07PA00078).

France: BNP Paribas (FR0000131104), Credit Agricole (FR0000045072), Societe Generale (FR0000130809), Natixis (FR0000120685).

Germany: Deutsche Bank (DE0005140008), Commerzbank (DE000CBK1001).

India: State Bank of India (INE062A01020), ICICI Bank (INE090A01021), HDFC Bank (INE040A01026), Punjab National Bank (INE160A01022), Bank of Baroda (INE028A01039), Bank of India (INE084A01016), Canara Bank (INE476A01014), Axis Bank (INE238A01034), Idbi Bank (INE008A01015), Central Bank of India (INE483A01010), Kotak Mahindra Bank (INE237A01028), Indian Bank (INE562A01011).

Indonesia: Bank Mandiri (ID1000095003), Bank Rakyat Indonesia (ID1000118201), Bank Central Asia (ID1000109507), Bank Negara Indonesia (ID1000096605), Bank Cimb Niaga (ID1000098007).

Mexico: Gpo. Financero Banorte (MXP370711014), Grupo Financiero Inbursa Sries 'O' (MXP370641013).

Russia: Sberbank of Russia (RU0009029540).

South Africa: Standard Banking Group (ZAE000109815), Firstrand (ZAE000066304), Barclays Africa Group (ZAE000174124), Nedbank Group (ZAE000004875), Capitec Bank (ZAE000035861), RMB (ZAE000024501).

Spain: Banco Santander (ES0113900J37), BBVA (ES0113211835), Caixabank (ES0140609019), Banco de Sabadell (ES0113860A34), Bankinter 'R' (ES0113679I37).

Turkey: Turkiye Is Bankasi 'C' (TRAISCTR91N2), Tki.Garanti Bksi. (TRAGARAN91N1), Akbank (TRAAKBNK91N6), Yapi Ve Kredi Bankasi (TRAYKBNK91N6), Turkiye Halk Bankasi (TRETHAL00019), Tki.Vakiflar Bankasi (TREVKFB00019).

United Kingdom: HSBC (GB0005405286), Barclays (GB0031348658), Lloyds Banking Group (GB0008706128), Royal Bank of Scotland (GB00B7T77214), Standard Chartered (GB0004082847).

United States: JP Morgan Chase & Co. (US46625H1005), Bank of America (US0605051046), Wells Fargo (US9497461015), Citigroup (US1729674242), US Bancorp (US9029733048), PNC Finl.Svs.Gp. (US6934751057), BB&T (US0549371070), Suntrust Banks (US8679141031), Fifth Third Bancorp (US3167731005), Keycorp (US4932671088), Regions Finl. (US7591EP1005), M&T Bank (US55261F1049), Huntington Bancshares (US4461501045), Comerica (US2003401070), Zions Bancorp. (US9897011071), New York Community Bancshares (US6494451031).

[1] Listed by asset size as of end-2016.

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