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July 17, 2020

TECHNICAL NOTE

RISK ANALYSIS AND STRESS TESTING THE FINANCIAL SECTOR

Prepared By
Monetary and Capital Markets Department

This Technical Note was prepared in the context of an IMF Financial Sector Assessment Program (FSAP) mission in the United States held during February–March 2020 led by Ms. Michaela Erbenová. It has been factually updated to incorporate COVID-19-related events in March and April 2020. It contains technical analysis and detailed information underpinning the FSAP's findings and recommendations. Further information on the FSAP program can be found at http://www.imf.org/external/np/fsap/fssa.aspx

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Glossary

ABS	Asset-Backed Security
AE	Asset Encumbrance
AFS	Available-for-Sale
AR	Auto Regressive term
BBB	BBB Rating class
BHCs	Bank Holding Companies
BIS	Bank of International Settlement
BNY Mellon	Bank of New York Mellon
BPs	Basis Points
CAR	Capital Adequacy Ratio
CB	Central Bank
CBC	Counterbalancing Capacity
CBOE	Chicago Board Options Exchange
CCB	Capital Conservation Buffer
CCP	Central Clearing Counterparty
CET1	Core Equity Tier 1
CLASS	Capital and Loss Assessment under Stress Scenarios
CLO	Collateralized Loan Obligations
CMO	Collateralized Mortgage Obligation
CoVaR	Conditional Value at Risk
CRD IV	Capital Requirements Directive IV
CRR	Capital Requirements Regulation
CUSIP	Committee on Uniform Securities Identification Procedures
C&I	Commercial and Industrial
DFAST/CCAR	Dodd-Frank Act Stress Tests/Comprehensive Capital Analysis and Review
DSGE	Dynamic Stochastic General Equilibrium
EaD	Exposure at Default
EA	Exposure Amount
ECB	European Central Bank
EDFs	Expected Default Frequencies
EM	Emerging Market
ES	Expected Shortfall
ETFs	Exchange Traded Funds
FCI	Financial Conditions Index
Fed	Federal Reserve System
FFIEC	Federal Financial Institutions Examination Council
FI	Financial Institution
FINRA	Financial Industry Regulatory Authority
FRB	Board of Governors of the Federal Reserve System

FR-Y	Federal Reserve report form
FSAP	Financial Sector Assessment Program
GAAP	Generally Accepted Accounting Principles
GaR	Growth at Risk
GAS	Global Assumptions
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GFM	Global Macrofinancial Model
GSE	Government-Sponsored Enterprise
G-SIB	Global Systemically Important Bank
G-SIFI	Global Systemically Important Financial Institution
GVD	Generalized Forecast-Error Variance Decomposition
HTM	Held-to-Maturity
HY	High-Yield
HQLA	High-Quality Liquid Assets
ICI	Investment Company Institute
ICPF	Insurance Companies and Pension Funds
IHC	Intermediate Holding Company
IMF	International Monetary Fund
IRB	Internal Rating-Based Approach
IT	Information Technology
LCR	Liquidity Coverage Ratio
LEI	Legal Entity Identifier
LGD	Loss-Given Default
LMTs	Liquidity Management Tools
MASS	Macrofinancial System Simulator
MBS	Mortgage-Backed Securities
MF	Mutual Fund
MMF	Money Market Fund
NAIC	National Association of Insurance Commissioners
NAV	Net Asset Value
NPL	Nonperforming Loan
N-PORT	Portfolio Investments Report
Non-GSIB	Non-Global Systemically Important Banks
OFR	Office of Financial Research
OTC	Over-the-Counter
PD	Probability of Default
PI	Price Impact Measure
PiT	Point in Time
PPML	Pseudo-Maximum Likelihood
PPNR	Pre-Provision Net Revenue
P&C	Property & Casualty
RBC	Risk-Based Capital

RCR	Redemption Coverage Ratio
RWAs	Risk-Weighted Assets
SEC	Securities and Exchange Commission
SFTs	Securities financing transactions
SNL	S&P Global Market Intelligence (formally known as SNL)
SSM	Single Supervisory Mechanism
ST	Stress Test
STA	Standardized Approach [to capital requirements]
SVAR	Structural VAR
TBA	To-Be-Announced securities
TD	Top-Down
TRACE	Trade Reporting and Compliance Engine
TTC	Through-the-Cycle
U.S.	United States
UST	United States Department of the Treasury
U.K.	United Kingdom
VA	Variable Annuities
VAR	Vector Auto-Regression
VIX	CBOE Volatility Index
WEO	World Economic Outlook

EXECUTIVE SUMMARY[1]

The U.S. financial system is very large, well-diversified, and home to numerous financial institutions which are significant at a global scale. Eight Global Systemically Important Banks (G-SIBs) are incorporated in the U.S., as well as several other large financial institutions, such as asset managers, insurers, and money market funds. Assets of the financial system amounted to about US$100 trillion at end-2019 and accounted for 500 percent of GDP. While the eight G-SIBs dominate the U.S. banking landscape, banking system assets represent only about 22 percent of total financial system assets. The systemic risk assessment (including stress testing) of this FSAP reflect the highly diversified nature of the U.S. financial system and focuses on banks, mutual and money market funds, insurance companies as well as cross-institutional and cross-sectoral linkages and exposures.

The U.S. financial landscape has experienced significant transformation since the global financial crisis as financial intermediation and concomitant risks increasingly shift to non-bank financial institutions. Banking regulation and supervision have been overhauled and large banks have strengthened their capital and liquidity buffers. The financial sector has seen significant deleveraging, with the sector's indebtedness falling from 125 percent of GDP at the height of the Global Financial Crisis (GFC) to about 77 percent currently. This process was accompanied by the growing role played by the non-bank financial intermediaries. These institutions are supplying a significant proportion of credit to the economy as well as providing liquidity transformation. Many of these intermediaries provide funding to households and nonfinancial corporates. Funding provided by the non-banks is growing faster than funding provided by depositary institutions. At the same time, non-bank intermediaries often depend on banks for liquidity and short-term funding.

The FSAP was conducted and this note was largely written prior to the pandemic onset and did not assess the impact of the shock and effectiveness of policy measures to mitigate that impact. Reflecting post-mission developments, baseline economic growth projections have been significantly revised downward in the April 2020 WEO and subsequently in the June 2020 WEO Update. The U.S. authorities implemented urgent measures to address health concerns, to safeguard economic and financial stability and to prevent adverse macrofinancial feedback loops. Nevertheless, the FSAP's risk analysis remains broadly relevant. The data cut-off point for this note was Q3 2019, except for the interconnectedness and liquidity analysis performed in March 2020 and the banking sector solvency stress test that relies on Q1 2020 data and June 2020 economic forecasts.

For the past few years, corporate leverage was on the rise, especially among a growing number of highly leveraged firms, while household indebtedness has fallen substantially. Total business sector debt stood at about US$16 trillion (75 percent of GDP) at the end of 2019, with

[1] The work on the technical note was carried out between October 2019 and March 10, 2020, ahead of significant market disruptions caused by the spread of a new public health risk (COVID-19). The work was overseen by Peter Breuer and the authors are Carlos Caceres, Mindaugas Leika, Fabian Lipinsky, Dulani Seneviratne, Eva Yu (all IMF), and Antoine Bouveret, and Timo Broszeit (external consultants).

corporate sector debt (comprising corporate bond debt and bank loans) accounting for about two thirds. Easy financial conditions and the search for yield have been accompanied by a rapid increase in 'leveraged finance' to about 7 percent of total business sector debt—issuance of syndicated loans or non-investment grade bonds by highly-leveraged companies and related structured products, such as Collateralized Loan Obligations (CLOs). This segment has seen a rise in issuance with less covenant protections, and the solid performance of leveraged loans in recent years—characterized by low default rates—is being challenged by developments following the COVID-19 outbreak. Many nonfinancial firms remain vulnerable to changes in the availability and cost of funding and will likely face pressures from falling revenues due to the dual COVID-19 outbreak and oil price shock, most notably the energy sector. In contrast, households entered the crisis on a stronger footing. Total household debt declined from close to 100 percent of GDP at the onset of the crisis to about 75 percent currently. The reduction in indebtedness—and mortgage debt in particular—has been widespread across all income groups, with a large portion of new mortgage loans accruing to relatively high quality borrowers. Nevertheless, rising unemployment and faltering income will put pressure on households debt servicing capacity, particularly those working in hardest hit sectors (leisure, hospitality, transportation services), many of which tend to be relatively low-wage earners.

Risks could be spread through sizeable domestic exposures among banks and non-bank financial institutions, though links with foreign economies are relatively small. Intra-financial system interconnectedness analysis reveals that banks provide significant short-term funding to non-bank financial institutions, households and corporates. Unused credit lines and other funding commitments provided by banks constitute about 15 percent of intra-financial system exposures. At the same time, the U.S. banking system's average capital impairment due to their exposure to foreign banking systems could be as low as 2 percent of regulatory capital. The U.S. banking system, however, has substantial interconnections with global financial markets including foreign banks.

Outward spillover risk is mitigated by large banks' solid capital and liquidity buffers, which help to withstand severe economic and funding distress. Banks entered the COVID-19 outbreak well prepared: with substantial capital and liquidity buffers and ability to expand balance sheets to support the real sector. The systemwide Common Equity Tier 1 capital ratio (CET1) before the COVID-19 crisis was 12 percent on average and liquidity (LCR) ratios above 100 percent. Adding to this, banks are subject to a less procyclical (compared to the Internal Ratings Based approach) standardized approach to capital adequacy requirement calculation. In the baseline scenario, which follows the June 2020 WEO update, capitalization levels decline, but all G-SIBs stand above the regulatory minima. In the medium to long term (3 to 5 years), declines in interest rates and intensified pressure from the non-bank financial sector, especially Fintech firms, could lead to a compression of interest margins and loss in revenue from fees and commissions. To capture uncertainty related to the time profile and other specifics of the COVID-19 shock, the FSAP simulated multiple adverse sensitivity scenarios in conjunction with the baseline scenario. In the baseline scenario, industry-wide CET1 ratios decline by 390 basis points on average, reaching their lowest point after 2 years of stress. Smaller, non-G-SIB banks experience the largest impact. If the recovery is as fast as projected in the baseline scenario, the impact on CET1 ratios by the end of the 5-year horizon would be 50 basis points. The declines in the systemwide CET1 ratio in the outer years are mostly driven by a decline in net interest income due to compressed margins. In the adverse sensitivity scenario, which assumes an additional month of containment measures, median capitalization at the lowest point of the horizon is 7.6 percent, which is lower than the CET1 ratio under the baseline by 190 basis points. In the case of a more severe recession, such as a second wave of infection and subsequent contagion measures, the impact on the systemwide CET1 ratio at its lowest point would be 450 basis points compared to the baseline and 630 basis points compared to the median CET1 ratio at Q1 2020. Nevertheless, all G-SIBs would maintain CET1 ratios above the minimum regulatory requirements.

Interconnectedness analysis indicates that G-SIBs' exposure to each other's solvency and liquidity stress can be contained, but vulnerabilities in Non-Global Systemically Important Banks (Non-GSIBs) tend to increase. Illiquidity or default of a G-SIBs would affect other banks via counterparty losses, liquidity shocks and asset fire-sales. A joint IMF-FRB analysis indicates that these effects are relatively small within the group of 6 G-SIBs. However, vulnerabilities in smaller banks could increase as they ramp-up risk taking and reduce liquidity buffers in the context of recent regulatory relief. The stress test results indicate that in times of market shocks these banks may struggle to provide liquidity to customers.

Corporate sector stress could have a considerable impact on the non-bank financial sector and a moderate impact on banks. A large proportion of corporate sector debt resides outside of the banking sector,[2] including in insurance companies, mutual funds, pension funds, and foreign investors. Over half of leveraged loans outstanding are owned by CLOs, which are in turn held by a wide range of investors, with banks mainly holding the AAA-rated tranches. Stress in the corporate sector would result in significant losses in the non-bank financial sector, especially holders of equity tranches, resulting in some funding redemption pressures for open-ended funds, albeit fire-sales channel would be contained by the contractual structure of CLOs funds. Even in such a scenario, marked-to-market losses would be contained, with the impact on banks being moderate by virtue of their limited direct exposure.

Mutual funds stress tests conducted by IMF staff indicate that most funds would be able to withstand severe redemption shocks, but high yield and loan mutual funds would face significant shortfalls. More than 90 percent of funds (measured by assets under management) would have enough highly liquid assets to meet investors' redemption. However, funds exposed to high yield and leveraged loans would need to sell less liquid securities in their portfolio, (assuming that they do not use any liquidity risk management tools), potentially giving rise to fire sale dynamics. Funds with large exposures to derivatives could face liquidity demands related to variation margins depending on market conditions. Sensitivity analysis shows that potential variation margin calls could be higher than their liquid assets, increasing the potential risk of forced sales.

While the insurance sector appears resilient to a severe market shock, its profitability is vulnerable in a scenario of continued low interest rates and rising corporate defaults. The

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[2] Banks' exposure to the corporate sector is largely through commercial and industrial (C&I) loans.

stress test covered more than 70 percent of the life and non-life market by assets and included smaller, regionally concentrated non-life firms. A materialization of the adverse scenario would have a substantial balance sheet impact, especially in the life sector, stemming from impairments on shares, non-investment grade debt, and other investment assets. While current buffers as well as the valuation and solvency regime would prevent major disruptions, persistently low interest rates are expected to further erode profitability of life insurers. In turn, a large interest rate hike, triggering a mass lapse and large cash outflows from the life sector, would affect insurers very heterogeneously: some insurers would need to liquidate only small amounts of Treasury bonds, but a few would have to liquidate larger amounts of assets, including potentially less liquid corporate bonds.

Climate related risks would have a relatively contained impact on the financial system in the near term, but some companies and segments, like insurers, municipal bond market would be affected more. A very severe hurricane (expected to occur every 250 years) would have a major impact on companies and households in affected regions, but large and diversified non-life insurers would have enough capital to pay out compensations. Several smaller and more regionally concentrated insurers would face capital shortfalls. Overall impact estimates fall under a wide range considering increased probabilities of extreme weather events and potential damages. Further impact may come from insurers leaving affected regions, a deterioration of income of affected municipalities and a negative impact on municipal bond market.

While the U.S. financial system's resilience is strengthened by diversified sources of credit to the economy, the potential system-wide impact of valuation losses of corporate debt securities and leveraged loans is not easily quantifiable and may be non-negligible. The migration of activities from well-regulated, public and transparent financial institutions, such as banks, towards more opaque, private and unsupervised entities creates challenges for the identification and assessment of systemic risks. Public data is scarce on exposures of regulated financial institutions as well as the ultimate risk holders of leveraged loans and associated securitization vehicles. Greater transparency about those exposures would strengthen market discipline and allow for constant assessment of systemic risk. Results of a system-wide interconnectedness stress test confirm that some corporate bond mutual funds and insurers may have considerable direct losses in the scenario of distress in corporate debt markets. Banks, however, would experience smaller losses because of their limited exposure to the sector, except for potentially higher credit line drawdowns by corporates and non-bank financial institutions.

INTRODUCTION

A. Objective

1. The objective of the risk analysis component of the FSAP is to identify macrofinancial vulnerabilities. The analysis identifies and quantifies risks which could potentially lead to severe disruptions in the provision of financial services in the U.S., including international spillovers via U.S. financial companies' exposures abroad.

2. The approach to the systemic risk assessment reflects the high degree of complexity and cross-sectoral interconnectedness of the U.S. financial sector.[3] The FSAP team analyzed links among banks, insurers and asset management industry, as well as characteristics of financial companies' exposures, and different business models, such as global diversification. Holdings of similar securities, exposures to specific asset classes (such as collateralized loan obligations, asset backed securities) were considered in designing the stress test methodology as well as the scenarios.

3. A comprehensive set of risk analyses and stress tests was conducted to assess the resilience of the U.S. financial system and shed light on linkages and potential risks and vulnerabilities. The assessment is based on multiple individual stress tests, which simulate the financial health of banks, mutual funds, and insurers under severe yet plausible (counterfactual) adverse scenarios and various sensitivity tests. The stress tests are largely independent but linked via scenarios where possible.[4] Scenarios include global and regional financial market stress (shocks to term and risk premiums and resulting asset price corrections) and a major slowdown of economic activity. This risk analysis relies on models and approaches designed by the FSAP team for solvency (banks, insurance companies), liquidity (banks, mutual, money market funds) and solvency-liquidity feedback analysis (fire-sales of assets across the financial sector). The approach is thus different form the ones employed by the U.S. regulatory agencies.

4. This note provides a comprehensive overview of all qualitative and quantitative work done by the U.S. FSAP Systemic Risk team. The note is structured as follows: The first section describes key structural features of the U.S. financial system, including interlinkages within domestic sectors and foreign jurisdictions. The second section analyzes key risks and vulnerabilities. Scenarios provide qualitative assessment of risks and quantification of shocks. The following sections discuss the impact of potential shocks on nonfinancial corporates, banks, insurers, mutual and money market funds. The note concludes with a systemic risk overview and an analysis of interconnectedness across various parts of financial system. The appendices provide further technical and analytical details of some of the approaches and models developed.

[3] We only refer to consolidated banking groups at the level of bank holding companies referred as banks in this note.

[4] Rapid developments during the COVID-19 crisis prevented updating all individual stress tests with the new scenarios.

B. Stress Testing Work Done by the Authorities

5. The Federal Reserve supervisory stress tests project the impact of the macroeconomic scenarios on banks' capital position and income using granular models and confidential supervisory data. By contrast, the FSAP stress test are broader and focus on system-wide risks. For banks, the FSAP stress test is a top-down exercise mostly relying on public and non-confidential data as well as scenarios generated by in-house models developed by the FSAP team.[5] Relative to the Federal Reserve's regulatory stress test (CCAR/DFAST), while both the FSAP and the Federal Reserve scenarios broadly share a consistent narrative of risks, they differ in terms of the granularity of data inputs, the calibration of the various shocks and models used. Hence, the Federal Reserve and IMF top-down stress test bank solvency stress testing results are not directly comparable. Stress Testing Matrix (Appendix I) provides further details about FSAP Stress Testing models and assumptions.

6. Mutual funds are not subject to stress testing requirements (with the exception of Money Market Funds) by their managers or by the SEC. Recently, the SEC has proposed that funds using derivatives would be required to perform stress tests.

7. While U.S. authorities perform and are developing a variety of stress tests and analyses, they do not regularly conduct macrofinancial stress tests for the insurance sector. As part of the solvency regime, companies are required to calculate the impact of various natural disasters, and to conduct various sensitivity analyses for their interest rate risks (liability adequacy test). The NAIC is currently developing a liquidity stress test which is expected to be applicable to certain large insurance companies at end-2021. A few state supervisors, e.g., California, have conducted climate-related stress tests, also looking into the transitional risk of carbon-intense investments. Furthermore, the NAIC conducts market-wide exposure studies for various asset classes, e.g., CLOs, on an ad-hoc basis.

C. Risk Analysis and Stress Testing under the U.S. FSAP Program

8. The risk analysis covers multiple types of financial institutions and places strong emphasis on domestic and foreign exposures-based interconnectedness. Risk analysis conducted a battery of stress tests of banks (34 largest institutions), insurance companies (53 large groups and 17 medium-sized and smaller regional insurers), mutual funds (about 2,000 largest players) and selected money market funds (208). The selection is based on the size of banks (assets more than USD 100 billion)[6] and insurers (the insurance stress test aimed at a coverage of at least 70 percent of the life and the non-life sectors, comparable to most recent FSAPs also with the aim of having representative sample across different types of insurers).[7] Mutual fund stress tests included

[5] Following common practice in FSAPs, the baseline scenario follows the projections published in the IMF's *June 2020 World Economic Outlook (WEO) Update*.

[6] 33 banks with assets above USD 100 billion and one bank with assets close to 100 billion.

[7] The inclusion of smaller property & casualty insurers was motivated by concerns about regionally concentrated companies and their exposure to natural disasters.

all fixed income and mixed mutual funds covered by Morningstar. Interconnectedness and systemic risk analysis links stand-alone stress tests. Common exposures and simulated asset fire-sales provide system-wide stressed loss estimates. The exercise gauges the level of resilience of the financial system against simulated severe yet plausible macro and financial shocks.

9. **Like in other FSAPs in large advanced economies, the IMF scenario design is based on multiple approaches and severity benchmarks**. The FSAP team used WEO baseline projections, which included assumptions about duration and severity of COVID-19 crisis, inference about severity from 2019 DFAST/CCAR scenarios, and the 2008–2009 Global Financial Crisis (GFC).

10. **Analytical approaches in FSAP risk analysis are divided into multiple blocks (Figure 1)**. The risk analysis covers solvency of banks and insurers, limited (because of data availability) liquidity analysis of banks and mutual and money market funds. Sectoral risk assessment, scenario design and interconnectedness provide an envelope for linking various risks together. Systemic risk analysis relies on a set of models developed by FSAP team.

11. **This technical note reflects discussions, presentations and consultations with the authorities, private sector and data sources available to the team.** Some analyses (banking sector interconnectedness) were undertaken in close collaboration with the FRB staff to preserve confidentiality of the underlying input data based on supervisory reports. The analysis is nevertheless the IMF's work product and does not reflect the views of the U.S. regulators.

12. **The FSAP team used various public and commercial data sources to perform the analysis and cooperated with the FRB on banking sector interconnectedness and liquidity analysis.** Full-fledged market and liquidity risk analysis of banks and mutual funds typically requires access to supervisory data. The U.S. regulatory agencies require supervised and regulated institutions to publish large amounts of data which otherwise are considered confidential in many other jurisdictions. This enabled the FSAP team to perform analysis of banks, mutual and money market funds using public data. The results need to be interpreted with caution, however, as the FSAP team was unable to conduct a granular stress test of trading books which considers issues such as portfolio hedges and short positions, and also incorporates potential changes in banks' balance sheets. Insurance stress testing was based on confidential supervisory data. Liquidity stress test of banks are based on public 30-day Liquidity Coverage Ratio (LCR) disclosure templates and omits other time horizons, namely 1 day, 5 days, or 3 months typically employed in other systemic jurisdictions.[8] Structural liquidity risk analysis did not elaborate on Asset Encumbrance because such data were not available.

[8] Except for liquidity risks for six G-SIBs for which the test was performed by the FRB using supervisory data.

Figure 1. United States: FSAP Systemic Risk Assessment Framework

USA FSAP Systemic Risk Assessment Framework: systemic risk analysis

Solvency of Banks		Solvency of Insurers	Liquidity of banks, mutual and money market funds	Interconnectedness	Scenario design and sectoral risk assessment
Balance-sheet regulatory approach based on exposures (domestic/foreign).		Balance-sheet regulatory approach based on exposures Aligned with macrofinancial scenarios used for the banking ST.	Bank liquidity Limited analysis using public data (LCR disclosure reports) 33 banks: 8 G-SIBs; 9 subsidiaries of foreign banks and 16 other domestic banks.	Cross-Sectoral exposures Flow of funds among the different econ sectors: financials, households, corporates, public sector, foreign entities	Scenario design and macro conditions COVID-19 Baseline and the three Adverse scenarios based on duration of containment measures and a second wave of contagion.
Forecast of balance sheet and income statement items. 57 equations based on the refined CLASS model. Three or five year ST horizon.	Forecast of pre-loss income, credit and market losses, changes in RWAs based on refined CLASS model as well as internal models and	Sensitivity analyses (e.g., interest rate shocks, default of largest banking counterparties). Coverage: 70 insurance groups.	Mutual funds Fund liquidity: redemption shocks. Emphasis on US fixed income and mixed funds.	Exposure based analysis US interbank, cross-border (incl. aggregated cross-border exposure analysis)	Housing sector analysis Expansion of non-bank mortgage lenders
Sensitivity analyses (e.g., Real estate price risk). Risks from common exposures (fire-sales of assets).			Money market funds Fund market risk: interest and credit spread shocks.	Market-data based Interconnectedness analysis (domestic and foreign linkages)	Corporate vulnerabilities Leveraged lending Securitization and CLOs
Top-down: 34 banks (8 G-SIBs; 11 subsidiaries of foreign banks and 16 other domestic banks).					

Source: IMF staff.

FINANCIAL SYSTEM: RISKS AND VULNERABILITIES

A. Financial System Structure and Performance

The U.S. Financial System: An Overview

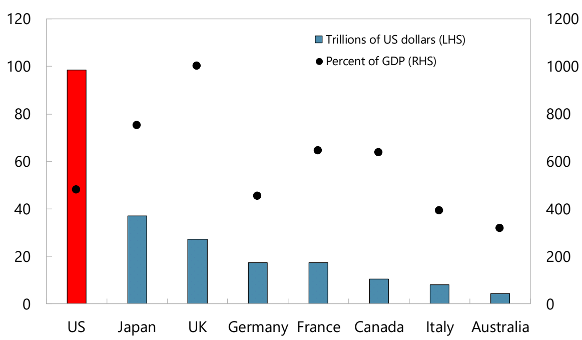
13. The U.S. financial sector is one of the largest and most complex financial systems in the world (Figure 2). The size of the financial system surpassed US$100 trillion in 2019 and amounts to about five times the U.S. nominal GDP. The U.S. banking sector is one of the largest in the world, although private depository corporations account for about 20 percent of the financial system reflecting the deep and liquid capital markets. Pension funds, MMFs and mutual funds, and insurance industries are also sizable. The mutual funds sector, which encountered a sharp decline in its balance sheet size during the GFC, has now surpassed its pre-crisis peak reaching 16 percent of the financial sector share as of 2019 (Appendix Figures VII.1–3).

14. The U.S. financial system is well diversified: it allocates savings, investments and provides capital through a vast number of financial institutions and instruments. Diversification creates resilience against sudden stop of credit flow via one type of institution (e.g., banks). Capital is allocated via deep and liquid capital markets with equity market capitalization above US$50 trillion (as of 2019) and sizable debt securities markets in addition to loans and deposits. Financial instruments also include personal investment products such as pension entitlements, with assets about US$30 trillion. Mortgages—home, multi-family residential, commercial, and farm mortgages—also remain sizable at about US$15 trillion as of 2019.

15. The systemic importance of the U.S. financial system remains high in the global financial landscape, in part owing to the safe heaven assets and the strength of the U.S. dollar. The demand for safe heaven assets from global investors remained high against the backdrop of external vulnerabilities. For instance, the average daily trading volume of U.S. Treasury securities grew by 10 percent year-over-year in 2019, reaching nearly US$600 billion per day on average. Overall, the portfolio investment position of foreign residents on the U.S. amounted to above US$20 trillion in 2019, while U.S. residents' portfolio investment position in the rest of the world was over US$12 trillion. Owing to the reserve currency status of the U.S. dollar in the global trade and financial landscape, financial institutions including foreign-owned entities carry-out lending in U.S. dollars and participate in U.S. dollar funding markets as well as rely on foreign exchange swaps vis-à-vis the U.S. dollar. The share of dollar-denominated cross-border claims amounted to about 50 percent of global banks' total cross-border claims in 2019. Foreign-owned banks maintain dollar-denominated cross-border claims over US$12 trillion, amounting to about 10 percent of their cross-border claims on average (October 2019 GFSR Chapter 5).

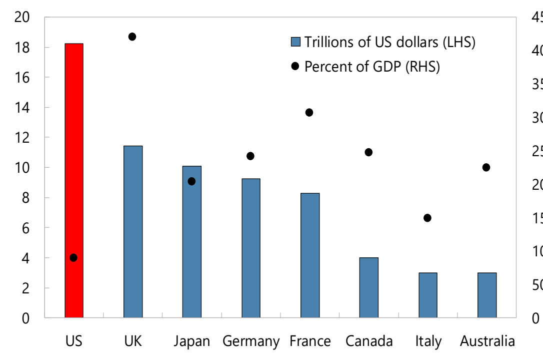
Figure 2. United States: Financial Sector

Size of the Financial Sector
(As of end-2018)



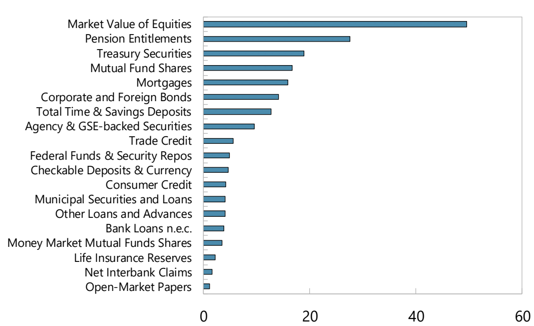
Sources: FRB, Flow of Funds; Haver Analytics.

Size of the Banking Sector
(As of end-2018)



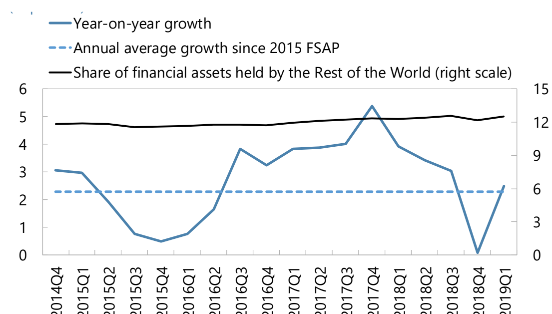
Sources: FRB, Flow of Funds; Haver Analytics.

Financial Instruments in the U.S.
(In trillions of U.S. dollars; as of 2019Q3)



Source: FRB, Flow of Funds.

Financial Sector Asset Growth and the Share Held by the Rest of the World
(In percent)



Sources: FRB, Flow of Funds; Haver Analytics.

Banking Sector

16. **The U.S. banking system has grown in size, even as banks consolidated over time.** The system has undergone numerous mergers and acquisitions in addition to a few bank failures,

bringing down the number of banks operating in the system to less than 5,000 from over 10,000 that existed at the end of the last millennium. The U.S. banking system is now dominated by 34 large bank/intermediate holding companies (BHCs/IHCs)[9] with consolidated assets over US$100 billion each, accounting for nearly 80 percent of U.S. banking system assets. The banking system is home to eight globally systemically important banks (G-SIBs), that hold more than 50 percent of banking system assets. The list of 34 banks also includes 12 large intermediate holding companies (IHC) (i.e., foreign-owned). Four IHCs among these are classified as *large and complex* when combined with their branch operations and are supervised under the Federal Reserve's Large Institution Supervision Coordinating Committee (LISCC) along with the eight G-SIBs. The rest of the holding companies among the 34 are domestically owned large entities, termed "Non-Global Systemically Important Banks" (Non-GSIBs) for the purposes of this note.

17. Assets of the largest BHCs in the stress testing sample have increased by 23 percent since the 2015 U.S. FSAP. While the total contribution of the banking sector towards credit provision to corporate and household sectors is falling in relative terms, the largest contributing factor for the growth in their assets (10 percent) is net loans and leases. Net loans and leases are also the largest component of banks' balance sheets (40 percent of total assets). Growth in trading assets and remaining non-tradeable securities portfolios was more modest. Highly liquid federal funds assets and reverse repos, account nearly 12 percent of total assets. The search for yield contributed for the decline in the share of cash and balances with the central banks, which accounted for 12 percent of the balance sheet during the previous FSAP, but now accounts for only 8 percent.[10]

18. Loans outstanding have increased steadily by 26 percent since the last FSAP, owing to the robust growth in commercial and industrial (C&I) and commercial real estate (CRE) categories. Real estate loans remain the largest component in banks' loan book at 35 percent of total loans, contributing 5 percent towards the total loan growth. The second largest loan component, C&I, accounts for 24 percent of total loans, contributing 8 percent to the overall loan growth. While the underwriting standards for loans in this category has slightly tightened in 2019, growth in some C&I loan subcategories such as leverage loans experienced decline in covenants. Credit card-related loans, which have the highest loss rate, account for 11 percent of the total loan

[9] These 34 institutions broadly align with, but do not exactly match, the set of domestic bank holding companies and intermediate holding companies listed in the October 2019 FRB-OCC-FDIC final rule on tailoring: https://www.federalreserve.gov/aboutthefed/boardmeetings/files/tailoring-rule-visual-20191010.pdf. See also Appendix V, Table V.1., for a listing of the 34 banks included in this FSAP's stress testing analysis.

[10] See Appendix Figures IV.4–IV.7 for banking sector performance.

portfolio. Automobile loans and other consumer loan categories account for 10 percent of the loan portfolio.

19. Banks' funding to a large extent remains domestic and the share of stable funding increased. Liabilities of the largest banks increased, mostly due to the growth in domestic deposits which account for 52 percent of the total liabilities. Growth in deposits have allowed to keep unsecured wholesale funding growth (captured through other borrowed funds) contained. Other borrowed funds still account for 15 percent of total assets. Federal funds and repos also account for nearly 9 percent of the total liabilities and have contributed nearly 3 percent to the growth in total liabilities.

20. Banks maintained robust levels of capital, with the CET1 ratio doubling compared to pre-GFC levels and reaching 12 percent at the aggregate level as of 2019Q3. The increase in CET1 is mostly attributed to the steady growth in retained earnings, amidst higher risk weighted asset levels banks are required to maintain. Significant disparities in CET1 ratios, however, exist among banks, where most IHCs record significantly higher CET1 ratios compared to domestic banks in the sample. The leverage ratio (i.e., Tier1 capital-to-assets) also increased significantly since the pre-crisis levels, reaching about 8.7 percent as of 2019:Q3.

21. Off-balance sheet exposures relative to the size of the balance sheet have declined by a factor of about three since 2009 mainly due to lower derivatives positions, but credit line commitments remained stable as of 2019 (Appendix VII). Total gross off-balance sheet activities accounted for about 110 percent of total assets in 2019. Both, credit derivatives purchased and sold have significantly declined since the crisis from over 100 percent to low double-digit levels.[11] Unused credit line commitments relative to balance sheet size remain above 40 percent and are the largest off-balance sheet exposure category (see Appendix VII Figure 4)[12]. Increase in credit line utilization by corporates and households is expected during economic downturns, hence banks need to have adequate liquid assets to be able to meet those financing commitments without imposing liquidity shocks to the real sector. For instance, based on 8-k filings, credit line utilization between March-mid April 2020 had surpassed $200 billion.

22. Asset quality of the bank holding companies has improved significantly since the GFC, while underwriting standards for most loan categories show a slight tightening in 2019. Non-

[11] The decline was to a large extent driven by migration of derivatives to Central Clearing Counterparties (CCP), which allowed banks to net exposure against CCP.

[12] Rest of the off-balance sheet exposures include credit derivatives purchased (16 percent at of 2019:Q3), credit derivatives sold (14 percent), spot foreign exchange contracts (12 percent), securities lent (9 percent), securities borrowed (7 percent), and letters of credit and guarantees (4 percent).

performing loans (NPLs) of the 35 largest BHCs have substantially declined reaching the lowest levels seen. The NPLs-to-gross loan ratio for delinquencies longer than 90 days fell below 1 percent in 2019. Past due loans of 30 to 89 days also depict similar trends. Moreover, BHCs maintain ample reserves against NPLs, with the reserve-coverage-ratio (i.e., allowances for reserves over the stock of NPLs) steadily increasing in recent years. NPL ratios by loan category reveal relatively higher NPL ratios related to residential real estate loans, albeit the asset quality of this category has significantly improved since the crisis. On the contrary, NPLs on consumer loans show a slight uptick in recent years, calling for continued vigilance in maintaining asset quality.

23. Large banks continue to maintain sound profitability levels, including when compared internationally, owing to favorable macroeconomic conditions. Banks have maintained robust levels of interest income amidst the low interest rate environment and have maintained healthy levels of non-interest income. While non-interest expenses have risen since the crisis, provisions have declined since then. A major contributing factor for the latter is the significantly lower levels of net charge-off levels incurred by the largest banks. Moreover, a sharp rise in profitability was recorded starting 2018 due to the reduction in the corporate tax rate in late 2017, by increasing the return on equity (ROE) of these large banks by about 4 percentage points on average. However, significant dispersion in profitability across banks exists, with foreign banks on average recording lower profitability ratios. Overall, sound profitability conditions have enabled the U.S. banks to maintain regulatory capital levels that are twice as high as the pre-GFC levels.

Mutual and Money Market Funds Sector

24. Fixed income and mixed funds play a significant role in credit intermediation and liquidity transformation. Funds invest in a range of asset classes, including corporate bonds and leveraged loans, thereby providing financing to the real economy. Mutual funds hold more than 15 percent of all U.S. corporate bonds outstanding and about 10 percent of leveraged loans. At the same time, mutual funds play a key role in liquidity transformation by offering daily liquidity to investors.

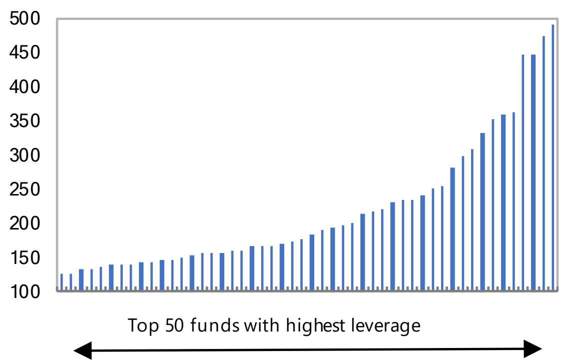
25. Some mutual funds can be exposed to a liquidity mismatch. While the liquidity of funds' holdings vary, all mutual funds offer daily redemptions to investors. Funds that are significantly invested in potentially less liquid securities, have not effectively managed their liquidity risk and are faced with significant investor redemption demands could be forced to sell assets to meet redemptions. If significant in the aggregate, these sales could contribute to declines in asset prices. For funds using derivatives, liquidity demands can also arise from mark-to-market losses on derivatives exposures, resulting in variation margins. In that context, mutual funds are subject to regulatory requirements related to liquidity risk as well as limits on the use of leverage. Requirements include the need by funds to establish a written liquidity risk management program reasonably designed to assess, manage, and periodically review the fund's liquidity risk, including under reasonably foreseeable stressed conditions, and generally, to maintain a minimum amount of highly liquid assets; and to limit purchases of illiquid assets to 15 percent of the fund's net assets.

26. While most funds make limited use of leverage, some funds have large exposures through the use of derivatives. Under current rules, mutual funds are only allowed to borrow from banks up to 50 percent of their net asset value, resulting in a maximum balance sheet leverage of 1.5x. However, mutual funds can use derivatives for hedging and also to get exposures to underlying markets, which can result in an increase in synthetic leverage (due to the use of derivatives). According to the SEC (2019), about 60 percent of mutual funds do not use derivatives and 20 percent of mutual funds have adjusted notional amounts above 10 percent of NAV. However, some funds rely heavily on the use of derivatives, which could allow the build-up of a high level of synthetic leverage. The SEC reports that about 14 percent of mutual funds have gross exposures above 50 percent of their NAV. Based on commercial data on fixed income and FX derivatives only, some mutual funds report gross leverage more than four times the NAV (Figure 3).

Figure 3. United States: Mutual Funds' Leverage and Insurers' Asset Allocation

Some funds have large exposures through the use of derivatives

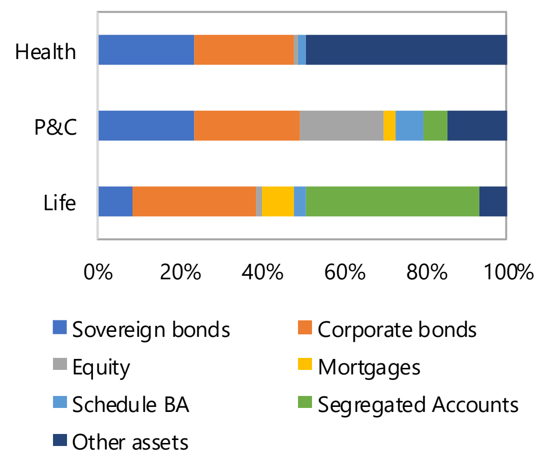
Gross Exposures in Percent of NAV of Selected Funds



Note: Gross leverage(sum of long and short exposures) of selected funds. Data indude only fforeign exchange and fixed income derivatives.
Sources: Morningstar, IMF staff.

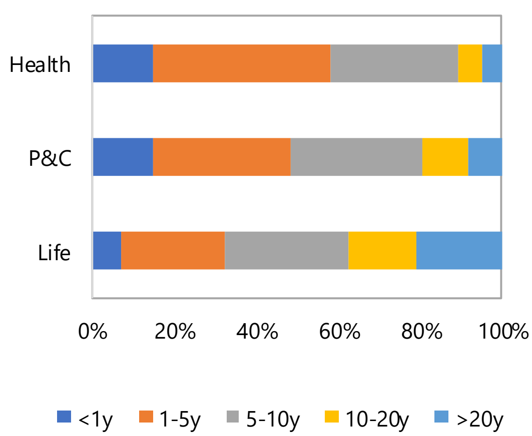
42 percent of life insurance sector assets are held in segregated accounts; in the general account, corporate bonds dominate.

Asset Allocation



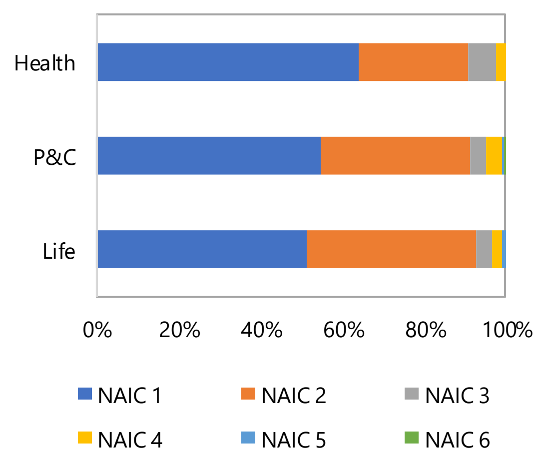
Bond maturities are longest in life insurance, as can be expected, with 38 percent of bonds having a maturity of 10 years or more.

Bonds: Maturities



More than 90 percent of corporate bonds in each sector have an investment grade rating (NAIC 1 and 2).

Corporate Bonds: Rating Breakdown



Notes: Stress test sample only. Sovereign bonds include sub-sovereigns and government-sponsored entities.
Source: IMF staff calculations based on NAIC data.

Insurance Sector

27. The U.S. life and health insurance sector is exposed to significant interest rate risks, and has furthermore expanded into less liquid assets. U.S. life insurers actively underwrite long-term annuity products with liability durations exceeding asset durations. The risk-based capital framework includes (mostly factor-based) capital charges associated with asset-liability mismatches. Still, the recent less restrictive stance of the U.S. monetary policy could have a negative impact on life and health insurers with large duration gaps. If long-term interest rates stay low for long, the accounting and solvency positions of life and health insurers would deteriorate gradually but significantly over time.

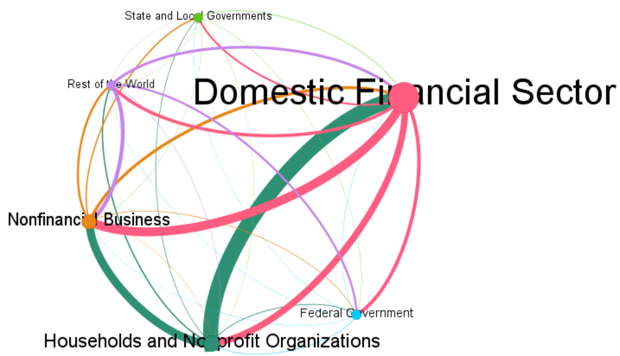
28. Market risks in life insurance are to a large extent shifted to policyholders in segregated accounts and are rather diversified in the general account (Figure 3, panels 2–4). Segregated accounts represent 42 percent of the life sector's balance sheet. The remainder (general account) comprises corporate and sovereign bonds with 30 percent and 9 percent, respectively. Equity investments play a minor role in the general account, while corporate bonds are the dominant asset class. Most insurers' investments are still liquid, but life insurers are taking on more liquidity risks by allocating 8 percent of total assets to mortgages and being important buyers of CLOs. The asset allocation of the non-life sector appears to be more biased towards equity exposures, however this is mainly driven by very few large outliers. Health insurance is mostly a cash-flow business, so investments are typically very liquid and less risky.

The Interconnectedness Landscape

29. The resilience of the financial system depends on the financial health of individual institutions and the interplay of vulnerabilities through direct and indirect exposures within and between segments of the financial system. These exposures can result in amplification or, mitigation of shock transmission. Understanding contagion risks and channels is thus key to the assessment of systemic risk. In addition to the direct interconnectedness between the financial sector agents such as banks, insurance, pension funds, money market and mutual funds, sectors are indirectly interconnected through exposures to common asset classes, such as corporate bonds, equities, agency and treasury securities markets. The exposures to the common asset classes amplify the risk transmission when vulnerabilities arise in one financial subsector through significant marked-to-market losses.

30. The U.S. financial sector is highly connected with the real economy, where credit provisioning remains well diversified. Relatively large share of financial assets of the domestic financial sector is held by household and corporate sectors, while the largest asset share is held within the financial sector (Figure 4, panel 1). The largest proportion of the financial assets of households is also held by the financial sector followed by the corporate sector. In fact, households' financial assets issued by the financial sector is the largest linkage between any two sectors (see Figure 4 heatmap). Moreover, within the financial sector, non-banks also have large exposures to households. For instance, about two-thirds of the residential real estate loans are held by the non-bank entities (Figure 4, panel 3). Among the 25 largest mortgage originators and servicers, non-banks currently originate 51 percent of mortgages and service 47 percent (FSOC annual report, 2019). The non-bank financial sector also plays a pivotal role in corporate sector financing, thus maintaining larger exposure levels vis-à-vis the domestic corporate sector (Figure 4, panel 3).

Figure 4. United States: Macrofinancial Linkages



Heatmap: Cross-Sectoral Exposures

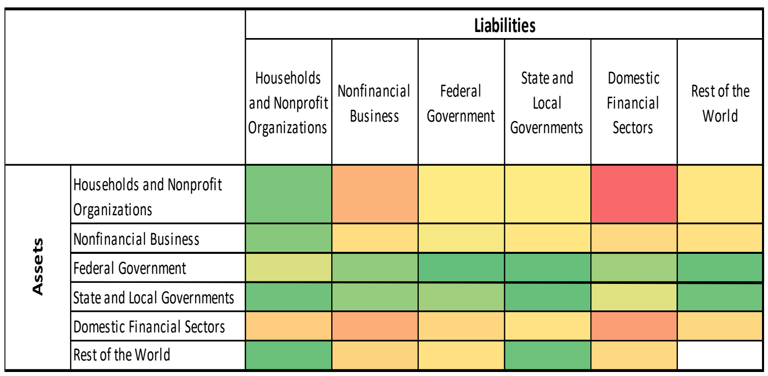


Illustration of Cross-Sectoral Exposures

(In trillions of US dollars)

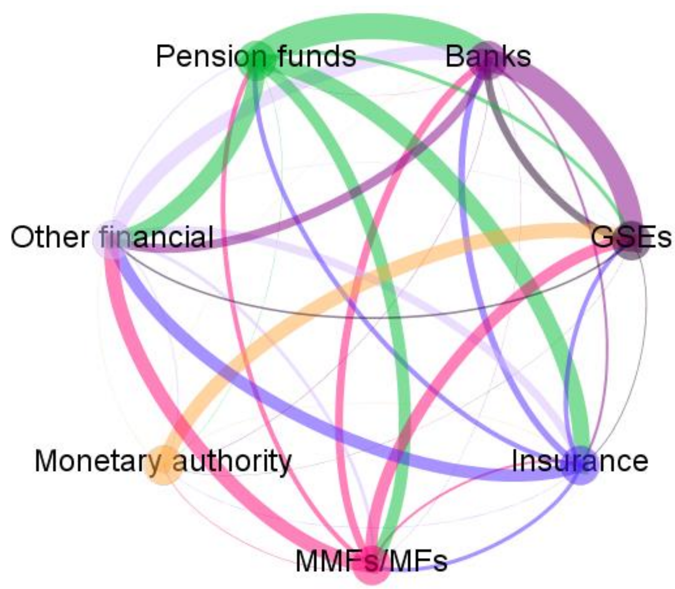
		Banks	Non-bank Financial Sector
Households	Mortgages	3.2	7.6
	Consumer Credit	2.2	0.6
Businesses	Bonds	0.7	5.9
	Other Loans	2.1	2.8
	CRE and Other Mortgages	2.4	2.1

Sources: FRB, Flow of funds.

Note: Data as of 2018:Q4 except for panel 3 with the illustration (as of 2019:Q3). Panel 1: Node size in reflects the intra-sectoral flow of funds. Edge color in the network map denotes the assets of the sector with the same colored node vis-à-vis the other sector (i.e., liabilities of the other sector). Edge width illustrates the relative size of the linkages between two sectors. Panel 2: Colors in the heatmap are based on the size of the linkages, where red denotes largest linkages and darker shades of green denoting smallest linkages.

31. Financial subsectors are interconnected through their cross-exposures to numerous financial instruments (Figures 5, 6). The insurance sector held nearly 26 percent of corporate bond, while mutual funds held nearly 17 percent of corporate bonds (Figure 6) as of year-end 2018. In addition, mutual funds and pension funds had over 60 percent and 20 percent of assets invested in equities respectively. Agencies and U.S. Treasury securities combined consist of half of the assets of money market funds balance sheet. From a direct intra-sectoral exposure standpoint, insurance sector has exposure to mutual funds, while mutual funds have exposure to banks through providing short-term funding. Such cross-exposures may amplify the transmission of spillovers through asset fire sales.

Figure 5. United States: Intra-Financial Sector Linkages

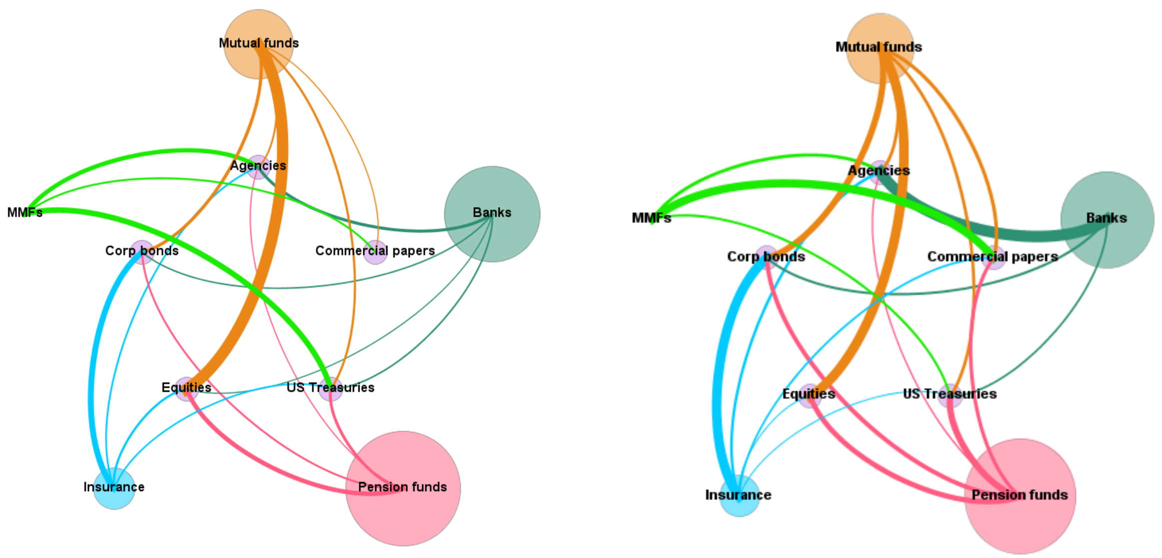


Sources: FRB, Flow of funds.

Note: Data as of 2018:Q4. Node size reflects the intra-sectoral flow of funds. Edge color denotes the assets of the sector with the same colored node vis-à-vis the other sector (i.e., liabilities of the other sector). Edge width illustrates the relative size of the linkages between two sectors.

Figure 6. United States: Intra-Financial Sector Linkages through Common Exposures

Asset Exposure | **Market Exposure**



Sources: FRB, Flow of funds.
Note: Data as of 2018:Q4. Outer nodes represent sectors, while inner nodes represent asset classes in which the sectoral assets are invested in. The size of the outer nodes reflects the balance sheet size of each sector. Edge color denotes the assets of the sector with the same colored node invested in the respective asset classes. In panel 1, the edge width is proportional to each sector's exposure vis-à-vis the asset class relative to sectoral balance sheet size; in panel 2, the edge width is proportional to each sector's investment in the asset class relative to total investment of the particular asset class.

U.S. Banks Links to Domestic Financial Institutions

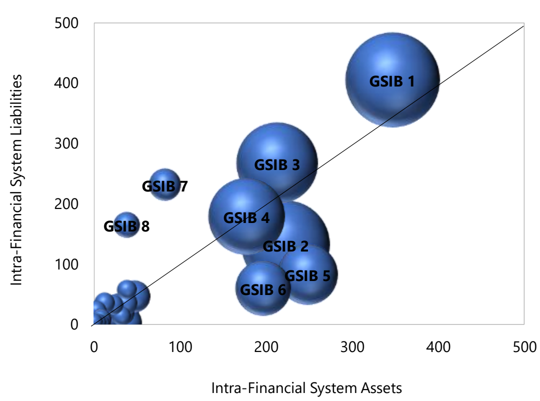
32. **While the role of banks in providing long-term credit to corporates and households has diminished over time, banks still maintain a key role in distributing liquidity in the U.S. financial system.** They offer payment services and liquidity support, other credit lines, hedging services to other banks, non-bank financial institutions. These on and off-balance sheet exposures could propagate shocks during stress times.

33. **As expected, the G-SIBs are the key players in domestic financial system.** Banks' domestic interconnectedness indicators reveal strong intra-financial system exposures, reflecting the distribution of capital and liquidity within the system. From a systemic standpoint, G-SIBs maintain the largest assets and liabilities positions against the financial system (Figure 7, panel 1). Some of these banks provide specialized custodial, secured lending, settlement services, thus relate to virtually every other financial institution in the system.

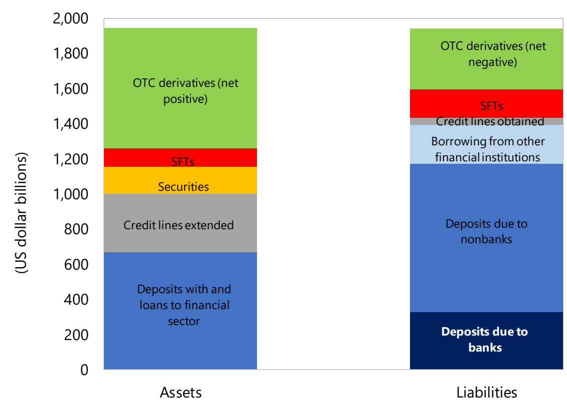
34. Banks have sizable amounts of over-the-counter (OTC) derivatives and unused credit lines that are extended within the domestic financial system. Composition of assets and liabilities reveal significant linkages within the domestic financial system through deposits and OTC derivatives positions (Figure 7, panel 2). About one-half of the liabilities position comes from non-

Figure 7. United States: Banks' Domestic Intra-Financial System Interconnectedness

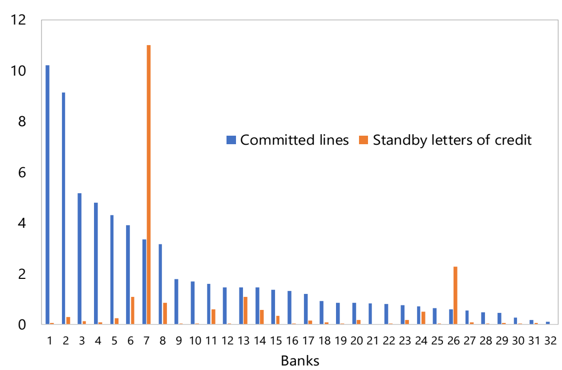
Banks' Exposures vis-à-vis the Domestic Financial System
(In billions of U.S. dollars)



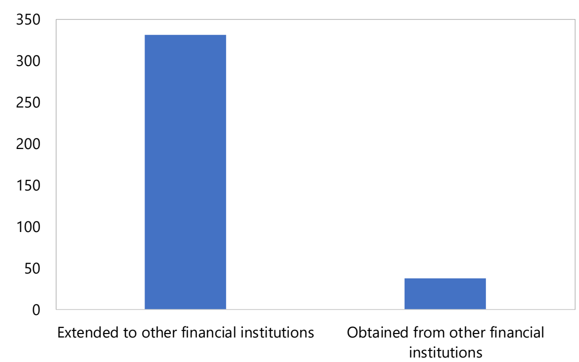
Composition of Intra-financial System Assets and Liabilities of 35 BHCs



Unused Portion of Committed Lines and Standby LCs Extended to Other Financial Institutions
(In percent of bank's exposure)



Banks' Total Unused Position of Credit Lines vis-a-vis the Financial System
(In billions of U.S. dollars)



Source: FRB, FR Y-15, and IMF staff calculations.
Note: Data as of 2019Q3. The size of the bubbles in panel 1 is based on the total exposure; total exposure includes on-balance sheet exposures, derivatives and repo-style transactions exposures, and other off-balance sheet exposures. Bank names are anonymized.

bank deposits, while OTC derivatives suggest large positions are held against non-banks.[13] Banks also have sizable amounts of unused credit lines in the network. On aggregate, about 15 percent of the total intra-financial exposures consists of unused credit lines. It is also evident that some banks have unused credit line commitments that are sizable even when measured against their total exposures (Figure 7, panel 3). While banks maintain such sizable unused credit line commitments vis-à-vis the financial system, the amount of unused credit lines obtained from the financial system is only about one-tenth of the amount extended. This suggests that the extended credit lines are mostly against the non-bank financial sector (Figure 7, panel 4). A rapid draw-down in such off-balance sheet commitments during stress episodes increase the potential for contagion.

Cross-Border Interconnectedness of the U.S. Banking Sector[14]

35. Nearly a quarter of the U.S. banking system's consolidated claims are held against foreign borrowers. Consolidated claims based on residency of the ultimate borrowers show some pockets of concentrated exposures. Claims against borrowers in the United Kingdom and Japan stand out with each accounting for about 3 percent of total assets or 35 percent of Tier1 capital of the U.S. banking system, while claims on Germany, France, and Canada are also above 1 percent of the U.S. banks' assets[15] (Figure 8, panel 1). Foreign claims of the eight U.S. G-SIBs depict similar trends at aggregate level, with the United Kingdom and Japan accounting for about 4 percent of assets or nearly 50 percent of Tier1 capital of the eight G-SIBs as of 2019:Q3; claims on borrowers in Germany, France, and Canada also account for 1–3 percent of the eight G-SIBs' assets. From a sectoral standpoint, U.S. banks' claims vis-à-vis foreign non-bank financial sectors is the highest cross-border sectoral exposure category. Exposure to foreign non-bank financial sectors is at 8 percent of the U.S. banks' assets. Exposure to foreign banking systems amount to 4 percent of the U.S. banks' assets at aggregate level (Figure 8, panel 2). Among the exposures on foreign banking systems, the U.K. and Japanese banking systems are the largest counterparty banking systems.[16]

[13] Imbalance in derivatives net positive and net negative positions shows the portion of OTC derivatives position held outside the entities in the sample.

[14] Data used in this descriptive analysis does not allow us to distinguish between secured and unsecured exposures as well as understand what type of collateral is used for secured exposures. Therefore, the analysis is based on very conservative assumptions that all of the exposures are unsecured.

[15] The U.S. banks have sizable claims vis-à-vis the Cayman Islands as well; however, this analysis does not focus on exposures vis-à-vis the Cayman Islands given its status as an offshore center for many other counterparty economies.

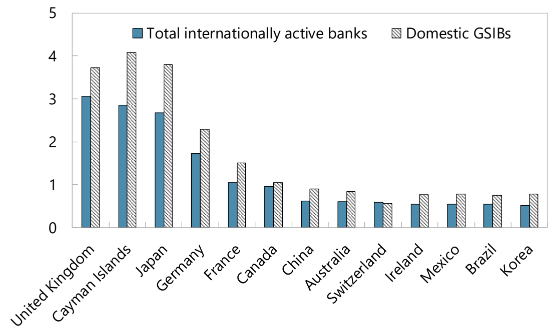
[16] While the presence of concentrated exposures per se may not give rise to contagion risks, the nature of the exposures would determine the potential vulnerabilities. For instance, contagion risks could arise if the repayment capacities of borrowers of unsecured claims (or those that are pledged with low-quality collateral) are severely hindered in stress episodes.

36. U.S. banks are also interconnected with the rest of the world through cross-border off-balance sheet exposures. Derivatives make up the largest share of cross-border off-balance sheet exposures, though unused commitments vis-à-vis foreign borrowers are also sizable. The latter, amounting to 5 percent of the U.S. banking system assets, may particularly increase the potential for vulnerabilities if borrowers rapidly draw down on unused credit lines during tight financial conditions. From a counterparty point of view, the largest off-balance sheet exposures are vis-à-vis the borrowers in the U.K., France, Germany, and Japan with exposures amounting to 5, 4, 3, and 2 percent of the U.S. banking system assets, respectively.

37. Bank-level exposures identify several entities with large cross-exposures (i.e., presence of large cross-border claims and domestic intra-financial system liabilities). In particular, some G-SIBs have large liabilities to the domestic financial system, while also maintaining large cross-border claims (Figure 8, panel 3). To a lesser intensity, some non-G-SIBs including intermediate holding companies (IHCs) also have relatively sizable cross-exposures (Figure 8, panel 4). These tendencies may warrant continued vigilance given the potential for cross-border spillovers to propagate into the domestic financial system through these entities' liabilities vis-a-vis the domestic financial system (e.g., due to deleveraging and asset fire sales). Bank-level exposures further reveal that banks' exposure vis-à-vis foreign banking systems are mostly concentrated in banking systems in the U.K., Japan, Germany, and Canada (Figure 8, panel 5). Moreover, a large proportion of IHC' claims are concentrated in their parent banking systems.

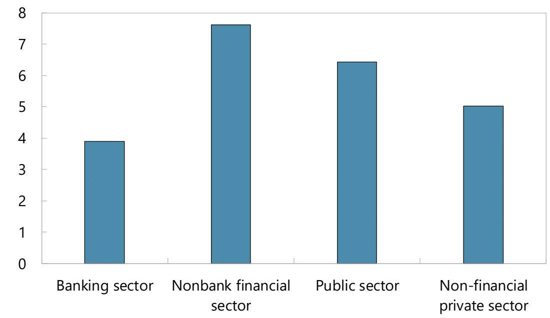
Figure 8. United States: Banks' Claims Based of the Ultimate Risk of the Borrowers

Cross-Border Claims of U.S. Banks
(In percent of U.S. banks' assets; ultimate borrower risk basis)



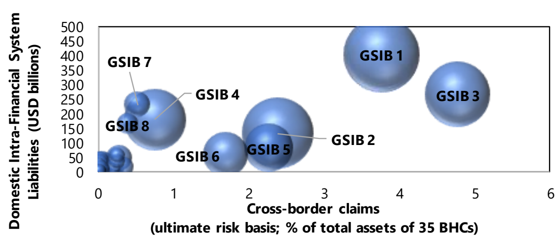
Source: Data as of 2019Q3. FFIEC E. 16 Country Exposure Lending Survey and Country Exposure Information Report.

Cross-Border Claims of U.S. Banks on Foreign Borrower Sectors
(In percent of U.S. banks' total assets; ultimate borrower risk basis)



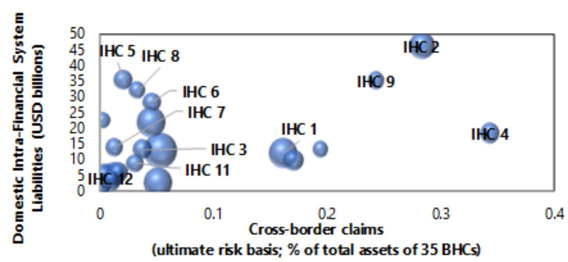
Source: Data as of 2019Q3. FFIEC E. 16 Country Exposure Lending Survey and Country Exposure Information Report.

Cross-Border Claims on Ultimate Risk Basis vs. Liabilities against Domestic Intra-Financial System: 2019Q3



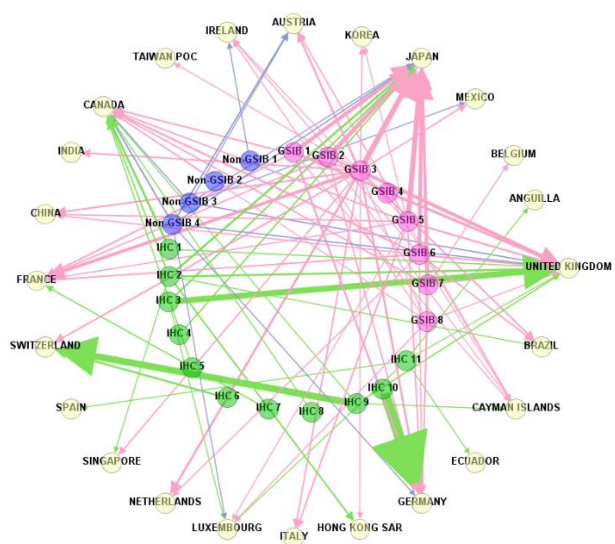
Source: FRB report FR Y15
Note: Data as of 2019Q3. Bubble size = total exposure of the entity.

Cross-Border Claims of Non-GSIBs vs. Liabilities against Domestic Intra-Financial System: 2019Q3



Source: FRB report FR Y15
Note: Data as of 2019Q3. Bubble size = total exposure of the entity.

Banks' Cross-Border Claims vis-à-vis Foreign Banking Systems on Ultimate Risk Basis



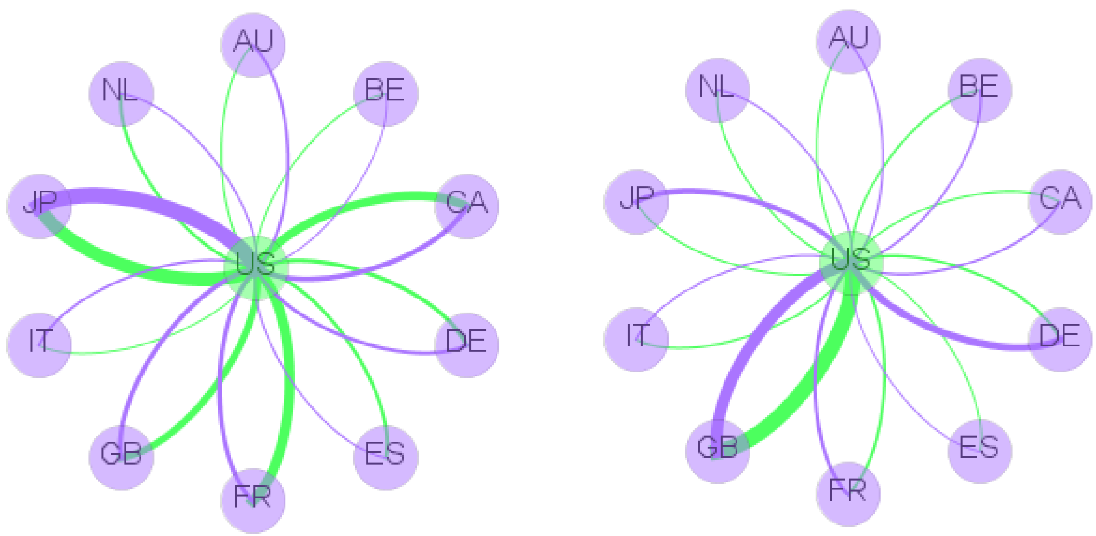
Source: FFIEC 009a.
Note: Data as of 2019Q3. Edge width = proportion of BHC's claims vis-à-vis the foreign banking systems.

38. **Cross-border funding exposures at banking system-level reveal several important counterparties from the funding-side**. Among the U.S. banking system's consolidated liabilities to the top 10 counterparty banking systems, funding coming from the Japanese banking system is notably larger than the rest of the counterparties, followed by Canada (see purple arrows in Figure 9, panel 1). Further analyses using unconsolidated nationality-based exposures[17] reveal large liabilities to the U.K. banking system, and to the German banking system to a lesser extent (see purple arrows in Figure 9, panel 2). These could be particularly relevant to these banking systems' deposits held for FX transactions (e.g., U.S. dollar funding activities) and settlement purposes.

Figure 9. United States: Banks' Claims

U.S. Banking Systems' Largest Cross-Border Claims and Liabilities vis-à-vis Foreign Banking Systems on Consolidated Basis

U.S. Banking Systems' Largest Cross-Border Claims and Liabilities vis-à-vis Foreign Banking Systems on Unconsolidated Basis



Sources: BIS consolidated claims on ultimate risk basis (panel 1); BIS unconsolidated claims and liabilities on nationality basis (panel 2).
Note: Data as of 2019Q2. Edge width = proportion of claims vis-à-vis the recipient banking system. Edge color = direction of claims; green arrows are the claims of the U.S. banking system on top 10 foreign banking systems, while purple edges are the claims of foreign banking system on the U.S. banking system (i.e., funding coming into the U.S. banking system).

[17] Consolidated balance sheet data however may understate spillovers in the presence of heavy financial intermediation such as in the case of financial centers. To circumvent this, unconsolidated level balance sheet exposures are also explored using BIS locational nationality and residency basis datasets.

B. Resilience and Vulnerabilities of Borrowers

Household Sector Indebtedness and Resilience

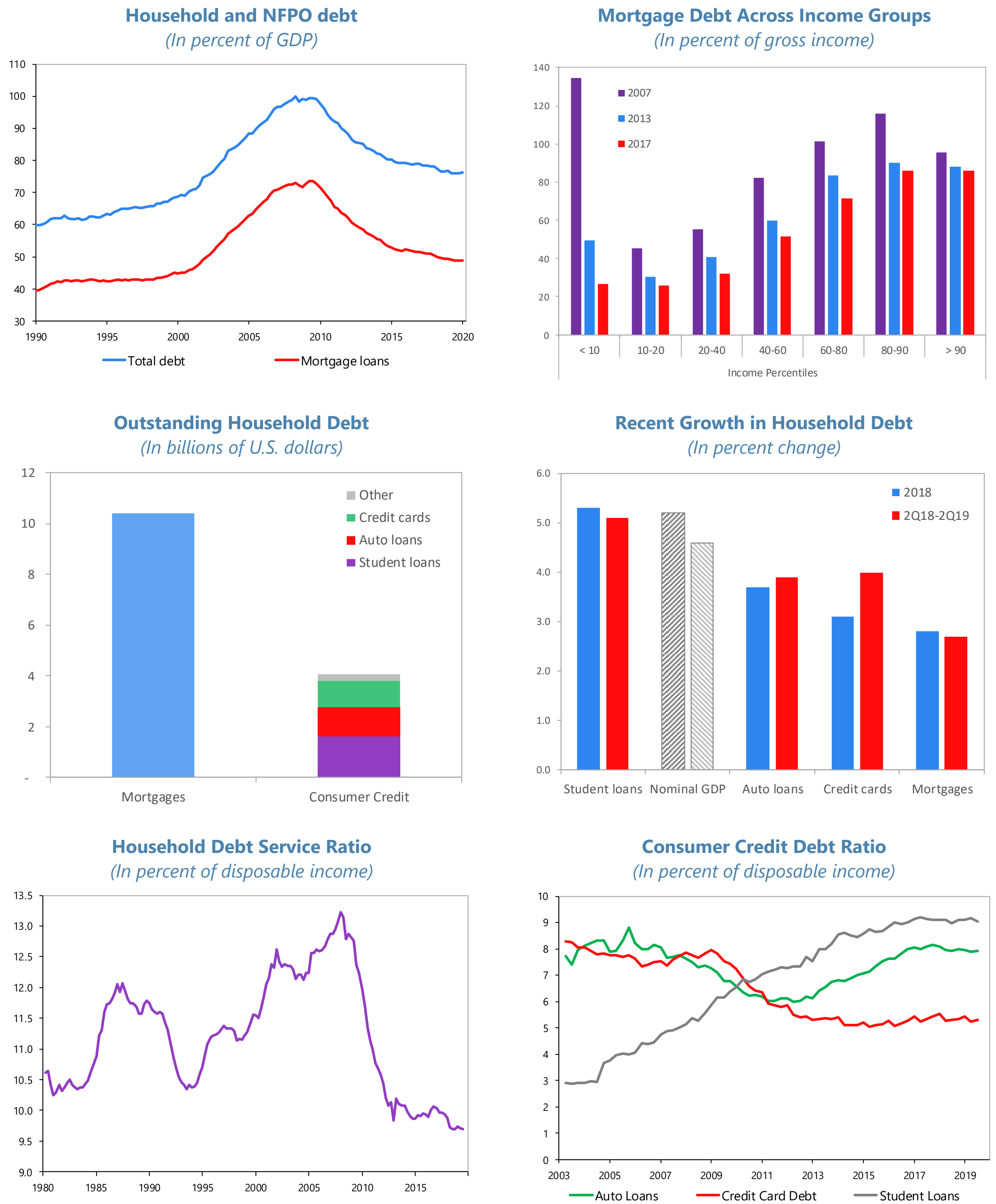
39. Households have continued to reduce their overall indebtedness over the past decade, driven by a large fall in housing-related leverage. Residential mortgage debt has decreased substantially since the Global Financial Crisis (GFC) across all income groups, mortgage loan performance has been robust (with low delinquency rates, particularly for newly originated mortgages), and debt servicing costs have been falling and maturities extended as households refinanced their mortgages benefiting from low interest rates (Figure 10). That said, the mortgage market is large, with outstanding mortgages exceeding US$10 trillion (roughly 50 percent of GDP, or two-thirds of total household debt), and a deterioration in credit quality could adversely impact financial stability.

40. Certain segments of consumer credit are rising rapidly. Although still relatively small, student loans and some segments of consumer credit debt (auto loans) are on the rise—albeit a large part of that growth accrues to households with prime credit scores. Given that most student loans are issued under government programs, the risks to the financial institutions remain limited. That said, delinquencies on student loans remain high, underscoring pre-existing debt repayment pressures among certain households, most notably younger cohorts. The relatively small share of subprime debt in overall consumer debt is a relatively positive development. However, rising vulnerabilities in these sub-segments of household credit would still call for close monitoring, to ensure that these do not reach systemic proportions.

41. Vulnerabilities in specific segments combined with adverse effects from the COVID-19 outbreak could put pressure on household debt-servicing capacity. Notwithstanding the abovementioned vulnerabilities, households entered the current crisis with lower indebtedness levels than at the onset of the global financial crisis. House price deviations from fundamentals were significantly smaller too, as evidenced by lower house price-to-income and house price-to-rent ratios. However, the COVID-19 outbreak and related-containment measures are expected to have a significant impact on employment and income. In particular, if economic strains owing to long-lasting hysteresis effects and behavioral changes related to social-distancing norms leads to subdued demand, with significant output and employment losses in hard-hit sectors (e.g., entertainment, hospitality, transportation services)—which tend to have relatively low wages—could severely impact households ability to service their debt, particularly at the lower end of the income distribution.[18]

[18] High-end service sectors, such as financial, legal, IT, and other professional & business services have experienced relatively small losses following the COVID-19 outbreak, in terms of both output and employment.

Figure 10. United States: Household Borrowing



Sources: FRBNY Consumer Credit Panel/Equifax; Haver Analytics; Bureau of Economic Analysis; PSID; and IMF staff estimates.
Notes: NFPO = Not-For-Profit Organizations.

42. The government continues to play a central role in the U.S. housing market. The Government-Sponsored Enterprises (GSEs)—most notably, Freddie Mac and Fannie Mae—currently own or guarantee about half of all mortgages. In the early 1980s, the GSEs owned or guaranteed about 8 percent of outstanding single-family mortgage debt. That share grew to 25 percent by the end of that decade and to 44 percent in the early 2000s, close to where it currently stands. Likewise, the share of outstanding multifamily debt owned or guaranteed by the GSEs grew from 25 percent at the onset of the global financial crisis to about 40 percent currently. Moreover, the GSEs—together with Ginnie Mae—dominate the MBS market, with outstanding MBS guaranteed by these entities of more than US$8 trillion, representing about 85 percent of that market.[19] Moreover, the market for MBS guaranteed by these entities is one of the most liquid fixed income markets worldwide, with average daily trade volumes exceeding US$200 billion. Given the size of the market, any reform to the housing finance market, could have significant financial depth and stability implications.

43. Non-bank lenders are important players in the mortgage loan market. The share of mortgages originated by non-depository mortgage companies has increased in recent years. Non-bank mortgage lenders' business model has also become more complex, with their range of activities including origination, loan servicing, as well as securitization of MBS. Their operations rely heavily on short-term credit lines for mortgage origination, which are subject to liquidity risks in periods of stress. In addition to the risks posed by their capital structure—with limited buffers to absorb adverse shocks—loan defaults pose additional liquidity risks, as servicers are usually required to comply with tax and insurance payments related to delinquent borrowers and, at times, make mortgage payments to MBS investors ("servicing advances") even when a borrower does not make a payment. Given their growing share of the market and complex interlinkages with the broader financial system, non-bank mortgage lenders could be a source of risk (see Box 2 of the 2020 FSAP FSSA).

[19] The GSEs and Ginnie Mae guarantee the timely principal and interest payment of these MBS, and benefit from an implicit—explicit in the case of Ginnie Mae—government guarantee.

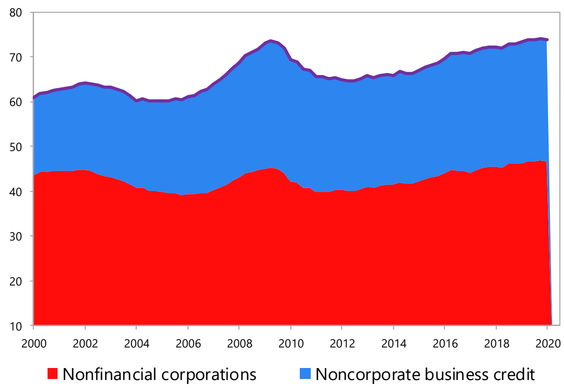
Corporate Sector Indebtedness and Resilience

44. Nonfinancial corporate sector debt in the U.S. is at a historic peak. Debt of nonfinancial corporates (NFCs) in the United States—at 47 percent of GDP—has surpassed the 2009 peak of 44 percent (Figure 11). Total debt of the business sector, i.e., including noncorporate firms, mirrored the same pattern, rising from 65 percent of GDP in 2012 to almost 75 percent of GDP. Its current level is comparable to household and financial sector leverage. The largest share (about two-thirds) of nonfinancial corporate debt is in the form of corporate bonds and commercial paper, amounting to about US$6.5 trillion. The remaining is comprised of bank loans (C&I loans) and leveraged loans, among others. In addition, the amount of outstanding commercial real estate (CRE) loans exceeds US$2 trillion, but has been growing in line with the economy in recent times.

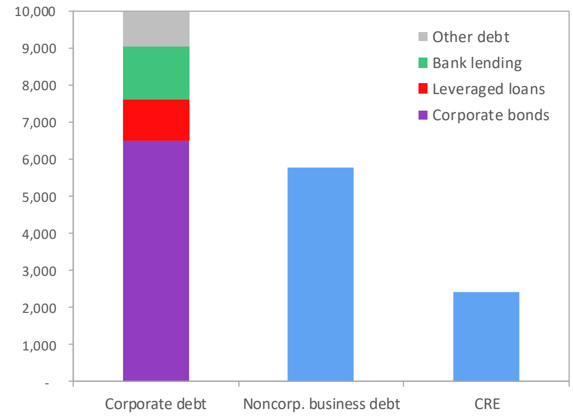
45. The recent deterioration in corporate earnings caused the debt-to-earnings and the interest coverage ratios to creep up. The ratio of corporate debt to earnings before interest and taxes (EBIT) improved in the years following the GFC but has recently shot up to about six (Figure 11). Similarly, the interest coverage ratio—ratio of EBIT to net interest expense—has weakened. In 2013–14, EBIT covered nearly seven times annual interest expense. That ratio stands at around five today, comparable to levels seen during the global financial crisis.

Figure 11. United States: Business Sector Borrowing

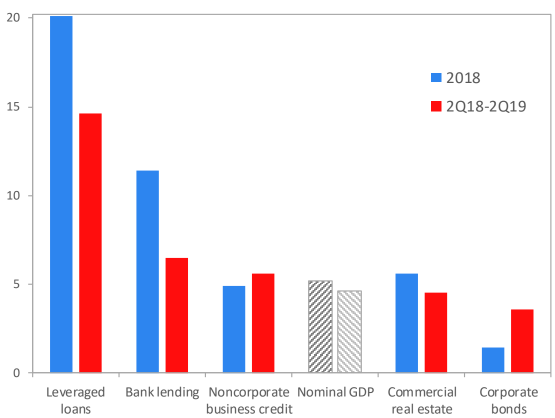
Business Sector debt
(In percent of GDP)



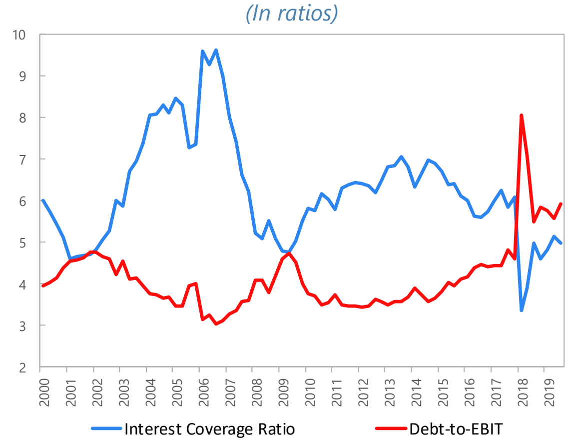
Outstanding Business Sector Debt
(In billions of U.S. dollars)



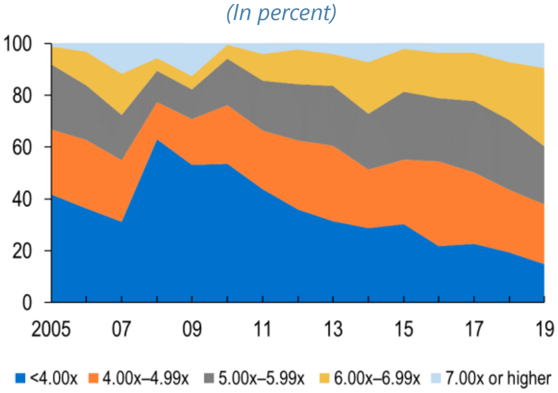
Recent Growth in Business Sector Debt
(In percent change)



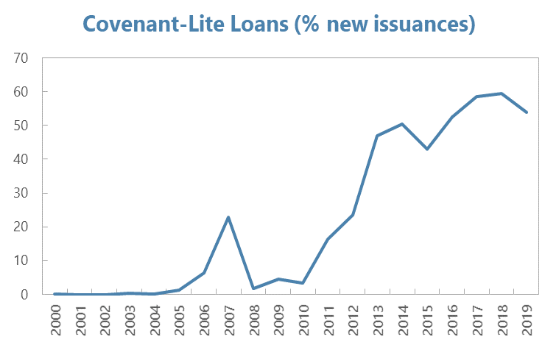
Debt Servicing Capacity Measures
(In ratios)



Leveraged-loan Issuance by Debt-to-EBITDA
(In percent)



Share of Covenant-Lite Loans
(In percent of new issuances)



Sources: FRB; Haver Analytics; PSID; and IMF staff estimates.
Notes: CRE = Commercial Real Estate; EBIT[DA] = Earnings Before Interest and Tax [Depreciation and Amortization].

C. Leveraged Finance: Leveraged Loans and CLOs

46. The recent flurry of borrowing by highly-leveraged corporates—the so-called "leveraged loans"—has emerged as a potential vulnerability. Both the historically high corporate borrowing and the concentrated increase in debt among the riskiest firms were highlighted as important vulnerabilities in the Federal Reserve's November 2019 Financial Stability Report and the IMF's recent Global Financial Stability Reports. The low interest rate environment has created an opportunity for highly leveraged corporates to obtain funding as investors accept greater risks in search of higher returns. The United States, which accounts for over 80 percent of global issuances, saw peak annual issuance of leveraged loans in 2017 at US$650 billion. Issuance volume has since come down, with US$491 billion issued in 2019. Institutional loans, i.e., those made by non-bank institutional investors, make up the bulk of primary market issuances. Corporates typically use leveraged loans for mergers and acquisitions (M&A), refinancing, leveraged buyouts, and recapitalization. The sectors that account for the highest shares of leveraged loan issuances are computers & electronics, followed by healthcare and services & leasing.

47. While leveraged loans remain a small share of corporate borrowing, its nature and rapid growth have drawn comparisons with the subprime mortgage market. Outstanding leveraged loans, currently estimated at US$1.1 trillion (about 5 percent of GDP), constitute a small share of the US$15.8 trillion total debt owed by the nonfinancial business sector (in mid-2019). But, fueled by easy financial conditions and the search for yield, the market has been growing at an average annual growth rate of nearly 15 percent since dipping to US$497 billion in 2010. Some measures of leveraged loan (e.g., that published by the Bank of England) which also include smaller, less liquid loans extended by non-banks as well as loans held by banks put the estimated size of the leveraged loan market at US$2.2 trillion.

48. A steady erosion of credit quality and investor protection was becoming apparent in the leveraged loan market. The underlying vulnerability in this market is likely even greater than suggested by reportedly highly debt-to-EBITDA ratios. In recent years, companies increasingly used "add-backs," which can include ill-defined items such as cost savings or synergies, to artificially boost their EBITDA and therefore lower their leverage ratio. Additionally, the borrower-friendly environment allowed for more leveraged loans to be issued without the traditional investor protections such as financial maintenance requirements that ensure the debt service capabilities of the borrower. These so-called 'covenant-lite' loans have accounted for more than half of new leveraged loan issuances in the U.S. market for the past four years (Figure 11). The concomitant deterioration in credit quality and investor protection would leave leveraged loan investors heavily exposed to a downturn in the corporate sector.

49. Related structured products such as Collateralized Loan Obligations (CLOs) have also fueled the leveraged loan growth. CLOs are special-purpose vehicles set up to invest in pools of leveraged loans. The pools are divided into tranches and sold to CLO investors. Of the US$1.1 trillion in outstanding leveraged loans, CLOs held roughly US$617 billion at end-2018. CLO investors are wide ranging and include, among others, U.S. and foreign banks, insurance companies, mutual funds, and pension funds. While data gaps impede a complete view of this market, estimates show that CLO holdings are concentrated among insurance companies, mutual funds, and banks. At end-2018, insurance companies held 28 percent of the market, mutual funds 15.5 percent, and banks 15 percent.[20]

50. Banks have a complex interconnection with the overall leveraged loan market. Banks are both directly and indirectly exposed to the leveraged loan market. Their direct exposure comes from the portion of the leveraged loans they originate and retain on their balance sheets as well as the revolving credit lines extended to leveraged corporates. Several channels indirectly connect banks to this market. Among these are loans in the form of "warehouse credit lines" to CLO arrangers to purchase leveraged loans.[21] Banks additionally invest in CLOs—albeit largely in higher credit AAA tranches. Lower-rated CLO tranches are mainly held by asset managers, insurers, hedge funds, and structured credit funds, as well as foreign entities, some of whom may have credit lines with banks.

51. A key concern is that the markets for leveraged loans and the associated CLOs, which have grown since the GFC, will experience significant stress during the ongoing macroeconomic downturn. While regulatory and underwriting standards for securitized products like CLOs have been strengthened since the crisis, the markets and their interlinkages are complex. There is uncertainty about how resilient the products will be under prolonged stress. Moreover, CLOs which are held by a wide range of investors could prove to be an important channel for spillovers.

52. The interplay between corporate vulnerabilities and the financial system is complex and can act through direct and indirect channels. Banks' direct exposure to corporate sector remains limited. Exposure to the leveraged loan market is mainly in the form of holdings of AAA-rate CLO tranches, and holdings of corporate bonds and commercial paper are relatively low following the global financial crisis and subsequent regulatory changes (e.g. Dodd-Frank Act). However, banks have important off-balance sheet commitments—mainly credit lines—provided to corporate clients estimated at around US$760 billion by the FSB, and facilities granted to CLO issuers for a smaller amount (around US$28 billion by end-2018 for U.S. banks). Funding liquidity stress, such as that observed at the onset of the COVID-19 outbreak, can trigger large uses of these credit lines by the corporate sector, potentially creating liquidity challenges for banks with lower liquidity buffers. These liquidity challenges could be further amplified by delays in repayment of warehouse facilities to CLO issuers. In addition, corporate stress can translate into added pressures to nonbank investors—for instance, loan funds and other funds facing potentially large redemptions (see mutual funds liquidity stress tests section). Waves of credit ratings downgrades for leveraged loans could also lead to stress for CLO tranches, through direct downgrades or by resulting failures of overcollateralization tests by CLO managers. Such stress could lead to asset sales by investors, and to a lesser extent by CLO managers as they seek to replace downgraded loans with higher quality

[20] Liu and Schmidt-Eisenlohr, 2019, "Who Owns U.S. CLO Securities?" FEDS Notes. Washington: Board of Governors of the Federal Reserve System, July 19, 2019, https://www.federalreserve.gov/econres/notes/feds-notes/who-owns-us-clo-securities-20190719.htm.

[21] International Monetary Fund, "Global Financial Stability Report," April 2019, https://www.imf.org/en/Publications/GFSR/Issues/2019/03/27/Global-Financial-Stability-Report-April-2019.

assets. Depending on the severity of a potential stress episode, and if large parts of the corporate sector are under stress, this could trigger contagion losses acting through indirect channels—such as through asset liquidations by exposed financial institutions, resulting in mark-to-market losses—which could affect other segments of the financial system, including banks. These mechanisms are analyzed in more detail in the "systemic risk, interconnectedness, and contagion analysis" section of this technical note.

53. Overall, the ongoing crisis will put significant stress and amplify existing vulnerabilities on an already leveraged corporate sector. The rise in leverage in the risky credit markets—including leveraged loans, high yield and private debt—combined with a weakening in underwriting standards could see segments of the U.S. nonfinancial corporate sector underperform under stress. Owing to the combined COVID-19 outbreak and oil price shock, corporates faced the combined effects of recent financial market volatility, tightening in financing conditions and, for many, a collapse in sales. Corporate short-term liquidity needs are large, but most of these are concentrated in investment-grade companies whose debt markets are supported by the recently introduced Fed liquidity facilities—including the so-called "fallen angels", which have recently lost their investment grade status. However, with the potential of a protracted economic slowdown and behavioral changes induced by evolving social-distancing norms, the long-term sustainability of certain business models could be challenged. Solvency risks could materialize, leading to large credit risk losses. Sectors such as energy, entertainment and leisure services, retail, and durable-goods manufacturers appear to be among the most vulnerable.

STRESS TESTING SCENARIOS

A. Scope

54. The sensitivity test-based scenarios developed by the FSAP team incorporated risks related to the corporate sector and followed Risk Assessment Matrix (RAM) (Appendix VI). The RAM takes into account existing vulnerabilities as well as salient risks, stemming in particular from the COVID-19 outbreak. In the years up to the current crisis, households experienced a significant deleveraging—mainly driven by a reduction in mortgage indebtedness—while nonfinancial corporates have seen their leverage levels reach record highs and a significant deterioration in the underwriting standard in a few sub-segments of this sector (notably, the leveraged loan market). The COVID-19 crisis represents a real-life stress event, materializing through adverse shocks to both macroeconomic and financial conditions. In this context, the scenario design aims at quantifying the potential shocks and their impact on adequacy of the capital and liquidity levels of financial institutions, examining some of the existing vulnerabilities among corporates, and assessing how potential risks and vulnerabilities would transmit among different sectors and institutions (i.e., contagion) in certain stress environments.

55. The FSAP team used one baseline and three separate sensitivity scenarios to conduct its stress testing. The design process of the scenarios was different to regular IMF FSAP stress testing exercises. Shocks to GDP were derived using a simple accounting-based framework which measured sectoral output losses subject to duration of containment measures, as well as intensity of recovery after re-opening of economic activity. Employment losses and the unemployment rate path are proportionately linked to the severity of each scenario in terms of GDP losses. Short-term interest rates are underpinned by the assumption that the policy rate remains at the effective zero lower bound (ZLB) throughout the projection horizon in all scenarios. Longer-dated Treasury bill rates are derived from short-term interest rates and a term premium component which varies according to the scenario severity. Other macro-financial variables remained similar to those observed during the Global Financial Crisis. Sensitivity scenarios include, in addition to a baseline scenario—based on the *June 2020 WEO Update* projections—which embeds the expected macroeconomic consequences from the COVID-19 outbreak, three additional scenarios as sensitivity analysis. The FSAP stress test scenarios cover a five-year ahead horizon over the period 2020–25. This complements the Federal Reserve's severely adverse CCAR/DFAST scenario, which has a three-year horizon.[22]

56. The scenarios were applied consistently to test the resilience across all types of financial institutions included in this note. These scenarios were used for the banking sector and corporate sector stress tests and inform the stress tests of other financial institution affected by market developments following the COVID-19 outbreak. The additional sensitivity scenarios, with appropriate modifications to reflect immediacy of realization of some market shocks, were used to stress test insurance companies, and mutual and money market funds.

B. Scenario Narrative and Calibration

57. The following scenarios have been used for the stress tests (Figure 12):[23]

- The FSAP baseline scenario follows the *June 2020 WEO Update* projections. It entails a sharp contraction (mainly in 2020Q2) owing to containment measures in response to the COVID-19 outbreak, and subdued activity and reduced demand in sectors affected by social-distancing norms. This is then followed by a tepid economic recovery as the economy starts to open again, but private sector balance sheet deterioration—with the unemployment rate peaking at 13½ percent in 2020Q2—combined with long-lasting behavioral changes, keeping GDP below its pre-crisis (i.e., 2019Q4) level through end-2022. Asset prices face a commensurate short-term fall, and then recover back to their previous levels within two-year horizon.

- Three alternative sensitivity scenarios are also considered, which assume different length of containment and de facto mobility measures:

  Sensitivity Scenario 1: relative to the baseline, this scenario assumes that the reduced *de facto* mobility observed during the containment period lasts for the entire second quarter of 2020. Output losses during this period are assumed to be 25 percent (non-annualized) relative to pre-

[22] Most of the analysis in the FSAP was completed before DFAST/CCAR 2020 scenarios were published.

[23] See Appendix VIII for a numerical representation of the stress scenarios.

COVID levels. In other words, the level of economic output in 2020Q2 is equivalent to 75 percent of the pre-shock output level. This is then followed by a slower economic recovery relative to the baseline, hysteresis losses are assumed to be commensurately larger.[24] The fall in financial asset prices is proportionately adjusted to the severity of the output losses embedded in the scenario.

Sensitivity Scenario 2: this scenario follows the same logic as the above scenario, but the containment measures and reduced mobility are assumed to last for another quarter. In other words, output levels in both 2020Q2 and 2020Q3 are only 75 percent of the pre-crisis level. This would lead to larger employment, income, and business losses, thus also translating into larger and longer-lasting economic 'scarring' relative to the previous two scenarios.

Sensitivity Scenario 3: initially, this scenario follows the same patter as Sensitivity Scenario 1, but it also assumes another wave of increased infections followed by a new containment period in the first quarter of 2021. This leads to a "W-shape" in the level of output, triggering more economic and balance sheet losses for longer. Consequently, economic activity recovers even slower in this scenario in subsequent years. Compared to historical patterns observed in previous economic crises as well as the latest CCAR/DFAST scenario,[25] the economic losses in these FSAP scenarios are unprecedented, reflecting the unprecedented nature of the ongoing global pandemic. For instance, the sharp real GDP contraction in 2020Q2 in the June 2020 WEO Update is equivalent to 12 times the historical standard deviation of the quarterly growth series recorded since the end of WWII. This same number is equivalent to 17 standard deviations in the case of the adverse scenarios. In terms of financial variables, the FSAP stress test scenarios follow closely the behavior of these embedded in the CCAR scenario but adjusted proportionately to the severity of the output losses in the FSAP scenarios. This includes large shocks to corporate risk premia, stock market prices, and real estate prices (which tend to exhibit a more delayed response).

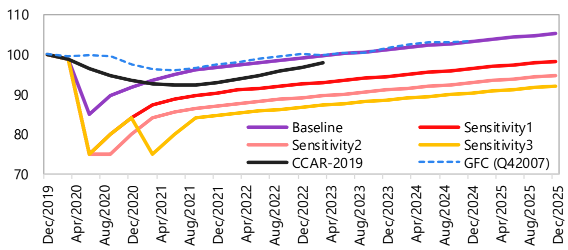
[24] Medium-term GDP growth rates are broadly similar across scenarios, but depending on the severity of the initial shock (intensity and duration of the reduced mobility period), output levels would thus differ across scenarios.

[25] This refers to the supervisory scenarios that were disclosed in February 2020 at the outset of the DFAST exercise, and not to the additional scenarios that the Federal Reserve disclosed subsequently in June 2020 as part of DFAST 2020 sensitivity analysis.

Figure 12. United States: Stress Test Scenarios

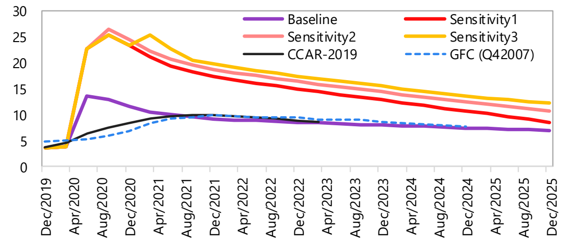
Delayed recovery leads to subdued activity ....

Real GDP Levels
(Index: 2019Q4=100)



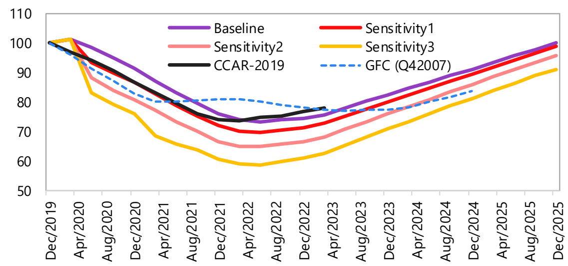
... and more persistent unemployment

Unemployment Rate
(In percent)



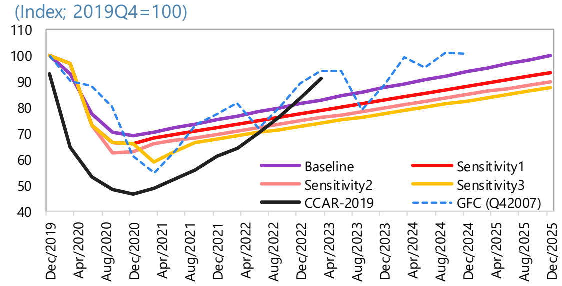
House prices fall...

House Price Index
(Index; 2019Q4=100)



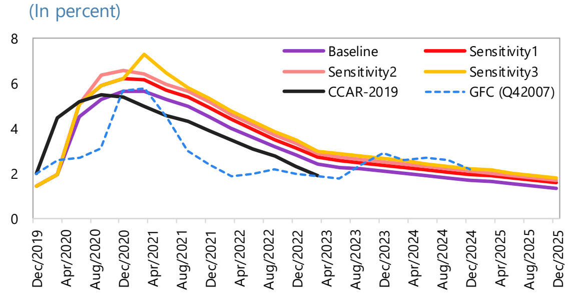
...following a contraction in the stock market

Stock Market Index
(Index; 2019Q4=100)



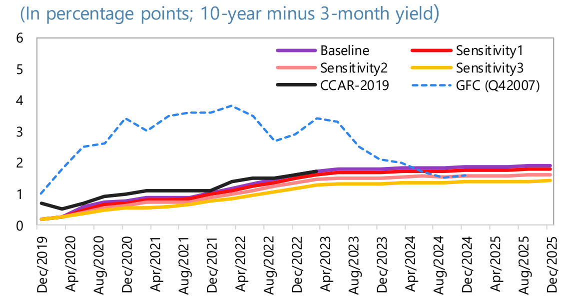
Risk premiums go up, especially for lower rated corporates....

BBB Corporate Spread
(In percent)



...despite policy rates expected to remain low for longer

Slope of the Yield Curve
(In percentage points; 10-year minus 3-month yield)



Sources: FRB, CCAR scenarios; Haver Analytics; IMF staff estimates.
Note: the baseline scenario is based on the *June 2020 WEO Update* projections.

C. Risks Related to High-impact Events and their Transmission Channels

58. **The FSAP considered the impact of extreme weather events and exposures of insurers to carbon-intense assets.** The frequency of extreme weather events increased in recent decades, thus raising the probability of severe damage to businesses, households, and municipalities located

in selected geographical areas, with direct implications for the insurance sector. Idiosyncratic risk includes weather-related catastrophes such as hurricanes and flooding (see Section 7 on Insurance Stress Testing). Structural risk factors include a shift in technology (such as focus on green energy and decline in carbon-intense production, transportation, etc.). These factors are beyond assessment of the FSAP because there is little probability that structural shocks which could lead to rapid adoption of new technologies would happen within the FSAP time frame. At the same time, weather-related severe events will make an impact on financial condition of private corporates public utilities and municipalities in the affected areas. Figure 13, while not being US specific, provides a general description of climate risk transmission channels with two specific highlighted ones described in this technical note.

Figure 13. United States: Climate-Related Risks

Institutions	Risks	Institutions most affected	Response
Banks	Credit losses due to exposure to corporates, commercial and residential mortgage portfolios in affected areas. See Figure 18 for a sectoral distribution of loans	Smaller, less diversified regional banks operating in high impact areas	Reduce exposure: diversify away or ration credit to corporates, households, municipalities
Insurance companies	Increase in reinsurance premiums, underestimation of severity/frequency of climate related events	Selected non-life insurance companies (See Chapter Insurance Siolvency Stress Tests)	Increase insurance premiums and/or leave the affected areas altogether
Investment funds	Market risk related to investments in stocks and bonds of corporates	Funds with high expsoure to affected corporate sectors, municipalities	Reduce exposure: diversify away or ration credit to corporates, households, municipalities
Corporates	Cash flow decline: carbon taxes, fall in demand, increase in liabilities and cost of insurance, damage to equipment and infrastructure	Sectors affected: energy (oil and gas), public utilities in affected areas, telecommunication, mining, real estate (in affected areas), transport, agriculture	Bankruptcies, restructuring
Municipalities	Decline in population (loss of tax revenue), increase in costs related to infrastructure/damage repairs	Municipalities located in high impact areas, particularly:	Bankruptcies, debt restructuring, increases in taxes

Source: IMF staff.

CORPORATE SECTOR STRESS TESTS

59. Stress tests were conducted to assess the resilience of the U.S. corporate sector, with a focus on 'leveraged firms.' Leveraged firms are active borrowers in the U.S. leverage loan and high yield corporate bond markets. Stress tests are used to assess solvency and liquidity risks of a sample of about 2,000 nonfinancial corporations with total assets amounting to US$19 trillion (87 percent of GDP) and aggregate indebtedness of US$9 trillion. Balance sheet and profit-and-loss data come from Capital IQ.[26]

[26] The list of companies that are active in the U.S. corporate bond and commercial paper market was extracted from Bloomberg, whereas the list of firms that borrow in the leveraged loan market was extracted from S&P Leveraged Commentary Data (LCD).

60. Stress tests consist of projecting the firms' net income and debt servicing capacity under different macroeconomic scenarios. The projected net income flows as well as debt amortization and rollover patterns are gauged against the firms' initial level of capital and liquidity buffers. For instance, when the cumulated net losses of a firm exceed the reported amount of capital, then the firm falls into negative equity—and is considered to be in "distress."[27] Similarly, to gauge the liquidity (or refinancing) needs of the corporates in our sample, we compare the amount of cash and cash equivalent held at the beginning of the stress period relative to the potential liquidity needs from amortizations and maturing debt as well as any other potential net cash inflows (such as retained earnings, investment spending, etc.).

61. Firms profit and loss items are linked to macroeconomic variables through regression analysis. In the stress tests, gross revenues are modeled as a function of real GDP growth, and for certain industries (such as food and energy and utilities), these also depend on oil price developments. Another important parameter is the degree to which companies are able to adjust their non-interest expenditures to changes in revenues. Intuitively, firms that can cut costs substantially during downturns (i.e., falling revenues) will be more successful at absorbing a macroeconomic shock relative to those with more rigid cost structures. Finally, interest expenditures are modeled based on the existing debt profile, accounting for the share of debt that can be re-priced (e.g., variable rate loans) at any given period and applying the corresponding interest rate from the stress test scenarios (see Caceres et al. (2020a) for details).

62. Corporate sector stress tests suggest that potential losses could be significant. Stress tests were conducted on approximately 2,000 companies that are active in the corporate bond and leveraged loan markets. Results suggest that leveraged firms—defined in the stress tests as those firms with a debt-to-EBITDA ratio higher than 5—are likely to experience relatively large solvency and funding pressures, representing roughly three quarters of all firms with negative equity under the *baseline* projections (Figure 14).[28] In such a situation, and despite the relatively small size of the leveraged loan market, these firms would account for a large share of the potential losses (over 80 percent of the US$400 billion in potential debt-related losses). In a more severe scenario (c.f. FSAP *Sensitivity Scenario 3*—which assumes a second wave of infections in early 2021), losses stemming from corporate debt holdings could reach US$675 billion (US$465 billion related to leveraged firms). Although these losses are sizeable, banks have limited direct exposure to these products, and would suffer more limited losses.[29] However, indirect exposures and market dislocations combined with liquidity shortages could play an amplifying role in a situation of stress

[27] In practice, firms with negative equity could continue operating if the market continues to provide funds to satisfy their cash needs. Conversely, firms with positive equity could default on their debt obligations, for instance, if they run out of cash or for other reasons. Nevertheless, in a stress testing setting, it would be difficult to model the motives and behavior of firms driving their decision to default on their debt obligations, and such approach would inherently need to rely on a set of arbitrary assumptions.

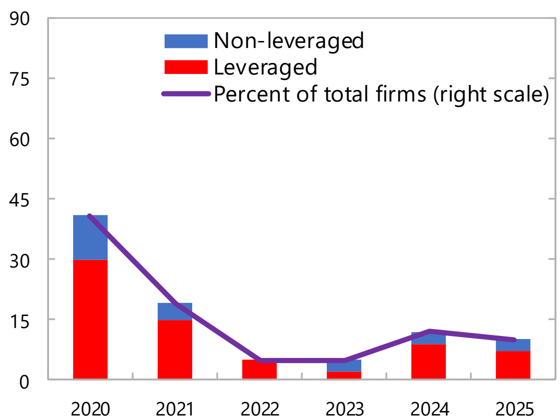
[28] These numbers do not correspond exactly to the potential losses for equity and debt holders. In case of default or liquidation, investors and lenders would still recover part of their investments. However, these numbers can be seen as equity and debt exposures "at the moment of stress".

[29] Banks hold slightly less than 20 percent of outstanding corporate bonds and loans, representing roughly one-tenth of their own assets.

Figure 14. United States: Corporate Stress Test Results

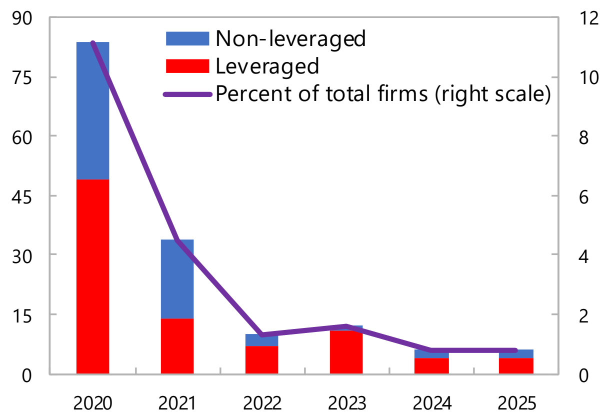
Number of New Firms with Negative Equity in the "Baseline Scenario"

(number; percent of total)



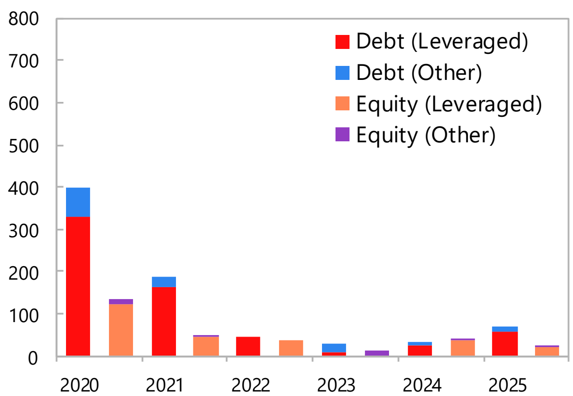
Number of New Firms with Negative Equity in "Sensitivity Scenario (3)"

(number; percent of total)



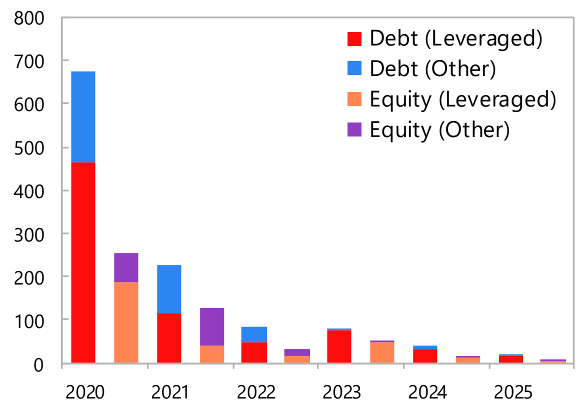
Equity and Outstanding Debt of Firms with Negative Equity in the "Baseline scenario"

(In billions of U.S. dollars)



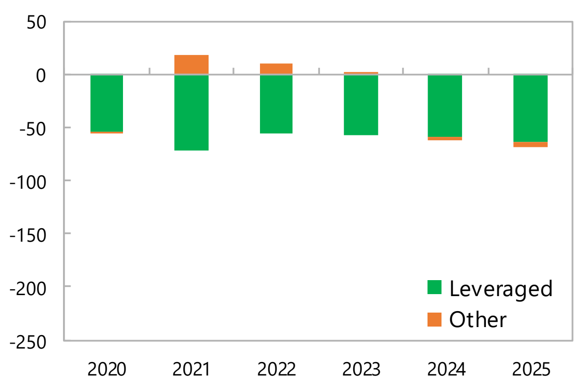
Equity and Outstanding Debt of Firms with Negative Equity in "Sensitivity Scenario (3)"

(In billions of U.S. dollars)



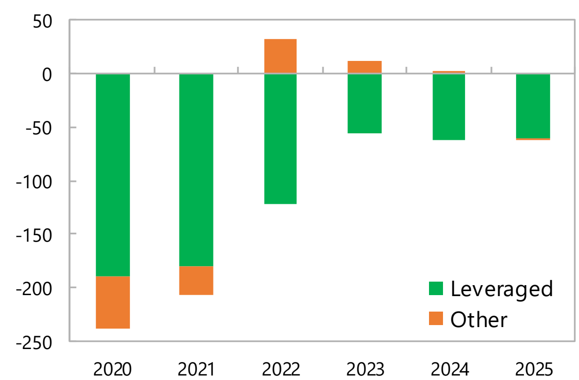
Equity Position of Firms in Negative Equity in the "Baseline Scenario"

(In billions of U.S. dollars)



Equity Position of Firms in Negative Equity in "Sensitivity Scenario (3)"

(In billions of U.S. dollars)



Sources: Capital IQ; Caceres et al. (2020a); and IMF staff estimates.

Notes: 'Leveraged' denotes firms with a debt-to-EBITDA ratio higher than 5.

BANKING SECTOR STRESS TESTS

A. Solvency

Scope

63. The key emphasis in quantifying risks to banks was placed on banks' ability to sustain losses due to a sharp deterioration of macroeconomic environment and increase in corporate default rates, at the same time distinguishing between different types of banks in terms of size, systemic importance and business models. This chapter analyzes how the baseline and adverse scenarios described in the previous section affect the solvency of banks. Elevated corporate sector vulnerabilities translate into large C&I loan losses, corporate defaults lead to higher unemployment. In turn, losses on loans to households rise, and pre-provision income and expenses (PPNR) falls because of lower income from trading, loan origination and associated fees. The FSAP team used various satellite models to translate these macro shocks into credit risk and market losses associated with all domestic and foreign exposures (aggregated). Analysis on derivative positions were not performed due to the lack of suitable data, and accordingly the associated risks were not fully assessed. Counterparty credit losses, as reported in DFAST/CCAR public disclosure, was added to the PPNR of relevant institutions.

64. Both top-down (TD) solvency and liquidity stress test were performed. The stress tests cover the 34 largest U.S. bank holding companies (BHCs), which account for about 86 percent of BHC assets, and 75 percent of total banking system assets (Appendix X). The TD stress test builds on the Capital and Loss Assessment under Stress Scenarios (CLASS) model developed by the Federal Reserve staff[30] and uses FRB and publicly available data (such as reported in FRB reporting templates FR-Y 9C, FR-Y 15). Given the importance of corporate credit losses in assessing risks, an additional robustness check was performed to compare stress testing results under accounting (write-offs) and market implied PDs (EDFs) models. Also, a set of additional sensitivity analysis was performed to account for challenges to banks' profitability given low interest rate environment, high shareholders' payout ratios, Fintech related competition and credit growth assumptions. A reference date for the banking data used in the stress test was Q1 2020.

Solvency Stress Testing Methodology

65. Bank balance sheet and income statement components are projected for bank holding companies (BHCs) using multiple panel regression models. The framework for this top-down stress testing exercise is based on a modified version of the CLASS model. Quarterly data from 1991 to 2020:Q1 from FR Y-9C report on consolidated financial statements for BHCs are used to gauge historical relationships between bank balance sheet and income statement variables and macrofinancial conditions. The elasticities obtained from these historical relationships are then used

[30] The Capital and Loss Assessment under Stress Scenarios. See Federal Reserve Bank of New York Staff Reports No. 663. July 2015.

in a model that forecasts income statement and balance sheet ratios (Appendix X). Based on the forecasted ratios through the stress testing horizon (i.e., 2025:Q1), net income, balance sheet, and capital ratios are calculated (see the schematic in Appendix X)

66. Overall, unemployment, house prices, corporate credit spreads and interest rates remain the most significant driving factors of losses. FSAP team satellite models reveal, that in line with FRB scenarios, a key set of macrofinancial variables in the CLASS model specifications explain the largest part of variation in accounting-based losses (charge-offs, recoveries) and pre-provision net revenue (PPNR). As expected, unemployment, housing prices impact losses on loans to households, while GDP, corporate spreads and interest rates losses on C&I loans. Overall, without adjustments explained in paragraphs below, loss rates (except for credit card loans (see Figure 18) would be slightly lower compared to the ones observed during the GFC; mainly due to lower interest rates and risk premiums than the ones prevailing at the onset of the crisis in 2008–09. The U.S. banks derive relatively small share of income from abroad (except for some trading banks), thus their ability to diversify away from the U.S. domestic recession is rather limited.

67. Rapid developments due to the COVID-19 outbreak highlighted the need to make adjustments to the model to reflect the unprecedented increase in unemployment and deep shocks to quarterly GDP. Satellite models calibrated using historical data before the COVID-19 crisis underestimated risks in certain exposure classes and overestimated the potential impact of other PPNR components. Namely, losses to corporate loans, commercial real estate loans may be higher due to specificity of this crisis which affected small businesses, travel, hotels, office rent and retail trade sectors disproportionately. At the same time the model overestimated potential expenses unrelated to credit risk, i.e., it is expected that banks would be able to minimize costly restructurings, face lower fines etc. which were prevalent after the GFC. Banks may also retain income by lowering capital and other expenditure, minimize shareholder payouts. To account for these factors, we used CLASS model adjustments outlined below.

68. Three types of adjustments to CLASS loan loss satellite models were explored: (i) based on market data[31]; (ii) a separate corporate risk stress test and COVID-19 market intelligence-based adjustments; (iii) adjustments for salaries growth as well as growth of non-interest expenses (excluding wages).

69. A market data-based alternative to accounting based (write -offs) loan loss specifications was performed to check robustness and compare results of corporate credit risk. The PD proxy for exposures to tradeable securities were extracted from bond yields using a Merton-based approach.[32] The FSAP team used data from public returns (FR- 9 Y) on the breakdown of financial assets to back out banks' exposures to various types of securities. It extracted estimates of probabilities of default (PD) from the spreads projected in the scenario using a reduced-form

[31] This test was performed before COVID-19 shock with cut-off date for the data as of end of 2019.

[32] An increase in sovereign issuer risk is reflected in higher loan loss impairment charges on HTM and AFS portfolios.

structural model.[33] Using the credit spreads for counterparty representing sector *i* linked to the scenario $S^{i}_{t,T}$, time to maturity (*T-t*), and assuming *LGD*=45 percent, the implied risk-neutral *PD* is backed-out as:

$$PD^{i}_{t,T} = \frac{1 - exp^{-S^{i}_{t,T}} \cdot (T - t))}{LGD^{i}_{t}}$$

70. Banks exposures to different sectors of the commercial and industrial loans was linked with estimates of market data-based PDs for these sectors. The banking system is exposed to various sectors of industry, with manufacturing and construction receiving most of the loans (Figure 18 below). A set of regressions was constructed to obtain stressed market data implied PDs. Overall, the results yielded shocks to PDs like the ones observed during the GFC (Figure 18). Flow of loan loss provisions was obtained by multiplying stressed PDs, LGDs, and bank-by-bank exposures.

71. Overall, the use of market-based commercial and industrial (C&I) loss estimates led to an additional decline in the system-wide CET1 ratio by 50 basis points. The impact was small given that models capture developments observed during several past crises, namely the dot-com bubble (2000–2001) and the GFC (2008–2010) (Figure 15). Based on that, the FSAP team did not use market data-based PDs, but utilized the second approach, i.e., made use of separate corporate risk stress test and COVID-19 market intelligence-based adjustments.

72. Historic data on C&I loan losses may not reflect structural risk related to rapid growth of leveraged loans with few or even without covenants. Instead of using the CLASS C&I loss satellite model, the FSAP team used the output from the corporate ST exercise to guide losses in the C&I exposure class. Team developed a multiplier approach, i.e., calculated a relative increase of C&I compared to the base quarter (Q1 2020). The multiplier then was applied for each bank C&I loan portfolio to derive the flow of provisions. The potential losses from the C&I loan category increase compared to the recent historic peak (reached during the GFC) : (i) in the baseline scenario, the loss rate reaches 11.2 percent and is 4 times higher; (ii) adverse sensitivity 1 scenario - losses reach 14.9 percent and are 5 times higher; (iii) adverse sensitivity 2 scenario: maximum losses reach 18.1 percent (6 times higher); (iv) In adverse sensitivity scenario 3: maximum losses reach 15 percent (5 times higher).[34]

73. The FSAP used market data to guide estimates of potential losses from commercial real estate (CRE) portfolios. The unprecedented nature of the crisis does not allow to fully rely on historic data about banks' losses from commercial real estate loans. These loan portfolios were hit

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[33] This approach assumes that the difference between a risk-free security and a risky security is the put option on the value of the assets which includes the loss induced by the stressed PD and LGD of the bond.

[34] Scenario 2 is more severe than Scenario 3 in terms of GDP losses in 2020 (it entails two quarters of reduced mobility, compared to only one quarter in Scenario 3); however Scenario 3 is more severe in 2021 (the second wave of infection triggers a quarter of reduced mobility in Q1 2021, which does not affect 2020). Accordingly, corporate sector expected losses are higher in Scenario 2 in 2020 (distress rate of 13 percent compared to 11.1 percent in Scenario 3), but corporate losses are higher in Scenario 3 in 2021 (4.8 percent compared to 1.3percent in Scenario 2). Cumulatively (over 2020-25), Scenario 3 entails larger losses than Scenario 2.

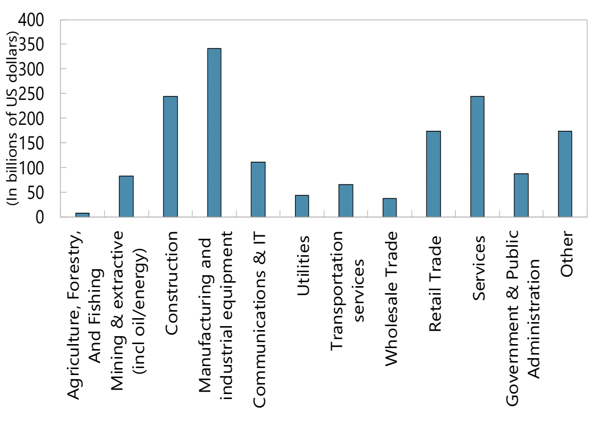
hard by the containment measures with expected losses far exceeding observed loss rates during previous cyclical downturns. CRE loan losses follow a path projected by market sources, with estimates that the impact will lead up to a 3-fold increase in losses exceeding those observed in 2008–9.[35]

74. Non-interest expense data shows high historic volatility (Figure 15), hence adds to the overall uncertainty of stress test estimations. A significant degree of uncertainty related to the ST results is driven by the largest components of non-interest related expenses: wages and all residual items, such as operating losses, mergers and acquisitions, restructuring costs, fines banks paid after the GFC. Many of these items are discretionary, thus their dependency on macro data are weak (except for wage growth). Applying a large increase in unemployment and a shock to quarterly GDP lead to an overestimation of shocks to these items in the ST. To overcome this issue, the FSAP team adjusted the model: It introduced upper bounds which are lower than historic average growth rates (reference period 2015–2019), i.e., assumed that annual wage growth would not exceed 1 percent and the residual non-interest expenses would not exceed 2.6 percent in all scenarios. Based on these caps, the estimated expenses omit some potential large discretionary expense items due to litigation, operational risk events etc. These items however are not determined by the scenarios, i.e., behavior of macro variables.

Figure 15. United States: Loss Estimation

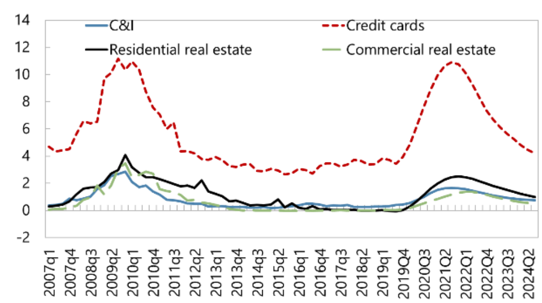
Decomposition of Commercial and Industrial Loans

(Aggregate decomposition of the 35 BHCs)



Accounting based corporate loss rates

Net Charge-off Rates



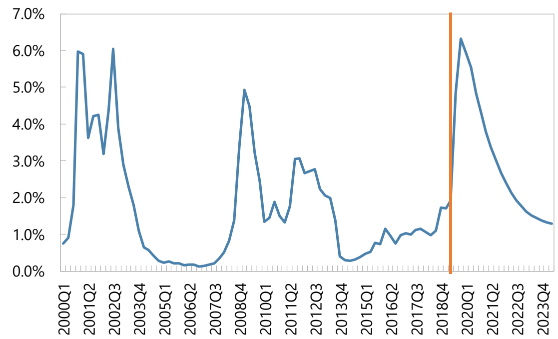
Sources: FR Y-9C & IMF staff

[35] See Moody's report: "Coronavirus (COVID-19): Credit Risk Impact on Commercial Real Estate Loan Portfolios"). https://www.moodysanalytics.com/-/media/article/2020/covid19-credit-risk-impact-cre.pdf

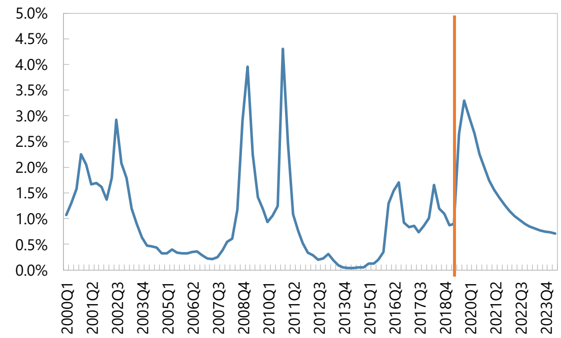
Figure 15. United States: Loss Estimation (concluded)

Market based corporate loss rates: simulations reveal an increase similar to the GFC

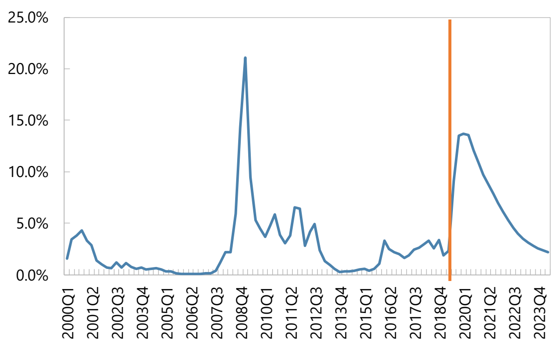
Manufacturing PD



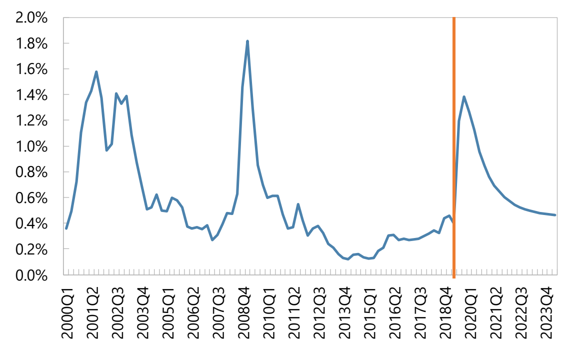
Communications and IT PD



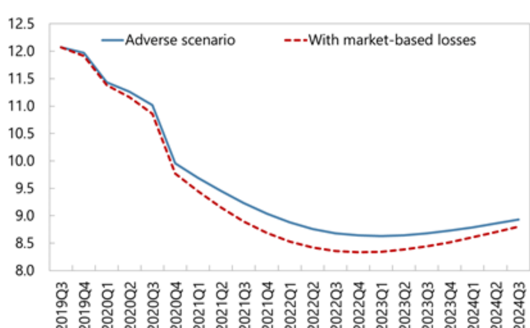
Retail Trade PD



Services PD

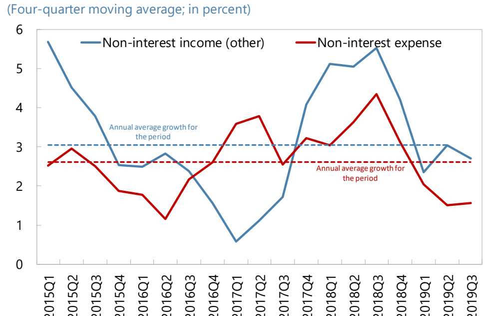


Market based loss metrics leads to an additional 50 basis points of CET1 impact.



Non-interest incme and expenses exhibit high volatility in the past five years

Historical Average Annual Growth
(Four-quarter moving average; in percent)



Source: IMF staff estimates.

Hurdle Rates

75. The definition of eligible capital and hurdle rates considers Basel III and the U.S. regulatory minima on CET1 ratios (4.5 percent), the Capital Conservation Buffer (CCB) and include additional requirements for Global Systemically Important Financial Institutions (G-SIBs) and leverage ratio. The capital definition includes CET1, Tier 1, and total CAR. The hurdle rate consists of a 4.5 percent CET1 requirement. The fully loaded level of capital conservation (CCB) buffer applicable in 2019 (2.5 percent) and the bank-specific G-SIB surcharge buffer is allowed to be depleted in the adverse scenario. The Tier 1 leverage ratio is based on the U.S. implementation of the Basel principles, namely 4 percent for all banks in the sample, except for the G-SIBs with more than US$700 billion of assets, for which 6 percent minima applies.

Results

Baseline

76. The banking system entered COVID-19 crisis with solid capital buffers, though future capital depletion is subject to multiple sources of uncertainty, including duration and intensity of COVID-19 containment measures. Solid capital buffers allowed banks to provide credit to the economy, namely extend credit lines to cash trapped corporates and households. Were the October 2019 WEO baseline macroeconomic scenario to materialize, banks would maintain high capital buffers and profitability. In contrast, the current June 2020 WEO Update—informed by the initial set of macroeconomic indicators since the pandemic crisis started unfolding—assumes sudden and a sharp decline in economic activity more severe than real and financial sector crisis in the past, which focused on a gradual increase in unemployment and decline in economic growth. The uncertainty around duration of the crisis and impact of various regulatory, monetary and fiscal measures required simulation of additional adverse scenarios and making of *ad hoc* assumptions listed below. Namely, the stress testing exercise thus incorporated multiple sources of uncertainty related to the recent outbreak and possible reaction of banks: sensitivity to duration of containment type of scenarios in addition to the COVID-19 baseline, assumptions about payouts to shareholders, dynamics of non-interest expenses, and credit portfolio growth. The stress tests exercise however was not able to fully estimate and incorporate impact of various fiscal measures, such as payments from the fiscal stimulus package and measures, like e.g., temporary postponement of loan repayments on condition of banks' borrowers.

77. Capital depletion rates are high in the *baseline (Figure 16)*, as expected given the unfolding sudden and sharp economic contraction yet remain manageable. The impact of COVID-19 is significant, and plays out mainly via two channels: i) immediate increase in credit losses, especially exposures to credit cards (losses of up to 3 percent of risk-weighted assets (RWAs)); C&I loans (losses of up to 1.8 percent of RWAs) ii) growth of RWAs due to a utilization of credit and funding lines, which lead to an additional depletion of CET1 of up to 1 p.p.[36] Banks are

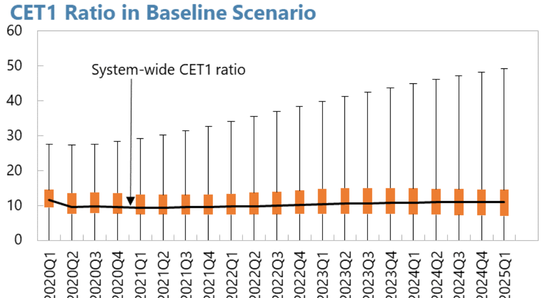
[36] Assuming a system-wide expected utilization of 20 percent (see Figure 12) and a credit conversion factor of 50 percent.

expected to generate a cumulative loss of 4 percent of total assets over the five-year scenario horizon. This compares to the 1.9 percent cumulative losses in the October 2019 WEO baseline. Net interest income offsets majority of losses, albeit declining margins due to policy rates being close to zero are lowering PPNR. Policy rates have a small additional positive effect on funding costs but a significant negative one on loan interest rates. Cumulative five-year gross interest income goes down from 15.5 to 12.2 percent of total assets (when compared to the October 2019 WEO baseline). This leads to a 360 b.p. annual capital uplift from net interest income compared to 420 b.p. one before the COVID outbreak. If shareholder payouts remain at an average level of 40 percent of net income, up to 4 banks (none of them G-SIBs) would need additional capital to meet the minimum 4.5 CET1 requirement within the three-year horizon.[37] Recapitalization amounts would be small (0.4 percent of GDP). No G-SIB would fall below minimum requirement also within the five-year horizon. Only one additional non-GSIB bank would fall below minimum, leading to the total number of five banks, requiring additional capital. Recapitalization needs would be around 0.8 percent of GDP. If shareholder payouts are zero for the stress test horizon, only four non-GSIBs would need additional capital with the recapitalization needs falling to 0.6 percent of GDP over the five-year horizon.

Figure 16. United States: Solvency Stress Testing Results—IMF Baseline Scenario1/

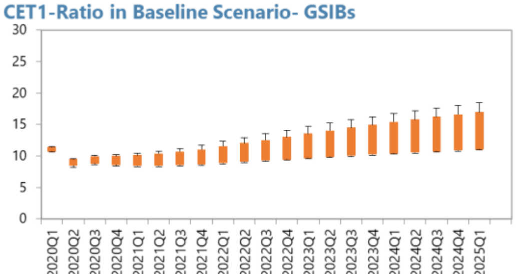
Banks started with strong capital position to support further growth of balance sheets, but declining interest margins coupled with high credit losses would lead to four non-GSIBs falling below minimum requirements…

CET1 Ratio in Baseline Scenario



G-SIBs have enough buffers to continue expanding loans yet the shareholder payouts at the current rates would reduce buffers going forward….

CET1-Ratio in Baseline Scenario- GSIBs



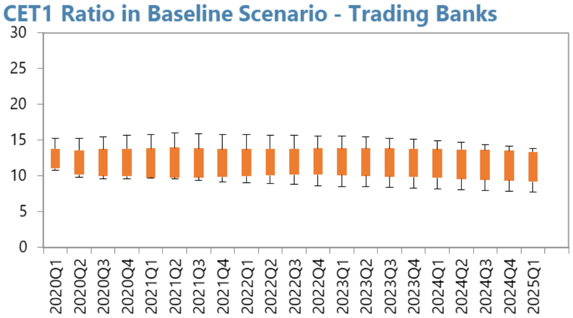
… as do trading banks which have low exposure to consumer loans.

Foreign banks fare relatively well, though some with significant retail exposures face a challenge…

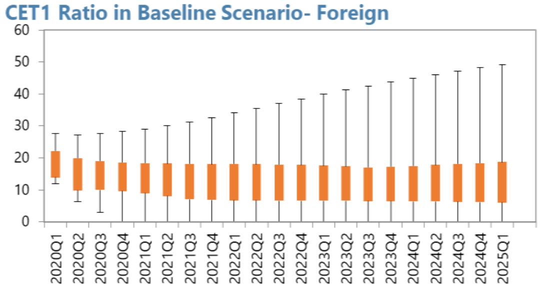
[37] For the purposes of comparing different business models of the banks, in the charts G-SIB group of banks includes 4 universal banks designated as G-SIB and excludes other 4 G-SIBs which fall under the trading banks category due to the underlying business model. In the text however, we refer to all G-SIBs to emphasize that no G-SIBs as defined by supervisors, require additional capital.

Figure 16. United States: Solvency Stress Testing Results—IMF Baseline Scenario (concluded)

CET1 Ratio in Baseline Scenario - Trading Banks



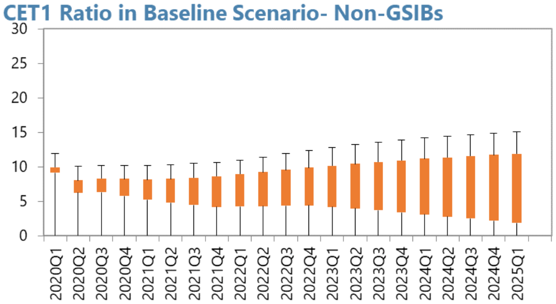
CET1 Ratio in Baseline Scenario- Foreign

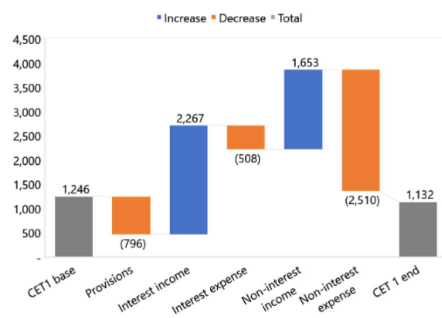


...as do Non-GSIBs' which started with lower levels of capital and profitability and have less diversified credit portfolios.

Non interest expenses may be further optimized: cost optimization, lower shareholder payouts would help in preserving capital base.

CET1 Ratio in Baseline Scenario- Non-GSIBs





Sources: IMF staff estimates.

1/ The box plots illustrate the interquartile range through the orange rectangular shaped objects, while the wiskers denote upper and lower bounds (latter is set to zero). The Baseline scenario assumes that shareholder payouts continue at an average of 40 percent.

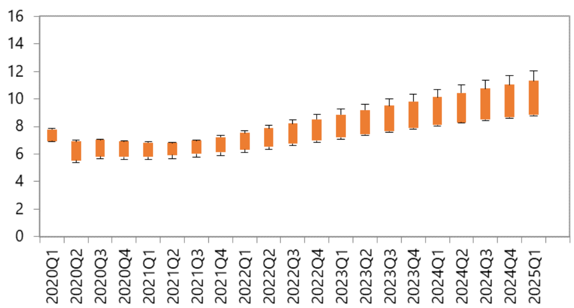
78. Most of the banks would be able to maintain leverage ratios above the minimum requirement (Figure 17). Some trading banks designated as G-SIBs would face a challenge in maintaining a 6 percent leverage ratio without the reducing the dividend payout ratio or asset growth. [38] Notwithstanding, the recent actions by the US supervisors to grant a temporary relief by excluding some assets from the calculation of the supplementary leverage ratio (which is at 3 percent in addition to the minimum) allowed G-SIBs to remain within the regulatory limits. Foreign and some non-GSIBs, which are not subject to the supplementary leveraged ratio rule, would need additional capital to remain within the minimum Tier 1 leverage ratio of 4 percent.

[38] The analysis did not take into account the temporary rule which excludes U.S. Treasury securities and deposits at Federal Reserve Banks from the calculation of the supplementary leverage ratio. See https://www.federalreserve.gov/newsevents/pressreleases/bcreg20200401a.htm.

Figure 17. United States: Solvency Stress Testing Results: Leverage Ratios under the Baseline Scenario

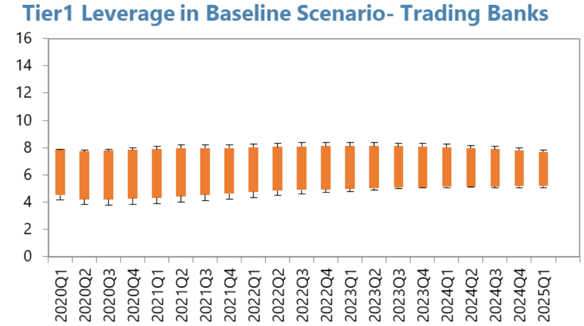
G-SIBs face little change to their leverage ratios, given the temporary regulatory relief…

Tier1 Leverage in Baseline Scenario - GSIBs



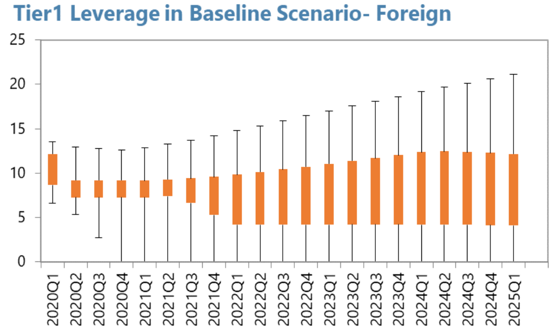
Some Trading banks are more affected by the crisis and need higher capital buffers to maintain 6 percent leverage ratio

Tier1 Leverage in Baseline Scenario- Trading Banks



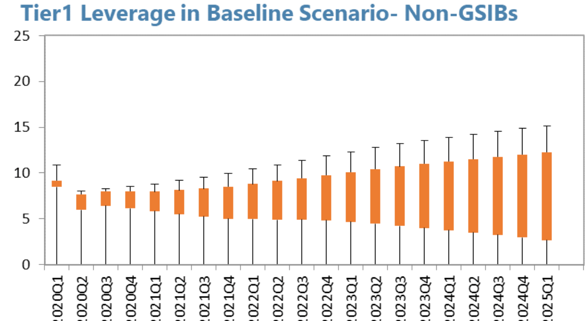
Foreign owned banks cannot maintain historic growth of balance sheet and continue to payout the same amount of retained earnings to parent companies. …

Tier1 Leverage in Baseline Scenario- Foreign



….Non-GSIBS may need to retain more profit as well.

Tier1 Leverage in Baseline Scenario- Non-GSIBs



Sources: IMF staff estimates.

79. The potential impact of competition from Fintech companies is relatively small system-wide, and highest for smaller non-GSIBs banks (Figure 18). The growing competition for deposits, fee revenues, and payment services from fintech companies will pose risks to banks' business models in the medium term, unless banks increase their spending on IT and other innovative technologies. Non-GSIBs are most vulnerable given that their market share in local deposits markets may decline as online channels would erode their natural advantage of physical presence in serving local communities. Moreover, smaller banks do not have the resources large banks deploy to upgrade and adapt their information technology (IT) systems to online distribution channels. As a result, non-GSIBs compared to G-SIBs may need to invest relatively more into IT systems. Industry estimates reveal that banks spend on IT about 15 percent of their total expenses on average, with an average spending growth rate increase of up to 4 percent annually.[39] Without such investments and upgrade in the infrastructure, smaller banks may lose up to 14.5 percent of potential revenue from payment processing.[40] In the sensitivity analysis we assumed that banks either increase investments into IT or risk losing potential revenue. Applying IT spending and revenue loss projections from industry surveys and rating company reports in the pre-COVID-19 period, sensitivity test leads to an average 10-basis point decline in CET1 ratio. An increase in IT expenses leads to a larger impact on CET1 than the loss of payment revenue in the sample of banks. The result is not surprising given a simplifying assumption that banks would maintain their share in payments market and that fees and commissions revenues would grow at an average historic rate. The uncertainty is driven by multiple factors, including a potential redistribution within the market resulting from increases in IT. Banks with better systems would gain the market share in payment revenues at the expense of other banks. Moreover, the analysis was conducted before COVID-19, and the impact of COVID-19 on digitalization of retail banking and pressures for cost cutting via closure of physical branches may accelerate further.[41]

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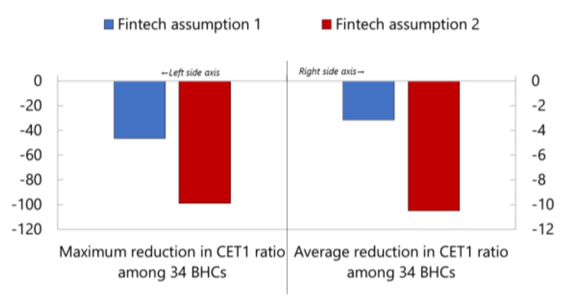
[39] See S&P Global ratings (2019). The Future Of Banking: The Growth Of Technology And Its Impact On The U.S. Banking Sector.

[40]See: Accenture (2019). Accenture Global Payments Pulse Survey 2019. Two ways to win in payments. Accenture, 2020.

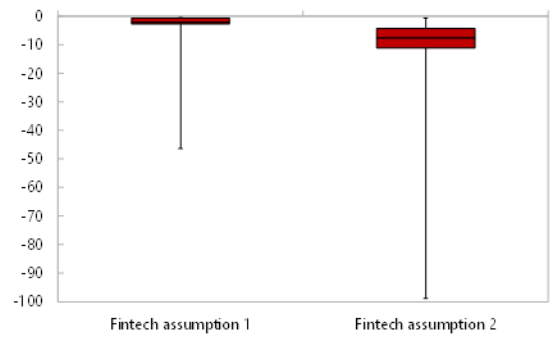
[41] The sensitivity analysis was performed using Q3 2019 data.

Figure 18 United States: Sensitivity Analysis—Impact of Fintech

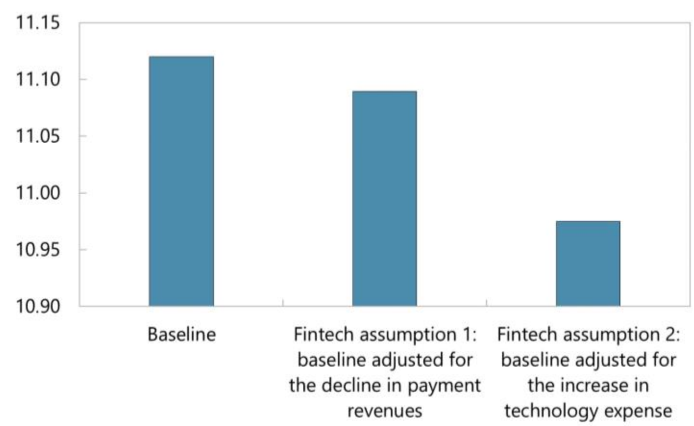
Decline in the CET1 Ratio Under Fintech Impact Simulation
(In basis points of RWAs)



Decline in the CET1 Ratio Under Fintech Impact Simulation
(In basis points of RWAs)



System-Wide CET1 Ratio at the End of the Simulation Horizon (Q1 2025)



Source: FRB, FR-Y9C; S&P Market Intelligence; S&P Ratings Direct; Accenture research; IMF staff.

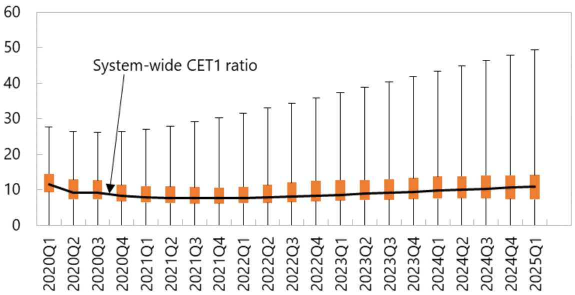
Adverse Sensitivity Scenarios

80. **Assuming a more prolonged economic disruption leads to a further depletion of banks' capital buffers, yet no G-SIB falls below the minimum required CET1 level within the three years (Figure 19).** Due to an unprecedented uncertainty about duration of the crisis, including potential second waves of infection, the three adverse scenarios focused on impact of credit losses on banks' capital position due to an extension of containment measures. Overall, C&I loans as well as consumer loans (credit cards) constitute the bulk of credit risk related losses. As expected, banks with the highest exposures to these types of loans are affected more. Figure 20 provides decomposition of evolution of the key PPNR items. Focusing on the three-year period, up to 6 banks (all of them are non-GSIBs) would need additional capital in the adverse sensitivity scenario 1. The overall capital shortfall against the 4.5 percent CET1 minimum is small and amounts to about 0.5 percent of GDP. Only one additional bank (non-GSIB) would need to be recapitalized if the stress test horizon is expanded to the five-year horizon. The scenario reveals that systemically important banks have high enough capital buffers to withstand the simulated shocks.

Figure 19. United States: Solvency Stress Testing Results—Sensitivity Scenario 1

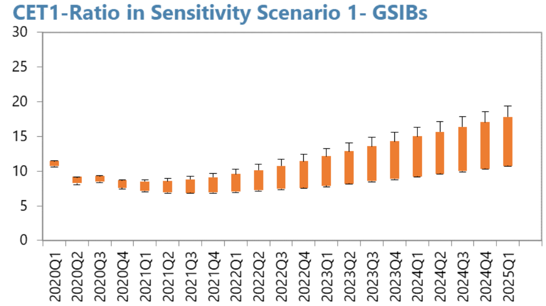
Most of the banks would stay above 4.5 percent CET1 minimum within the first year of the scenario…

CET1 Ratio in Sensitivity Scenario 1



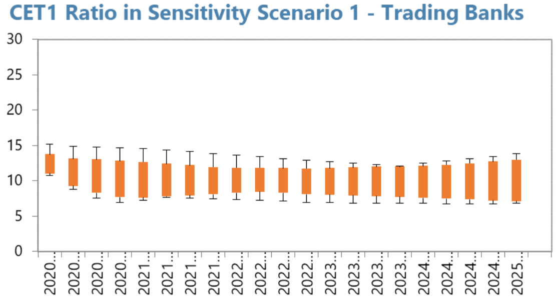
G-SIBS show greatest resilience due to the diversified nature of their business models and high initial capital buffers…

CET1-Ratio in Sensitivity Scenario 1- GSIBs



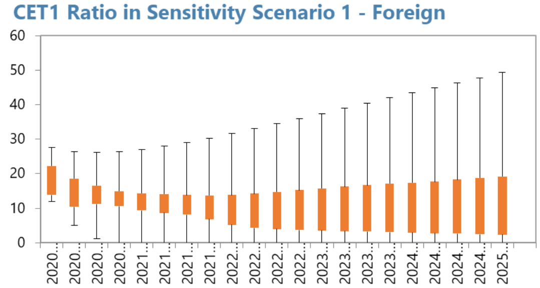
…while banks focused on market trading are hit less because of higher relative exposure to market and counterparty risks which are not assumed to materialize due to monetary and market support measures

CET1 Ratio in Sensitivity Scenario 1 - Trading Banks



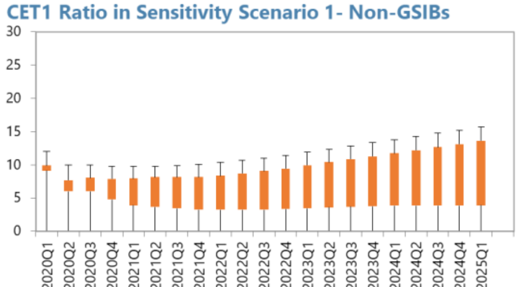
Some foreign banks would need additional capital buffers, especially those exposed to consumer lending segment….

CET1 Ratio in Sensitivity Scenario 1 - Foreign



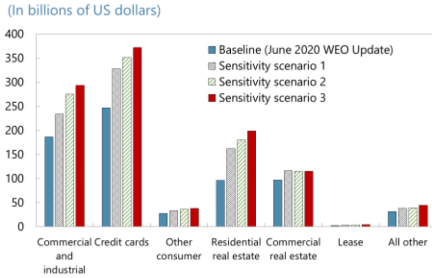
…as would Non-GSIBs, especially those with lower initial capital bufers and higher expsoure to consumer and C&I loans

CET1 Ratio in Sensitivity Scenario 1- Non-GSIBs



Overall, credit cards, C&I loans are the largest contributors to credit risk.

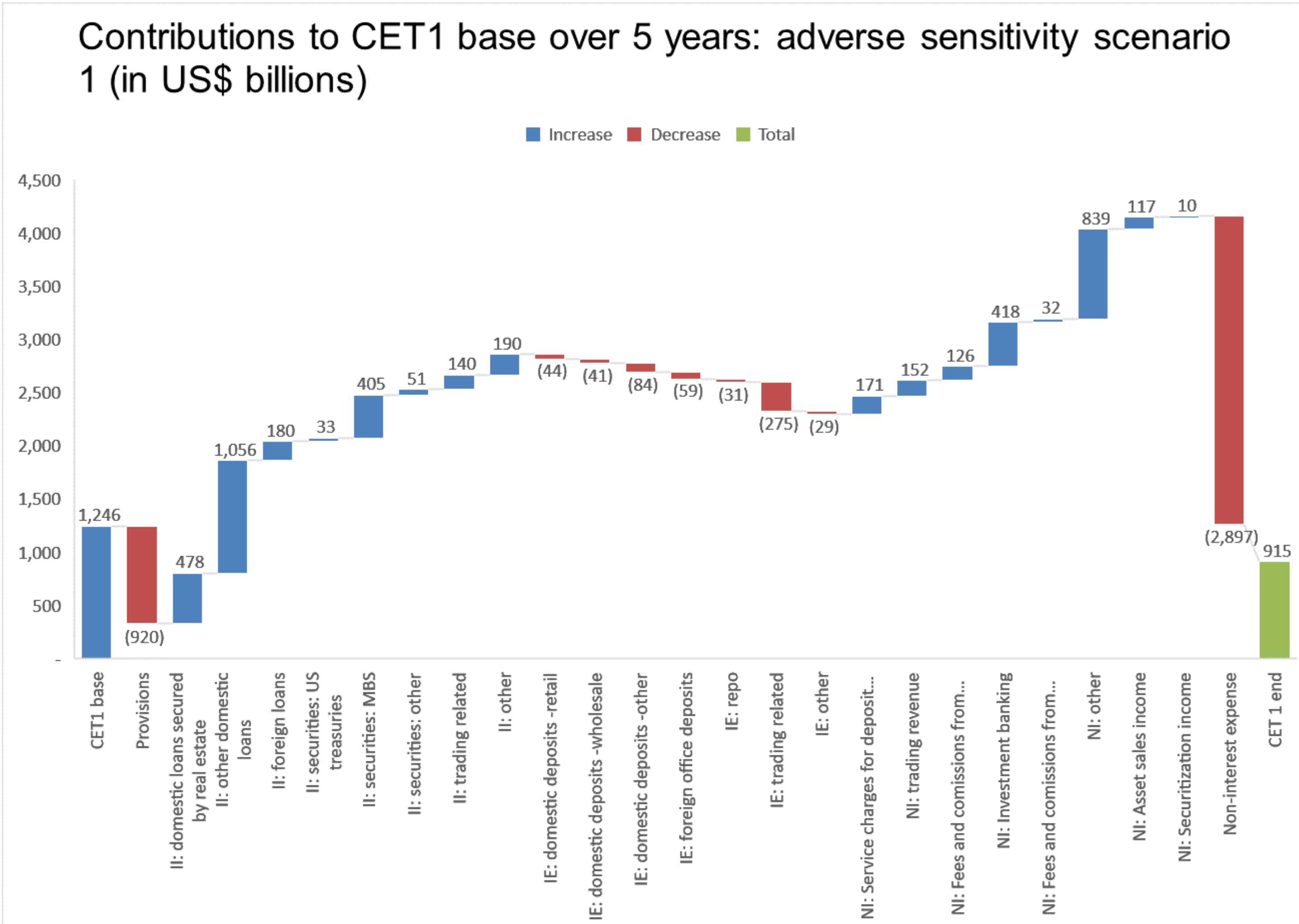
Loan Losses
(In billions of US dollars)



Sources: IMF staff estimates. 1/ The box plots illustrate the interquartile range through the orange rectangular shaped objects, while the wiskers denote upper and lower bounds (latter is set to zero).

Figure 20. United States: Solvency Stress Testing Results: Adverse Sensitivity Scenario 1

A detailed decomposition of evolution of P&L items in the Adverse scenario reveals that profitability of banks remains high even during the severe downturn, and most of the decline in CET1 is due to non-interest expenses, such as salaries.



Sources: IMF staff estimates.

81. Sensitivity analysis using different assumptions about duration of the current crisis and a hypothetical second infection wave indicates a range of impact on banks' capital positions. An additional quarter of lockdown reduces system wide CET1 ratio on average by an additional 90 b.p (Q2 2022); up to 8 banks (non-GSIBs) would need additional capital, but the overall capital shortfall against the 4.5 percent CET1 minimum is similar to Adverse Scenario 1 and amounts to about 0.6 percent of GDP. In case of a second wave of infections and subsequent reactivation of full containment measures, the CET1 declines compared to the baseline by additional 450 b.p. in the third year. Overall, prolonged containment (beyond Q2 2020) and the second wave of infection would lead to 10 non-GSIB banks failing to meet minimum CET1 within the first three years of the crisis. The capital shortfall against the 4.5 percent CET1 minimum amounts to about 0.8 percent of GDP. The recapitalization needs would be on average 0.1 p.p. lower in the scenarios which assume that shareholder payouts are zero during the simulated crisis period.

82. Banks with a high share of retail funding, diversified asset portfolios, and high initial CET1 capital buffers are more resilient. G-SIBs with diversified business lines fare well, with trading banks[42] experiencing limited impact on their balance sheets, mainly due to prompt actions from the FRB (setting up of various lending facilities to stabilize market liquidity[43]). Non-G-SIBs[44] and some foreign owned banks with considerable exposure to C&I loans, lower capital buffers, and large shareholder payout ratios are relatively more vulnerable to shocks. Non-G-SIBs are primarily exposed to losses from unsecured lending to households (e.g., credit cards), secured loans (e.g., residential mortgages), and commercial and industrial (C&I) loans, as well as commercial real estate lending. Some smaller non-GSIBs have high exposure to consumer lending, such as credit cards. Moreover, banks differ in terms of exposures to various sub-segments of consumer credit, with some banks having targeted lower income households which were particularly strongly hit by the crisis.

83. Leverage under the stress scenarios evolves in line with projected capitalization levels. As in the case of the baseline scenario, some of the G-SIBs would need additional capital to maintain their required minimum leverage ratios of 6 percent (without taking into account the temporary relief rule, which effectively reduced the CET1 requirements by up to 2 percentage points on

[42] Trading banks is the group of banks in the sample which have high share of trading related income and trading assets. This sample includes *inter alia* 4 G-Sibs.

[43] Liquidity stress tests were conducted prior to COVID-19 crisis, thus do not take into analysis FRB actions to support the economy. See Federal Reserve announces extensive new measures to support the economy; March 23, 2020 https://www.federalreserve.gov/newsevents/pressreleases/monetary20200323b.htm.

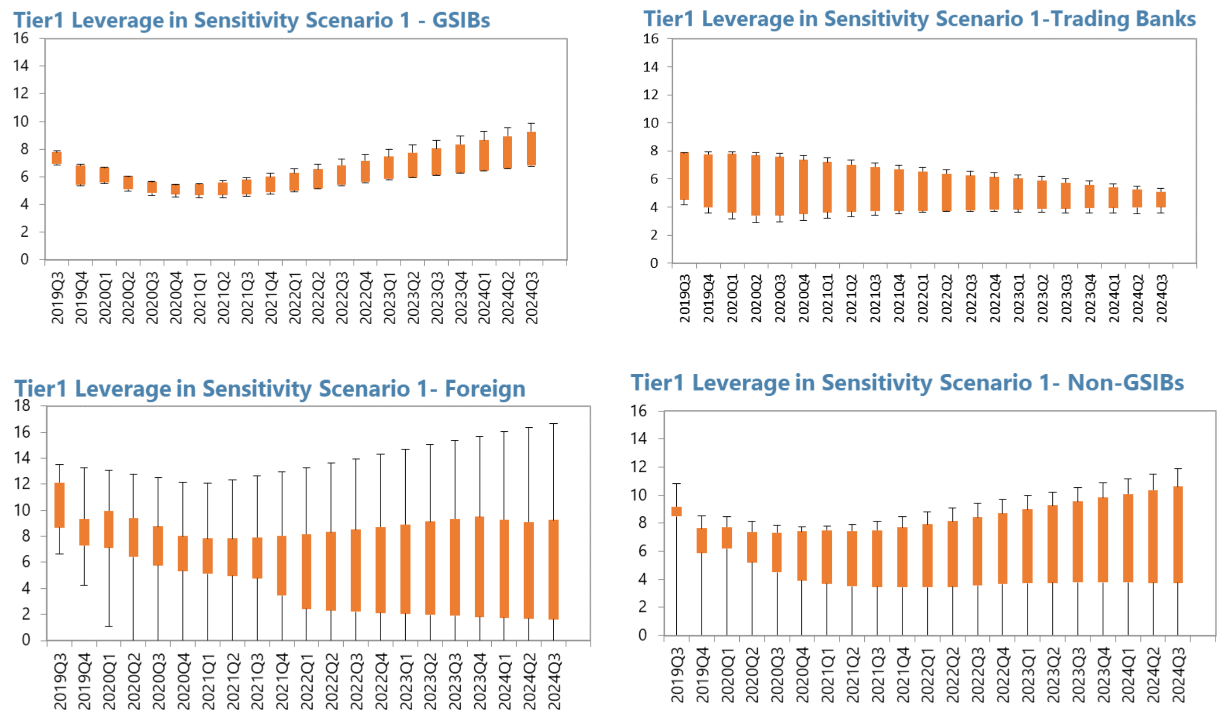
[44] This group includes large banks with consolidated total assets above US$100 billion, excluding U.S. G-SIBs and Intermediate Holding Companies.

average), albeit within the first two years of the stress horizon only. While foreign and non-GSIB banks are not subject to supplementary leverage rule and have lower Tier 1 leverage requirement they show less resilience due to a rapid decline in CET 1 capital base. The measure of their leverage (defined as total capital over total assets) falls below their required minimum of 4 percent (Figure 21).

Figure 21. United States: Solvency Stress Testing Results—Leverage Ratio under the Adverse Sensitivity Scenario 1/

Without regulatory relief, some G-SIBs would need additional capital or reduce balance sheet to maintain minimum leverage ratios in the sensitivity scenario within the first two years….

…as is the case for trading banks.



Sources: IMF staff estimates.

1/ The box plots illustrate the interquartile range through the orange rectangular shaped objects, while the wiskers denote upper and lower bounds (latter is set to zero).

Additional Sensitivity Tests

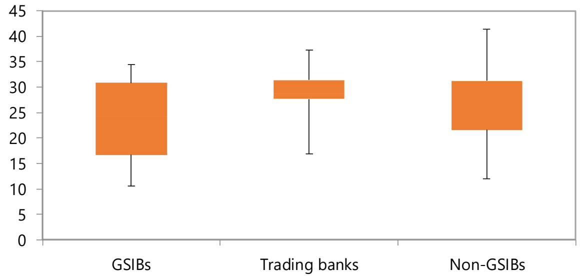
84. To gauge sensitivity of results to behavioral assumptions, the stress test considered two options for dividend payouts. The main set of simulations involved the assumption that banks would continue dividend payouts at long term historic average levels (i.e., at approximately 40 percent of net earnings, excluding share buybacks) and will reduce relative expenses while balance sheets will grow at the rate of up to 4 percent per year reflecting lower demand for credit compared to average growth rates of 7.5 percent. An alternative set of simulations assumed that banks would reduce shareholder payouts to zero. Based on these assumptions and the four scenarios, 8 simulations were performed in total.

85. Given the uncertainty of duration of the crisis and firmness of the post-crisis recovery, reduction in shareholder payouts would help to preserve capital in the *Baseline and Adverse scenarios*, while allowing banks to continue extending credit (Figure 22). Even under the adverse scenarios most of the banks earn enough interest income to offset credit risk related losses, yet other non-interest expenses drive the overall impact on capitalization. U.S. banks have a track record of reducing operational expenses quickly by closing branches and reducing workforce and staff compensation. Nevertheless, to ensure preparedness for the longer duration of the crisis and further growth of the loan portfolio even in the adverse scenario, higher share of earnings would need to be retained or a temporary moratorium on shareholder payouts instituted. By keeping shareholder payouts at zero for the duration of the crisis, banks would save an average of 60 b.p. of CET1 by the Q2 2022. This would also help banks to maintain staffing ensuring robust business continuity.

Figure 22. United States: Solvency Stress Testing Results—Results Under Multiple Adverse Scenarios and Assumptions About Dividend Payouts

Dividend payout rateacross all banks in the sample…

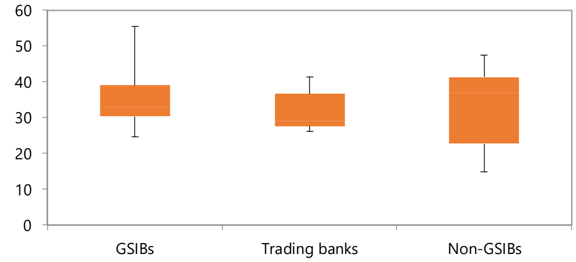
Dividend Payout Ratio: Post-GFC



…and were steadily increasing in the past years.

Dividend Payout Ratio: 2019:Q3

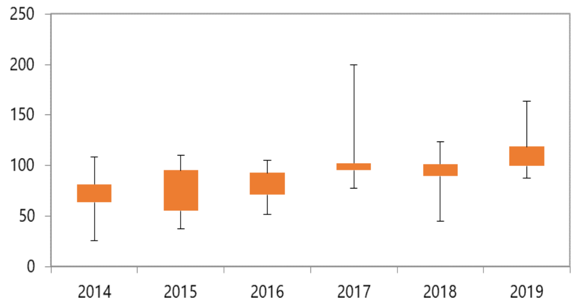
(In percent)



Overall, shareholder payout ratios (including share buy-backs) exceeeded net income in some banks.

Shareholder Payout Ratio for G-SIBs: 2014-19

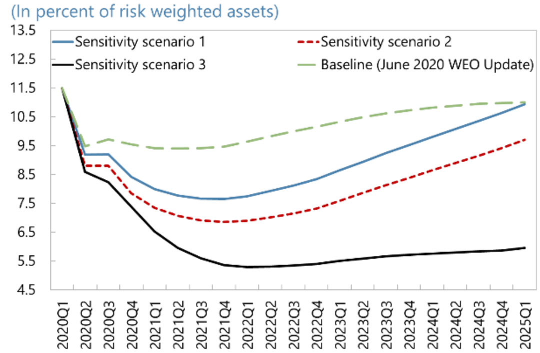
(In percent)



Systemwide CET1 ratio would remain above the 4.5 percent CET1 minimum within the stress test horizon…

CET1 Ratio — With Dividend Payouts

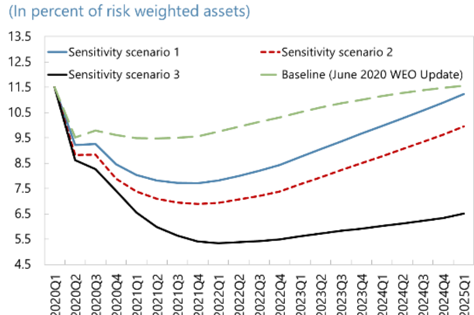
(In percent of risk weighted assets)



…and temporary lower or zero shareholder payouts would help to conserve additional capital which may be needed to remain above the minimum requirements in case of an extended duration of the current pandemics.

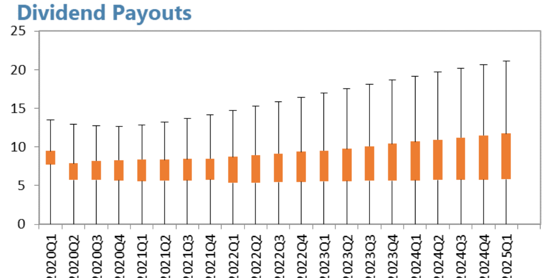
CET1 Ratio — Without Dividend Payouts

(In percent of risk weighted assets)



System-wide leverage ratio also improves, however marginally, as banks which face significant decline in CET1 ratios still struggle to remain above the minimum requirement.

Tier1 Leverage in Baseline Scenario Without Dividend Payouts



Source: IMF calculations.

Conclusions

86. The banking system has solid capital buffers, and thus system-wide capital shortfall in the baseline and adverse sensitivity scenarios is relatively small. While six smaller Non-GSIBs would fall below the CET1 ratio of 4.5 percent, recapitalization needs would be manageable from 0.52 in case of adverse sensitivity scenario 1 to 0.81 percent of GDP (10 banks, all of them non-GSIBs, below CET1 minima) in the most severe case of the double recession due to a second wave of COVID-19. In recent years' banks increased dividend payout ratios to shareholders, share buybacks and in some cases (especially Non-GSIBs) reduced their CET1 (see Figure 25). This leads to procyclicality of capital planning if additional severe shocks are to materialize, especially given the uncertainty related to the swift recovery from the negative impact the virus outbreak had on the economy. Additional sensitivity tests were conducted to estimate the impact of different assumptions regarding the impact of dividend payout ratio impact on the evolution of CET1/leverage ratios. The potential capital shortfall in terms of GDP under the scenarios would be higher up to 0.2 percentage points higher if banks maintain average dividend payout ratios of 40 percent to the shareholders.

87. The stress tests results are subject to numerous uncertainties, however they also demonstrate that the banking system has flexibility to cut expenses and ability to generate income to adjust to the COVID-19 crisis without unnecessarily reducing exposure to the real sector, Banks are primarily exposed to risks related to losses from unsecured lending to households (credit cards) as well as secured loans: residential and commercial real estate. C&I loan losses would be high under a distress in corporate sector scenario, which assumes increase in default correlations of highly leveraged companies. Nevertheless, even under the adverse scenario most of the banks earn enough interest income to off-set credit risk related losses. As in the case of the baseline scenario, the U.S. banking system benefits from labor market flexibility: the largest expense item—administrative costs—may be adjusted further downwards by reducing staff number, salaries, and bonuses.

88. The stress test results also confirm that leverage requirements become more binding during stress scenarios, Simulation results indicated, that some of the banks, including G-SIBs would face challenges to maintain leverage ratios above minimum requirements. Absent the recent changes to the supplementary leverage ratio calculation, affected banks would need to either increase their capital base by retaining higher share of profit, raising additional equity or shrinking their balance sheets, for example, by reducing exposures to counterparties, holdings of securities etc.[45] All of these actions by banks would introduce several system-wide effects, such as asset fire sales, shocks to funding liquidity and thus further amplify liquidity shocks in the markets.

[45] The analysis did not take into account the temporary rule announced in April which excludes U.S. Treasury securities and deposits at Federal Reserve Banks from the calculation of the supplementary leverage ratio and will be in effect until March 31, 2021. See https://www.federalreserve.gov/newsevents/pressreleases/bcreg20200401a.htm.

B. Banking Sector Liquidity Risk Analysis and Stress Tests

89. The aim of the liquidity risk analysis and stress testing is to evaluate to what extent U.S. banks would be able to sustain severe funding shocks and at the same time continue to provide liquidity to the customers. As emphasized in the previous chapters of this note, banks play an important role in providing short-term funding and liquidity to various non-bank financial institutions as well as corporates and households. For example, existing commitments to the leveraged loan borrowers account for US$760 billion in credit facilities (drawn and undrawn revolvers).[46] The capacity to extend those credit lines to customers depends on banks' ability to obtain liquidity in the market, cope with the stressed liquidity outflows without breaching regulatory requirements.

90. To assess liquidity risks, a comprehensive analysis of large banks' structural liquidity ratios is complemented with a variety of liquidity stress tests. The structural analysis considers the Basel III liquidity coverage ratio (LCR) and funding concentration. While the former measures short-term liquidity risks, the latter ratios gauge more structural longer-term refinancing and funding risks. Cash flow-based liquidity stress tests were conducted using public (LCR disclosure) and, for the six G-SIBs - supervisory (FRB) data. This approach employs multiple scenarios of increasing severity covering a 30-day horizon with varying assumptions regarding liquidity buffers and shocks to cash inflows and outflows.

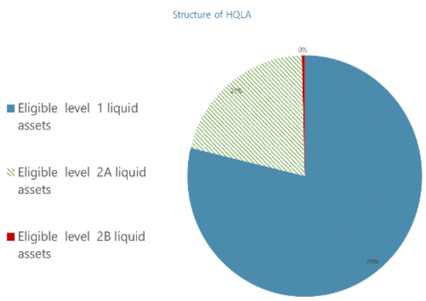
Funding Structure and Concentration

91. Banks rely on cash, central bank reserves and U.S. Treasury securities to meet expected and stressed outflows, but Non-GSIBs hold smallest relative amount of highly liquid assets. The quality of HQLA is very high (see Figure 23), as nearly three-quarters of it consists of highly liquid assets (such as Treasury securities) which tend to perform a role of safe heaven during market distress events. At the same time, HQLA assets represent just a fraction of all potential sources of liquidity in a stressed environment. All unencumbered assets can be used to obtain liquidity in a market or (subject to collateral eligibility) a central bank. While data on asset encumbrance is not available, the FSAP team used balance sheet FR Y9 data for structural liquidity assessment. Overall, in the current low yield environment, banks tend to hold bonds with longer maturities which implies lower liquidity and higher haircuts for sales and/or repo transactions. The share of HQLA is highest in market trading banks, which reflects their market making activities and higher reliance on wholesale funding. Smaller domestic banks have lower regulatory liquidity requirements, hence target lower liquidity ratios overall.

[46] See "Vulnerabilities associated with leveraged loans and collateralized loan obligations," Financial Stability Board, December 19, 2019.

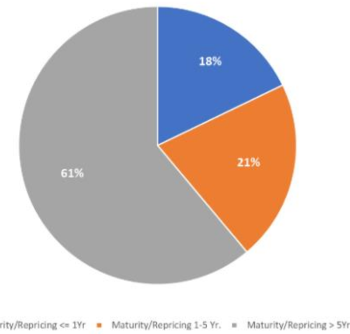
Figure 23. United States: Funding Structure and Liquid Assets

Much of the HQLA is comprised of Treasury securities, cash and CB reserves.

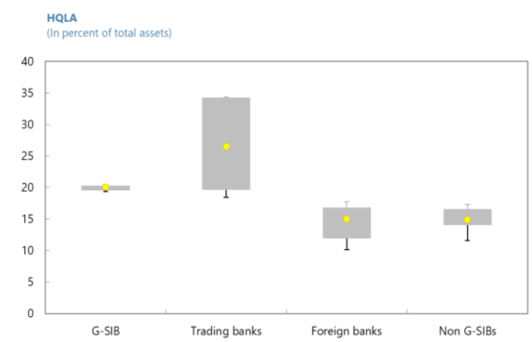


Sources: IMF staff estimates

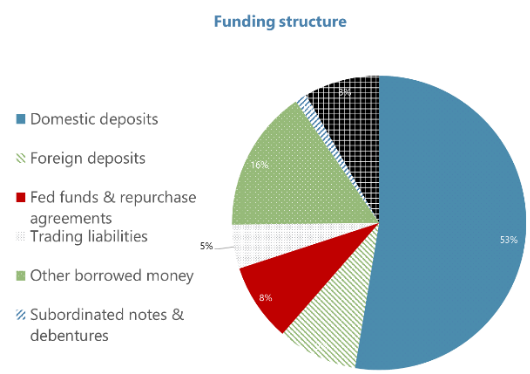
Most of the securities banks hold are long-term, hence subject to higher haircuts for secured funding transactions.



Foreign banks and Non-GSIBS have lowest relative HQLA buffers.

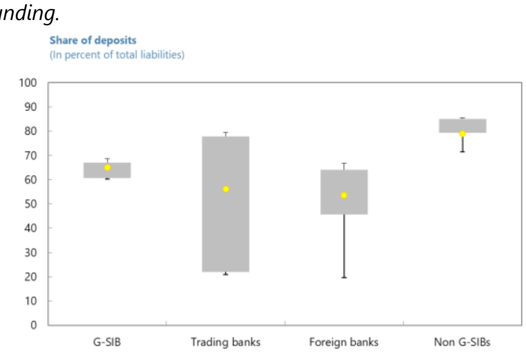


Domestic deposits establish the largest funding source for banks.

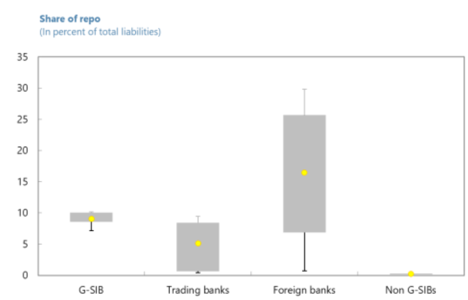


Sources: IMF staff estimates

...Non-GSIBs have high share of stable, deposit-based funding, while trading banks and foreign banks rely on other types of funding.



Foreign banks to a large extent rely on secured lending inflows, thus vulnerable to disruption in secured funding market.



Sources: IMF staff estimates. Yellow dots represent sample median values while bars—quartiles.

92. Funding structure shows reliance on domestic deposits. Most of the domestic banks (G-SIBs and Non-GSIBs) rely on stable deposit-based funding sources, while some market trading banks as well as the majority of foreign-owned banks often depend on repo markets. COVID-19 crisis and massive market liquidity support provided by the Fed led to a significant (US$1 trillion) increase in bank deposits by households and corporates (as of Q1 2020). In case of repo market distress and/or funding shocks, these banks would face large challenges to maintain adequate liquidity. Due to stable funding sources and low reliance on secured and unsecured interbank borrowing, Non-GSIBs have the lowest share of highly liquid assets in their assets.

Structural Liquidity Risks[47]

93. All banks have LCR ratios above 100 percent (Figure 24). All banks in the sample meet 100 percent LCR requirements, albeit some of them only due to a 70 percent outflow multiplier applied by smaller banks (mostly Non-GSIBS). G-SIBS tend to have marginally lower LCR, due to the two factors: (i) the maturity mismatch add-on and (ii) higher assumed outflows due to absence of 70 percent outflow multiplier. To mitigate intraday mismatch risk when calculating LCR, supervisors require large systemically important banks to include maturity mismatch add-on in calculating LCR. The add-on reflects the largest potential gap within the 30-day period. This add-on is applied to selected banks (17 out of 33 in our sample) and requires them to keep additional liquid assets equivalent to 1 percent of total liabilities on average. Non-GSIBs have considerable structural liquidity risks: i) they have large contractual funding gaps, some of them have largest in the sample off-balance sheet committed facilities coupled with lowest expected utilization rates (Figure 24). Moreover, as highlighted in FRB (2017) publications,[48] commercial banks use Federal Home Loan Banks (FHLBs) as short-term wholesale funding providers, partially to benefit from LCR requirements (a maximum 25 percent run-off rate for FHLB advances in 30 days). FHLBs receive some of their funding form Money Market Funds (MMFs), hence any funding distress related to the MMF funding withdrawal could lead to a reduction of funding FHLBs provide to commercial banks. Withdrawal of funding from banks may be a source of risk. The IMF analysis conducted by FRB using supervisory data revealed that potential liquidity squeeze due to withdrawal of funding from FHLBs from the six largest G-SIBs is insignificant.[49] An additional set of scenarios was used to test the impact of a closure of repo markets for other than HQLA1 type of collateral (discussion and results in the Liquidity Stress Testing section).

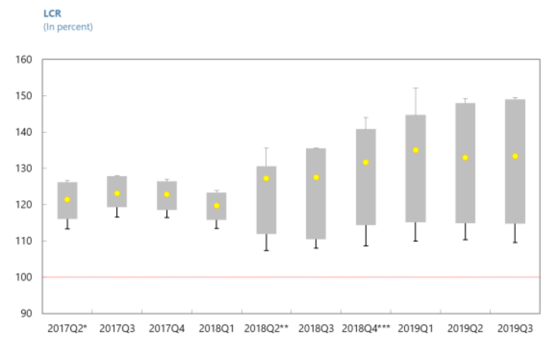
[47] Structural liquidity analysis as well as liquidity stress test focus on idiosyncratic (i.e. bank specific) risks and ignore system-wide distribution of liquidity as well as evidence that liquidity may dry up for some banks and at the same time other banks may experience large inflows.

[48] See https://www.federalreserve.gov/econres/notes/feds-notes/the-increased-role-of-the-federal-home-loan-bank-system-in-funding-markets-part-3-20171018.htm (accessed on 01/31/2020).

[49] At the same time, the importance of FHLBs on the rest of the banks in the sample was not tested due to the lack of access to supervisory data.

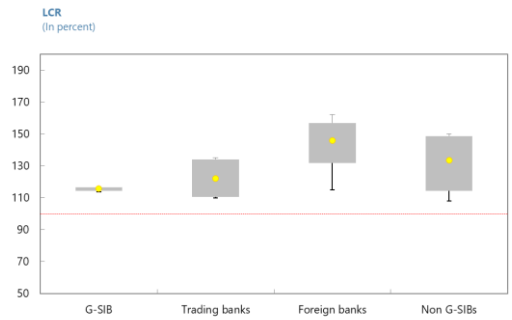
Figure 24. United States: Structural Liquidity Ratios

The median LCR ratio increased since 2018 and all banks have buffers above 100 percent…

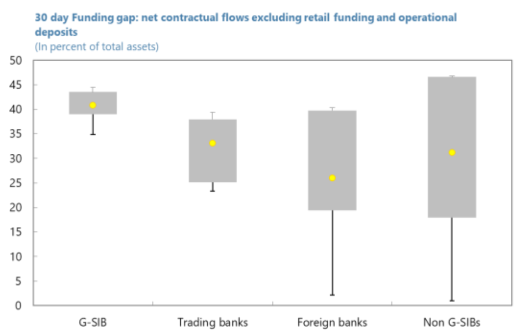


* 8 banks (G-SIBs), ** 17 banks, *** 33 banks.

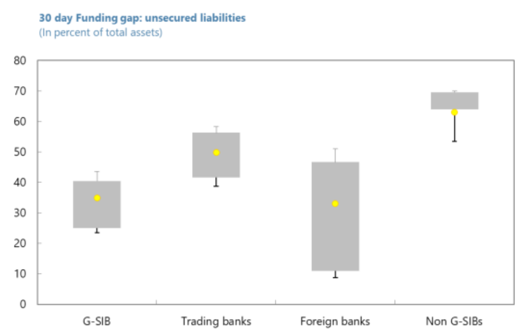
…with foreign banks maintaining highest average ratios



Overall, liquidity risk expsoure is high, with the 30 day funding gap close to 40 percent of total assets…

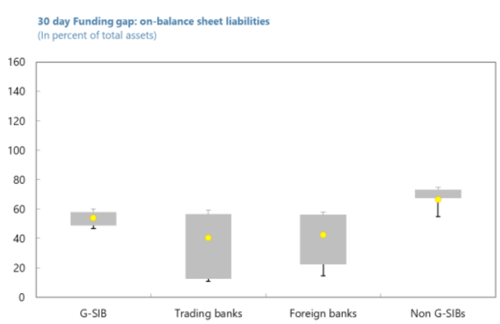


*Non-GSIBs have the highest unsecured funding gap, but the source of the gap is stable retail deposits which are typically insured and sticky**

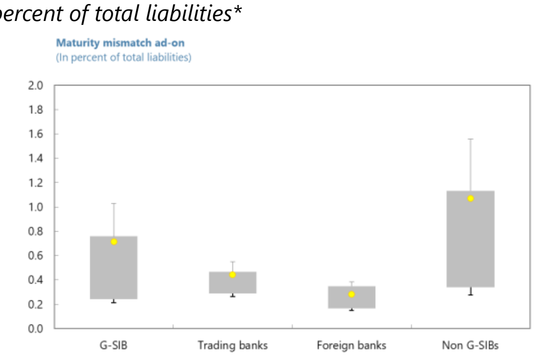


* Calculated as Deposits+Unsecured funding outflows – Inflows over total liabilities

Excluding off-balance sheet commitments, 30 day contractual funding gap is on average of 50 percent of TA



*Maturity mismatch add-on is on average an additional 1 percent of total liabilities**



*only some banks in the sample are subject to add-on requirements.

Sources: IMF staff estimates. Yellow dots represent median values while bars – quartiles. Red line – 100 percent minimum requirement (LCR).

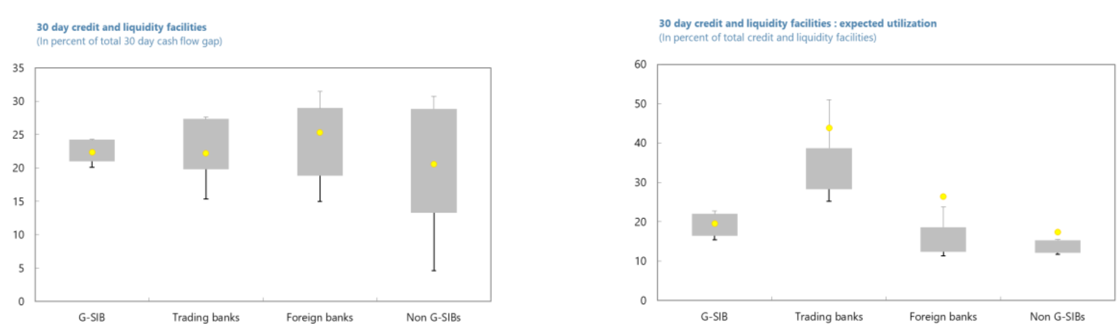
94. The gap between contractual inflows and outflows at the 30-day horizon excluding retail and operational deposits is high, and mostly driven by off-balance sheet financing facilities. The contractual funding gap[50] represents the most severe liquidity risk scenario for a bank. As evidenced during crisis times, affected banks experience outflows approaching contractual maturity. On-balance sheet net cash and securities flows (including retail, sight and operational deposits) over 30-day period constitute on average around half of banks' balance sheet. Off balance sheet credit and liquidity facilities constitute another 25 percent of Total Assets (TA). Most of these commitments are credit lines to corporations and households (credit cards), loans to other financial institutions, including mutual, investment, hedge funds. Banks do have leeway to estimate expected utilization of such lines for LCR purposes.

95. Evidence suggests that in the past banks with a low utilization rate of credit and liquidity facilities may underestimate liquidity risks (higher outflows than expected) during stress scenarios.[51] As evidenced during the GFC**,** and during the COVID-19 stress period**,** more financial and nonfinancial counterparties utilize revolving credit facilities (due to inability to obtain term loans, refinance existing debt, receive trade credit, etc.), credit card accounts, etc. as loans of last resort before declaring insolvency or illiquidity. In a business as usual scenario, banks may underestimate potential outflows due to the need to grant such facilities in stressed market conditions. For example, many of these loans may be committed, but have multiple covenants or be uncommitted with a bank having an option to unilaterally cancel the line. While it would be perfectly rational for a bank to cancel the lines, macro consequences of such a collective behavior would lead to further increase in corporate default rates. As evident from the LCR disclosure data, some of the Non-GSIBS have a high share of credit and liquidity facilities coupled with low expected utilization rate (Figure 25).

Figure 25. United States: Credit and Liquidity Facilities and their Utilization

Most of the banks expect that only about a quarter of amounts of credit and liquidity facilities will be utilized…

….with Non-GSIBS having the lowest modeled ratios.



Sources: IMF staff estimates. Yellow dots represent median values while bars—quartiles.

[50] Measured as all contractual inflows minus contractual outflows.

[51] See for example research by Reich and Falato (2019) which documents that during stress times firms are more likely to draw banks' credit lines and the FSB report "Vulnerabilities associated with leveraged loans and collateralized loan obligations," Financial Stability Board, December 19, 2019" which highlights LCR limitations by not distinguishing higher credit utilization rates by lower rated corporates.

Liquidity Stress Testing Methodology and Scenarios

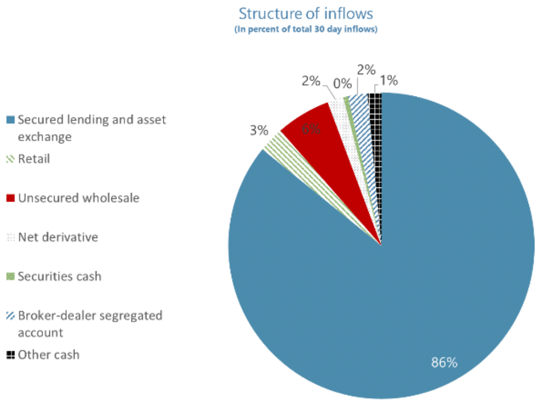
96. Liquidity stress tests incorporated various assumptions on how banks and their clients would behave under stressed market conditions. To deal with parameter uncertainty, the cash flow tests were conducted over a wide range of scenarios featuring different degrees of severity. Public LCR cash flows disclosure templates were used to calculate system-wide average inflow/outflow parameters as well as haircuts on HQLA.

97. Haircuts on liquid assets holdings of banks are based on an empirical attempt to quantify asset fire-sales during different market liquidity regimes. Multiple types of securities (Treasury, Corporates, Mortgage-Backed, U.S. Agencies, etc.) are included into Counterbalancing Capacity (CBC) of banks. The stress test applied non-linear estimation techniques, such as Markov regime switching models, to calibrate haircuts on CBC securities. It was assumed that during distress in the markets, these securities will be sold under asset fire sales prices, i.e., with significant haircuts (see Appendix XVII). Haircuts were determined based on collective amount of assets sold (as opposed to linear haircuts and individual amounts). The estimations reveal, that asset prices (haircuts on them) tend to behave non-linearly with haircuts being much higher during market turmoil. Increase in market volatility tends to be a good predictor of illiquidity, thus higher haircuts on assets sold.

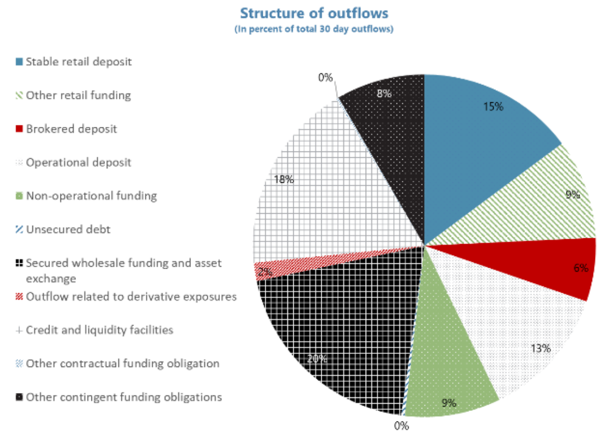
98. Secured cash inflows and off-balance sheet commitments represented the key risk drivers in the 30-day tests (Figure 26). Liquidity stress test scenarios assumed wholesale funding shock, high utilization of credit lines and asset fire-sales. In line with key risks stemming from corporate sector, it was assumed that banks would need to provide liquidity to cash strapped companies. This scenario assumed a gradual increase in utilization ratios of credit and liquidity facilities. Another scenario assumed withdrawal of wholesale funding, including a partial closure of repo markets. The most important caveat is that stand-alone liquidity stress tests are not meant to simulate redistribution of liquidity within the banking system, i.e., situations when withdrawal from one bank or group of banks leads to an increase in inflows in another one(s) or when credit line utilization leads to redistribution of deposits within the same bank.

Figure 26. United States: Cash Flows Over 30-Day Period

Secured funding inflows (asset swaps, reverse-repo) dominate in the 30-day cash flow window....



... while repos and off-balance sheet commitments are the largest items on the outflow side,



Source: IMF staff estimates based on public LCR data.

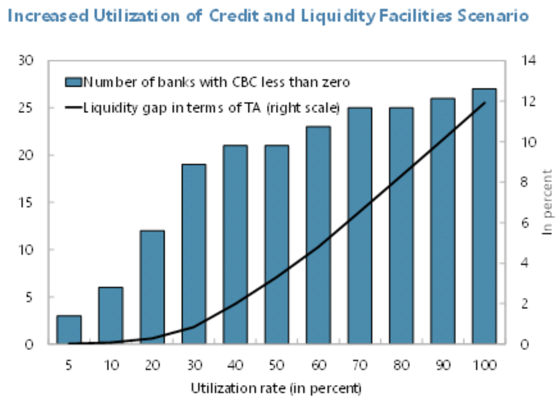
Liquidity Stress Test Results

99. A gradual increase in utilization of credit and liquidity facilities scenario leads to a significant shortage of liquidity in several individual banks, but the system-wide impact is contained (Figure 27). It is expected that in times of stress nonfinancial corporates, households would increase utilization of available credit and liquidity facilities from banks. Liquidity stress tests reveal, that many banks (including G-SIBs) would need additional liquidity to provide funding to distressed corporates and other institutions in times of wholesale funding stress or adverse conditions in the market, if drawdowns exceed 30 percent.[52] Depending on the share of committed and uncommitted credit lines, assumed credit conversion factors, additional depletion of CET1 ratios due to the increase in RWAs would be from 20 (minimum of 5 percent drawdown) to 250 basis points were banks to allow full drawdown of the lines. Failure to grant credit lines would lead to various non-linear feedback effects within the financial sector and further defaults of distressed (cash trapped) corporates. While the FRB actions at the outset of the COVID-19 outbreak helped to shore up liquidity, it is therefore important to ensure that banks have high enough liquidity buffers and predictable access to central bank liquidity facilities.

[52] The test assumed that banks' inflows/outflows follow LCR rates, except for higher (standardized for all banks) outflow (utilization) rates applied for credit and liquidity facilities. Full amount of HQLA without haircut is used to cover the gap. The test does not distinguish between committed/uncommitted lines.

Figure 27. United States: Liquidity Stress Testing Results

System-wide liquidity needs are small in case of increase in drawdowns on revolvers of up to 30 percent of utilization rates with some Non-GSIBS driving the overall impact due to assumptions about low expected drawdowns



Sources: IMF staff estimates using public LCR and FR 9Y disclosure data.

100. Additional cash flow-based stress test was conducted by the FRB using IMF scenarios and models to assess funding and market liquidity risks in the network of U.S. G-SIBs (see Appendix XVII for technical details[53]). The test focused on two key scenarios: (i) the LCR-based shock scenario, which used LCR stress parameters but assumed more severe outflow rates on contingent liquidity items, such as credit and liquidity facilities, derivatives, loss of rehypothecation rights; (ii) the LCR-based shock scenario coupled with the assumption of a partial closure of repo markets (i.e., repos with MBS, agency, and corporate securities not possible) and outflow rates on selected cash flow items the same as in scenario i).

101. G-SIBs have enough liquidity to withstand severe LCR-like liquidity shock coupled with additional contingent liquidity and committed line outflows over 1-, 5-, and 30-day horizon. Compared to the results of the analysis above conducted for 35 banks using public LCR data (where a number of Non-GSIBs were illiquid), the G-SIBs do not have a gap after HQLA sales and do not need to repo assets. The liquidity gap and impact on CET1 are thus zero across all scenarios and maturity horizons. There is also no further transmission of funding risk in the network due to counterparty exposures among the G-SIBs.

102. Closure of the repo market for non-treasury securities would lead to a small and short-lived cash flow gap in several banks, but the system-wide impact from asset fire sales is small.[54] Unless daily asset trading volume exceeds five times the historic average, an immediate

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[53] The analysis was performed by the FRB staff using IMF scenarios and models and does not reflect the views of the U.S. regulators. Further details are in Caceres, C., M. Leika, D. Seneviratne and E. Yu "Keeping It Real": Enhanced Network Analysis in IMF FSAPs." IMF Working paper (2020c), forthcoming.

[54] The test was performed before the COVID-19 and did not consider that ability to repo or sell US sovereign securities may be limited. Moreover, that test did not considered increase in RWAs because of utilization of credit lines.

closure of the non-Treasury repo markets affects banks during the one-day to five-day horizons (Figure 28). The worst observed cash flow gap (before a bank needs to repo treasury securities) would be from 0.09 percent of total assets (one day) to 0.27 percent (one week). This gap is fully covered by other inflows on the 30-day horizon (i.e., no shortage of liquidity is observed). If affected banks liquidate assets in stressed markets, this would lead to an insignificant 9 basis points decline of CET1 on average (because the assets liquidated are treasury securities). No bank would become technically illiquid and there would be no additional losses due to interconnectedness among G-SIBs. It is worth noting, that in case of a complete closure of repo markets (i.e., including Treasury securities), affected banks would face higher asset liquidation needs. Albeit probability of such a scenario is very low. Withdrawal of funding from FHLBs itself would not lead to a cashflow gap.

103. Closure of repo market may lead to illiquidity of a G-SIB when this severe shock is combined with an increased utilization of credit and liquidity facilities by other financial institutions or corporates. The stress test found one G-SIB illiquid, albeit under an assumption of very high outflow rates from the credit and liquidity facilities (40 percent and above) and only under a 30-day test horizon. Overall, the impact of asset fire sale, including repricing of remaining assets on affected G-SIBs balance sheets, is small with a similar decline in CET1 capital by 9 basis points as in the previous case, and funding gap of only 7 basis points of total assets in the worst-case scenario (Figure 31). The liquidity impact depends on changes in market depth: the largest impact on daily liquidity of banks comes from assumptions about changes in average daily trading volumes of HQLA securities.

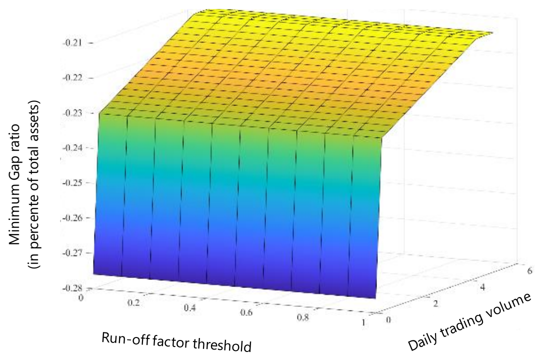
104. Overall, "liquidity pipeline" risk in the financial system is high as banks maintain their central role in providing liquidity to other financial and nonfinancial customers which do not have access to central bank facilities.[55] Analysis in the next chapter shows how the sample of banks is linked to the rest of the banking and financial system. This analysis and liquidity stress tests reveal that banks' role in liquidity provisions to the financial system is critical: failure to grant credit lines would lead to various non-linear feedback effects within the financial sector and further defaults of corporates. It is therefore important to ensure that banks have high enough liquidity buffers, predictable access to central bank liquidity facilities.

[55] See for example, Sooji Kim, Matthew C. Plosser, and João A.C. Santos "Macroprudential Policy and the Revolving Door of Risk: Lessons from Leveraged Lending Guidance," FRB NY Staff Reports May 2017 Number 815. The report estimated that nonbank financial institutions (NBFIs) increased borrowing from banks by 125 percent in 2016–2017. The loans were used to extend NBFIs' investments into leveraged loans.

Figure 28. United States: Liquidity and Asset Fire Sales Scenario for U.S. G-SIBs

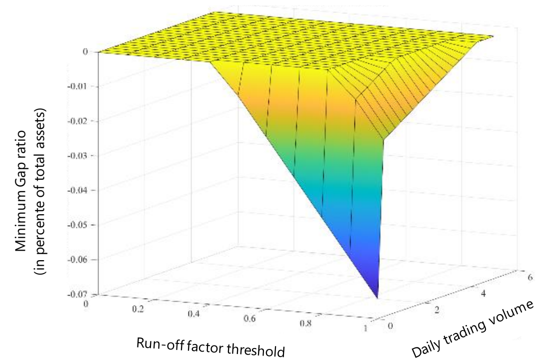
Impact of the closure of the repo market is small, and on its own will not lead to illiquidity of banks (one-week horizon is shown), especially if they can sell multiple amounts of liquid securities (5 times average daily trading volume in the figure below means that the gap becomes zero).

Minimum Gap Ratio after Liquidation
(In percent of total assets; horizon = 1 week; liquidation strategy for funding shocks = slicing; stress regime = stress ; repo threshold = 1 times estimated threshold)



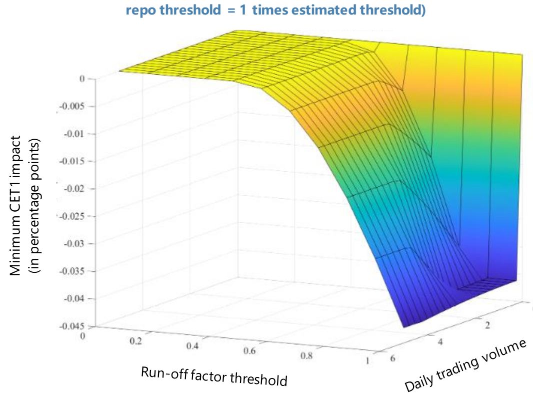
Under the 30-day scenario, all G-SIBs would retain positive cash flow gap if outflow shock on credit facilities would remain below 40 percent.

Minimum Gap Ratio after Liquidation
(In percent of total assets; horizon = 30-days; liquidation strategy for funding shocks = slicing; stress regime = stress ; repo threshold = 1 times estimated threshold)



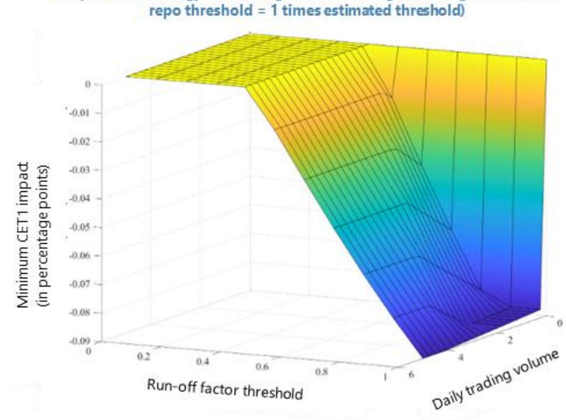
CET1 capital impairment solely due to liquidation losses is about 4.5 basis points

Minimum CET1 Impact: Liquidation Loss Only
(Liquidation strategy for funding shocks = slicing; stress regime = stress ; repo threshold = 1 times estimated threshold)



...while marked-to-market losses are also around the same level, thus yielding a combined CET1 impact of 9 basis points

Minimum CET1 Impact: Liquidation Procedure Only
(Liquidation strategy for funding shocks = slicing; stress regime = stress ; repo threshold = 1 times estimated threshold)



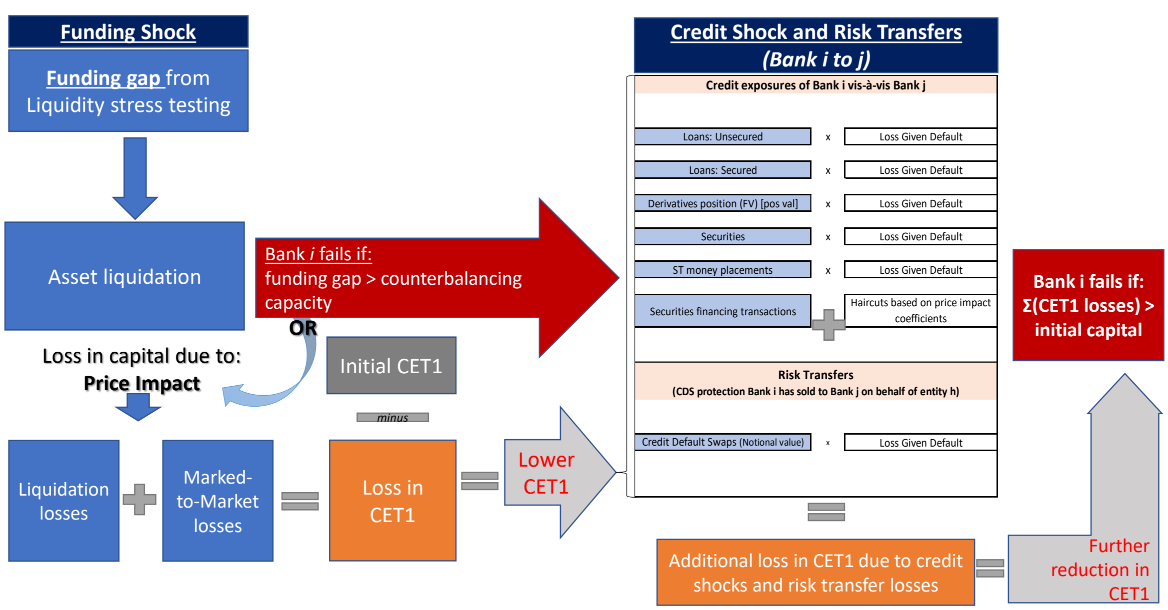
Sources: IMF calculations performed by the FRB based on FRB supervisory data.

C. Banking Sector Interconnectedness

Domestic Interbank Network Stress Testing

105. Modelling domestic bank interconnectedness reveals that direct (funding and credit) contagion among G-SIBs is small and failure of one G-SIB would not lead to direct default of another one. The joint interconnectedness modelling exercise performed by the FSAP team in collaboration with the FRB staff assessed the propagation of such idiosyncratic and systemic shocks through the network of U.S. G-SIBs, linking solvency and liquidity risks (Figure 29). The analysis considered unsecured, secured (repos/reverse repos, swaps, etc.) and contingent (derivatives, CDS contracts) exposures among six largest G-SIBs. While the closure of non-Treasury repo markets coupled with severe scenario parameters would lead to one G-SIB becoming illiquid over 30-day horizon, the impact of asset fire sale on remaining banks in the network is limited to a decline in CET1 by 25 basis points, depending on banks' asset liquidation strategies and daily trading volume constraints (Figure 30).[56]

Figure 29. United States: Enhanced Interconnectedness Analysis—Solvency and Liquidity Risk Linkages



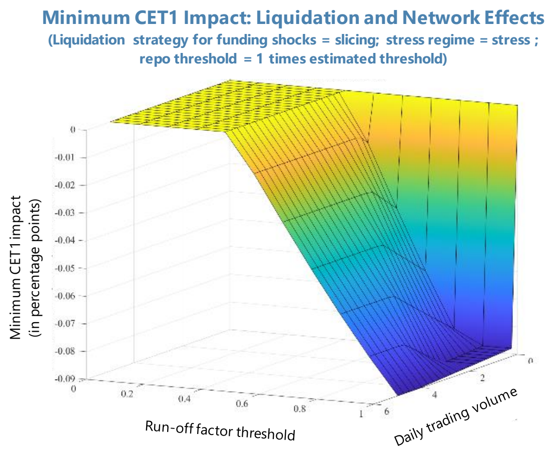
Source: IMF staff.

Note: The analysis is based on two stages. First stage—funding liquidity risk based on cash flow data, second stage—network contagion model. The first stage simulates conditions under which a bank would be illiquid or insolvent under severe yet plausible funding shocks; in the second stage a bank which fails the first stage (illiquid because of revaluation of its assets using fire-sale prices) does not meet its contractual obligations to the other banks in the network. Entity h in this illustration refer to any entity outside of bank i and j.

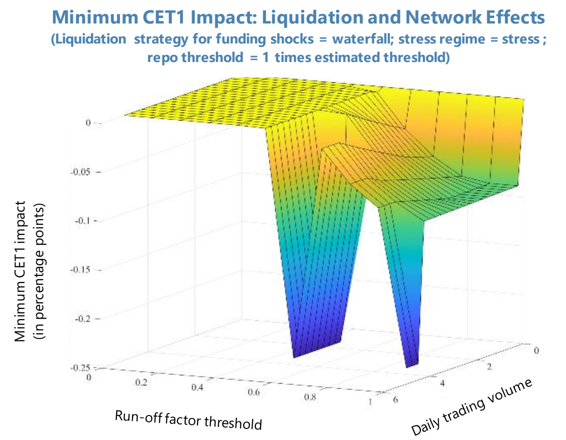
[56] The test used two strategies: waterfall when banks liquidate most liquid assets first and slicing when banks liquidate proportional amount of each type of security.

Figure 30. United States: Liquidity and Asset Sales Scenario Propagation in the U.S. G-SIBs Network

The impact of asset sales on CET1 would be 9 basis points for affected banks if they use proportional liquidation approach to sales (slicing)…



…the network contagion and fire-sales impact would be higher if banks were to adopt waterfall liquidation strategy (i.e., liquidate most liquid assets first), albeit no one bank would be insolvent and final impact would be 25 basis points of CET1 loss.



Sources: IMF calculations performed by the FRB based on FRB supervisory data.

Cross-Border Bank Network Analysis[57]

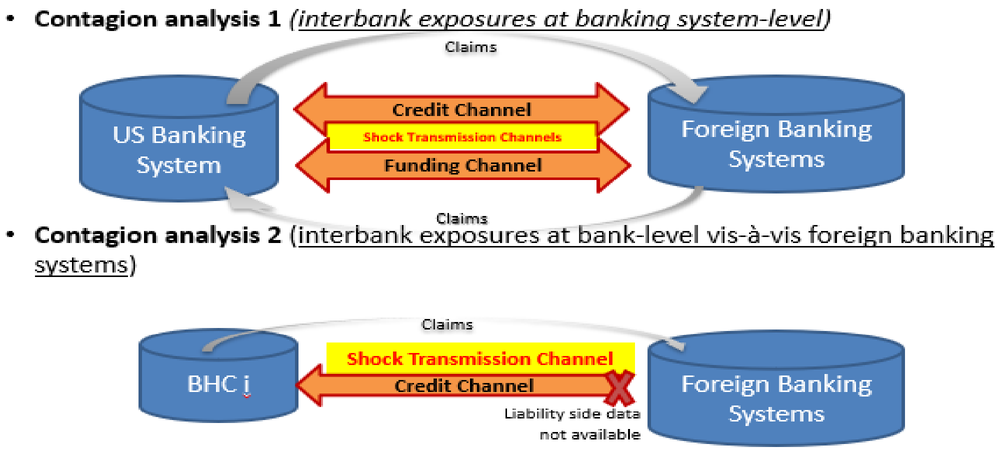
106. Potential cross-border contagion risks are assessed using exposure-based network analyses. The analyses aim at quantifying the capital impairment incurred by the U.S. banking system or BHCs due to an idiosyncratic shock originated in a counterparty banking system or transmitted via a counterparty banking system (i.e., the cascade effect). Two shock transmission channels are explored. First, spillovers are assumed to be transmitted through a credit shock in which—due to a hypothetical default of a counterparty banking system—the U.S. banking system/BHC does not recover a fraction of its claims on the system in distress. Second, spillovers are amplified due to a funding shock assuming that the hypothetical default of a counterparty banking system would lead to liquidity pressures owing to foregone funding and asset fire sales. These analyses are performed using the network contagion model and methodology developed by Espinosa-Vega and Sole (2010).[58] The cross-border bank network analysis consists of two separate

[57] Data used in the analysis does not allow us to distinguish between secured and unsecured exposures as well as understand what type of collateral is used for secured exposures. Therefore, the analysis is based on very conservative assumptions that all of the exposures are unsecured. It is worth noting however that, based on supervisory data, 2019 France FSAP stress testing technical note reveals that majority of U.S. dollar funding exposures of the French banking system are secured exposures. Based on BIS cross-border exposures, nearly 50 percent of all reporting countries exposures is denominated in U.S. dollars.

[58] Due to the lack of granularity in the available cross-border exposures data, cross-border network analysis does not use the enhanced interconnectedness model developed during this FSAP in collaboration with the FRB staff for the domestic interconnectedness analysis.

analyses: the first set of simulations assesses network contagion at banking system-level; the second set of simulations assesses network contagion at U.S. BHC vis-à-vis foreign banking system level (see Figure 31).

Figure 31. United States: Schematic Representation of the Network Contagion Analyses



Source: IMF staff.

Contagion Analysis 1: Network Contagion at Banking System Level

107. Network analysis in this section quantifies the potential spillovers[59] between the U.S. banking system and large counterparty banking systems through several types of exposures.[60] First, spillovers emanating from exposures unrelated to intra-group positions are assessed, thus quantifying the spillovers between U.S.-owned banks and foreign-owned banks. Nevertheless, the presence of branches and subsidiaries (the latter to a lesser extent in many cases based on the regulatory landscape) may alter the spillover transmission between banking systems; For example, sizable exposures may exist due to large credit lines provided by parent entities. The role of financial centers, large banks, and foreign banking operations in intermediation of cross-border flows of funds—for instance related to FX transactions including U.S. dollar funding activities—may also amplify potential spillovers particularly in deleveraging episodes. The second and third exposure types aim at capturing additional spillovers due to such activities, while the distinction between the

[59] The term "spillovers" in this section refer to the capital impairment incurred by an entity or a system due to distress in another banking system.

[60] The analysis is based on BIS consolidated and locational statistics (both residency and nationality basis) and uses the 10 largest counterparty banking systems for which bilateral consolidated and locational interbank exposures are available.

two exposure types rely on how the banking system is defined (i.e., banking systems including foreign operations vs. banking systems based on the domicile).[61]

108. The following scenario and assumptions are used in the simulation on shock transmission through credit (solvency) and funding (liquidity) channels:

- The scenario considers the effect of a severe credit shock combined with a funding shock under the assumptions below;
- Assumptions: 100 percent of the interbank lending provided to the banking system in distress is not recovered (i.e., loss-given-default parameter is 1.0).[62] Assets are liquidated to meet the funding gap at a 50 percent discount during an asset fire sale. It is also assumed that banking systems will be able to roll-over 65 percent of the lost funding through other means such as raising equity (therefore, the share of lost funding that is not recovered is 0.35).

109. The analysis suggests inward spillovers into the U.S. banking system from other large counterparty banking systems is limited on average. The sources of potential vulnerabilities—due to direct exposure as well as through the cascade effect of other foreign banking systems with exposure to the U.S. banking system—are concentrated in few large foreign banking systems such as the United Kingdom and Japan (Figure 32). At a much lower intensity, potential vulnerabilities may also arise from the banking systems in Canada, Germany, and France.[63] The results also suggest that the quantification of vulnerabilities may benefit from capturing different types of exposures such as those that are previously discussed, as the intensity of spillovers may vary based on the nature of stress episodes. Potential vulnerabilities could in fact diverge depending on the type of exposure assessed. Specifically, potential inward spillovers into the U.S. banking system ranges between 2–8 percent of initial regulatory capital of the U.S. banking system depending on the type of exposure. This capital impairment is transmitted mostly via the credit channel (i.e., due to direct and second-round credit exposures). However, incorporating funding shocks in the simulations increase the systemic importance of some banking systems from a liquidity point of view, thus increasing inward spillovers into the U.S. banking system by one-third.

110. The U.S. banking system has the potential to be a source of significant contagion to large banking counterparts. In particular, the potential contagion risks transmitted through a

[61] Specifically, in the second exposure type, the residency-based exposures are reorganized to include exposures of branches and subsidiaries domiciled outside the parent country along with the parent country exposures. The third type is based on residency-based exposures, where foreign branches and subsidiaries are included under the host banking system.

[62] A loss-given-default rate of 100 percent is used with the assumption that these exposures are unsecured exposures and due to the difficulty of recovering assets at the time of banking system failure. Data used in this analysis does not allow us to distinguish between secured and unsecured exposures as well as understand what type of collateral is used for secured exposures. Therefore, the analysis is based on very conservative assumptions that all of the exposures are unsecured.

[63] These five banking systems are the largest potential spillover transmitters into the U.S. banking system based on all three exposure types assessed.

credit shock result in an impairment of about 10 percent of the initial regulatory capital of recipient foreign banking systems on average (Figure 33). Additional amplification of potential contagion through the funding channel also amounts to about one tenth of the capital impairment from the credit shock. However, the contagion effect could also vary depending on the type of exposure that would transmit spillovers. For instance, the average impairment stemming from contagion risk to foreign-owned banks could increase from 10 percent of capital to 40 percent of initial capital when contagion risks to host banking systems is considered.

111. Contagion risks are concentrated in several banking systems and concentrations vary depending on the type of exposures (Figure 32). Canadian-owned, Japanese-owned, and French-owned banks (latter to a lesser intensity) at aggregate level have the highest potential contagion risks due to a hypothetical systemic shock to U.S.-owned banks. This alludes particularly to heavy financial intermediation activities between foreign-owned banks and globally active U.S. banks including dollar funding activities carried out via large U.S.-owned banks. On the other hand, when foreign banking systems including branch and subsidiary operations are considered, the U.K. banking system has the highest potential for contagion. This is not only due to the United Kingdom's direct exposure to the U.S. banking system, but also due to the cascading effect owing to U.K.'s exposures to other foreign banking systems that are large counterparties of the U.S. banking system. The role of the U.K. banking system as a financial center in intermediation of cross-border flows is in part behind these large contagion effects.[64] The host banking systems in Canada, the United Kingdom, and Japan (France and Germany to a lesser extent) have large potential for contagion, also emphasizing the ability of contagion to cascade in the presence of branch and subsidiary operations.

112. Potential contagion from the U.S. banking system would still be significant under a less severe scenario. Given the uncertainty surrounding the loss-given-default parameter used, as it may vary depending on the nature of exposures—unsecured or secured—and the collateral pledged, a sensitivity analysis is performed. For robustness, the scenario assumes a 50 percent loss-given-default rate.[65] Results reveal that even under this scenario, foreign banking systems would lose a sizable share of their capital due to contagion from the U.S. banking system by about 5 percent to 15 percent of their initial regulatory capital (Figure 34). Compared to the severe scenario presented earlier, this is about a one-half reduction in losses. Similar to the previous simulation results, contagion is specifically larger in the U.K., Japan, and Canada. Potential capital impairment of the U.S. banking system is also about one-half lower in this scenario (ranges from 1–3 percent of initial capital of the U.S. banking system).

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[64] Belgium also has large potential contagion risks, owing to financial intermediation such as cross-border dollar funding activities conducted through Belgium banks' foreign operations. Spillover analysis performed at host country-level reveal that the presence of foreign operations increases the potential for contagion to the host banking system.

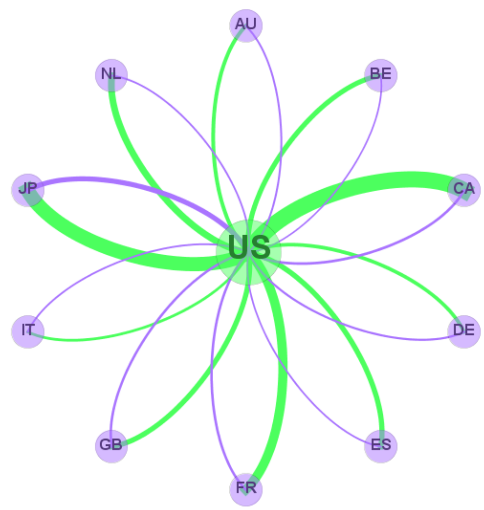
[65] Banking systems is assumed to roll-over 90 percent of lost funding (share not recovered = .1) under this scenario, while assets are liquidated at a 10 percent haircut.

Figure 32. United States: Cross-Border Inward and Outward Spillovers by Type of Exposure

(Purple edges = inward spillovers to the U.S. banking system; green edges = outward spillovers)

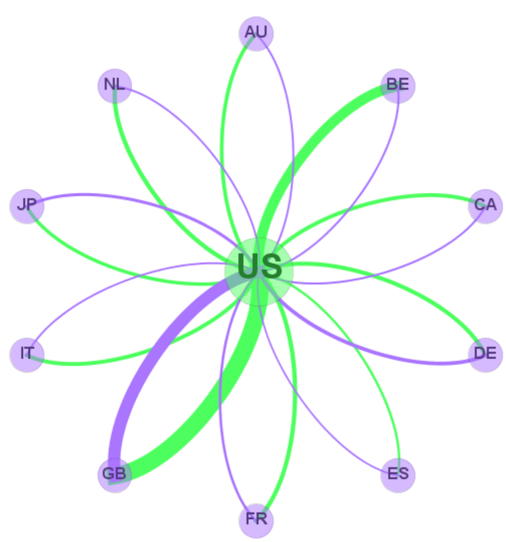
Exposure Type 1: Spillovers between U.S.-owned and Foreign-owned Banking Systems

Banking system defined at parent country level (without intra-group operations): against counterparty banking systems on ultimate counterparty/ guarantor residency

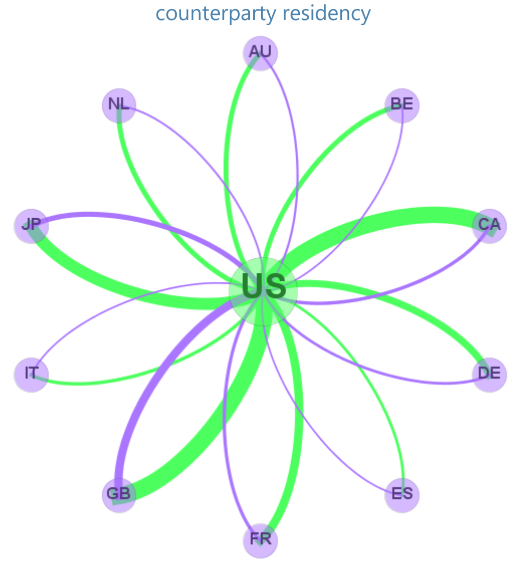


Exposure Type 2 & 3: Spillovers between U.S. and Foreign Banking Systems (with Intra-group Operations)

Exposure type 2: banking system defined at parent country level: against counterparty banking systems based on counterparty residency



Exposures type 3: banking system defined at host country level: against counterparty banking systems based on counterparty residency

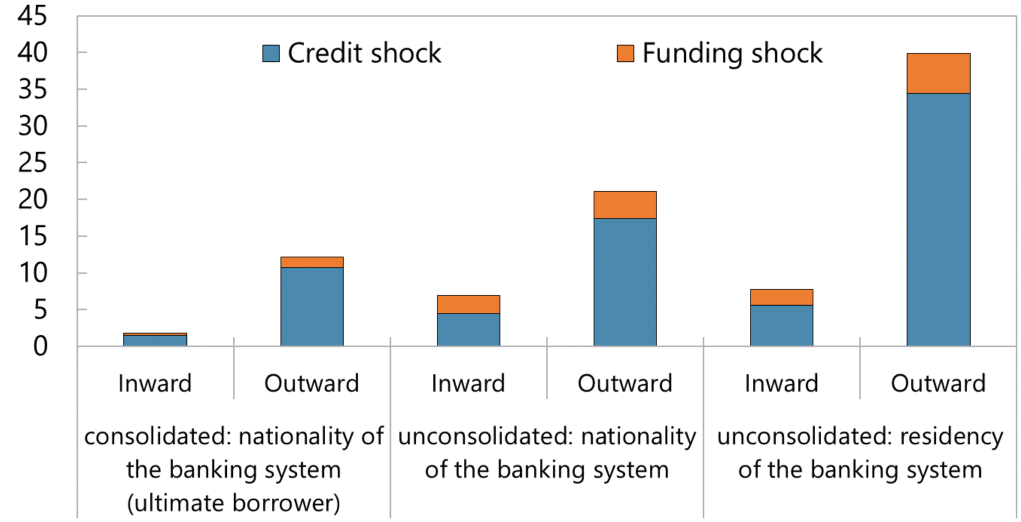


Sources: BIS, IMF FSI, IMF staff.

Edge width = proportion of contagion vis-à-vis the recipient banking system. Edge color = direction of contagion; green edges are the potential contagion emanating from the U.S. banking system into top 10 foreign banking systems (i.e., outward spillovers), while purple edges are the potential vulnerabilities (i.e. inward spillovers) from foreign banking systems into the U.S. banking system.

Figure 33. United States: Average Spillover between the U.S. Banking System and Foreign Banking Systems

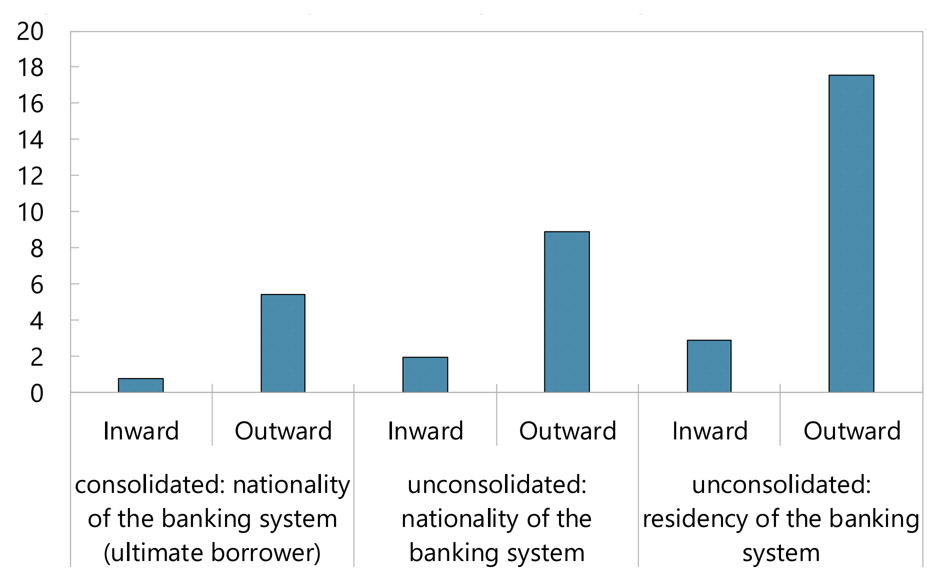
(In percent of initial capital of the spillover recipient)



Sources: BIS, IMF FSI, IMF staff.

Figure 34. United States: Sensitivity Analysis using a Less Severe Scenario: Average Spillover between the U.S. Banking System and Foreign Banking Systems

(In percent of initial capital of the spillover recipient)



Sources: BIS, IMF FSI, IMF staff.

Contagion Analysis 2: Network Contagion between U.S. Banks and Foreign Banking System

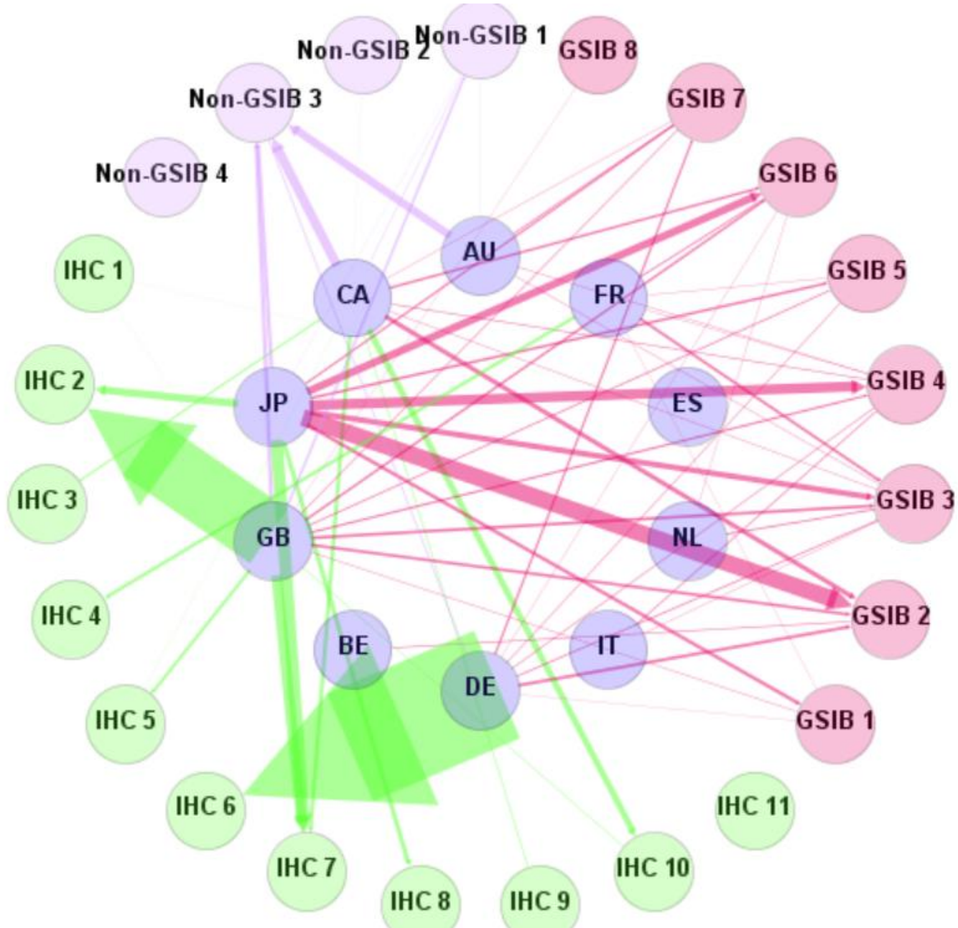
113. A separate simulation is performed in order to assess the spillovers at individual BHC-level using publicly available data on cross-border claims against foreign banking systems.[66] In the absence of liabilities-side data and bilateral bank-to-bank exposures, the analysis is performed under several major caveats. First, this analysis only captures the first-round effects direct exposures; in the absence of exposure against other banks in the network, the analysis does not capture the cascading effect due to other large counterparty banks' exposure to large foreign financial systems. Second, the simulations are limited to a credit shock scenario given the liability-side cross-border exposures are not available. This scenario assumes 25 percent of the credit provided to the foreign banking systems is not recovered[67].

114. Results reveal some concentrated inward spillovers due to a hypothetical distress in foreign banking systems transmitted through a credit shock, though spillovers are modest on average (Figure 35). Domestic G-SIBs have particularly larger direct inward spillovers emanating from the Japanese banking system. While the analysis is unable to capture the cascading effect given the data limitations, U.S. banks with limited inward spillovers may also experience larger spillovers if their counterparty exposure vis-à-vis the G-SIBs are sizable. On average, potential capital impairment incurred solely due to direct exposures by a G-SIB is about 1.2 percent of their initial regulatory capital. Other domestically owned BHCs in the sample on average have potential capital impairment of less than 1 percent of their initial capital, when the cascading nature of spillovers are not considered. Intermediate holding companies (IHCs) on average are susceptible to potential inward spillovers due to direct exposures at about 1 percent of initial capital. These potential spillovers could amplify in the presence of large counterparty exposures vis-à-vis the other banks in the network. However, significant concentrations exist among the IHCs against potential spillovers emanating from their parent banking systems.

[66] Data for this section comes from FFIEC 009a report.

[67] The assumption of LGD at 25 percent as oppose to a more stringent assumption at a higher LGD is used given the partial availability of the exposure data (i.e. exposure of a bank vis-à-vis a banking system, as oppose to bank-to-bank exposures).

Figure 35. United States: Bank-Level Inward Spillovers from Foreign Financial Systems



Sources: FRB FFIEC 009a , IMF FSI, IMF staff
Note: Edge (arrow) width represents the size of inward spillovers into the bank, proportionate to spillovers of other banks. Edge color corresponds to the group of the spillover recipient. The inner circle represents foreign financial systems.

LIQUIDITY STRESS TESTING FOR U.S. MUTUAL FUNDS

A. Objective and Scope

115. This stress testing exercise examines liquidity risk for U.S. mutual funds. The objectives are to assess whether mutual funds are able to withstand severe but plausible redemption shocks, identify which types of funds are potentially more vulnerable to liquidity risk and estimate and the extent to which funds can transmit shocks to the financial system.[68]

116. The emphasis is on fixed income mutual funds, since they invest in a range of fixed income assets with varying degrees of liquidity. Based on commercial data, the sample includes 2,743 funds for a net asset value of about US$6.4 trillion as of end-2019, covering the entire mutual

[68] For the remainder of the document "funds" refer to mutual funds unless specified otherwise.

fund universe tracked by the Investment Company Institute (see Appendix XI for details). The sample is subdivided into nine categories reflecting the type of fixed income instruments mutual funds invest in. The categories are IG and HY corporates, loan funds, global bond funds, EM funds, government bond funds, municipal bond funds, mixed funds and multi-strategy funds (Table 1).

D. Methodology

117. The stress tests are based on three pillars: calibration of the redemption shock, composition of asset sales and the price impact of sales. The analysis compares for each fund the level of redemptions with the level of highly liquid assets at the disposal of the manager. Then, following the shock, it is assumed that the manager will sell some of the assets in the portfolio according to a liquidation strategy. When assets are sold, sales are assumed to have a negative price impact on the market, the extent to which depends on the amounts of sales and on the absorption capacity of the market (see Appendix XII for details about the methodology).

Calibration of Redemption Shocks

118. One set of redemption shocks are calibrated based on historical data. For each fund, historical data are used to calibrate the redemption shocks based on the most extreme outflows observed in the past by funds in the same category. Within each of the nine fund categories, funds face the same redemption shock ('homogeneity assumption'), which is calibrated based on the average of the worst 3 percent net flows observed by funds in a given category.[69] The resulting levels of redemptions range from 7 percent of the net asset value for municipal bond funds to more than 15 percent for HY and EM bond funds, which tend to experience more volatile flows (Table 1). The redemption shock is also calibrated at fund-level ('heterogeneity assumption'), where each single fund faces an idiosyncratic shock based on its own historical net flows. The levels of shocks are in line with previous FSAPs (see IMF (2015, 2016, 2017, 2018)).

119. A second set of redemption shocks is calibrated using the adverse scenario. The banking sector adverse scenario is utilized to estimate redemption shocks for funds. Given the projected levels of macrofinancial variables, returns are estimated for each fund and given the flow-return relationship, net flows are estimated, as detailed in Appendix XII.[70] Overall, the redemption shocks are milder compared to the historical approach, with most funds facing levels of redemption below 3 percent (Table 1). However, under the adverse scenario, all funds face redemption shocks at the same time, which could result in a large amount of forced sales.

[69] As a robustness check, other thresholds and methods are used, resulting in twelve different redemptions shocks.

[70] Using the adverse scenario designed for the banking sector stress test allows the possibility to assess the aggregate impact of shocks across all mutual funds at the same time. This analysis therefore complements the historical approach, where results cannot be aggregated since the different fund categories would not face severe outflows all at the same time.

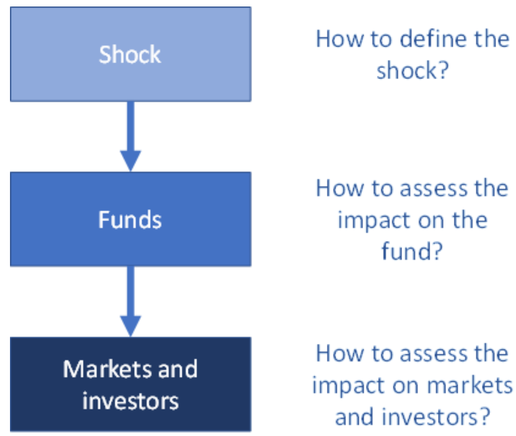
Table 1. United States: Mutual Funds Stress Test—Sample and Approach

Sample of U.S. Mutual Funds

Fund category	Net asset Value (US $ bn)	Number of funds
Corp. IG	2,427	608
Mixed funds	1,752	792
Municipal	799	567
Multisector	432	182
Government	326	161
Corp. HY	257	192
Global	247	87
Loan funds	91	58
EM funds	66	96
Total	6,398	2,743

Sources: Morningstar, ICI, IMF staff calculations

Steps in Mutual Fund Stress Tests



Redemption Shocks by Fund Category

	Historical approach		Adverse scenario		
Fund category	Homogeneity	Heterogeneity	Returns (%)	Flow sensitivity to returns	Net flows
Municipal	6.8	5.8	-1%	0.5	0.7
Mixed funds	8.6	6.7	-10%	0.3	2.8
Corp. IG	12.9	10.3	-2%	0.7	1.1
Multisector	13.2	9.9	-3%	0.6	0.9
Loan funds	13.3	12.3	-1%	0.9	0.8
Global	14.3	11.8	-3%	0.3	0.6
Government	14.4	11.3	1%	0.3	-0.5
HY	15.0	11.8	-7%	0.6	4.8
EM funds	17.5	13.8	-11%	0.9	10.3

Redemption shocks in % of NAV. Median net flows under the heterogeneity approach. Positive values indicate outflows.
Sources: Morningstar, IMF staff.

Liquidity Demands Raising from Derivatives Exposures

120. Variation margins on swap and forward exposures are estimated in the context of interest rate and foreign exchange shocks. For a sample of 10 funds with large derivative exposures totaling US$41 billion in total assets, variation margins are estimated assuming a 50 basis points interest rate increase and a 1 percent depreciation of the U.S. dollar against all currencies. The variation margins are calculated using the duration of each instrument, based on regulatory filings by mutual funds (SEC form N-PORT as of end-2019). It is assumed that variation margins can only be paid in cash, in line with industry practices.[71]

[71] According to the 2018 ISDA margin survey, cash accounts for 75% of collateral posted for variation margins (ISDA, 2019).

Ability of Funds to Withstand Shocks, Liquidation Rules, and Transmission of Shocks

121. Redemptions are compared to funds' holdings of highly liquid assets to assess their ability to withstand shocks. The redemption coverage ratio (highly liquid assets to redemption, both in percent of NAV) is used to estimate the ability of funds to meet redemptions without resorting to the sale of less liquid assets in their portfolio.

$$RCR = \frac{Highly\ liquid\ assets}{Redemption\ shock}$$

Highly liquid assets are estimated at fund-level using the composition of the portfolio and applying liquidity weights derived from Basel III framework for the calculation of High-Quality Liquid Assets (HQLAs).[72] When funds have an RCR below one, a liquidity shortfall is computed, as the difference between the redemption shock and the available highly liquid assets.

122. Fund managers can use different liquidation approaches when facing redemptions. Following the redemption shocks, we assume that fund managers will sell some of the fund assets to meet investors' redemptions. Different liquidation strategies can be used: vertical slicing (pro rata)—where the manager sells each asset class in proportion of their weight in the fund's portfolio—waterfall (where most liquid assets are sold first), or a mixed approach where cash is used first and then the manager follows a slicing approach.

123. The sales of securities by funds following redemptions can have an impact on markets. Given a redemption shock and a liquidation strategy, funds have to sell a given amount of securities across different asset classes. To estimate the price impact of the sales, the volume of sales is compared to the liquidity of the underlying market. Liquidity is measured by market depth which is positively related to the ratio of average daily trading volumes to asset volatility. Market depth is measured under average trading conditions and during stress periods (see Appendix XII for details).

Vulnerabilities of U.S. Mutual Funds and Interconnectedness

124. Some fund categories might be more vulnerable or more likely to transmit shocks than others. The analysis of vulnerabilities and interconnectedness within mutual funds is based on two concepts of risk. Vulnerable funds are funds that are likely to be in distress when other funds (or the market) are in distress. Spreader funds are institutions for which other funds are likely to be in distress when the spreader fund is in distress. The identification of vulnerable and spreader funds is based on two methodologies: tail-dependence using copula and the interconnectedness approach (Diebold and Yilmaz, 2016). Under the first approach, the dependence structure of net flows across funds categories is modelled using historical data, conditional on one fund category being in distress (i.e., facing large outflows), expected net flows for the other categories are then calculated. Under the interconnectedness approach, weekly returns for a sample of 70 funds (the 10 largest for 7 categories) are used to estimate spillovers from and to each fund in the sample.

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[72] A similar approach was used for the 2017 Luxembourg FSAP (IMF, 2017).

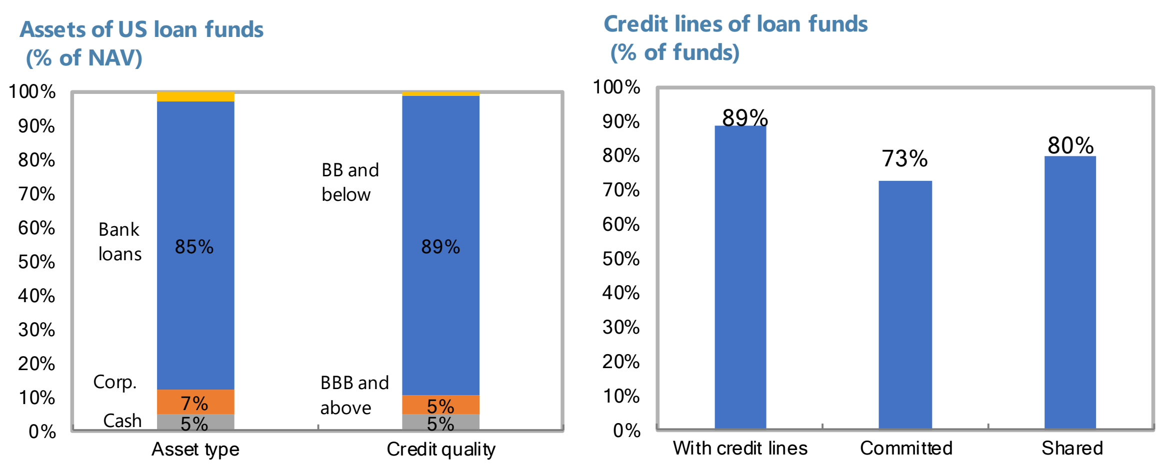
E. Results

Funds' Ability to Withstand Severe Redemption Shocks

125. Under the historical approach nearly all funds would be able to withstand severe redemptions, with the exception of high yield (HY) and loan mutual funds. Overall, more than 90 percent of the funds would have enough highly liquid assets to meet investors' redemptions. However, most funds exposed to HY and leveraged loans would not have enough highly liquid assets and would need to sell liquid securities in their portfolio, assuming that they do not use any liquidity risk management tools. The result remains valid when shocks are calibrated at category level (homogeneity) and at fund-level (heterogeneity).

126. Loan funds may be particularly vulnerable to redemption shocks, but a large majority has credit lines. Loan funds invest mainly in leveraged loans, which are less liquid than corporate bonds and are subject to relative long settlement (average of 10 days according to LSTA), which make them subject to significant potential liquidity risk (Figure 36). Most loans funds have credit lines in place, which usually are committed lines from banks, and most of them are shared with other funds. Such credit lines could provide liquidity buffers to funds experiencing large outflows. However, due to the shared nature of the credit lines, under stress other funds could need to draw on the same line at the same time.

Figure 36. United States: Loan Funds



Sources: Morningstar, IMF staff.

Sources: SEC form N-CEN, IMF staff.

127. Under the adverse scenario, almost all funds would be able to withstand redemptions (Figure 37). The result is directly related to the very mild shock in the adverse scenario (less than 3 percent of NAV for most funds). Only 1 percent of funds would not have enough highly liquid assets to meet redemptions, all HY funds.

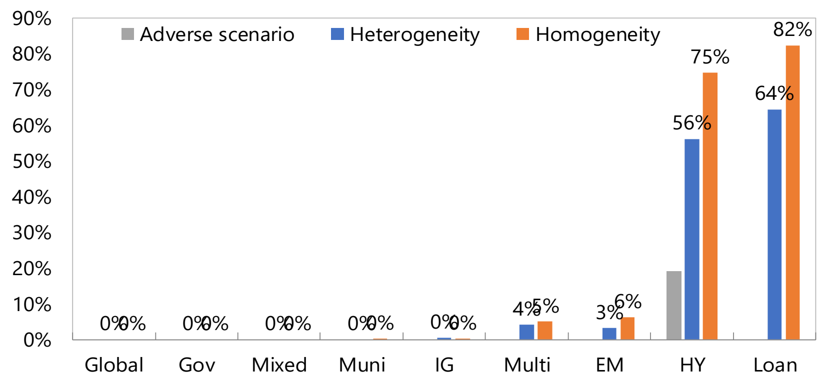
Figure 37. United States: Results of the Liquidity Stress Test for the Historical Approach

	Homogeneity			Heterogeneity			Adverse scenario		
Fund category	Funds with RCR<1	% funds with RCR<1	% NAV with RCR<1	Funds with RCR<1	% funds with RCR<1	% NAV with RCR<1	Funds with RCR<1	% funds with RCR<1	% NAV with RCR<1
Global	0	0%	0%	0	0%	0%	0	0%	0%
Gov	0	0%	0%	0	0%	0%	0	0%	0%
Mixed	0	0%	0%	0	0%	0%	0	0%	0%
Muni	1	0%	0%	0	0%	0%	0	0%	0%
IG	1	0%	0%	2	0%	0%	0	0%	0%
Multi	6	5%	2%	5	4%	2%	0	0%	0%
EM	4	6%	11%	2	3%	2%	0	0%	0%
HY	109	75%	71%	82	56%	39%	28	19%	18%
Loan	37	82%	86%	29	64%	67%	0	0%	0%
Total	158	8%	4%	120	6%	4%	28	1%	1%

Note: RCR is the Redemption Coverage Ratio (Highly Liquid Assets/Redemption shock).

Sources: Morningstar, IMF staff.

Share of funds with a liquidity shortfall



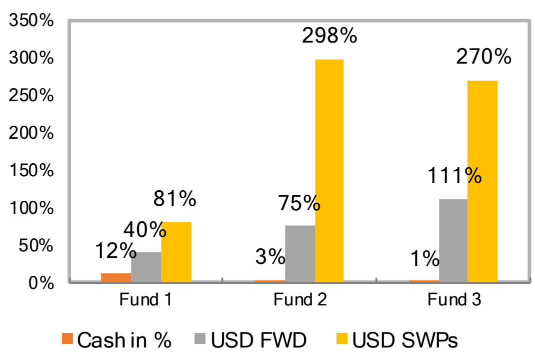
Note: Share of funds (by category) whose Redemption Coverage Ratio (highly liquid assets to redemption) is below one .
Sources: Morningstar, IMF staff.

128. Funds with large exposures to derivatives could face significant liquidity demands related to variation margins. A 1 percent depreciation of the USD and a 50 bp increase in interest rate would cause variation margins on the derivatives portfolio that would range between 3 percent and 10 percent of the NAV. For several funds the variation margins would be more than 50 percent of available cash and cash equivalents, depleting funds liquidity buffers (Figure 38). Results are illustrative since the sample is small and only focuses on simple derivatives. In practice, funds use other types of more complex derivatives (such as swaptions), which were not considered in the analysis.

129. Under the current derivatives proposal, mutual funds using absolute Value at Risk (VaR) risk measures could potentially be substantially leveraged. Under the SEC proposed rule, synthetic leverage would be indirectly limited by a VaR limit of either 150 percent of a reference benchmark or 15 percent of the one-month VaR of a fund (absolute VaR), rather than by a limit based on the NAV. For funds using absolute VaR, allowable synthetic leverage could potentially be high, if the funds invest in a portfolio with a low VaR: for a portfolio with a VaR of 5 percent, the fund could lever up to 3x times to reach the 15 percent VaR limit (5 times for a VaR of 3 percent etc.). A simulation exercise shows that for the 15 percent VaR constraint to be binding, the volatility of the underlying portfolio would need to be very high (about 25 percent annualized volatility, see Box 1). In addition, the current proposal includes an exemption for some funds which would allow them to be leveraged up to three times (provided that (i) funds disclose in their prospectuses that they are not subject to the proposed limit on fund leverage risk and (ii) funds would be subject to sale practice rules).

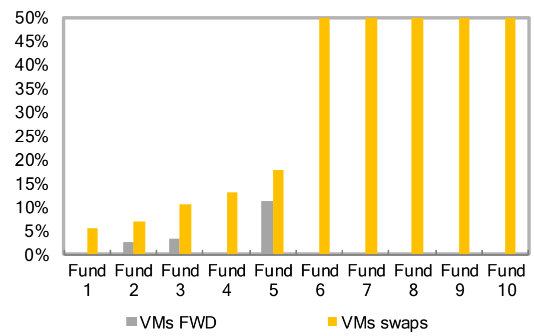
Figure 38. United States: Use of Derivatives and Liquidity Demands

Use of USD fx forwards and USD swaps
(% of NAV)



Sources: SEC form N-PORT, IMF staff.

Variation margins
(% of cash and cash equivalents)



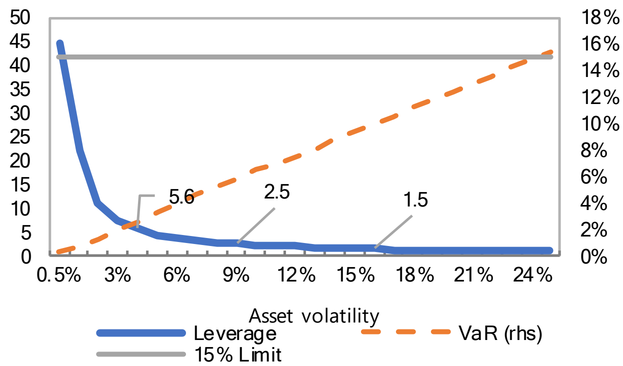
Note: Variation margins in % of cash and cash equivalents as reported in B.2.f. Sources: SEC form N-PORT IMF staff.

Source: IMF staff calculations.

Box 1. Maximum Allowable Leverage under the Absolute VaR Approach

For funds using the absolute VaR approach, leverage is indirectly limited by the absolute VaR limit: the one-month 99 percent losses should be below 15 percent of the NAV of the fund. To assess the maximum allowable leverage, it is assumed that the returns of the portfolio of a fund follow a lognormal distribution. The VaR depends solely on the expected returns and the volatility of the portfolio. The figure below shows the result one-month 99 percent VaR given different levels of asset volatility: if the asset volatility is 4 percent, then a fund could lever up to 5.6 times the NAV since the VaR would be 2.7 percent.

Maximum allowable leverage under 15% VaR limit
(Multiple of NAV)



Note: Maxmimum leverage (y-axis) as a function of asset volatility (x-axis) and VaR (rhs, in % of NAV).
Source: IMF staff.

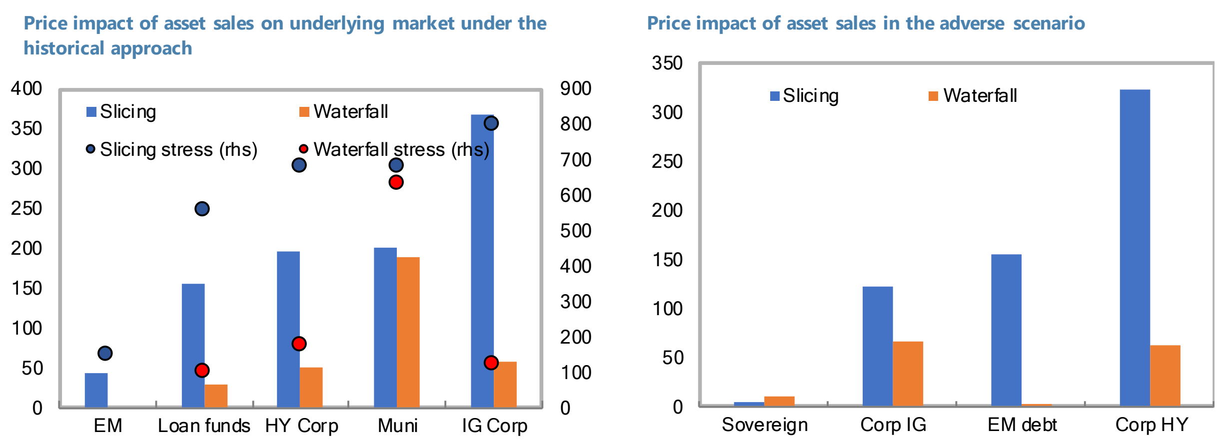
Impact of Funds' Forced Sales on Markets

130. Asset sales by mutual funds to meet redemptions could have a sizeable impact on markets, based on certain assumptions. Under the slicing approach—where funds sell securities in proportion of their weights in the portfolio—mutual funds exposed to less liquid asset classes (such as EM bonds, HY corporate bonds or leveraged loans) would sell large amounts of bonds, which would create some downward pressure on prices. Under the waterfall approach, the price impact would be more limited since funds would sell first their most liquid assets. However, remaining investors would end up with a less liquid portfolio, which could amplify the first-mover advantage (i.e., the incentive to redeem before other investors as trading costs are not passed on redeeming investors). At fund-level there is a trade-off between reducing the price impact of sales (thereby preserving the returns of the fund) and maintaining the portfolio allocation in line with the investment objective.

131. Under the historical approach, prices would experience large declines, especially under stressed conditions. Overall, the price impact of sales from mutual funds on their underlying market ranges between 50 to 200 basis points in normal times, and between 150 to 700 bps during stress periods under the slicing approach. If funds sell their most liquid assets first (waterfall approach), the price impact on underlying markets is muted (less than 100 bps under normal conditions and less than 200 bps under stress for most asset classes).

132. Under the adverse scenario, the combined sales of assets would mainly impact EM debt and HY bonds. Under the slicing approach, the price of HY bonds would decline by more than 300 bps, mainly due to sales from HY funds (220bps) (Figure 39). IG bond prices would decline by about 120 bps, due to the combined selling of IG bond funds (70bps) and mixed funds (40 bps). The impact on the sovereign bond market is muted due to limited sales and deeper liquidity.

Figure 39. United States: Market Impact: Historical Approach and Adverse Scenario



Note: Price impact of asset sales by liquidation strategy, in bps.
Sources: Morningstar, IMF staff.

Note: Price impact of asset sales by liquidation strategy, in bps.
Sources: Morningstar, IMF staff.

Source: IMF staff calculations.

133. Asset sales can generate second-round effects. Due to the price impact of asset sales, funds return would be negatively affected, causing additional outflows from investors. Overall, the second-round effects are limited under normal trading conditions, but outflows could be more sizeable under stress conditions, with additional outflows above 3 percent of NAV for IG, HY and loan funds under the historical approach. The higher effect for IG corporate bond funds is explained by the large size of IG corporate bond funds (US$2,427 billion) rather than by the relative liquidity of the IG corporate bond market.

Vulnerability Analysis

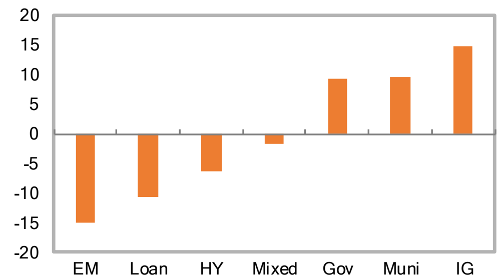
134. Based on our assumptions, some fund categories are potentially more vulnerable to distress in the fund industry. When other fund categories are in distress (i.e., facing large outflows), EM bonds funds are likely to experience large outflows. IG corporate bond funds are also vulnerable to distress affecting municipal and government bond funds.

135. Based on our assumptions, some fund categories may be more systemic than others. When some fund categories are in distress, other funds' categories might also be in distress at the same time, indicating the systemic nature of the first category. Systemic categories include IG corporate bond funds, multi-strategy bond funds and to a lesser extent municipal bond funds, mixed funds and global funds. Fund categories which are most exposed to liquidity risk such as HY, EM and loan funds are not systemic since when they are in distress, other fund categories do not experience large outflows, partly due to substitution effects, with investors moving out of those funds into safer funds (government or IG corporate bond funds).

136. The interconnectedness analysis based on funds' returns yield similar results. According to our analysis, HY bond funds appear to be net receivers of spillovers from other funds and hence more vulnerable (Figure 40). Similarly, IG bond funds may be more vulnerable to spillovers from municipal and government bond funds. On the other side, government, municipal and corporate bond funds appear to be net senders of spillovers to the rest of the fund industry.

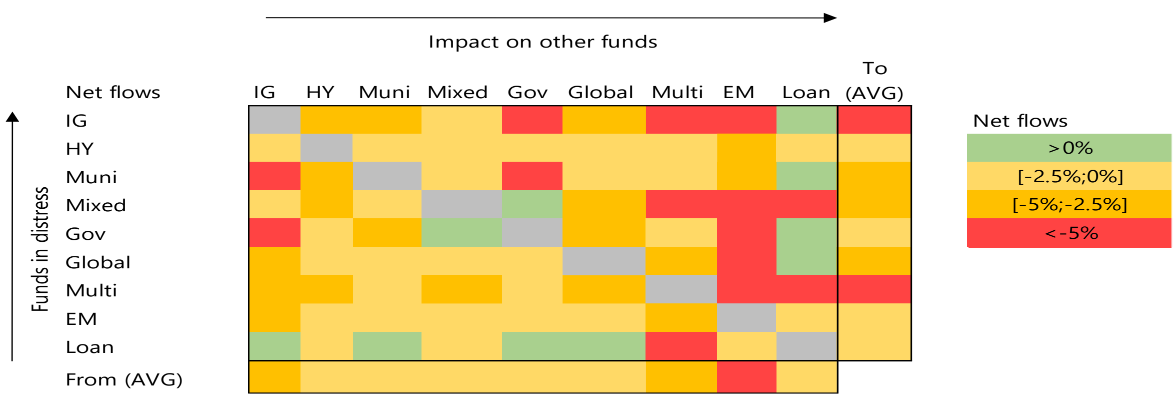
Figure 40. United States: Vulnerability Analysis across Fund Categories

Average Net Spillovers



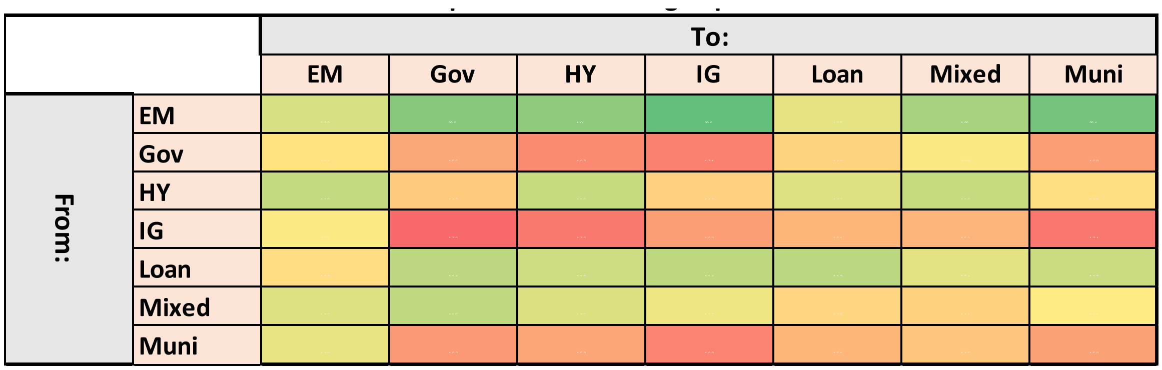
Note: Average spiillovers from other fund categories.
Sources: Morningstar, IMF staff.

Potential Flow Spillovers



Note: Expected net flows conditional on distress in %.
Negative values indicate outflows.
Sources: Morningstar, IMF staff.

Heatmap: Relative Average Spillovers



Source: IMF staff calculations.

MARKET RISK STRESS TESTING FOR MONEY MARKET FUNDS

A. Objective and Scope

137. The 2014 Money Market Fund reform required non-government institutional MMFs to maintain a floating NAV, reflecting the mark-to-market value of the fund instead of maintaining a constant NAV (CNAV). Since the reform, the overwhelming majority of the MMF market remains CNAV (government CNAV or Prime retail CNAVs), as VNAV prime funds only account for 15 percent of the industry and tax-exempt municipal MMFs for less than 1 percent (Panel 1).

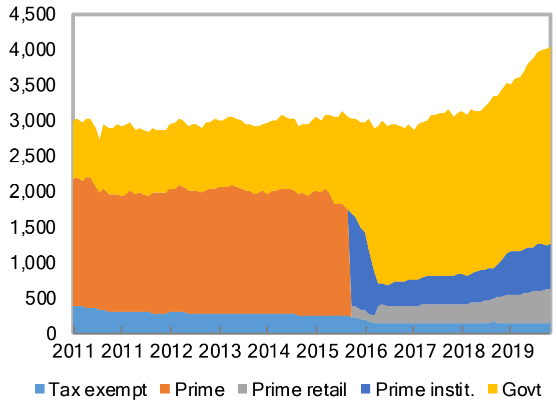
138. Money market funds holdings are diversified according to the MMF type. Prime MMFs invest mainly in commercial paper and certificate of deposits, tax exempt MMFs in municipal debt, government MMFs in U.S. Agency debt and repo as well as UST debt and repo while Treasury MMFs invest in UST debt and repo (Panel 2).

139. U.S. MMFs have increased their exposures towards Federal Home Loan Banks and FICC through sponsored repos. Discount notes issued by FHLB account for 16 percent of U.S. MMFs holdings, and MMFs provide about 60 percent of FHLB funding through those instruments. Most FHLB notes are short-term (within 60 days) so that they can be considered weekly liquid assets according to the SEC definitions. Recently, MMFs have increased their exposures to FICC by entering into sponsored repo, where a large bank sponsors the MMF so that repo trades can be cleared through FICC (Figure 41). Sponsored repos are concentrated, with the top three banks accounting for 50 percent of repos.

140. As part of the 2014 Money Market Fund reform rules, the SEC requires MMFs to perform regular stress tests. MMFs using CNAV must be able to maintain a mark-to-market NAV within 0.5 cent of US$1, i.e., the shadow NAV must not fluctuate by more than 0.5 percent.

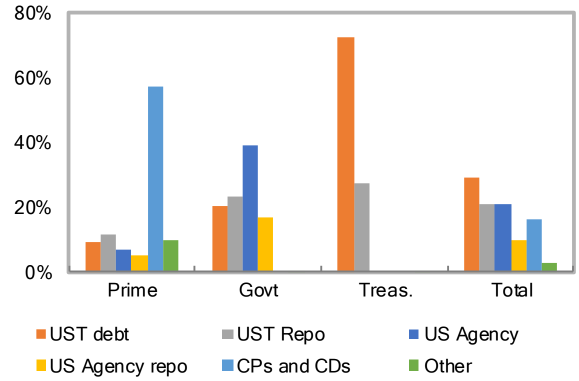
Figure 41. United States: Money Market Funds (MMFs)

MMFs by type (USD billion)



Sources: OFR, IMF staff.

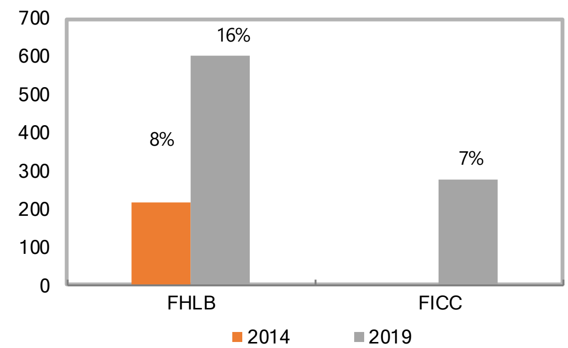
MMFs holdings (in % of NAV)



Note: Holdings by instrument and MMF type. Data as of December 2019. Sources: CRANE, IMF staff.

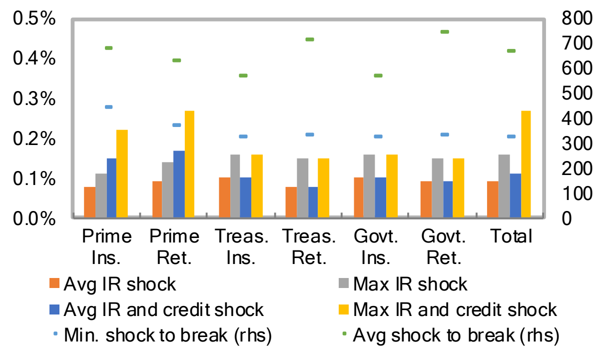
Source: IMF staff calculations.

Selected exposures of US MMFs (USD bn and % of NAV)



Sources: CRANE, IMF staff.

Impact of interest rate and credit spread shocks (% of NAV lhs, IR shocks in bps rhs)



Note: Impact of 100 bps interest rate and 100 spread shocks. Dots show required shocks (in bps, rhs) for MMFs to break the buck (except for Prime Ins.). Sources: CRANE, IMF staff.

Source: IMF staff calculations.

B. Methodology and Results

141. Stress tests estimate the impact of interest rate and credit spread shocks on the NAV of MMFs. The stress test was applied to 208 funds (see Table 2). MMFs are subject to two different and complementary shocks: (i) an increase in interest rates, and (ii) a widening of spreads on non-collateralized instruments held by MMFs. The impact of the shocks is calculated by computing the duration of each instrument in the portfolio of each MMF and using this measure to estimate the mark-to-market losses due to the shocks. The interest rate and credit spread shocks are calibrated based on the largest daily increase observed in 2008 and are both equal to 100 bps. The credit spread is applied to all MMFs holdings excluding UST and U.S. agency debt as well as UST and U.S. agencies repo.

142. All U.S. MMFs would be able to withstand large shocks to yields. Under a 100 bps interest rate shock, U.S. MMFs NAV would not fluctuate more than 0.16 percent, which is well within the allowable range, due to the low duration of MMF portfolio (about 0.1 year on average). Under a combined interest rate and spread shock of 100 bps each, prime retail funds would see their NAV fall up to 0.27 percent, within the allowable range.

143. Very large yield shock would be required for MMFs to break the buck. Reverse stress tests are used to estimate the interest rate shock required to produce a 0.5 percent deviation from US$1. Interest rates would need to rise by more than 600 bps on average to produce such a deviation. For MMFs, with the highest duration, the required shock would be about 350 bps.

144. Liquidity risk was not assessed for Prime MMFs. The stress tests did not asses the liquidity of MMFs which do not use constant net asset value (Institutional prime MMFs). During the beginning of the COVID outbreak in March 2020, institutional prime MMFs experienced very large outflows from investors. At the same time, prime MMFs faced challenges in selling their assets due to strains in short term money markets. As a result of those combined shocks on the asset and liability side, some prime MMFs received sponsor support in March. Two affiliate banks purchased assets from the MMFs to improve their liquidity position. Following multiple steps taken by a number of government agencies to support the economy liquidity stress receded and prime MMFs had inflows starting early April.

Table 2. United States: Results of the MMF Stress Test

				100 bps shock		100 bps shock+100 bps spread		Reverse stress test (bps)	
Type	Valuation	Size (USD bn)	No. of funds	Average	Max	Average	Max	Min	Average
Treasury Retail	CNAV	91	14	0.10%	0.14%	0.10%	0.14%	353	551
Prime retail	CNAV	460	27	0.09%	0.14%	0.17%	0.27%	364	622
Prime instit.	VNAV	605	38	0.08%	0.11%	0.15%	0.22%	444	675
Gov. retail	CNAV	627	37	0.08%	0.15%	0.08%	0.15%	326	710
Treasury Instit.	CNAV	781	40	0.10%	0.16%	0.10%	0.16%	319	560
Gov. Instit.	CNAV	1248	52	0.09%	0.15%	0.09%	0.15%	329	742
Total		3,812	208	0.09%	0.16%	0.11%	0.27%	319	660

Sources: CRANE, IMF staff

Note: Impact of a 100 bps interest rate shock on the NAV of the MMF and impact of a combined 100 bps interest rate shock and 100 bps increase in yields on uncollateralized instruments.

THE INSURANCE SOLVENCY STRESS TESTS

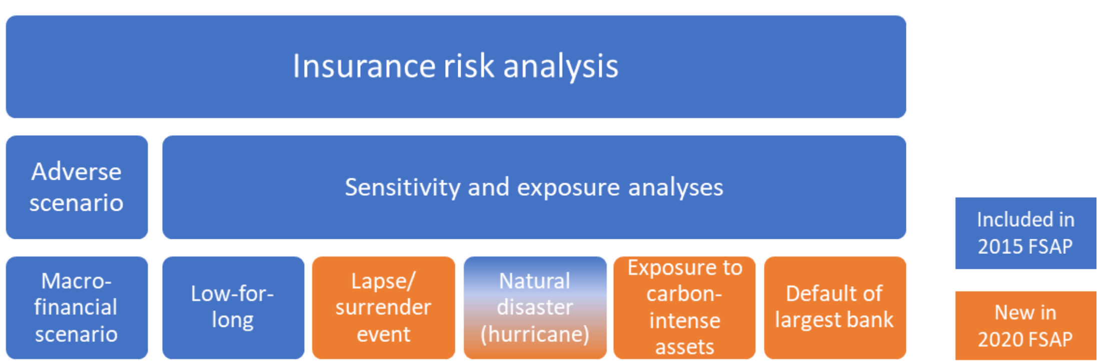
A. Objective

145. To quantify the risks, the FSAP used a broad range of scenario analyses, sensitivity tests and exposure analyses. In addition to the macrofinancial scenario which is broadly aligned with the narrative and severity of the banking sector stress test, further insurance-specific sensitivity analyses were performed (Figure 42). These analyses included:

(i) a prolonged period of low interest rates;
(ii) a lapse and surrender event with liquidity outflows from the life insurance sector;
(iii) the default of the largest banking counterparty; and
(iv) a stock-take on exposures to carbon-intense sectors.
(v) The results of these analyses are not added to the outcome of the main stress scenario, although it is possible to assume that the materialization of the stress scenario coincides with (i) or (ii), or both of them.

146. Compared to the 2015 FSAP, the FSAP uses a broader variety of analytical tools and more granular data, in particular on the asset side (Figure 42). The NAIC has shared detailed asset holdings of insurance groups in the stress test sample, most notably Schedule D, which includes all equity and bond exposures. The cut-off date for all analyses is December 31, 2018.

Figure 42. United States: Risk Analysis Tools for the Insurance Sector



Source: IMF staff.

B. Valuation and Capital Standard

147. An important point of context for the stress test is that statutory accounting and U.S. GAAP do not require a full market-consistent approach to the valuation of assets and liabilities. Under statutory accounting, the liabilities of P&C insurers are generally not discounted which adds a layer of conservatism. Also, under statutory accounting, life insurance liabilities are discounted with a rate that is set at the time when the policy is sold to the policyholder or with a discount rate based on the expected return of assets associated with the insurance liabilities. This currently results in average discount rates above current market rates. Under statutory accounting, amortized cost is the predominant accounting regime for fixed income assets,[73] which means that neither unrealized gains nor losses are recognized.

148. For the stress test model, this results in a significant difference in the impact of a shock to the risk-free interest rate: In a truly economic balance sheet with a fully market-consistent valuation of both assets and liabilities, life insurers, with their structural mismatch of assets and liabilities which is very common in that type of business, would see their liabilities increase more than their assets with falling interest rates. While the duration mismatch is usually smaller for non-life insurers, the same mechanics apply. State insurance regulation requires that companies perform an asset adequacy analysis at least annually to measure the structural mismatch of assets and liabilities under a range of different interest rate scenarios.

149. Under statutory accounting, also the impairment rules for life insurers differ from a fully market-consistent regime. Investment assets are impaired only when the fair value loss is deemed to be other than temporary. Once impaired, a bond cannot be written back up to its original fair value after recovery.

C. Sample

150. The macrofinancial stress test includes a sample of 50 insurance groups (See Appendix XV). FSAP insurance stress tests strive for a market coverage of at least 70 percent both in life and non-life, typically calculated based on gross written premiums. This target coverage was reached in the United States by including 21 groups predominantly active in life insurance business and 22 in Property & Casualty (P&C) business. In addition, seven health insurers with a market share of about 45 percent form a third group. For analytical purposes, sub-samples were formed of a) life insurers with a high share in VA business (6 companies) and b) foreign insurers (6) were formed. Most of the groups in the sample are publicly listed.

[73] The actual treatment depends on the credit quality: For life insurers, fixed income assets in NAIC credit quality buckets 1 to 5 (i.e., AAA – CCC) are valued at amortized costs, and so are, for P&C insurers, assets in buckets 1 and 2 (i.e., AAA – BBB). For the remaining credit quality buckets (6 in life and 3 to 6 in P&C) the lower value of amortized cost and market value is used.

D. Stress Test: Adverse Scenario

151. The scenario for the insurance top down stress test builds on the narrative and severity of the banking sector stress test. Given the nature of insurance business and its balance sheet structure, the main focus of the stress test is on investment assets. The market risk stresses include shocks to bond holdings (sovereigns, municipals, and corporates), securitizations, equity, property and other investments (such as hedge funds and private equity). All stresses are assumed to occur instantaneously. Table 3 provides an illustration of the granularity of shocks.

152. Some shocks were slightly adjusted to make them more operational for the insurance stress test. The equity shock was re-calibrated and effectively lowered to be meaningfully applicable at end-2018 when equity markets were temporarily depressed. The yield increase of fixed-income instruments reflects a sizable portion in insurers' portfolios of debt instruments for which no market prices exist—hence the shocks are a bit lower than those shocks applied to the banks' trading books. Finally, the haircut on mortgage loans acknowledges a relatively high quality of the mortgage loan portfolio with average loan-to-value ratios about 60 percent.

Table 3. United States: Market Risk Parameters

		Impairment / Default	Yield increase
Equity	Unaffiliated	-40.4	--
	Affiliated	-20.0	--
Property held for sale		-23.2	
Fixed-income instruments	NAIC 1	--	--
	NAIC 2	--	--
	NAIC 3	-3.0	+2.8
	NAIC 4	-5.0	+4.0
	NAIC 5	-9.0	+5.3
	NAIC 6	-15.0	+7.0
Mortgage Loans	First Lien	-2.0	--
	Other	-10.0	--

Source: IMF staff.

E. Stress Test: Modeling Assumptions and Output

153. The stress test used publicly available, consolidated data of insurance groups from regulatory returns. As data files published by S&P Global Market Intelligence lack the necessary granularity for some of the analyses proposed, the NAIC has provided data on investments on an asset-by-asset basis.

154. Given the specificities of the statutory accounting for insurance companies, the modelling of the adverse scenario included the following steps:

- Mark-to-market impairment, based on the macrofinancial scenario, for holdings in equity, fixed-income instruments below investment grade, other investment assets (so-called Schedule BA assets);
- Default losses in the corporate bond and securitizations portfolio as well as on mortgage loans.

155. The U.S. regulatory framework does not include a capital requirement for insurance groups at the consolidated level. Hence, the stress test produces only a balance sheet impact expressed as the reduction in statutory capital, in line with the 2015 FSAP methodology.

156. The stress test did not take into account any mitigating effect from hedging, profit-sharing, or other management actions. Insurance companies usually apply a sophisticated hedging strategy regarding their interest rates (mainly via swaps and swaptions), and also hedge against declines in the stock market via options and futures. As these hedging activities can vary substantially among companies, it is difficult to estimate the mitigating effect in times of stress. In any case, it is very likely that the stress test gives a maximum impact. A range of life insurance products includes profit sharing features between the insurance company and the policyholder which allow the insurer to (partially) pass on investment losses by reducing discretionary benefits. In a risk-based solvency regime, it is also possible for the companies to de-risk their investments in order to reduce their capital requirements, resulting in higher solvency ratios; similarly ceding risks to a reinsurance company could be considered. Finally, dividend policies, both up-stream from subsidiaries to the top (holding company) level and from the top level to shareholders can be actively managed, especially with larger and diversified groups. As the range of management actions is very broad, no general modeling result can be provided based on available data.

157. The stress test was performed before the COVID-19 outbreak started. Box 2 provides a summary of the outbreak impact on insurance sector.

Box 2. COVID-19 Impact on the Insurance Industry

The insurance sector is affected by the pandemic mainly through higher claims, operational challenges and lower investment returns. Claims will be made under various types of household and commercial insurance. Revenues are expected to decline, at least temporarily, as the demand for insurance coverage declines. The risk of fraudulent claims increases when economic conditions deteriorate. All insurers face investment losses as a result of stock market declines, bond defaults and spread increases, while lower interest rates weigh heavily on life insurers with return guarantees. Equity exposures are material, but a substantial share of market-value changes is directly passed on to policyholders through investment-linked products. As the duration of the liabilities is generally longer than the assets, reinvestment risk has increased. Bond downgrades to non-investment grade would have substantial impact due to the requirement for capitalization of higher risk exposures. Finally, insurers are generally more liquid than their liabilities require, but some may face liquidity pressures if product cancellations and surrenders increase sharply while new business and renewals decline.

Life insurance

Beneficiaries on life insurance policies with a death coverage will submit claims on those policies, while annuity providers might experience reduced payouts given higher mortality rates. Excess mortality is covered by reinsurance to a large degree, mostly with U.S. affiliates of reinsurers outside the U.S.[74] One global reinsurer has indicated that its exposure to COVID-19 life and health insurance claims, even under a very severe 1-in-200 years scenario, is similar in scope to a medium-sized natural catastrophe. Mortality increases might appear to be an immediate financial gain for annuity providers, but many of these products have guarantees that effectively reduced any perceived benefit for the insurer. Lower investment returns are a significant negative for life insurers, both in terms of reinvestment risks and the difficulty to earn a guaranteed rate of return.

Health insurance

Health insurers face higher costs and claims as policyholders may require testing, more medical care, and hospitalizations. An increase in unemployment will affect the level of uninsured health expenses. Under the Affordable Care Act, consumers who lose their coverage or become eligible for subsidies due to loss of income are able to enroll in coverage on the Exchange and most state-based Exchanges have created special enrollment periods to facilitate coverage. COVID-19 testing, hospitalizations, and premium grace periods have impacted insurer costs and incomes. At the same time, delays in other, non-emergency care have significantly reduced insurer spending in the first part of 2020, and many are looking at, and some have announced, premium holidays.

The Families First Act and the CARES Act, complementing the Affordable Care Act, requires insurers to waive all cost-sharing, including deductibles, for medical services provided to people with any type of private health coverage related to medically necessary COVID-19 testing and associated visits. In addition, any preventive services, which include any future vaccine, must be covered by the principle of no cost-sharing. The new Act also enables states to provide free coverage for coronavirus testing for uninsured residents. However, the Act does not impose any federal requirement to waive cost-sharing for COVID-19 related medical treatments, and thus individuals may be subjected to significant out-of-pocket costs.

Property & casualty insurance

Most business interruption clauses included in commercial property insurance policies are only triggered in case of physical damage to the property of the policyholder due to a covered peril. There are differing views on whether the contamination of a property by a virus would be considered physical damage. Policies that more generally provide coverage for business interruption due to physical damage or loss of use may be more likely to be determined to provide coverage of pandemic-related business interruption losses. Many commercial policies apply exclusions that could apply to a viral contamination such as COVID-19. For example, the standard Insurance Services Office commercial property policy used in the U. S. applies an exclusion for "loss or damage caused by or

Box 2. COVID-19 Impact on the Insurance Industry (concluded)

resulting from any virus, bacterium or other microorganism that induces or is capable of inducing physical distress, illness or disease." Yet it is unclear how many commercial policies do have such a clear inclusion or exclusion.

Major legal and regulatory risks may emerge. For example, in New Jersey, a legislative proposal has been put forward to require that all commercial property policies providing coverage for business interruption or loss of use of property also provide coverage for interruption resulting from COVID-19. As proposed, insurers that incur claims as a result of this legislation could seek reimbursement from the Commissioner of Banking and Insurance who would then recover those costs from all insurers writing business in New Jersey. While this legislation is on hold at the time of this report's finalization, a similar legislation has been introduced in Ohio and Massachusetts. At the federal level, a group of members of the House of Representatives has requested insurers to consider retroactively covering financial losses from COVID-19 under business interruption coverage provided in commercial policies, suggesting that containment measures should be considered as civil authority orders that trigger coverage. The NAIC has written to Congress noting that such a measure would result in substantial solvency risks for P&C insurers and significantly undermine the ability of insurers to pay other types of claims.[75]

Travel insurance is affected through coverage of medical treatments and trip cancellation. The overall industry exposure to trip cancellation claims is not significant relative to other lines of business. Some insurers have changed the terms of travel insurance policies or stopped selling new travel insurance policies. For existing policies, medical treatment during travel would be covered in most cases, unless a travel advisory was in place. Insurance coverage for trip cancellation will usually only reimburse expenses after all attempts for refunds have been exhausted and only when there are no official advisories against travel at the time of booking.

Claims can arise from liability insurance, including workers compensation. Employees may claim compensation for lost wages and medical expenses if they believe they were infected at workplace, which could invoke coverage under workers compensation insurance. They could also make claims for distress, bodily injury, discrimination or financial losses due to isolation that could potentially be covered by employment practices liability insurance. For businesses whose premises are accessible to the public or to their customers, claims could be made in case of infections provided a proof of negligence regarding the spread of the virus is obtained.

Motor insurance is contributing to an overall resilience of the P&C sector. Individual traffic has declined as a result of public health measures and lower economic activity results in reduced commercial road use. In the longer term, however, it is likely that renewals will reset and underwritten volumes will shrink.

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[74] In U.S. individual life insurance, almost 30 percent is reinsured. The market for life reinsurance is highly concentrated both globally and, in the U.S., with the largest five reinsurers having a market share in the U.S. of around 90 percent. Of these five companies, four are part of European groups, and one is a domestic group. See Munich Re, 2018 Life Reinsurance Survey Results.

[75] See https://content.naic.org/article/statement_naic_statement_congressional_action_relating_covid_19.htm .

F. Stress Test: Results

158. In the adverse scenario, the life sector experiences a substantial hit on its statutory capital, though it is overall largely shielded by the current valuation and capital framework (Figure 43). The aggregated reduction in statutory capital of US$226 billion equates to 30.9 percent of the sample's statutory capital and 3.9 percent of consolidated balance sheet assets—this equates to 1.1 percent of the U.S. GDP. Sizable parts of the balance sheet are not sensitive to market price fluctuations which would be different under a fully market-consistent valuation regime. The absence of a group capital framework in the U.S. makes it difficult to estimate the stress test outcome in terms of a risk-based solvency regime. Solvency ratios of U.S. solo companies tended to be well above the regulatory thresholds recently, so that based on the current calibration of the risk-based capital, it can be expected that even in this adverse scenario the vast majority would still continue to be adequately capitalized.

159. Stress test results are very heterogenous in the life and P&C sector. In the life sector, capital declines by US$74.3 billion (-35.7 percent), in P&C by US$149.8 billion (-31.7 percent), and in the health sector by only US$1.4 billion (-2.8 percent). Depending on the business model and investment allocation, the capital impact can differ significantly both within the life and the non-life sector. Among the 21 life insurance groups, the decline in capital ranges from 14 to more than 60 percent, with the median company recording a decline of 32 percent and 50 percent of companies ranging between -21 and -36 percent. In the P&C sector, the median company loses 19 percent of its capital, and results across the sample range from -5 to -53 percent.[76] Only in the health sector, companies' risk profiles are very similar, resulting in a low affectedness by the market stress scenario for all sample firms—for the median company, capital declines by just 1 percent, and even the most affected company sees its capital shrinking by only 8 percent.

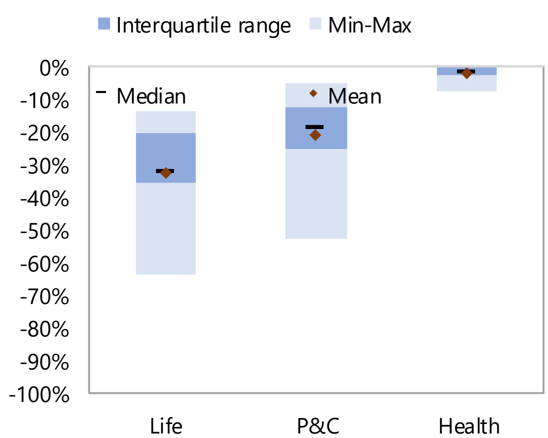
160. Shocks to other investment assets, non-investment grade corporate bonds and stocks contribute most to reductions in statutory capital. In the life sector, the shock to other investment assets (Schedule BA) contributes most to the overall reduction in statutory capital, while in the P&C sector, the stock price decline is more relevant on aggregate. For most P&C firms, however, the equity exposure is relatively small, and the sector-wide impact is a bit overstated and driven by a very small number of larger companies with sizable investments. Mortgage defaults contribute 10 percent of the overall impact in the life sector, as companies in the other two sectors barely engage in such lending activities.

[76] Some groups are active both in life and non-life business, so that some outliers in each respective sector can be explained by relatively large activities in the other sector.

Figure 43. United States: Insurance Stress Test Results

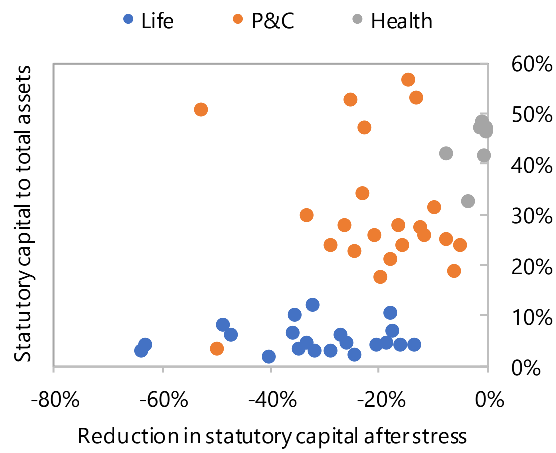
Statutory capital of the median life company declines by 32 percent, and by 19 percent for the median non-life insurer.

Reduction in Statutory Capital



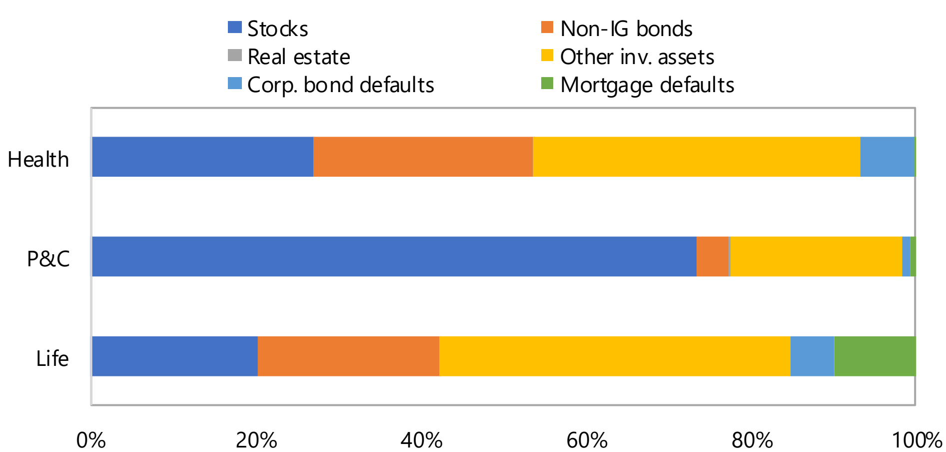
Health insurers with their high pre-stress capital are barely affected by the market shock, while results in the other two sectors are very heterogenous.

Reduction in Statutory Capital



In the life sector, the shock to other investment assets (Schedule BA) contributes most to the overall reduction in statutory capital, while in the non-life sector, the stock price decline is more relevant (though a bit overstated as many non-life companies have only small exposures to the stock market, and the aggregated result is driven by a very small number of larger companies).

Aggregated Contribution of Individual Shocks



Source: IMF staff calculations based on NAIC data.

G. Sensitivity Analysis

Low-for-Long Scenario

161. The analysis of a prolonged period of low interest rates ("low for long") focused on investment spreads and ultimately profitability. The NAIC has provided an analysis that compares the net investment yield of the life insurance sector against the average credited rate. For the years 2016–18, the resulting net investment spread averaged 1.1 percent (Figure 44). Like the 2015 FSAP, a future trend of the investment yield was projected, acknowledging that the downward trend in portfolio yields might flatten out in the future when fixed income instruments with higher coupons have already expired. The average credited rate would also decline, as new business would be issued with lower contractual guaranteed interest rates.

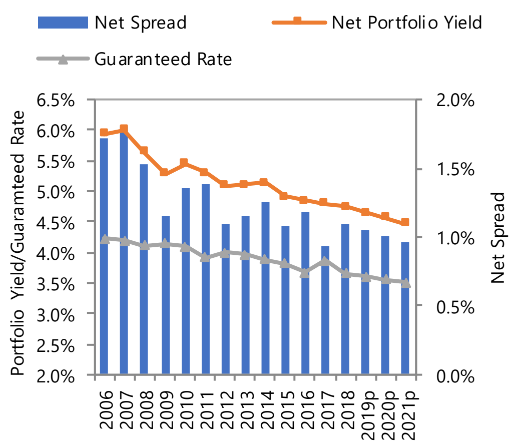
162. The low-for-long projection is conducted for the whole U.S. life insurance market. It is based on sector-wide aggregated data on investment yields and guaranteed rates, complemented by an approximated maturity profile based on the 21 life insurance companies of the stress test sample.

163. With continued low interest rates, the net investment spread is expected to decline further (Figure 44). The guaranteed rate in life insurance is relatively sticky but continues to decline. With about 7 percent of bond investments to be rolled over every year, the net portfolio yield is also declining, likely at a slightly higher pace than the guaranteed interest rate. By 2021, the net investment spread could therefore drop below 1 percent, only slightly above the recent minimum of 0.93 percent observed in 2017.

Figure 44. United States: Life-Business: Investment Spread and Maturity of Fixed-income Assets

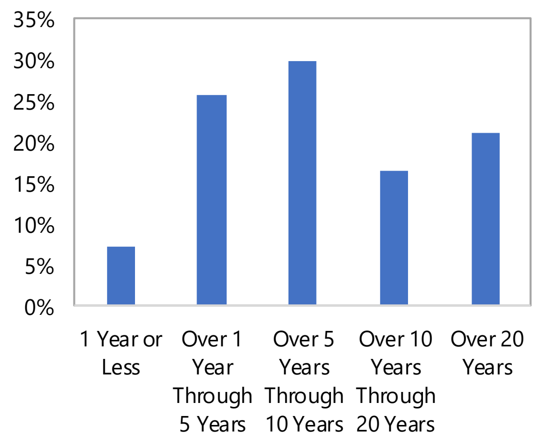
The net investment spread has been rather steadily declining since 2007 and will, in a scenario of persistent low rates, continue to be a drain on profitability.

Net Investment Spread
(Net portfolio yield over guaranteed rate)



Seven percent of the sample's fixed-income assets mature within less than a year and need to be rolled over.

Maturing Bonds in Life Insurers' Portfolios



Source: IMF staff calculations based on NAIC data.

Lapse/Surrender Event

164. To assess potential vulnerabilities from the trend towards less liquid investment, the impact of a sudden cash outflow from the life insurance sector was modeled. The scenario assumed that policyholders are incentivized to terminate their life insurance policies after a sharp hike in interest rates. In the past decade, termination rates in the U.S. life insurance sector have been rather stable, hovering about 6 percent recently with no significant difference between individual lines and group business (Figure 45).

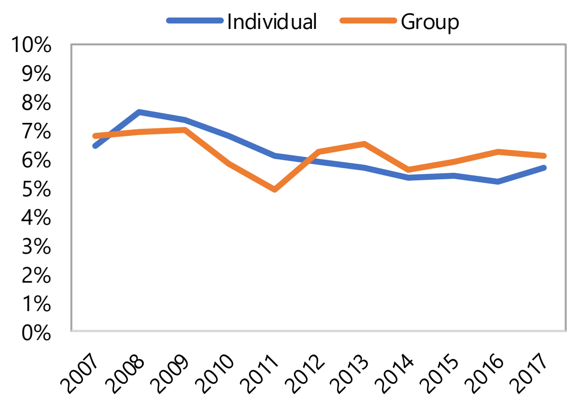
165. The sample for the lapse/surrender event includes the same 21 life insurance groups as the macrofinancial scenario stress test. Data for the analysis stems from the annual regulatory reporting, obtained from S&P.

166. Net cash outflows stemming from higher lapse and surrender rates were modeled for each life insurance group in the sample. It is assumed that lapse rates for life policies (general account only) which can be terminated at book value without any adjustment would double compared to the 2018 rates. Policies which foresee a surrender charge of at least 5 percent were assumed to experience an increase in lapse rates of 50 percent (Scenario 1). Various alternative paths of lapse increases were modeled to better control for each company's own historic lapse pattern (see Figure 49 and the accompanying notes). All other policies (about two thirds of the general account) which cannot be withdrawn at the discretion of policyholders, or which are redeemed at fair value or with a market value adjustment, were not included in the analyses as their lapse rates are likely less sensitive to interest rate hikes. Termination of such policies might, however, increase in a recession scenario when household income shrinks.

Figure 45. United States: Life-business: Termination Characteristics

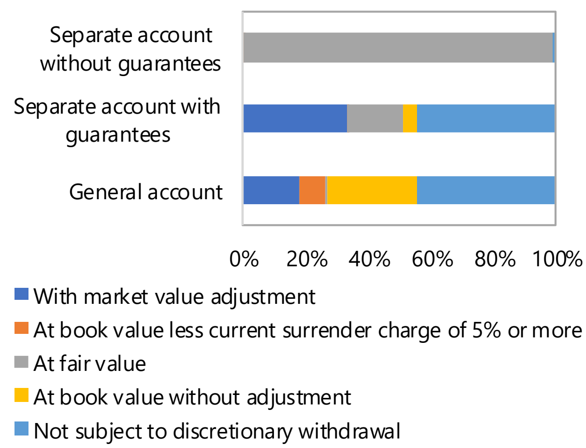
Annual termination rates were rather stable over the last decade, hovering about 6 percent.

Termination Rate
(Based on face amount)



29 percent of general account liabilities redeemable at book value without any adjustments.

Surrender Characteristics



Source: IMF staff calculations based on NAIC data.

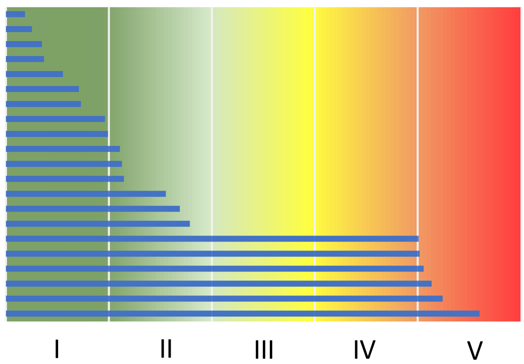
167. Insurers were assumed to react to net cash outflows by liquidating investment assets. This results in the need to realize losses at distressed market levels. It is assumed that companies would sell up to 50 percent of their U.S. Treasury bonds, government-sponsored enterprises (GSEs) issues and municipals first, followed by corporate bonds starting with the highest rating category (NAIC 1). Cash positions and deposits are assumed to be kept unchanged to allow companies to make regular payments and expenses.

168. A few life insurers would need to liquidate sizable parts of their bond portfolio to meet cash outflows after a sharp increase of lapse rates (Figure 46). The sample of insurers can roughly be clustered in three categories of almost equal size. About one third is able to meet the outflow simply by selling parts of their U.S. Treasury bond portfolio which are generally seen as the most liquid asset. Another group would sell U.S Treasuries up to the assumed cap of 50 percent, and also sell some bonds of U.S. GSEs. Another four to six companies (depending on the scenario) would ultimately also have to liquidate parts of its corporate bond portfolio, even after having sold U.S. state and municipality bonds. These corporate bond holdings, despite carrying low credit risk, might be subject to (temporarily) restricted liquidity, so that large-scale sales are only possible at a discount. The total amount of U.S. Treasury bond sales in the four scenarios ranges from US$23–33 billion, while for U.S. GSEs and corporate bonds the ranges are from US$13–15 billion and from US$4–11 billion, respectively.

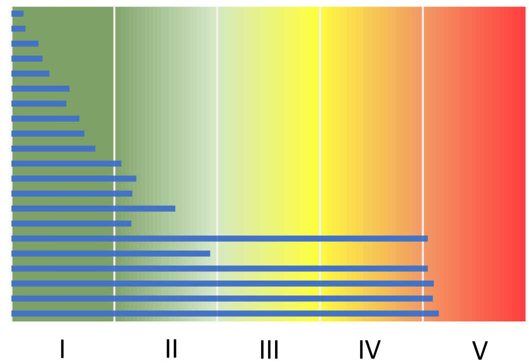
Figure 46. United States: Need to Liquidate Assets after Lapse Shock

The need to liquidate investments after the realization of a lapse shock differs significantly among life insurers. While some companies can easily meet the cash outflows by selling moderate amounts of U.S. Treasury bonds, a few others would also need to liquidate corporate bonds in potentially less liquid markets.

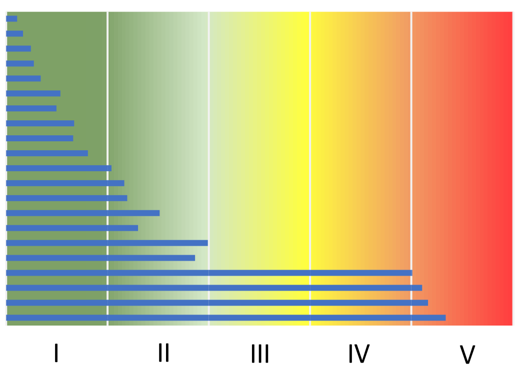
Need to Liquidate Assets after Surrender Shocks: Scenario 1



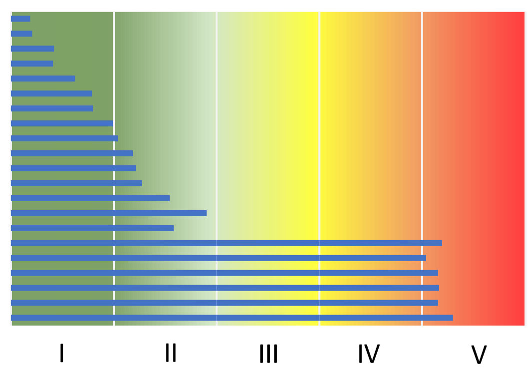
Need to Liquidate Assets after Surrender Shocks: Scenario 2



Need to Liquidate Assets after Surrender Shock: Scenario 3



Need to Liquidate Assets after Surrender Shock: Scenario 4



Notes: In each panel chart, the five segments denote the waterfall of asset liquidations, namely U.S. Treasuries (I), U.S. GSEs (II), U.S. Political Subdivisions (III), U.S. State bonds (IV), and corporate bonds in the NAIC 1 rating category (V). Scenario 1 assumes an increase of the 2018 lapse rate by 100 percent for life policies which can be terminated at book value without any adjustment, and an increase by 50 percent for policies which foresee a surrender charge of at least 5 percent. Scenario 2 assumes lapse shocks which correspond to the maximum termination rate observed in the period from 2009 to 2018, and the 75th percentile observed in the same period, for the two types of policies respectively. Scenario 3 assumes an increase of the lapse rate by two standard deviations and one standard deviation, respectively. Finally, scenario 4 assumes a lapse rate equal to 200 and 150 percent of each company's mean lapse rate between 2009 to 2018, respectively.

Source: IMF staff calculations based on NAIC data.

Weather-Related Catastrophes

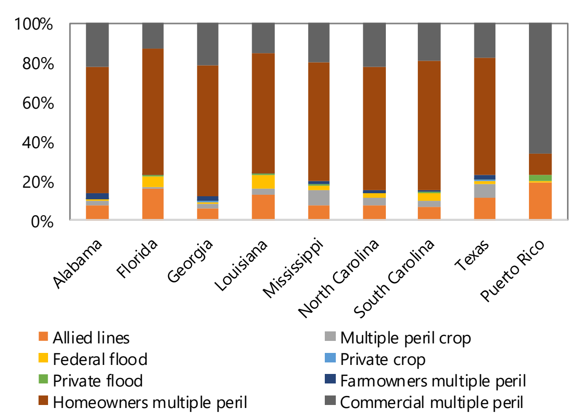
169. The impact of more frequent or more severe weather-related natural catastrophes might potentially be uneven across the P&C sector, with smaller and regionally active insurers being more exposed. The 2015 FSAP found overall a manageable impact of a severe hurricane on the solvency position of P&C insurers which could be explained by the diversification of risks the large insurers of the sample have underwritten. Smaller P&C companies which are active only in one or a few states tend to be more vulnerable as their exposures to tail risks are more concentrated. While the overall risk is unlikely to be nationwide systemic, conclusions could be drawn on regional vulnerabilities and—from a microprudential point of view—risk management practices in these smaller institutions.

170. Vulnerable lines of business were identified based on their coverage in the event of natural disasters and the observed volatility of loss ratios. NAIC data provides the necessary insights (Figure 47). Based on gross premiums, the most relevant line of business is homeowners' multiple peril, followed by commercial multiple peril and allied lines—amongst these three, loss ratios are most volatile for allied lines business with peaks above 150 percent in 2005 (hurricanes Katrina, Rita and Wilma) and 2017 (hurricanes Harvey, Irma and Maria).

Figure 47. United States: Vulnerable P&C Lines of Business

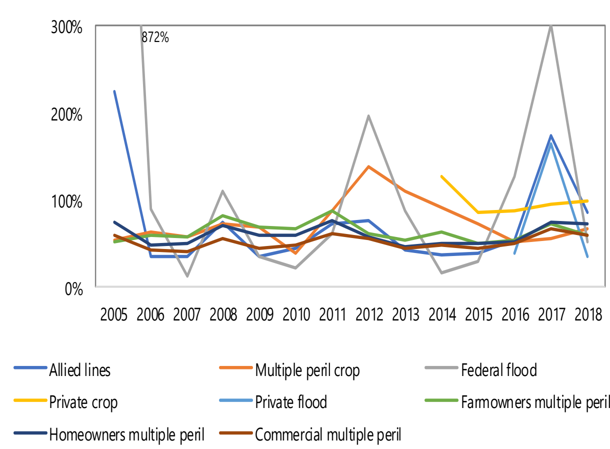
Homeowners' multiple peril is the most sizable insurance class in terms of premiums which could be affected by natural disasters.

Composition of "vulnerable" lines of business in selected states



Loss ratios tend to be significantly more volatile in federal flood insurance, allied lines and private flood.

Loss ratios in "vulnerable" lines of business (nation-wide)



Source: IMF staff calculations based on NAIC data.

171. The analysis uses a bifurcated sample of (a) 538 solo entities being part of the 22 large and diversified P&C groups in the stress test sample as well as (b) 44 entities of small and regionally concentrated P&C insurers focused in nine Southeastern jurisdictions (Table 4). Those regionally active P&C insurers with concentrated exposures towards hurricanes and windstorms were identified based on the NAIC Market Share Report 2018, considering the distribution of their business across states and vulnerable lines of business.

Table 4. United States: Sample of Regionally Concentrated P&C Insurers

	State	Premiums, P&C ($ millions)	o/w in "vulnerable" states and lines (minimum)	Share of "vulnerable" states and lines (minimum; pct)	Notes
Company A	AL	0.04	0.04	100	1/
Company B	AL	1.35	0.31	23	
Company C	FL	0.87	0.36	41	
Company D	NC	n.a.	0.05	n.a.	
Company E	GA	n.a.	0.19	n.a.	
Company F	LA	0.07	0.05	75	
Company G	PR	n.a.	0.08	n.a.	
Company H	NC	1.15	0.39	34	
Company I	MS	1.50	0.19	12	
Subsidiary Ia	LA	0.15	0.09	64	1/, 3/
Subsidiary Ib	SC	0.08	0.07	84	1/, 2/, 3/
Company J	TX	1.30	0.45	34	
Company K	TX	n.a.	0.42	n.a.	
Company L	FL	0.69	0.61	88	
Company M	PR	0.72	0.13	18	
Company N	FL	1.19	0.94	79	
Company O	PR	0.03	0.02	45	2/

Notes:

1/ Total premiums as of 2017

2/ Total premiums sourced from AM Best

3/ Subsidiary of Company I

Source: IMF staff calculations based on NAIC data

Source: IMF staff calculation based on NAIC data.

172. A proper modeling of increased frequencies and varying degrees of severity would require detailed policy and exposure information from companies.[77] As a workaround, the one-off effect of a very severe event simultaneously hitting all "vulnerable" states equally[78] is modeled instead of assuming a higher frequency. Hence, the analysis cannot directly provide an estimate for the cumulated impact of a series of multiple events, e.g., a full hurricane season. Furthermore, the

[77] See e.g., Nicholson et al. (2018), The Florida Insurance Market: An Analysis of Vulnerabilities to Future Hurricane Losses, *Journal of Insurance Regulation*, Vol. 37, No. 3.

[78] Alternatively, each insurer is individually hit by a very severe event in the same year.

analysis does not take into account any physical damage to an insurer's own properties or any second-round effects of a (regional) economic downturn after the hurricane.

173. The analysis draws on companies' own estimates of the impact of hurricanes on its coverage of the risk-based capital (RBC) requirement. As part of their regular reporting, insurers have to submit the impact of hurricanes at various occurrence probabilities, which include 1-in-50, 1-in-100, 1-in-250, and 1-in-500-year events. By design, the actual assumptions about which type of hurricane constitutes one of these events differ among companies—a 1-in-500-year hurricane in Puerto Rico will typically be different from a 1-in-500-year hurricane in Texas. Still, one hurricane might affect insurers in different states.

174. The NAIC has provided aggregate statistics for the RBC coverage ratios before and after stress. The dataset also includes the impact on the available capital with and without the mitigating effect from existing reinsurance contracts.

175. Large and diversified P&C insurers are relatively resilient to individual disasters, even of a larger scale (Figure 48). A single event which can be expected to occur every 50 years and assumed to hit all insurers simultaneously would result in an 8.1 percent reduction of available capital (gross)—taking into account recoverables paid by a reinsurer or recovered from alternative risk transfer instruments, the reduction is only 3.9 percent (net). For hurricanes with an occurrence expected every 250 and 500 years, the net capital impact increases to 5.8 and 8.6 percent, respectively. In the 1-in-250-year event, the capital of four out of 538 insurers would drop below the regulatory minimum, triggering supervisory action.

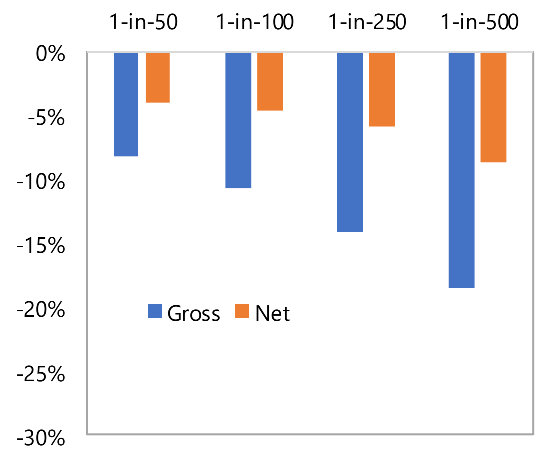
176. Smaller and more concentrated P&C companies would be severely affected by major hurricanes in their respective home markets. Smaller insurers rely substantially more reinsurance for more frequent hurricanes than larger firms. For a 1-in-50-year hurricane, that hit each insurer in this sample simultaneously, available capital in the sample of smaller P&C insurers would decline by 81.4 percent—taking reinsurance recoverables into account, the net impact amounts to only 5.7 percent. Excessive costs seem to prevent small companies from buying the same level of reinsurance coverage for more remote events. In case of a 1-in-250 and 1-in-500-year hurricane, the net impact on available capital is 58.6 and 164.3 percent, respectively. Already in the less severe of these two events, ten out of the 44 companies in the sample would record a shortfall in their capital adequacy.

177. The impact of insurance failures on policyholders is mitigated through various protection schemes. Insurance guarantee funds and, in states where those exist, dedicated catastrophe funds, funded by the P&C insurance sector as a whole would ensure that policyholder claims are paid out, however delays and disruptions in renewing contracts could occur and would require close attention by state supervisors.

Figure 48. United States: Impact of Major Hurricanes

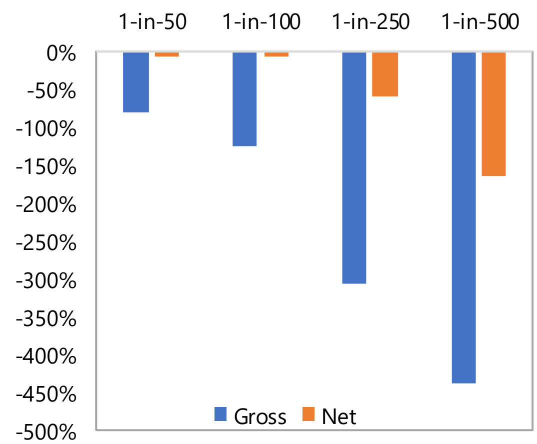
The claims stemming from a simultaneous 1-in-500 year hurricane would decrease the capital of large and diversified insurers by 9 percent (net, after reinsurance)…

Impact on available capital: Large, diversified insurers



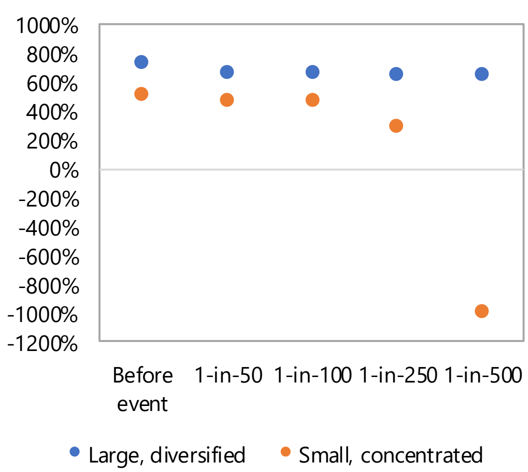
…while for small and concentrated insurers, the same event would result in claims which equate 164 percent of statutory capital.

Impact on available capital: Small, concentrated insurers



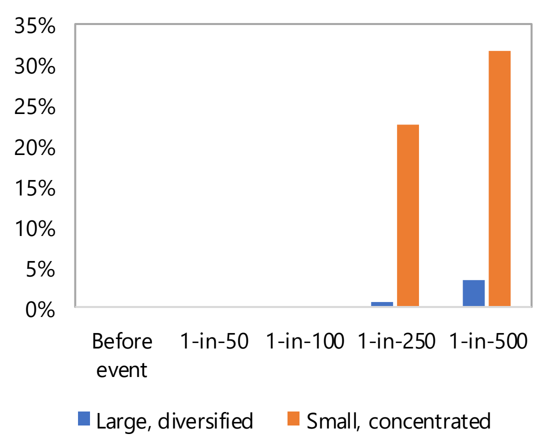
A significant share of small companies would record a negative capital after a 1-in-500-year hurricane, and….

25th percentile of the RBC distribution



…already after a 1-in-250-year hurricane, four (out of 538) solo entities of large P&C groups would see their RBC ratio drop below 100 percent, as well as ten (out of 44) small insurers.

Percent of companies triggering RBC action



Source: IMF staff calculations based on NAIC data.

Banking Counterparty Default

178. A further asset-side shock centered around a default of the largest banking counterparty. Like the natural disaster event, this analysis did not imply a homogenous scenario as the largest banking counterparty differs for each insurance company in the sample. Furthermore, this type of analysis can only show the direct impact of one isolated default—second-round effects or a more widespread contagion after a major bank's default are not factored in.

179. The sensitivity analysis was performed for the 50 insurance groups which were also subject to the macrofinancial stress test. The NAIC provided detailed asset exposures based on Schedule D, which allowed for the identification of relevant equity and bond exposures towards individual banks.

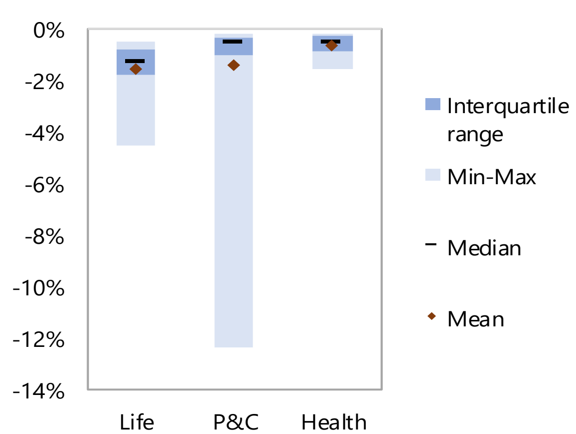
180. Shocks were applied as haircuts on investment assets. According to the nature of exposure, different haircut levels were applied. Equity exposures were assumed to lose their entire value, while the LGD for unsecured bond exposures was assumed to be 50 percent. Subordinated bonds would suffer from a 100 percent haircut, and the market value of secured bonds would decline by 15 percent.

181. The vast majority of insurance companies would experience a limited capital impact if the largest banking counterparty defaults (Figure 49). The median life company would lose 1.2 percent of its capital, and half of the sector's firms range between 0.8 and 1.8 percent. In the P&C and health sector, the concentration towards the largest banking counterparty is even lower—in both sectors, the median insurer would experience a 0.5 percent loss in capital. Outliers exist, in particular in those cases where an insurer holds a participation in a large bank.

Figure 49. United States: Default of the Largest Banking Counterparty

For the vast majority of insurance companies, the default of the largest banking counterparty has only a minor direct impact on the capital position. The median life company would lose 1.2 percent, and in the P&C and health sector, the loss in capital would amount to only 0.5 percent. However, outliers with much higher losses can be seen in the sample.

Reduction in statutory capital



Source: IMF staff calculations based on NAIC data.

Exposure Analysis: Carbon-Intense Investments

182. The FSAP undertook a stock-take of carbon-intense investments of the U.S. insurance sector—it did however not assume a change in the pricing of carbon-intense assets. While it can be assumed that global institutional investors will continue re-allocating parts of their assets from carbon-intense to less carbon-intense assets, this is expected to be more of a longer-term transitional risk. Technological shocks, like e.g., a breakthrough in battery technologies or substantial increases in the efficiency of renewable energies might speed up this transition, but unlikely impact assets prices in the very short term.[79]

183. Carbon-intense assets were identified by using the "FFI The Carbon Underground Top 200 List"[80] which identifies companies based on their carbon footprint—to a large extent, the list features fossil fuel producers and mining companies. Bonds and shares issued by those companies were matched against insurers' holdings are reported in Schedule D which was provided by the NAIC for this analysis. Additionally, further securities were included when the issuer name included terms like e.g., "oil", "coal", or "petroleum".

184. Carbon-intense assets in a very narrow sense do not represent a major asset class (Figure 50). Taking into account the limitations of the identification process, the share of bonds issued by carbon-intense companies amounts to 3.5 percent of all corporate bond exposures. In the equity portfolio, the share is 1.6 percent. Together, the identified carbon investments account for 1.1 percent of the sample's total balance sheet assets. Notwithstanding these small amounts, transition risks could also exist in other economic sectors, e.g., related to transport or heavy industries, which were not included in the analysis in the absence of missing data on direct or indirect carbon emissions.

185. Repricing risks in the transition to a less carbon-intense economy are likely not only restricted to carbon-intense equity and bond exposures. Mortgage loan exposures or mortgage-backed securities with collateral in areas becoming more frequently hit by windstorms, floods or wildfires could be repriced by investors, acknowledging more explicitly the underlying long-term risks. The same might apply to municipality bonds in such regions or to debt issued by local utility providers.

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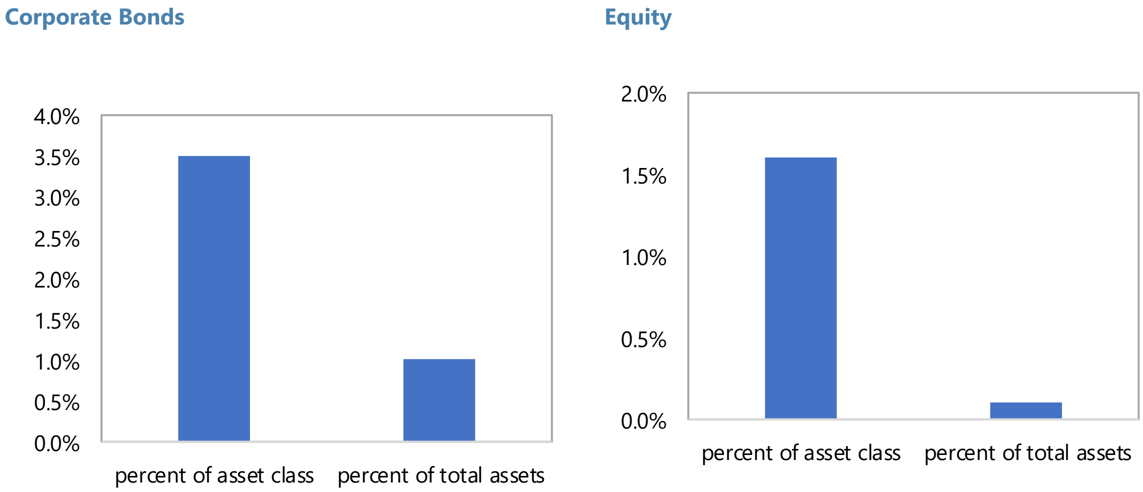
[79] A macrofinancial stress test with several different types of energy transition risks was developed and run by the Dutch Central Bank. See De Nederlandsche Bank (2018) An energy transition risk stress test for the financial system of the Netherlands, Occasional Paper, Volume 16-7.

[80] See www.fossilfreeindexes.com.

Figure 50. United States: Insurers' Carbon-Intense Investments

Carbon-intense bond exposures account for 3.5 percent of all corporate bond investments...

...while 1.6 percent of the equity investments are identified as carbon-intense.



Source: IMF staff calculations based on NAIC data.

SYSTEMIC RISK, INERCONNECTEDNESS, AND CONTAGION ANALYSIS

A. Scope

186. The systemic risk and interconnectedness analysis complements balance sheet stress tests and assesses the transmission of risks across the financial system. Previous sections focused on stress testing individual institutions and provided an overview of the resilience of the different sectors separately—namely, the banks, the mutual funds (including money market mutual funds), insurance companies, and nonfinancial firms. This section aims to bridge that analysis by providing a quantification of the transmission of risks and vulnerabilities across sectors of the U.S. financial and nonfinancial sectors.

187. Systemic risk assessment consists of two complementary analyses. The first one is the contagion analysis between banks, non-banks and nonfinancial companies, which accounts for the direct and indirect cross-sectoral interconnectedness in the U.S. financial landscape. The second one is the market-based analysis which aims at capturing important correlation and co-movement patterns embedded in financial asset prices across different institutions and sectors.

B. Contagion Between Banks, Non-banks, and Nonfinancial Corporates

Overview

188. The domestic cross-sectoral contagion analysis aims at capturing potential spillover risks between banks and other financial and nonfinancial institutions. Given that over half of financial intermediation takes place outside of the banking system, this analysis aims to complement the banking sector network analyses described earlier by extending the coverage to include non-bank financial institutions (e.g., mutual funds, insurance companies, etc.). Moreover, this analysis aims at quantifying how the materialization of risk in a specific segment of the system transmits and reverberates across other segments of the financial system. In other words, and in contrast to previous sections where financial institutions (or sub-segments of the financial system) were analyzed in isolation, this part of the analysis takes into account how the endogenous behavior of certain institutions can affect other institutions across different segments of the financial system.

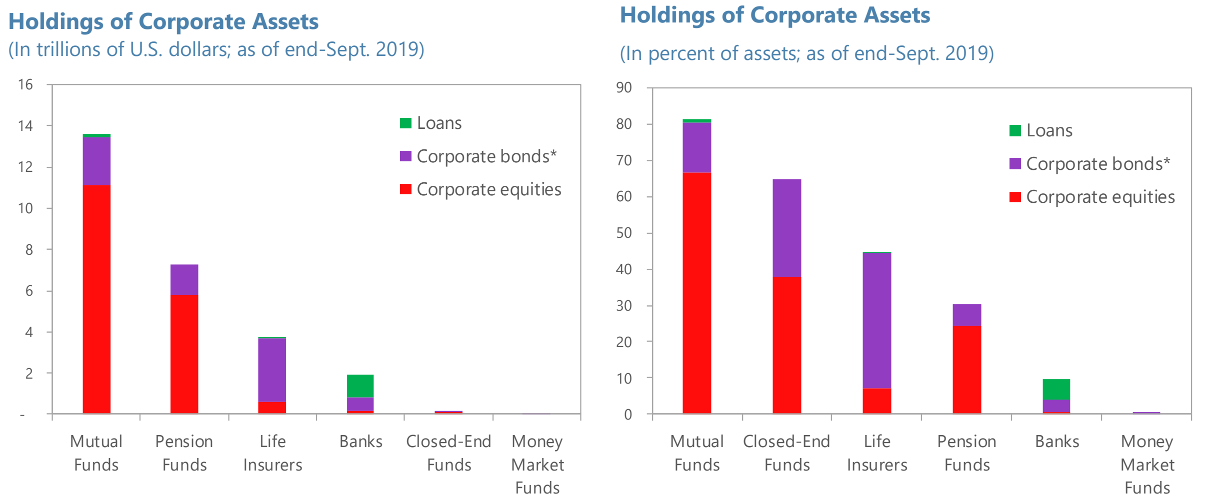
189. The analysis centers on assessing the resilience of banks and non-banks when facing potential stress in the corporate sector. Analysis of household and nonfinancial business sector resilience showed a rapid increase in vulnerabilities in the U.S. corporate sector, most notably among highly leveraged firms. Given the rapid rise of leveraged finance (e.g., leveraged loans, high yield, and private debt markets) and related products (e.g., CLOs), combined with a growing share of intermediation by the non-bank financial sector, this analysis focus on assessing the impact of potential stress in the corporate sector on both banks and non-bank financial institutions—including through their reaction in response to stress.

190. System-wide shocks could emerge and be transmitted instantly or via gradual adjustments in exposures of the financial institutions. An instant shock, such as for example the credit rating downgrade of many leveraged borrowers at the same time, would lead to fire-sales in the market. A gradual adjustment of exposures in the financial system would be due to rebalancing of portfolios of banks, insurers, mutual funds because of an increase in credit risk related losses but would not necessarily lead to a fire sale of corporate debt securities and leveraged loans. As gradual adjustment would be less severe than asset fire sales, in the subsequent analysis we focus on an instant market shock which lasts for one month and which leads to an immediate asset liquidation.

Exposures and Risk Transmission Channels

191. Direct exposures to the U.S. corporate sector are concentrated among the non-banks. Financial institutions exposures relate mainly to investment in nonfinancial firms' equities as well as holdings of corporate debt instruments (e.g., corporate bonds, commercial paper, etc.). Mutual funds, life insurers, and pension funds exhibit relatively large exposures to corporate securities (Figure 51), while bank holdings of these instruments are limited. Banks are exposed to the corporate sector mainly through bank term loans and revolvers (committed and uncommitted credit lines). Accordingly, non-bank financial institutions would suffer larger direct losses in case of financial stress in the corporate sector than banks.

Figure 51. United States: Exposure to Nonfinancial Corporate Securities



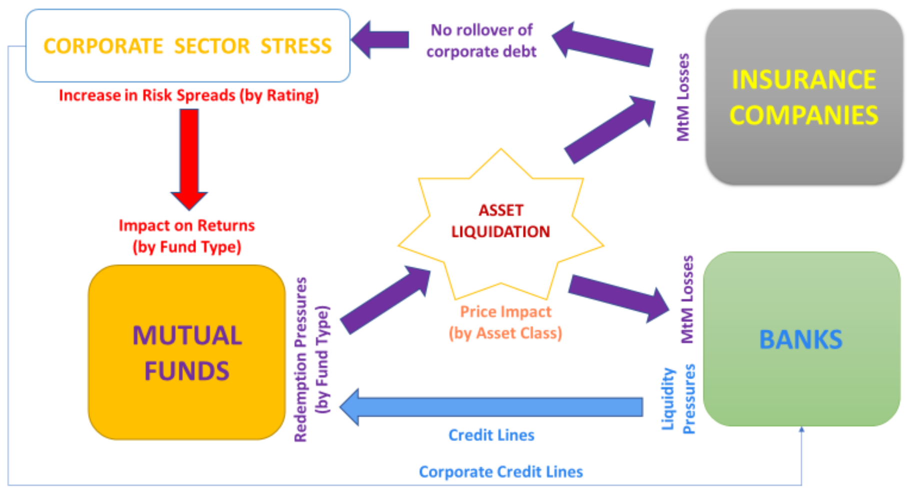
Sources: FRB; and IMF staff estimates.
Note: * = includes corporate and foreign bonds

192. Corporate sector risks could manifest through the complex interlinkages with bank and non-bank financial institutions. Previous sections assessed the vulnerability of mutual funds to corporate debt. However, stress in the corporate sector could translate into wider losses throughout the entire system through direct linkages (i.e., cross-sectoral exposures) among different segments of the financial system, as well as indirect linkages—similar asset holdings, market reaction, asset liquidation, and marked-to-market losses.

193. The contagion analysis assumes that corporate stress impacts the mutual funds, which in turn lead to spillovers onto other financial institutions. Stress in the corporate sector manifests through rising corporate spreads. The shock to the BBB corporate spreads embedded in the FSAP stress scenarios is mapped into rising spreads across different credit ratings, with lower-quality rated companies experiencing a larger rise in spreads. Mutual fund returns suffer though their direct exposures to the corporate sector, which in turn may trigger redemption pressures for these funds. To meet redemptions, we assume that mutual funds will start to liquidate some of their assets, which—depending on the asset class and absorption capacity of the market—results in falling asset prices. Asset liquidations may lead to mark-to-market losses in other financial institutions, namely banks and insurance companies. These companies could also reduce funding means to the nonfinancial corporate sector, which could exacerbate the stress in that sector, feeding additional rounds of spillover. In addition to mark-to-market losses, banks might also face liquidity pressures from their committed credit lines to mutual funds (which themselves would be facing liquidity pressures).[81] These risk transmission dynamics are presented schematically in Figure 52.

[81] Conversely, if banks cut the credit lines to the mutual funds, it would exacerbate the potential liquidity stress in the mutual funds sector.

Figure 52. United States: Schematic Representation of the Risk Transmission Mechanisms



Source: IMF staff estimates.

Price Impact and Potential Losses

194. Based on our assumptions, asset liquidations by mutual funds could potentially lead to significant price impacts on certain asset classes. Following the impact from stress in the corporate sector, we estimate that mutual funds would liquidate about US$97 billion (Figure 53). The liquidated amounts vary by the type of asset and the type of fund, with EM, HY, and EM funds suffering the largest redemption pressures. These asset liquidations translate to varying price impacts across asset classes (between 0.002 to 4.8 percent).[82] Appendix XVII provides details about fire-sale haircut estimation and market size of various securities.

195. Based on our assumptions, asset liquidations could lead to mark-to-market losses for mutual funds and reverberate through the financial system with non-negligible impact, particularly for non-banks. The shock was calibrated based on the corporate stress tests performed by the IMF, the linkages were analyzed based on balance sheet data. Although significant, potential losses appear to be manageable for the banking system, in large part owing to banks' limited direct exposure to the corporate sector. Assuming a market sentiment shock lasting for one month, liquidation losses for mutual funds amount to about US$0.9 billion (about 1 percent of the original value of assets sold). For banks, the resulting mark-to-market losses are close to US$10.8 billion (roughly equivalent to 0.06 percent of total assets). This would reduce banks' CET1 ratio by about 0.1 percentage points. In the case of insurance companies, this shock may roughly

[82] Price impact for sovereign IG, sovereign HY, corporate, securitized IG, securitized HY, and municipal securities are 0.0015, 0.4, 4.8, 0.2, 1.3, and 0.45, respectively.

translate into losses at about 1 percent of insurance sector total assets. In case of a systemic credit risk-related stress (which leads to an increase of annual default rates of leveraged corporates of up to 6 percent), banks would face US$230 billion losses on commercial and industrial loans and CLO holdings.[83] Five Category IV banks (Non-GSIBS) would require recapitalization. Insurance sector will be hit by around US$300 billion losses, at the same time they do not have to mark these to market given the existing regulatory treatment of their asset valuation.

Figure 53. United States: Redemption Shock and Asset Liquidation of Mutual Funds: Price Impact Measures

Assets Sold
(In billions of U.S. dollars)

	Cash	SOV IG	SOV HY	Corp IG	Corp HY	Securitized IG (Agency)	Securitized HY	Equities	Muni Bonds	EM debt	Total	Return shock (in percent)	Redemption shock (in percent)
EM	0.4	2.4	0	0.3	1.3	0.0	0.1	0.0		2.0	6.4	-10.57	10.31
Global	0.1	0.4	0.0	0.1	0.0	0.0	0.1	0.0			0.7	-3.06	0.56
Gov	-0.1	-0.8	0.0	0.0	0.0	-0.3	-0.1	0.0			-1.3	1.31	-0.50
HY	0.6	0.2	0.0	0.9	9.8	0.0	0.1	0.3			12.0	-7.05	4.81
IG	1.2	7.1	0.0	8.8	0.3	1.7	5.7	0.0			24.7	-1.86	1.11
Loan	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0			0.6	-0.86	0.81
Mixed	3.1	3.8	0.6	4.9	1.4	1.2	0.9	28.9			44.8	-10.49	2.82
Multi	0.4	0.6	0.1	0.7	0.3	0.5	0.8	0.1			3.4	-2.84	0.90
Muni	0.1	0.0	0.8	0.0	0.0	0.0	0.0	0.0	4.7		5.5	-0.76	0.70
Total	5.8	13.8	1.5	15.7	13.5	3.2	7.6	29.2	4.7	2.0	96.9		

Source: IMF staff estimates.

196. This analysis, nevertheless, warrants several important caveats. Contagion dynamics are highly nonlinear, and thus inherently difficult to quantify. For instance, the estimation of price impacts relies on assumptions of market absorption capacity and are based on observed historical patterns. The liquidation strategy of different financial institutions is difficult to predict, as is the willingness to cut credit lines in a situation of stress by the providers of such lines. Insurance companies do not need to actively mark-to-market all assets on their balance sheets, and such losses would mainly materialize when disposing of these assets.

197. Stress losses could be compounded by systematic mispricing of risk. During the global financial crisis, financial risk was underestimated across a range of financial instruments—as was notably the case for asset-backed security CDOs. That experience showed that it is not only the underlying risk in the individual elements of structured product that can lead to higher than expected losses, but also the default correlation across these elements. To assess the effect from underestimating this risk, we estimate default correlations based on realized defaults and compare these correlations to those implicitly used in the ratings of CLO tranches (Box 2). The estimated default correlations can then be used to adjust the holding of CLOs (based on their adjusted ratings) across the different financial institutions that invest in these products.

[83] This assumes that banks would provide at least part of their US$760 billion committed lines to corporates.

Box 3. CLO Tranches, the Pricing of Risk, and Implications for Financial Institutions

Increased popularity of CLOs across different investors in recent years. Together with the rapid increased in leveraged finance—most notably, the so-called 'leveraged loans'—related structured products such as Collateralized Loan Obligations (CLO) has seen significant issuance in recent times. More than half of all leverage loan issuance ends up in CLOs. CLOs are securitized products which are in turn held by a wide range of investors, including domestic and foreign, insurance companies, mutual funds, hedge funds, among others. Different types of investors tend to invest in different CLO tranches. Banks tend to hold mainly triple-A-rated CLO tranches. Non-bank investors such as, for instance, asset managers, insurance companies, and hedge funds, tend to hold lower-rated tranches.

Default correlations are key for the adequate pricing of risk in CLO tranches. One of the lessons learnt from the global financial crisis is that the default correlation in structured products is a key driver of the overall creditworthiness of the bundled product. In particular, a large number of AAA-rated structured products, including several Mortgage Backed Securities (MBS) and Collateralized Debt Obligations (CDO), exhibited significantly larger than expected losses during the crisis. One of the main reasons was the systematic underestimation of default correlations. Since then, credit agencies have revised (up) some of the default correlations embedded in their ratings (see e.g., Nickerson and Griffin, 2017), but there has been limited quantitative work in estimating default correlation, particularly in the CLO market.[84]

This box presents quantitative estimates of default rates as well as default correlations of corporate debt instruments. Default correlations are estimated based on realized defaults in the spirit of Lucas (1995) and subsequent authors using a similar methodology (see Caceres et al. (2020b) for details). Default correlations are estimated for different elements within a given credit rating but also between different credit ratings. Essentially, the correlation between two elements (e.g., loan 1 and loan 2) with default events D_1 and D_2, with respective probabilities $P(D_1)$ and $P(D_2)$, is given by:

$$\rho_{D_1,D_2} = \frac{P(D_1, D_2) - P(D_1) \times P(D_2)}{\sqrt{P(D_1)\,(1 - P(D_1))} \times \sqrt{P(D_2)\,(1 - P(D_2))}}$$

The estimated default probabilities by credit ratings as well as the estimated default correlations within and between credit ratings can be seen in Table 6. As expected, lower-quality credit ratings tend to exhibit higher default correlations, suggesting that the most vulnerable elements tend to fall in distress concomitantly during periods of strain.

Applying the estimated default correlations to adjust the credit ratings of CLO tranches enables the computation of potential equity losses across financial institutions. Based on reported data of holding of CLOs by domestic banks and mutual funds, these holdings are repriced using the CLO tranche ratings implied from using the estimated default correlations.

[84] A few studies estimating default correlations include Lucas (1995), Nickerson and Griffin (2017), Li and Chen (2018), and Qi et al (2019).

Box 3. CLO Tranches, the Pricing of Risk, and Implications for Financial Institutions (concluded)

Estimation Results

Estimated 1-year ahead default correlations, by credit rating:

	A-AAA	BBB	BB	B	C-CCC
A-AAA	0.25	0.11	0.24	0.60	0.99
BBB	0.11	0.31	0.40	0.59	1.00
BB	0.24	0.40	0.63	1.29	2.19
B	0.60	0.59	1.29	2.69	4.54
C-CCC	0.99	1.00	2.19	4.54	8.69

Estimated 2-year ahead default correlations, by credit rating:

	A-AAA	BBB	BB	B	C-CCC
A-AAA	0.29	0.24	0.66	1.16	1.38
BBB	0.24	0.89	0.92	1.37	1.97
BB	0.66	0.92	1.79	3.00	3.96
B	1.16	1.37	3.00	4.97	6.50
C-CCC	1.38	1.97	3.96	6.50	9.70

Estimated 5-year ahead default correlations, by credit rating:

	A-AAA	BBB	BB	B	C-CCC
A-AAA	0.36	0.63	1.35	1.93	1.83
BBB	0.63	1.02	1.88	2.86	2.74
BB	1.35	1.88	3.83	5.62	5.43
B	1.93	2.86	5.62	8.39	8.48
C-CCC	1.83	2.74	5.43	8.48	9.90

Sources: Caceres et al. (2020b); and IMF staff calculations.

C. Complementary Market-Based Contagion Analysis

198. A market-based analysis is performed to assess indirect spillover risks between domestic banking entities and large foreign entities due to co-movement in asset prices. The spillover risks are analyzed using publicly available daily financial market prices—i.e., equity price returns. The spillovers analysis uses Diebold and Yilmaz's (2014) approach. This analysis evaluates the directional co-movement through equity price returns, as equity prices could—to some extent—reflect banks' current and expected fundamentals. A financial spillover from firm A to firm B is defined as the share of the variation in firm B's equity returns shocks that can be attributed to (contemporaneous or preceding) shocks to firm A's equity returns. The concept stresses idiosyncratic shocks and excludes co-movement across markets that is driven by common factors. The VAR is estimated using a lasso-estimator (see Zou and Hastie, 2005). Estimations are conducted by controlling for global conditions by using the VIX index. The specification is as follows:

$$A(L)Y_t + B(L)X_t = \varepsilon$$

$$D^H = \left[d_{i,j}^H\right]$$

$$X_t = [VIX, \dots]$$

Y is a vector of equity returns for all the firms in the sample, *X* is the Chicago Board Options Exchange Standard & Poor's 500 Implied Volatility Index (VIX), *A(L)* and *B(L)* are lag polynomials, *ε* is an error term, and *DH* is the H-step ahead generalized forecast error variance decomposition matrix.

199. The VAR model above is used to build a generalized forecast-error variance decomposition (GVD), using Pesaran and Shin's (1998) methodology, to identify uncorrelated structural shocks to FCIs.[85] The GVD for each firm is aggregated in a matrix, with the non-diagonal elements capturing spillovers effects. Specifically, the spillover from firm *i* to firm *j* is the percent of *j*'s total inward spillovers that are coming from i:

$$s_{ij} = \frac{d_{ij}}{\sum_{i\setminus\{j\}} d_{ij}}$$

The spillover therefore measures the fraction of the H-month ahead forecast error variance of firm *j*'s returns that can be accounted for by innovations in firm *i*'s returns.

200. Sample of institutions and calculations. The sample includes 160 large financial sector entities with asset size above US$100 billion in 20 countries. The analysis is performed using daily equity returns from 2015 through end-2019, estimated as log differences in equity prices. To control for the differences in trading hours in this cross-country setting, two-day averages are used (see Forbes and Rigobon, 2002). Estimations are conducted by controlling for global conditions by using the VIX index. Several sub-samples are assessed separately to explore domestic and cross-border equity return co-movement.

201. Results illustrate stronger equity return spillovers emanating from the U.S. G-SIBs. The directional co-movement ─controlling for common global shocks through the vix index─ shows relatively stronger co-movements in equity returns from the U.S. G-SIBs into domestic as well as foreign financial entities (Figure 54, panel 1). Inward spillovers from the U.S. G-SIBs into the U.S. Non-GSIBs are relatively high, while few Non-GSIBs with larger credit card operations reveal higher spillovers (Figure 54, panel 2). Large non-bank financial entities in the U.S. are also well connected with the domestic G-SIBs through equity return co-movement. Based on historical market conditions, spillovers emanating from Non-GSIBs and other U.S. non-bank financial entities are

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[85] The GVD identification framework is order invariant by construction, hence avoids the ad hoc ordering of structural shocks characteristic of recursive identification.

relatively subdued on average, compared to the spillovers from U.S. G-SIBs. In a nutshell, given the strong market-based interconnectedness between the G-SIBs' and other domestic financial entities as these results illustrate, monitoring market-based as well as exposure-based contagion between large domestic financial sector entities may provide room to identify potential vulnerabilities.

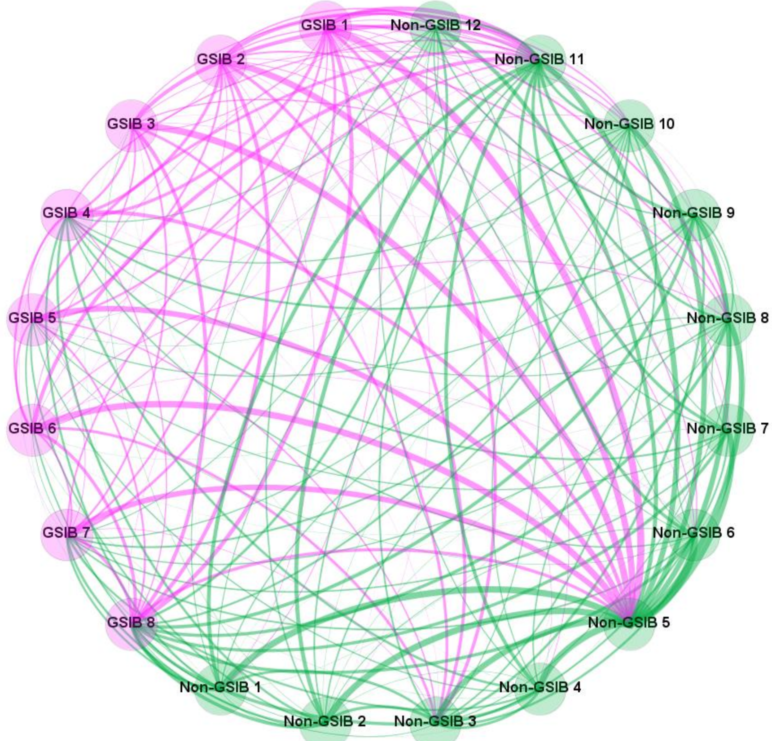
Figure 54. United States: Market-Based Banking Sector Interconnectedness vis-à-vis Domestic and Foreign Financial Sectors

Heat Map: Relative Spillovers, 2015–19

		From:					
		US GSIBs	US non-GSIBs	US Nonbank Financial Sector	Foreign GSIBs	Foreign non-GSIB banks	Foreign Nonbank Financial Sector
To:	US GSIBs						
	US non-GSIBs						
	US Nonbank Financial Sector						
	Foreign GSIBs						
	Foreign non-GSIB banks						
	Foreign Nonbank Financial Sector						

Equity Price Co-movement within the Domestic Banks: Net-Inward Spillovers

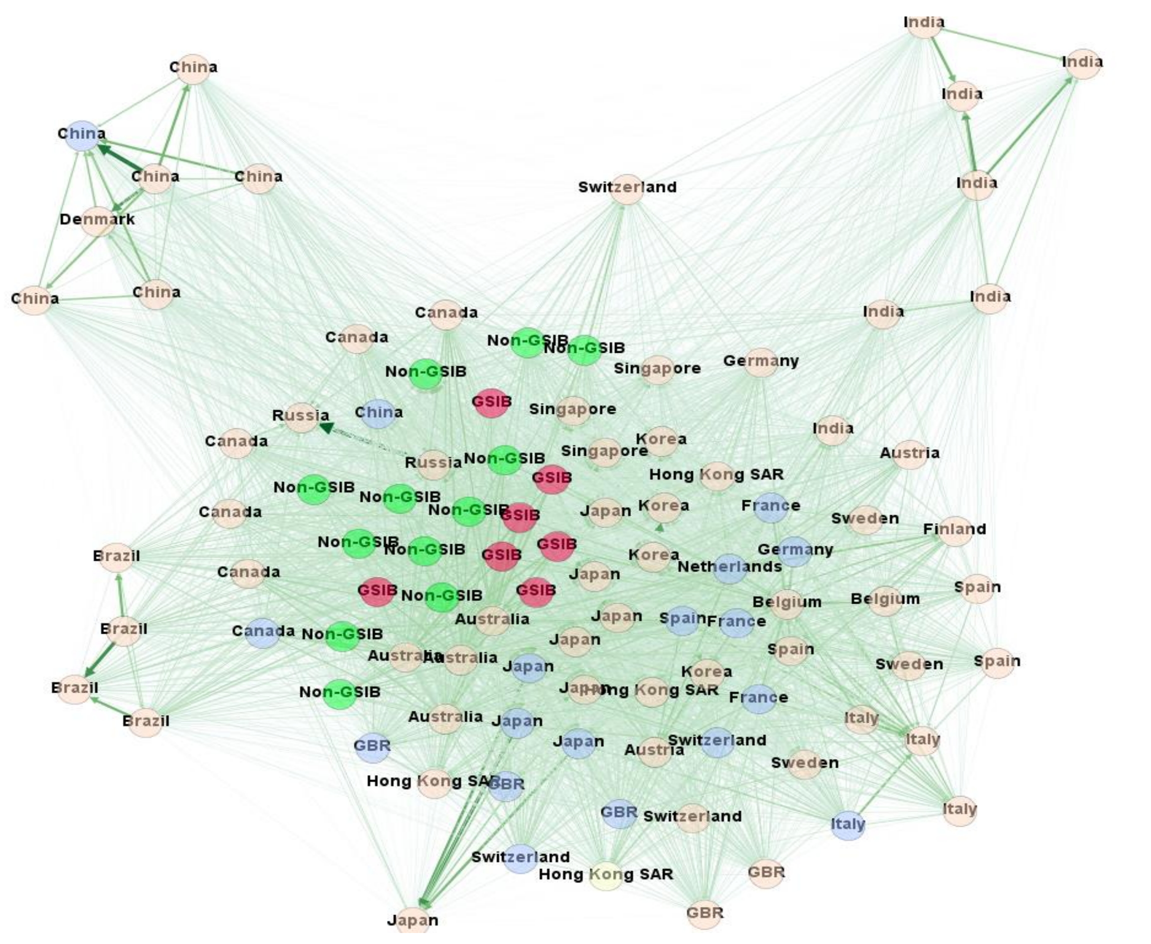
(Edge/line color = spillover transmitter color)



Sources: TR Datastream; Haver Analytics; IMF staff estimates.
Note: Data as of 2019:Q4. In panel 1, relative weighted average spillovers are shown. In panel 2, pink nods are domestic G-SIBs and green nods are other domestic BHCs in the FSAPs stress testing exercise. Edge width represents the intensity of the directional co-movement from similar colored nods into other nods.

202. Market-based interconnectedness reveals higher spillovers on average from the U.S. G-SIBs to foreign non-G-SIB banks, compared to the spillovers potentially transmitted through other groups of entities. While the spillovers from the U.S. G-SIBs into foreign G-SIBs are large, potential spillovers from U.S. G-SIBs into other foreign financial and domestic financial entities on average are relatively higher (Figure 55). The analysis also reveals spillovers emanating from foreign G-SIBs into domestic financial entities, though at a relatively lower intensity compared to domestic G-SIBs. These results also reveal that many U.S. banks are closely connected with major domestic and foreign banks and therefore centrally clustered in the network (Figure 58, where closer to the center suggests larger co-movement levels). Overall, the analysis highlights the role of the U.S. G-SIBs as a potential risk transmitter, and emphasizes that vulnerabilities could potentially emanate into the domestic banks from foreign G-SIBs.

Figure 55. United States: Market-based Cross-Border Banking Sector Interconnectedness: Net Inward Co-movement of Domestic Banks and Large Foreign Banks



Sources: TR Datastream; Haver Analytics; IMF staff estimates
Note: Data as of 2019:Q4. For banks outside the US, bank names are not shown; country names are shown instead, with country names representing where the bank is domiciled. Red nodes are U.S. G-SIBs, green nodes are U.S. Non-GSIBs in the FSAPs stress testing exercise, blue nodes represent foreign G-SIBs, and orange nodes are other large foreign banks. Proximity to the center suggests greater co-movement of equity price returns.

CONCLUSIONS

203. COVID outbreak put significant stress and amplified existing structural vulnerabilities in the financial system. The COVID-19 represents a real-life stress event, materializing through adverse shocks to both macroeconomic and financial conditions, exposing highly leveraged borrowers and lenders to default risks. US regulatory and supervisory agencies took swift and decisive actions to mitigate the effects of the outbreak on financial markets. Nevertheless, financial system is subject to numerous uncertainties related to the future financial conditions or borrowers, policy actions and priorities. Analysis conducted during the FSAP highlighted numerous changes compared to the previous crisis episodes, such as the GFC, differences of simulated shocks as well as remaining structural vulnerabilities.

204. After being at the epicenter of the global financial crisis, household mortgage debt has decreased substantially over the past decade, but other forms of consumer credit are on the rise. However, certain segments of consumer credit have seen a rapid growth in recent years. Auto loans now exceed US$1 trillion, and student loan debt is on the rise. If unabated, these segments could put pressure on households' debt servicing capacity, in light of tightened financial conditions, sharp increase in unemployment, exceeding the levels observed in the past crisis episodes. Banks stress test simulations reveal, that credit losses related to consumer credit and mortgages are the highest contributors to overall credit losses.

205. Corporate sector leverage is at its historic peak, while leveraged finance was growing rapidly. Increased financial risk taking, weakening underwriting standards and investor protections have allowed less creditworthy firms to access capital markets and increase their leverage. Much of this risk is distributed in the form of leveraged loans, private loans and CLOs, including abroad. Covenant protections for investors have weakened and the credit quality of new loans continues to deteriorate in light of COVID-19 shock. Important data gaps exist, particularly regarding direct and indirect exposures to leveraged and private loans across financial sub-sectors.

206. Corporate sector vulnerabilities could further amplify the COVID-19 shock to the most leveraged part of the corporate sector and delay an economic recovery as it reverberates through other sectors. Highly leveraged corporates already experience significant stress, leading to higher credit spreads, downgrades, inability to refinance debt, and defaults. As corporates de-lever and reduce costs, lay-offs would accelerate, consumer confidence decline, and the shock would spill to other segments of the economy. Financial institutions would suffer via direct and indirect exposures to the corporate and household sectors, resulting in funding liquidity stress, asset liquidations, and mark-to-market losses. Enhanced discretion resulting from weaker covenant protections for investors could imply delays in corporate restructurings and a subsequent economic recovery. Corporate stress test reveal, that up to 12 percent of corporates may face financial troubles in case of a prolonged recession, due to a second wave of COVID-19 infections. These results were taken into account in banking sector stress tests.

207. The U.S. banking system entered COVID-19 crisis well prepared: with strong capital and liquidity buffers. Observed behavior of banks at the outset of the crisis showed banks' ability to extend credit to the real sector and thus contain further amplification of the crisis impact on cash strapped corporates and households. Part of the preparedness of the banks is attributable to the authorities' DFAST/CCAR stress tests which are based on a conservative scenario. FSAP analysis shows, that stress test results for banks are comparable to those published by FRB (DFAST and CCAR) and use of market data proxies (EDFs) leads to only marginally more conservative estimates of loan portfolio losses compared to accounting data (also taking into account that many smaller companies are non-public). Overall, additional sensitivity analysis reveals that CET1 and leverage ratios do depend significantly on a net income and expense before credit/market risk losses.

208. The largest loan losses in the industry are generated by the credit card-related net charge-offs, followed by residential real estate and commercial and industrial net charge-offs. Overall, loan loss provisions contribute only a smaller fraction of the CET1 decline. Smaller domestic banks (Non-GSIBS) face most volatile CET1 and leverage ratios during stress compared to G-SIBS which have stronger market power and well diversified loan book and funding structure.

209. Non-GSIBS do depend more on interest income from loans, have relatively higher exposure to credit card and small business loans which exhibit the highest credit loss rates in the adverse sensitivity scenarios. Large banks (G-SIBs, Trading Banks) derive a larger share of their revenue from trading books, and thus are subject to additional losses due to marking-to-market of these trading assets and counterparty defaults. Going forward, it is important to ensure that Non-GSIBs have enough capital to support lending as well as be able to absorb losses in case of further deterioration of economic environment. This can be achieved assuming conservative capital planning and reducing or stopping shareholder payouts during the time of the crisis. Nevertheless, banks' capital shortfalls is moderate in the Baseline and Adverse sensitivity scenarios, ranging from 0.3 to 1.3 percent of GDP. The wide range of shortfall estimates reflect uncertainty regarding duration and severity of the crisis, balance sheet growth, as well as dividend payout/share buyback policies in quarters preceding downturn.

210. Banks maintain healthy liquidity buffers and were able to withstand severe funding outflows, at the same time, market liquidity dried out not just of mortgage and corporate but also sovereign bonds. G-SIBs and Non-GSIBS have large amount of stable deposit funding, while some trading as well as foreign owned banks still rely on repo markets to obtain liquidity. Partial closure of the repo market (only treasury securities accepted as collateral) would not have a significant effect on liquidity of G-SIBs, except when banks are not able to sell outright large amounts of sovereign (Treasury) securities. A similar shock was observed at the outset of COVID-19 crisis but was mitigated by a swift intervention from the Federal Reserve. Banks remain significant providers of short-term funding, including liquidity to corporates, households (credit cards), other banks and non-bank financial institutions. It is important to ensure that in times of stress all large banks, including Non-GSIBs, have enough liquidity buffers to continue provide funding to their clients and counterparts.

211. The U.S. banking system's vulnerability to shocks emanating from other banking systems is rather contained. The network analysis simulated a stress episode with shocks coming from credit and funding channels and evaluates the capital impairment due to contagion in the network of entities or banking systems. U.S. banking system play a larger role as a significant source of contagion. Results also suggest that capturing exposures based on different dimensions such as the level of consolidation and ownership reveal additional insights on where the pockets of vulnerabilities may arise and how the spillovers could amplify in potential stress episodes. A bank-level market-based analysis on equity return movements was also performed to complement the exposure-based analyses. The results reveal that the U.S. banks are closely connected with large foreign banks, thus centrally clustered in the network.

212. While the banking system was strengthened since the GFC, risks migrated to non-bank financial institutions. Highly leveraged institutions, such as investment, including hedge, funds, non-bank providers of funding such as mortgage lenders, may face higher liquidity and subsequent solvency risks during the downturn induced by COVID-19 pandemics.

213. Mutual funds are a key part of the U.S. financial system and are highly interconnected with other financial institutions through direct and indirect exposures. Some categories of mutual funds are subject to liquidity mismatches, as they invest in less liquid asset classes while providing daily redemptions. If significant in the aggregate, distress in the fund industry could have an important impact on financial stability.

214. Despite some mitigating effects stemming from the current valuation regime, parts of the insurance sector are vulnerable to severe market shocks and prolonged low interest rates. For insurance groups, analyses are complicated by the absence of a group capital requirement. The FSAP recommends the NAIC to develop and perform insurance solvency stress tests on a consolidated basis, in line with forthcoming group capital standards—also the work on liquidity stress tests should be further pursued. Public disclosures should be enhanced by requiring insurance companies to disclose market risk and interest rate sensitivities in a more harmonized manner.

215. Systemic risk analysis results indicate that not all institutions in the financial system are equally resilient: while banks have adequate capital and liquidity buffers, some risk takers (such as some categories of mutual funds, insurers) are more vulnerable. A marked rise in corporate stress would impact non-bank financial institutions, with a more moderate impact on banks, even though some large domestic banks are impacted more substantially. G-SIBs liquidity buffers are substantial, but high levels of utilization of credit and liquidity facilities would lead to a liquidity shortfall in some banks. Life insurers would face a significant reduction of their statutory capital in the adverse scenario, and a few less-diversified P&C insurers would face capital shortfalls after severe natural disasters. Most investment funds would be able to withstand severe redemptions, though high yield and loan funds would face significant shortfalls.

Appendix I. Banking Sector Solvency and Liquidity Stress Testing Matrix

A. Banking Sector: Solvency Test			
Domain		**Framework**	
		TD by FRB	**TD by FSAP Team**
1. Institutional perimeter	Institutions included	18 BHCs classified as *large and complex* were assessed during the 2019 DFAST/CCAR exercise (8 G-SIBs, 4 other domestic BHCs, 6 IHCs) based on conservative scenarios.	34 largest BHCs/IHCs. The criteria used to determine the institutional perimeter include: (1) FRB stress test sample of banks used in the 2018 DFAST/CCAR exercise; (2) firms' balance sheet size at or above US$100 billion (including one bank which assets are close to US$100 billion).
	Market share	About 65 percent of total banking sector assets in the United States.	About 78 percent of total banking sector assets in the United States.
	Data	Effective date: December 2018. Data: Mostly based on confidential FR Y-14A/M/Q reports and publicly available FR Y-9C report Scope of consolidation: Consolidated group basis.	Effective date: March 2020. Data: Based on publicly available FR Y-9C report accessed via S&P Market Intelligence platform, and supplemented by other data sources including Bloomberg, Dealogic, Haver Analytics, Moody's KMV, International Financial Statistics (IFS), IMF Global Assumptions (GAS), and IMF WEO. Scope of consolidation: Consolidated group basis.
	Stress testing process	The path of any additional macroeconomic or financial variable is derived in a way which is consistent with the scenario using FRB own models.	The FSAP team conducted its own TD stress test using *June 2020 WEO Update* forecast paths (baseline) and forecast paths generated by IMF's Global Macrofinancial Model (adverse) for all material geographies of included banks. The path of any additional macroeconomic or financial variable required by the IMF models is derived in a way which is consistent with the scenario (e.g., real estate prices, credit growth, equity prices, corporate bond yields, term spreads, etc.).

A. Banking Sector: Solvency Test			
Domain		**Framework**	
		TD by FRB	**TD by FSAP Team**
2. Channels of risk propagation	Methodology	FRB uses its own satellite models for: credit risk projections, bank interest rates and net interest margins, market risk, and banks' fee & commission income. FRB projects PPNR components using supervisory models that take the FRB's scenarios and firm-provided data as inputs. The FRB projects the paths of these variables as a function of aggregate macroeconomic variables included in the CCAR scenarios. FRB calculates projected pre-tax net income by combining projections of revenue, expenses, loan-loss provisions, and other losses.	FSAP team projected pre-tax net income at bank level by combining projections of PPNR components and loan loss provisions derived based on forecasted charge-offs and recoveries (57 separate specifications). The model's core set of regressions are used to forecast financial ratios related to pre-provision net revenue (PPNR), returns on AFS securities, and provisions conditional on macroeconomic conditions, lagged value of the ratio, and firm-level controls. FSAP team forecasted 26 PPNR-related ratios separately (8 interest income ratios, 7 interest expense ratios, 8 non-interest income ratios, and 3 non-interest expense ratios). The macroeconomic variables for these specifications are chosen based on the economic intuition rather than merely relying on the statistical significance. Bank-level controls such as various loan shares also enter the PPNR specifications to account for heterogeneity such as various business models these BHCs have. FSAP team forecasted charge-offs and recoveries ratios separately for 15 ratios (30 ratios in total) at industry-level as presented in the schematic below. The autoregressive nature of the specifications implies that the projected ratios will converge to their long-run steady state value. Solvency-funding cost interaction: bank-specific funding costs (interest expenses) conditional on stressed capital position.
3. Tail shocks	Scenario analysis	FRB scenarios is based on FRB policy statement and includes inter alia severe tail shocks such as increase in the level of unemployment by at least 4 p.p. up to a level not less than 10 percent. This corresponds to 1-in-100 years scenario.	The adverse scenario features a severe recession that occurs concurrently with significant financial market stress and a sharp housing and equity market correction and is characterized by a slow recovery. The main triggers are a deterioration of U.S. corporate debt markets and simultaneous downturns in Europe and China. The scenario is to a large extent similar to FRB's severely adverse scenario in terms of severity (less than 1 percent probability of occurrence).
	Sensitivity analysis	• Default of the largest counterparties	• Fintech impact on income and IT expenses. • Market shock on corporate loans, including CLOs/LLs. • Decreased reliance on FHLB funding.

A. Banking Sector: Solvency Test			
Domain		**Framework**	
		TD by FRB	**TD by FSAP Team**
4. Risks and buffers	Positions/risk factors assessed	Credit risk Estimated according to the FRBs stress testing framework. Framework is based upon accounting classification of assets. CLOs and securitization exposures are included. Off-balance sheet exposures using baseline and stressed Credit Conversion Factors (CCFs) are included. Traded risks Mark-to-market valuation of securities (from shocks to interest rates and credit spreads). For banks with large trading books, trading book exposures are shocked through a set of Global Market Shocks (GMS) with losses recognized in the first quarter of the planning period. In addition, DFAST applies a largest counterparty default shock (LCPD) to the trading firms and two other firms with substantial process and/or custodial operations. Both GMS and LCPD are add-ons to the macroeconomic scenarios. All sovereign issuers relevant for banks are included. Market stress from shocks to risk-free interest rates, exchange rates, credit spreads, commodities, and equity prices. Profit loss recognition. Losses/gains are recognized in the same quarter that a shock hit. Evolution of RWAs. RWAs for credit risk evolve according to STA approach as well as balance sheet growth requirements embedded into scenario. Net trading income from equity positions, debt instruments, and trading derivatives. Interest income declines by the amount of lost income from defaulted loans.	Credit risks: Estimated based on 15 charge-off and recoveries specifications for: first lien and junior lien residential mortgages, home equity lines of credit (HELOC), construction loans, multifamily and non-residential commercial mortgages, credit cards, other consumer loans, commercia and industrial (C&I) loans, loans to foreign governments, loans to depository institutions, agriculture loans, other residential real estate loans, and all other loans. Traded risks: Realized gains on AFS securities is estimated separately following the original CLASS model. Realized AFS gains and losses reflect a combination of asset price shocks, credit events, behavioral decisions about asset sales, and accounting judgment. Due to lack of access to detailed risk information such as mark-to-market losses at loan-level, this model may be more effective in forecasting variables for diversified firms. Market stress from shocks to risk-free interest rates, credit spreads, and equity prices are also incorporated into the framework through the FSAP macro scenario. Profit loss recognition. Losses/gains are recognized in the same quarter that a shock hit. Balance sheet and RWA projections Growth path of assets over the stress testing horizon is used to forecast the balance sheet variables and RWAs. The FSAP team first uses a simple approach of using the long-run historical asset growth, supplemented by additional approaches for robustness. The latter include: (1) assuming a zero growth in balance sheet in the stress testing horizon; (2) forecasting balance sheet growth to reflect dynamics of the nominal GDP path in the scenario. Tax rate: Assumed at 21 percent in the forecasting horizon

A. Banking Sector: Solvency Test			
Domain		Framework	
		TD by FRB	TD by FSAP Team
		Interest income from non-defaulting loans is estimated according to satellite models. Interest expenses increase due to rising funding costs linked to the macroeconomic scenario with empirically estimated pass-through, and add-on funding stress from a market event with no pass-through to lending rates. Net fee and commission income and other income evolve with macroeconomic conditions and banks' balance sheets. No change in business models (no rebalancing of portfolio). Balance sheets growth over the stress horizon. Starting in DFAST 2020, projections are based on the assumption that firms' balance sheets remain unchanged throughout the projection period. Also, in March 2020, the FRB amended its stress testing requirements to assume that a firm maintains a constant level of assets over the projection horizon and to assume that a firm will not pay any common dividends or make any issuance of common or preferred stock. Tax Rate The effective corporate income tax rate. Regulatory impact Stress tests results are compared against regulatory minima of CET1 and leverage ratios. G-SIB buffer is included into 4.5 percent CET1 minima and can be depleted. No conversion of additional Tier 1 capital is assumed during the stress horizon. If banks' capital ratio falls below regulatory minimum during the stress test horizon, banks are not able to return funds to shareholders (dividend payments as well as share buybacks).	Regulatory impact Stress test results are compared against a hurdle rate of 4.5. In addition to the hurdle rate, these BHCs are also subjected to a capital conservation buffer (CCB also includes the G-SIBs surcharge in the case of G-SIBs).
	Behavioral adjustments	Dynamic Balance Sheet: In line with 2019 FRB methodology.	Dynamic Balance Sheet: Balance sheet size is assumed to grow at historical industry growth rate

A. Banking Sector: Solvency Test			
Domain		Framework	
		TD by FRB	TD by FSAP Team
		Dividend Policy: Payout ratio set by 2019 FRB methodology.	Dividend Policy: Payout ratio projected based on a partial adjustment model with a payout rate of 45 percent for a portion of the net income. The specification is as follows: (0.9*(previous period's dividends) +((1-0.9) *(0.45*net income)).
5. Regulatory and market-based standards and parameters	Calibration of risk parameters	Parameter definition Net charge off ratios for credit risk (accounting definition)	Parameter definition Accounting portfolios.
	Regulatory standards	Capital definition according to national implementation of Basel principles, including CET1, Tier 1, leverage ratio and total CAR. Capital components that are no longer eligible for additional Tier 1 and Tier 2 capital components follow Basel III transitional path.	
6. Reporting format for results	Output presentation	Bank-by-bank: • Minimum CET1, Tier 1, CAR, and leverage ratio • Composition of P&L • Capital ratios • Profitability metrics: ROE; ROA; NII.	Contribution of key drivers to aggregate CET1 capital ratios Number of banks and share of total assets below hurdle rates. Capital shortfall in terms of nominal GDP. System-wide and by groups of banks: • CET1, Tier 1, CAR, and leverage ratio • Distribution of capital ratios (box plots) • Profitability metrics: ROE; ROA; NII

B. Banking Sector: Liquidity Test		
Domain		Framework
		TD by FSAP Team
1. Institutional Perimeter	Institutions included	33 banks on the consolidated basis
	Market share	Over 80 percent of total banking sector assets
	Output presentation	Public data: LCR disclosure templates containing cash flow data for 30 days period. Consolidated basis. Banks grouped by business model Baseline date: December 31, 2019
2. Channels of risk propagation	Methodology	Cash flow-based analysis using contractual LCR cash flow data aggregated for all currencies with assumptions about combined interaction of funding and market liquidity and different degrees of central bank support. Integrated Solvency-Liquidity-Network contagion framework with sequential recalculation of key solvency, liquidity and risk parameters to incorporate feedback loops due to asset fire-sales.

B. Banking Sector: Liquidity Test		
Domain		**Framework**
		TD by FSAP Team
	Feedback loops and links with solvency analysis	Solvency-Funding cost loop (price effect). Higher funding costs for those banks which experience significant decline in solvency ratios. CCP loop. Stress in collateral market (e.g., MBS, corporate securities downgrade etc.) leads to additional flows of collateral.
3. Sensitivity analysis	Perimeter and type of analysis	LCR distribution and volatility across banks
4. Tail Shocks	Size of the shock	Baseline: business as usual (as reported by banks under normal market conditions). Behavioral assumptions: all maturing liabilities are rolled-over. Collateral freeze scenario (e.g., due to cyber-risk related event at CCP) 1 day, 5 days and 1-month intermediate/severe market stress scenario: higher run-off rates on unsecured wholesale funding, and undrawn committed credit/liquidity lines on top of the mild stress scenario;
5. Regulatory and Market-Based Standards and Parameters	Regulatory standards	Threshold for cash flow-based analysis: net cumulative funding gap falls below 0.
6. Reporting Format for Results	Output presentation	Number of banks with negative net cumulative funding gaps; Aggregate negative cumulated counterbalancing capacity.

Appendix II. Interconnectedness Stress Testing Matrix

Banking Sector: Contagion Risk		
Domestic Interconnectedness: Exposure Based		
1. Institutional Perimeter	Institutions included	• Six domestic G-SIBs.
	Market share	• About 50 percent of the banking sector assets.
	Data and baseline date	• Confidential bilateral exposure data collected by the FRB for the BIS G-SIB hub and confidential liquidity data from FR 2052a. Given the confidentiality of the data used for this exercise, FRB will implement the analysis for the FSAP team. Data cutoff is as of end-December 2019.
2. Channels of Risk Propagation	Methodology	• First stage (Liquidity Shock) ○ Calibration of net outflows shock and comparison to the counter-balancing capacity ○ Liquidity channel-related contagion to the other entities occur due to the price impact of asset sales ○ Loss in capital due to liquidity channel-related losses (liquidation losses plus marked-to-market losses). These capital levels will carry forward to the second stage as the starting capital levels. • Second stage (Credit Shock and Risk Transfers) ○ Based on a modified version of Espinosa-Vega and Sole (2010) with [8] exposure categories separately.
3. Tail shocks	Size of the shock	• Redemption shocks/run-off factors in the first stage is scenario-based, calibrated based on historical evidence • Loss given default rates (LGDs) in the second stage varies by exposure category
4. Reporting Format for Results	Output presentation	• Capital shortfall in percent of initial capital before stage 1, by bank (without identifying individual banks by name); • Capital shortfall, system wide (with min, max, median values); • Heatmap with number of failed institutions given defaults.
Banking Sector: Contagion Risk		
Cross-Border Interconnectedness: Exposure Based		
1. Institutional Perimeter	Institutions included	• 22 large banking systems (both nationality/consolidated and locational residency basis) depending on bilateral exposures data availability through BIS
	Market share	• Includes exposures of internationally active banks in these banking systems
	Data and baseline date	• Based on publicly available and confidential BIS consolidated and locational data. Data cutoff is as of end-September 2019

Banking Sector: Contagion Risk		
Cross-Border Interconnectedness: Exposure Based		
2. Channels of Risk Propagation	Methodology	• Balance-sheet based; network contagion based on Espinosa-Vega and Sole (2010)
3. Tail shocks	Size of the shock	• Pure contagion: default of banking systems, 80-100 percent loss given default, 50 percent funding roll-over ratio. Further calibrations were conducted based on a range of LGD rates as sensitivity analyses.
4. Reporting Format for Results	Output presentation	• Capital shortfall, system wide on consolidated basis (i.e., based on nationality); • Capital shortfall, system wide on residency basis;
Banking Sector: Contagion Risk		
Domestic and Cross-Border Interconnectedness: Market Based		
1. Institutional Perimeter	Institutions included	• 120 depository institutions and 87 other financial entities in 23 countries. Out of the 207 total entities, 47 are U.S. entities.
	Market share	• All listed financial sector entities with consolidated assets above $100 billion.
	Data and baseline date	• Equity prices from Thompson Reuters DataStream (daily). Data cutoff is as of end-December 2019.
2. Channels of Risk Propagation	Methodology	• Market-based model: Diebold and Yilmaz's (2014) generalized forecast error variance decomposition approach. The analysis was conducted using either daily or weekly data. For daily data, following standard practice, two-day average was used to accommodate time differences across markets.
3. Tail shocks	Size of the shock	• Size of the correlation coefficient. Incorporates the asset size of these entities (i.e., asset-weighted coefficients).
4. Reporting Format for Results	Output presentation	• Heatmap of average co-movement between banks/non-banks in the US/Rest of the world • Network maps with co-movement between entities

Appendix III. Insurance Stress Testing Matrix

		Top-Down by IMF
Insurance Sector: Solvency Risk		
1. Institutional perimeter	Institutions included	• Macrofinancial scenario: 21 life insurance groups, 22 non-life insurance groups, 7 health insurance groups. • Low-for long: Life insurance sector. • Mass lapse event: 21 life insurance groups. • Natural disaster: 538 non-life insurers (solo), 44 small, regionally concentrated non-life insurers (solo). • Banking counterparty default: 21 life insurance groups, 22 non-life insurance groups, 7 health insurance groups.

	Market share	• Macrofinancial scenario (based on gross written premiums):
		  • Life: 70 percent.
		  • Non-life: 70 percent.
		  • Health: 45 percent.

	Data	• Regulatory reporting.
	Reference date	• December 31, 2018. [Possible update as of December 31, 2019]
2. Channels of risk propagation	Methodology	• Investment assets: other-than-temporary impairments on securities after price shocks, increase in the default rate for corporate bonds and loan exposures. • Insurance liabilities: unaffected by change in interest rates as discount rates are based on historic cost accounting. • Sensitivity analysis: effect on statutory capital.
	Time horizon	• Instantaneous shock.
3. Tail shocks	Scenario analysis	• Adverse macrofinancial scenario: Equity prices -40.4 percent (unaffiliated) and -20.0 percent (affiliated); property held for sale -23.2 percent; impairment on fixed-income instruments between 3.0 percent (NAIC rating category 3) and 15.0 percent (NAIC rating category 6); corporate bond yield increase between 2.8 percentage points (NAIC rating category 3) and 7.0 percentage points (NAIC rating category 6); impairment on mortgages 2.0 percent (first lien) and 10.0 percent (other mortgages).
	Sensitivity analysis	• Low-for-long interest rate projections. • Mass lapse event, triggered by a +2.0 percentage points interest rate hike for U.S. Treasury bonds. • Natural disaster: 1-in-50, 1-in-100, 1-in-250, and 1-in-500 years hurricane. • Default of the largest banking counterparty.
4. Risks and buffers	Risks/factors assessed	• Market risks: interest rates, share prices, property prices, credit spreads. • Asset-liability risks. • Credit risks, incl. counterparty risks. • Natural catastrophe risks. • Summation of risks, no diversification effects.
	Buffers	• None.

		Top-Down by IMF
		Insurance Sector: Solvency Risk
	Behavioral adjustments	• None.
5. Regulatory standards and parameters	Regulatory/ accounting standards	• U.S. Risk-Based Capital (RBC). • U.S. GAAP.
6. Reporting format for results	Output presentation	• Macrofinancial scenario: Impact on statutory capital and contribution of individual shocks; dispersion measures. • Low-for-long: Projection of net investment spread (investment return minus guaranteed interest rate). • Mass lapse event: Cash outflow, waterfall of assets which need to be liquidated; dispersion measures. • Natural disaster: Impact on statutory capital and RBC coverage ratio, number of companies with an RBC shortfall; dispersion measures. • Banking counterparty default: Impact on statutory capital; dispersion measures.

Appendix IV. Mutual Funds Stress Testing Matrix

		Top-Down by IMF
Mutual Fund Sector: Liquidity Risk		
1. Institutional perimeter	Institutions included	• All fixed income and mixed mutual funds covered by Morningstar (2,733 funds with total net assets of US$6,319 billion).
	Market share	• About 100 percent of the fixed income and mixed fund sector
	Data	• Commercial data (Morningstar)
	Reference date	• December 31, 2019
2. Channels of risk propagation	Methodology	• Calibration of redemption shock and comparison to level of highly liquid assets • Price impact due to asset sales • Second-round effects based on flow-performance relationship
	Time horizon	• Instantaneous shock
3. Tail shocks	Scenario analysis	• Adverse scenario: same as the banking sector scenario but converted to monthly frequency. • Pure redemption shock: severe outflows based on historical distribution: 3 percent expected shortfall (average of 3 percent worst net flows)
4. Risks and buffers	Risks/factors assessed	• Market risk: interest rates, share prices, credit spreads. • Liquidity risk: severe redemption shock
	Buffers	• Level of highly liquid assets
	Behavioral adjustments	• Choice of liquidation strategy used: slicing (prorata), waterfall (most liquid assets first) and mixed approach (cash then slicing) • Liquidity Management Tools are not taken into account
5. Regulatory standards and parameters	Regulatory/accounting standards	• N/A
6. Reporting format for results	Output presentation	• Number of funds with a redemption coverage ratio below one (ratio of highly liquid assets to redemptions). • Price impact of asset sales. • Redemptions due to second-round effects
Mutual fund Sector: Vulnerability analysis and contagion		
1. Institutional perimeter	Institutions included	• All fixed income and mixed mutual funds covered by Morningstar (2,733 funds with total net assets of about US$6.3 billion) and fixed-income ETFs.
	Market share	• About 100 percent of the fixed income and mixed fund sector
	Data	• Commercial data (Morningstar)
	Reference date	• December 31, 2019
2. Channels of risk propagation	Methodology	• CoVaR applied to fund flows and returns by fund category to identify most vulnerable funds and most contagious • Diebold-Yilmaz methodology applied to funds to identify most vulnerable funds and most contagious • Tail-dependence using copula

		Top-Down by IMF
Mutual Fund Sector: Liquidity Risk		
	Time horizon	• Monthly data
3. Tail shocks	Scenario analysis	• For Copula approach: expected net flows conditional on a fund category facing net flows worse than the 3 percent expected shortfall
4. Risks and buffers	Risks/factors assessed	•
	Buffers	•
	Behavioral adjustments	•
5. Regulatory standards and parameters	Regulatory/accounting standards	•
6. Reporting format for results	Output presentation	• Representation of interconnectedness among funds by fund category • Identification of fund categories most vulnerable to distress from other categories

Appendix V. Grouping of Banks

We grouped banks into different categories depending on business model and size of the bank. Appendix Table V.1 below shows grouping of banks by four different categories, namely G-SIBS (excluding four G-SIBS which are grouped as Trading Banks given their focus on trading related activities, investment banking and asset management services), Trading banks, foreign-owned banks and domestically institutions not considered systemically important (Non-GSIBs).

Appendix Table V.1. Banks included in the Stress Testing

Name	Stress Testing Category	Assets (2020: Q1); in th. USD
JPMorgan Chase & Co.	G-SIB	3,139,431,000
Bank of America Corporation	G-SIB	2,619,954,000
Citigroup Inc.	G-SIB	2,219,770,000
Wells Fargo & Company	G-SIB	1,981,349,000
Goldman Sachs Group, Inc.	Trading bank	1,089,759,000
Morgan Stanley	Trading bank	947,795,000
U.S. Bancorp	Non-GSIB	542,909,000
Truist Financial	Non-GSIB	506,229,000
Bank of New York Mellon Corporation	Trading bank	468,155,000
TD Group US Holdings LLC	Foreign	447,268,871
PNC Financial Services Group, Inc.	Non-GSIB	445,567,546
Capital One Financial Corporation	Non-GSIB	396,878,031
State Street Corporation	Trading bank	362,528,000
HSBC North America Holdings Inc.	Foreign	297,535,664
BMO Financial Corp.	Foreign	187,756,342
American Express Company	Non-GSIB	186,054,000
Fifth Third Bancorp	Non-GSIB	185,391,070
BNP Paribas USA, Inc.	Foreign	183,085,293
Ally Financial Inc.	Non-GSIB	182,527,000
Barclays US LLC	Foreign	179,955,000
Citizens Financial Group, Inc.	Non-GSIB	176,981,456
MUFG Americas Holdings Corporation	Foreign	165,696,005
UBS Americas Holding LLC	Foreign	163,248,851
Northern Trust Corporation	Trading bank	161,709,179
KeyCorp	Non-GSIB	157,003,466
Santander Holdings USA, Inc.	Foreign	152,144,560
RBC US Group Holdings LLC	Foreign	137,944,290
Regions Financial Corporation	Non-GSIB	133,638,000
Credit Suisse Holdings (USA), Inc.	Foreign	131,778,058
M&T Bank Corporation	Non-GSIB	124,577,833
DB USA Corporation	Foreign	117,159,000
Huntington Bancshares Incorporated	Non-GSIB	113,897,248
Discover Financial Services	Non-GSIB	112,656,646
BBVA Compass Bancshares, Inc.	Foreign	94,325,559

Source: IMF staff; and S&P Market Intelligence

Appendix VI. Risk Assessment Matrix

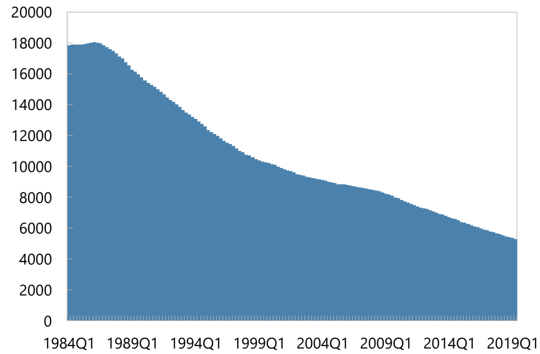
Nature of Risk	Overall Level of Concern	
	Medium-term Likelihood of Realization	**Expected Impact if Risk Materializes**
Sharper and longer growth slowdown	**High** Longer containment and uncertainties about the intensity and the duration of the COVID-19 outbreak reduce supply and domestic and external demand. Deteriorating economic fundamentals and the associated decline in risk appetite would result in a second wave of financial tightening and in debt service and refinancing difficulties for corporates and households.	**High** A sharp recession would have a negative impact on both the U.S. and the global economy. Rising unemployment and bankruptcies would impact banks' NPLs and increase credit risks, translating into financial institutions' losses and forcing them to cut credit, with further adverse implications for growth.
Sharp rise in risk premia	**High** An abrupt deterioration in market sentiment (e.g., prompted by policy surprises, pandemic, trade or geopolitical tensions) could trigger risk-off events such as recognition of underpriced risk. Financial asset prices could fall sharply, and credit spreads widen given the bulk of securities in the lowest investment grade rating.	**High** Liquidity could dry up in some funding and securities markets (e.g., leveraged loan market) reducing intermediation impacting banks and NBFIs. Higher risk premia cause higher debt service and refinancing risks; stress on leveraged corporates, and to a lesser extent households, disruptive corrections to stretched asset valuations—all depressing growth.
Cyber-attacks	**Low** Cyber-attack on the interconnected financial system reliant on a broadening array of interconnected platforms could trigger systemic financial instability or widely disrupt socio-economic activities.	**High** Shock to critical infrastructure causes delay, denial, disruption, breakdown or loss of services, affecting many institutions that rely on the attacked hub. This could also lead to a loss of confidence in the functioning of the financial system.
Distress of a major CCP or other financial infrastructure	**Low** Regulation and oversight of systemically important U.S. FMIs are generally adequate and effective. However, outcomes of the implementation of the relevant internationally agreed risk management requirements by CCPs is uneven in certain areas at select CCPs that may potentially exacerbate financial stability risks.	**High** The high interconnectedness and concentrated nature of major FMIs, interdependencies with the largest banks and quasi-monopolies for clearing specific asset classes could trigger a systemic event both domestically and globally.
Inadequate preparations for LIBOR transition	**Medium** While progress has been made in moving to a new benchmark, there are still significant risks that public and private entities may not be ready for the transition by the end of 2021.	**Medium** With more than $200 trillion of LIBOR-based contracts, problems in transitioning to a new benchmark could cause very significant disruption in financial markets.

Note: The Risk Assessment Matrix shows events that could materially alter the baseline path (the scenario most likely to materialize in the view of IMF staff). It reflects views of the FSAP team on the sources of financial stability risks surrounding the baseline, relative likelihood of their realization sometime in the next three years, and the overall level of concern.

Appendix VII. Structure of the U.S. Financial System

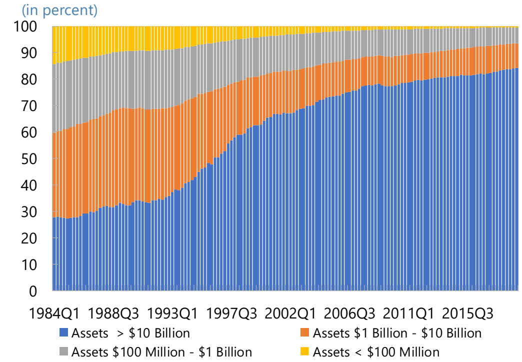
Appendix Figure VII.1. United States: Bank Funding and Shadow Banks

Number of commercial banks - FDIC insured



Sources: FDIC.

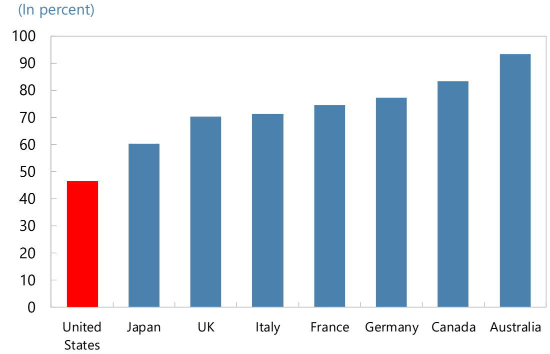
Distribution of banks by size
(in percent)



Sources: FDIC.

U.S. banking sector concentration is relatively low, compared to the peers...

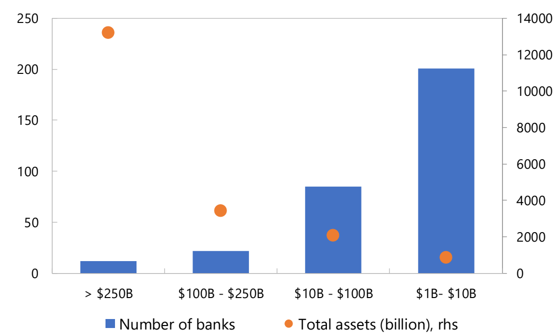
Market Share of Top 5 Banks
(In percent)



Sources: Global Financial Development database.

...although a significant amount of assets is held by large banks

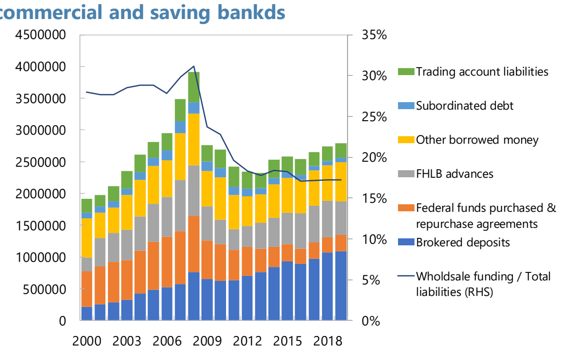
Banks by Asset Size



Sources: Flow of Funds.

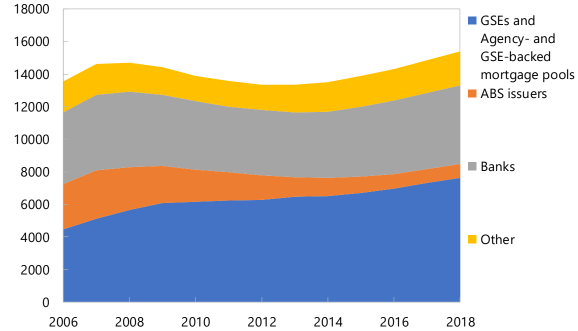
Appendix Figure VII.2. United States: Bank Funding and Shadow Banks

Structure of wholesale funding: commercial and saving bankds



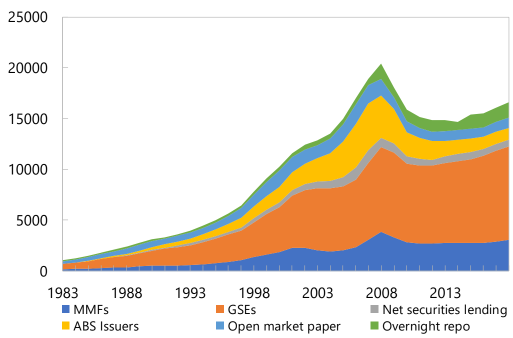
Sources: FDIC.

Mortgage market
(billion of US$)



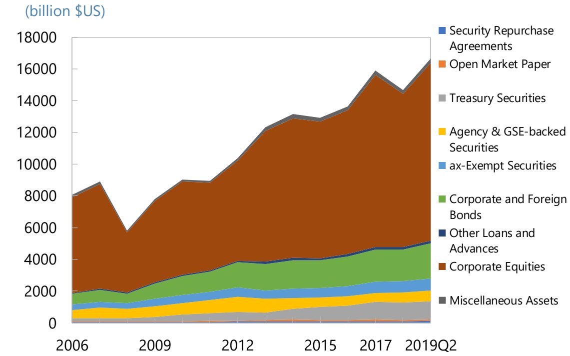
Sources: Federal Reserve (Flow of Funds).

Shadow banking system
(Billion US$)



Sources: Flow of Funds.

Mutual Funds assets
(billion $US)

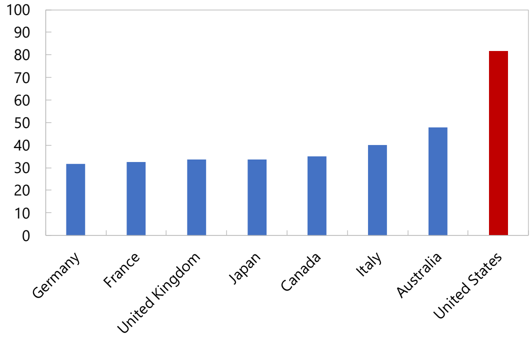


Sources: Flow of Funds.

Appendix Figure VII.3. United States: Banking Sector Indicators

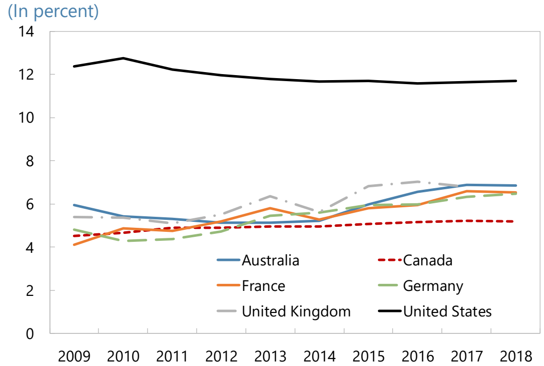
Structural and regulatory specificities increase the average risk-weight of U.S. banks exposures….

Risk Weighted Assets-to-Total Assets
(In percent)



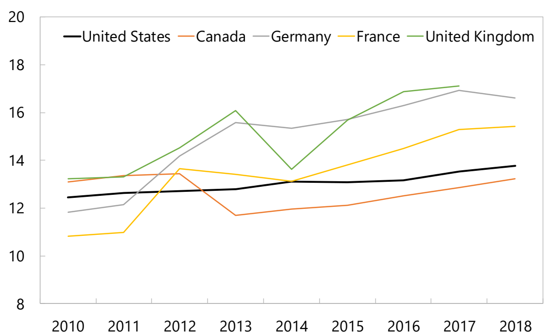
…contributing to relatively low leverage in the sector…

Capital-to-Total Assets
(In percent)



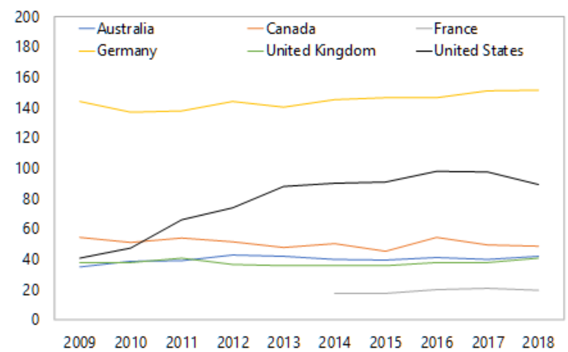
…despite average capital ratios below peers.

Tier 1 Capital-to-Risk Weighted Assets
(In percent)



Banks profitability is substantially above peers.

Liquid Assets-to-Short-Term Liabilities
(In percent)



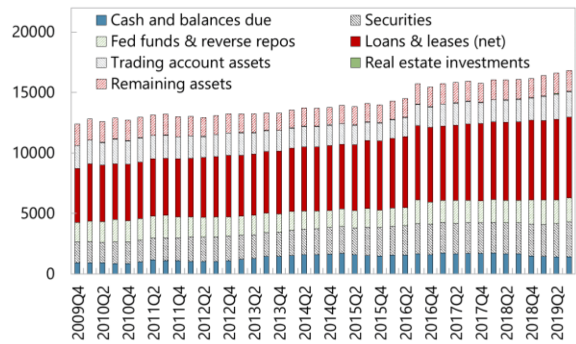
Sources: IMF, Financial Soundness Indicators database; IMF staff calculations.

Appendix Figure VII.4. United States: Banking Sector: Composition of Assets and Liabilities

There were a few shifts in composition of banks' balance sheets since the GFC: an increase in cash and CB reserves….

Composition of Assets

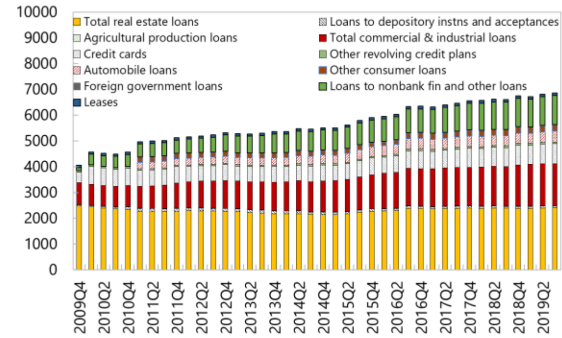
(In billions of US dollars; aggregate for 35 BHCs)



…and rising share of credit provided to non-bank financial institutions (incl. "shadow banks")

Composition of Loans and Leases

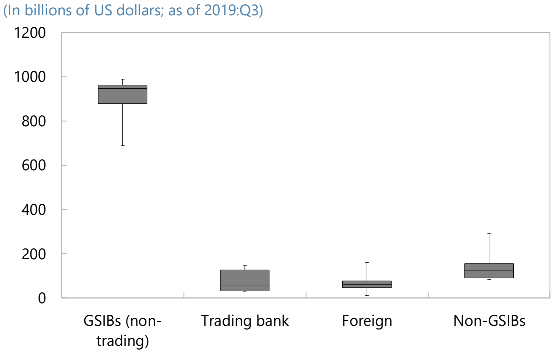
(In billions of US dollars; aggregate for 35 BHCs)



Loan market concentration is high by the 6 G-SIBs having a share almost four times higher than smaller domestic banks

Net Loans and Leases

(In billions of US dollars; as of 2019:Q3)

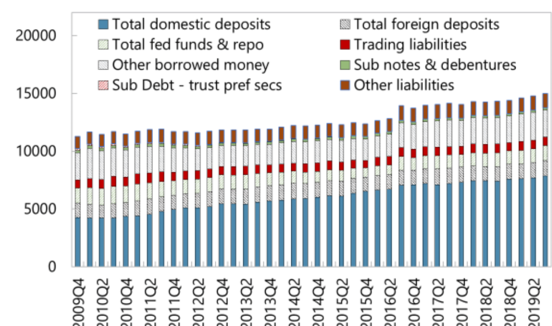


Sources: FRB; S&P Market Intelligence

Banks' funding remains domestic too: share of domestic deposits steadily went up, and foreign funding remains small

Composition of Liabilities

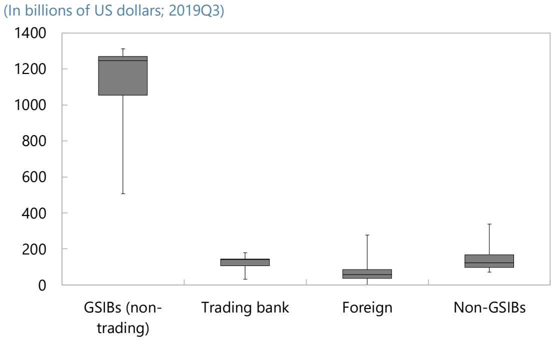
(In billions of US dollars; aggregate for 35 BHCs)



Most of the deposits concentrated in the largest 6 G-SIBS

Domestic Deposits

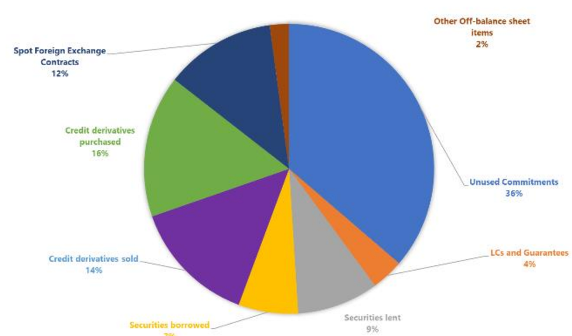
(In billions of US dollars; 2019Q3)



Sources: FRB; S&P Market Intelligence.

Unused commitments represent the largest item in off-balance sheet exposures

Off-balance Sheet Exposures

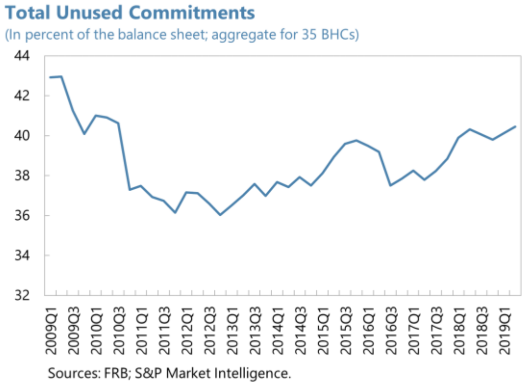


Sources: S&P; IMF staff calculations.

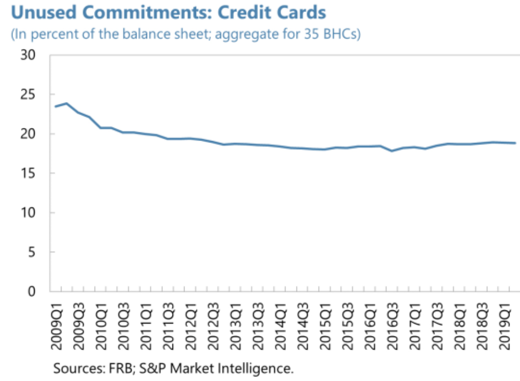
Note: In panels 3 and 5, the horizontal bars in between the boxes denote the median.

Appendix Figure VII.5. United States: Banking Sector: Selected Off-Balance Sheet indicators

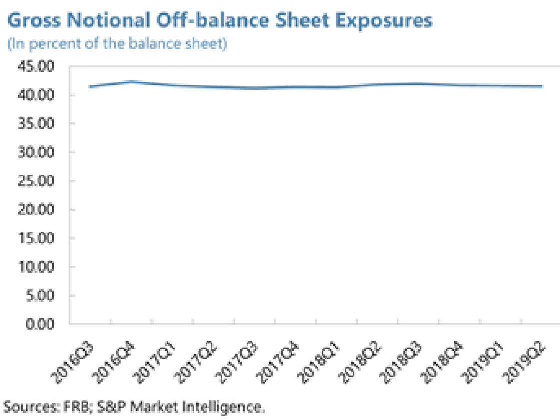
Unused commitments for the sample of 35 banks did not reach the levels seen during the GFC, however they show an increasing trend in the last couple of years…



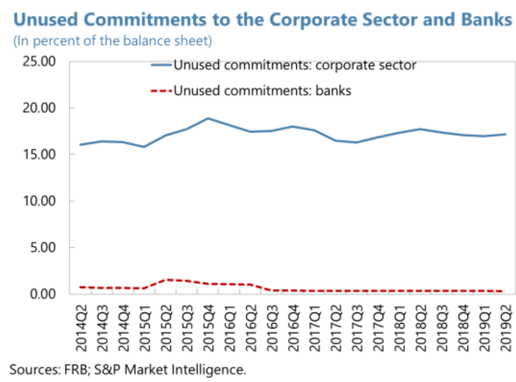
Consumer credit cards is the largest item among unused commitments: credit and liquidity facilities.



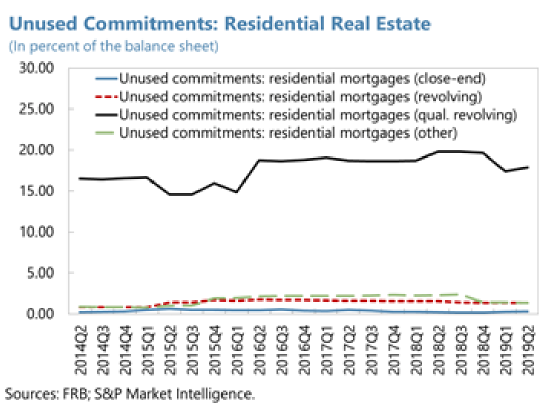
For the most complex and largest banks (13 banks in the sample) which use Internal rating-based approach, off balance sheet commitments are stable in recent years and constitute about 40 percent of the on-balance sheet exposures….



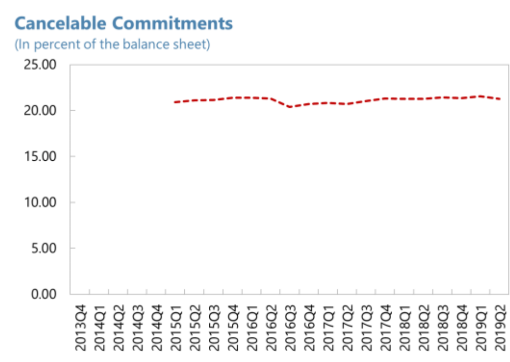
…with unused commitments for corporate sector accounting for almost half of total commitments.



Residential real estate loans represent another significant share of off-balance sheet exposures.



Almost half of the commitments are unconditionally cancelable.

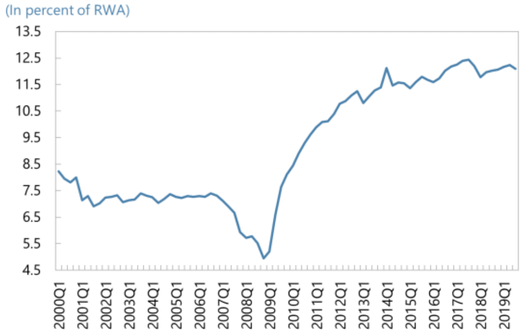


Sources: S&P; IMF staff calculations.

Appendix Figure VII.6. United States: Banking Sector: Capital and Leverage

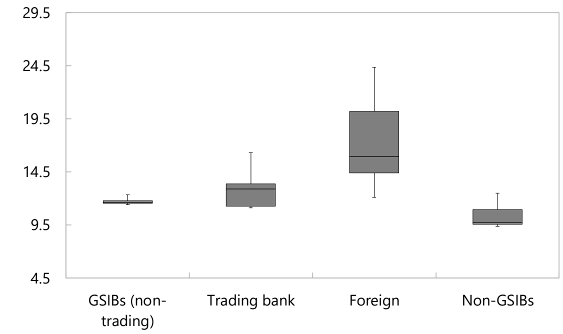
CET1 ratio increased almost three times since the GFC……

CET1 Ratio
(In percent of RWA)



…with foreign owned banks reporting the highest CET1 ratios on average

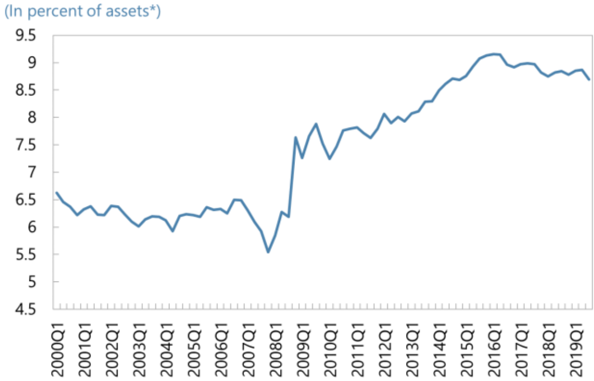
CET1 Ratio
(In percent of RWA; 2019Q3)



Sources: FRB; S&P Market Intelligence.

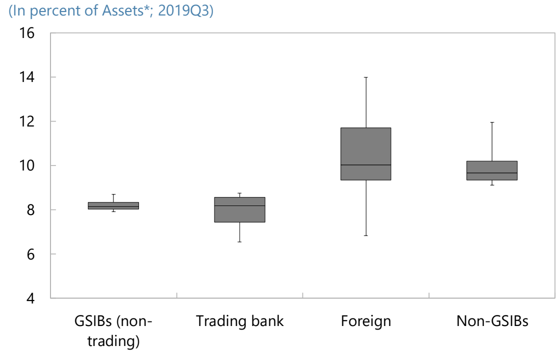
Leverage decreased steadily….

Tier1 Leverage Ratio
(In percent of assets*)



…although foreign banks remain the most leveraged institutions….

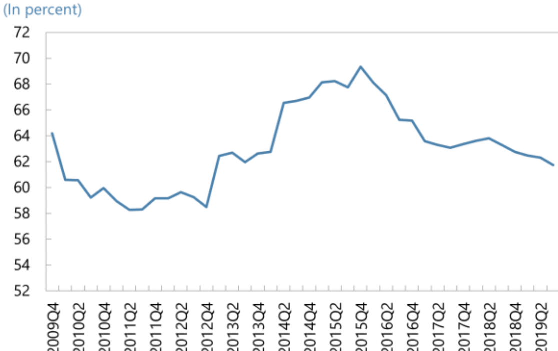
Tier1 Leverage Ratio
(In percent of Assets*; 2019Q3)



Sources: FRB; S&P Market Intelligence.

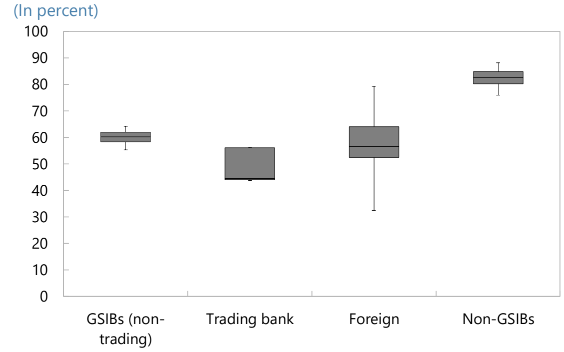
…which explained by the fact that while RWAs density went down…

Risk Weighted Asset Density
(In percent)



Foreign and trading banks have lowest density due to high share of Treasury bonds and other low risk weight assets

Risk Weighted Asset Density
(In percent)



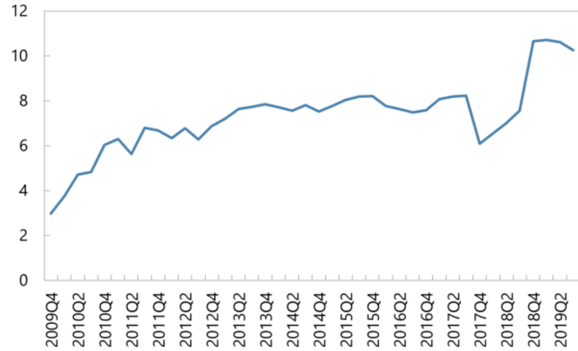
Sources: FRB; S&P Market Intelligence.

Sources: S&P; IMF staff calculations.
Note: In panels 2, 4 and 6, the horizontal bars in between the boxes denote the median.

Appendix Figure VII.7. United States: Banking Sector: Profitability

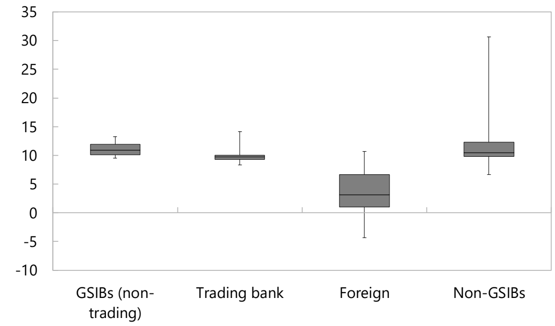
Return on equity steadily went up given strong demand for loans, increased share buybacks and dividend payments…

Return on Equity
(In percent)



…but foreign owned banks still trailing behind domestic ones

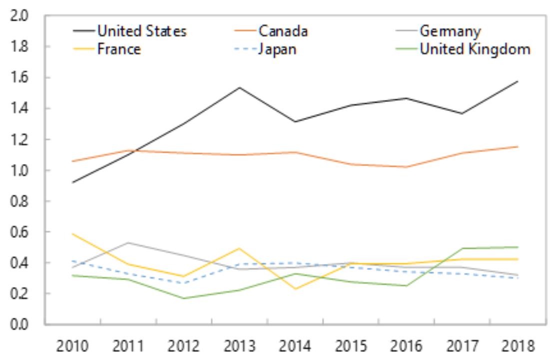
Return on Equity
(In percent)



Sources: FRB; S&P Market Intelligence.

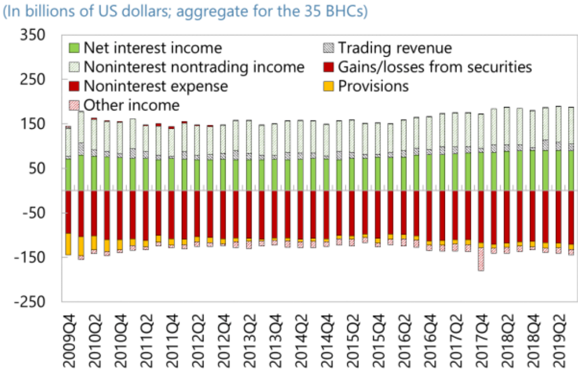
Overall, U.S. banks are strongest performers across peers….

Return on Assets
(In percent)



…maintaining healthy shares of interest and non-interest (less cyclical) income

Income Composition
(In billions of US dollars; aggregate for the 35 BHCs)

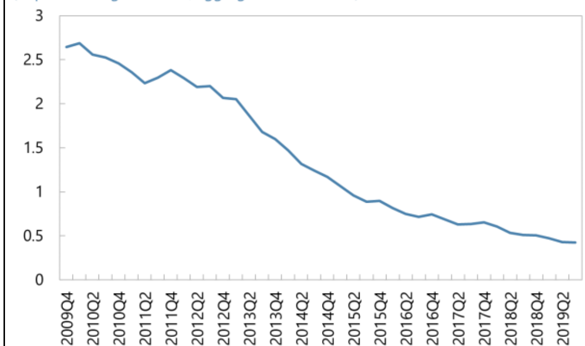


Sources: S&P; IMF staff calculations.
Note: In panel 2, the horizontal bars in between the boxes denote the median.

Appendix Figure VII.8. United States: Banking Sector: Loan losses

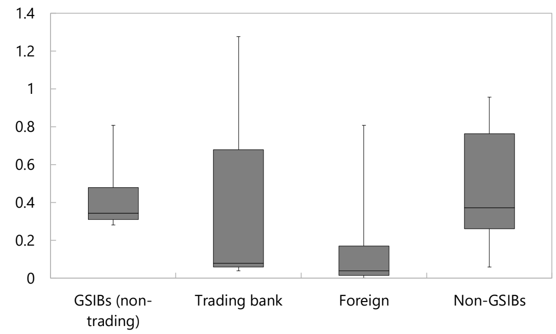
NPLs declined to its lowest level since the GFC.....

NPLs: Past Due 90-days or More
(In percent of gross loans; aggregate for 35 BHCs)



...with G-SIB and D-SIB having relatively higher levels of past loans reflecting their higher exposures to nonfinancial corporate and household sectors

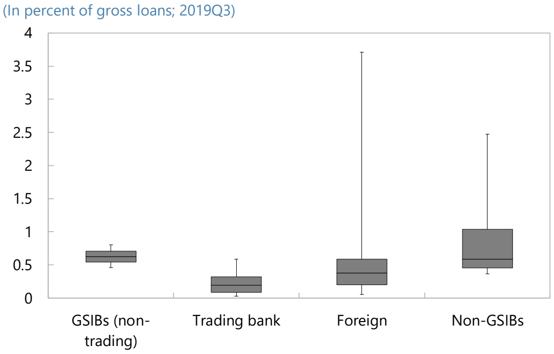
NPLs: Past Due 90-days or More
(In percent of gross loans; 2019Q3)



Sources: FRB; S&P Market Intelligence.

Loans past-due by less than 90 days exhibit similar trends across different categories of banks....

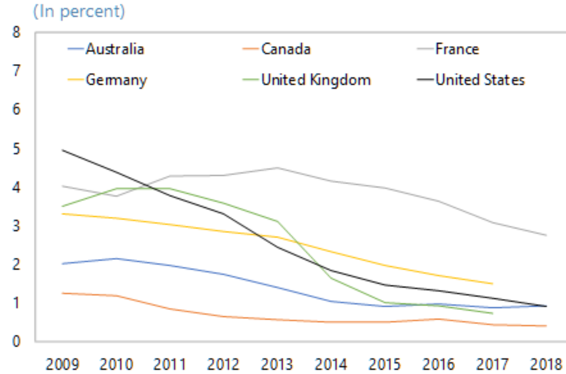
NPLs: Past Due 30-89 Days
(In percent of gross loans; 2019Q3)



Sources: FRB; S&P Market Intelligence.

U.S. has a relatively low level of NPLs compared with other large countries

Non-Performing Loans-to-Total Gross Loans
(In percent)



Sources: S&P; IMF staff calculations.
Note: In panels 2 and 3, the horizontal bars in between the boxes denote the median.

Appendix VIII. Stress Test Scenarios

Appendix Table VIII.1. Baseline Scenario Based on the *June 2020 WEO Update* Projections

	Real GDP Growth *(percent, Q-o-Q annualized)*	Unemployment Rate *(percent)*	3-Month Treasury Rate *(percent)*	10-Year Treasury Bond Yield *(percent)*	BBB Corporate Bond Yield *(percent)*	Stock Market Index *(2019Q4=100)*	House Price Index *(2019Q4=100)*
2019Q4	2.1	3.5	1.6	1.8	3.3	100.0	100.0
2020Q1	-5.0	3.8	1.1	1.4	3.3	92.9	101.3
2020Q2	-44.9	13.5	0.1	0.7	5.2	77.7	98.4
2020Q3	22.8	12.9	0.1	0.9	6.1	70.5	94.8
2020Q4	10.7	11.5	0.1	0.9	6.5	68.9	91.3
2021Q1	8.0	10.6	0.1	1.0	6.6	70.5	87.1
2021Q2	6.1	10.0	0.1	1.0	6.2	72.0	83.1
2021Q3	4.2	9.5	0.1	1.0	5.9	73.6	79.4
2021Q4	3.2	9.2	0.1	1.1	5.6	75.1	75.8
2022Q1	2.8	9.0	0.0	1.2	5.2	76.7	73.9
2022Q2	2.5	8.9	0.0	1.3	4.9	78.2	73.3
2022Q3	2.2	8.7	0.0	1.5	4.6	79.8	73.8
2022Q4	2.2	8.6	0.0	1.6	4.4	81.3	74.5
2023Q1	2.1	8.4	0.0	1.7	4.1	82.9	75.7
2023Q2	2.1	8.3	0.0	1.8	4.1	84.4	77.9
2023Q3	2.1	8.1	0.0	1.8	4.0	86.0	80.1
2023Q4	2.1	8.0	0.0	1.8	3.9	87.6	82.3
2024Q1	2.1	7.9	0.0	1.8	3.8	89.1	84.5
2024Q2	2.0	7.8	0.0	1.8	3.7	90.7	86.7
2024Q3	2.0	7.6	0.0	1.8	3.7	92.2	89.0
2024Q4	2.0	7.5	0.0	1.9	3.6	93.8	91.2
2025Q1	2.0	7.4	0.0	1.9	3.5	95.3	93.4
2025Q2	2.0	7.3	0.0	1.9	3.4	96.9	95.6
2025Q3	1.9	7.2	0.0	1.9	3.3	98.4	97.8
2025Q4	1.9	7.0	0.0	1.9	3.3	100.0	100.0

Appendix Table VIII.2. Sensitivity Scenario 1

	Real GDP Growth *(percent, Q-o-Q annualized)*	Unemployment Rate *(percent)*	3-Month Treasury Rate *(percent)*	10-Year Treasury Bond Yield *(percent)*	BBB Corporate Bond Yield *(percent)*	Stock Market Index *(2019Q4=100)*	House Price Index *(2019Q4=100)*
2019Q4	2.1	3.5	1.6	1.8	3.3	100.0	100.0
2020Q1	-4.8	3.8	1.1	1.4	3.3	96.8	101.2
2020Q2	-66.8	22.8	0.1	0.6	5.8	72.9	93.3
2020Q3	29.5	25.3	0.1	0.8	6.8	66.6	89.9
2020Q4	21.6	23.3	0.1	0.8	7.1	66.1	86.6
2021Q1	16.1	21.1	0.1	0.9	7.1	68.4	82.6
2021Q2	7.3	19.5	0.1	0.9	6.7	69.7	78.7
2021Q3	4.2	18.3	0.1	0.9	6.4	71.0	75.2
2021Q4	3.2	17.4	0.1	1.0	6.0	72.3	71.9
2022Q1	2.8	16.7	0.0	1.1	5.6	73.6	70.1
2022Q2	2.5	16.1	0.0	1.3	5.3	74.9	69.6
2022Q3	2.2	15.5	0.0	1.4	5.0	76.3	70.4
2022Q4	2.2	15.0	0.0	1.5	4.8	77.6	71.3
2023Q1	2.1	14.4	0.0	1.6	4.4	78.9	72.6
2023Q2	2.1	13.9	0.0	1.7	4.3	80.2	75.0
2023Q3	2.1	13.4	0.0	1.7	4.3	81.5	77.4
2023Q4	2.1	12.8	0.0	1.7	4.2	82.8	79.8
2024Q1	2.1	12.3	0.0	1.7	4.1	84.2	82.2
2024Q2	2.0	11.8	0.0	1.7	4.0	85.5	84.6
2024Q3	2.0	11.2	0.0	1.7	3.9	86.8	87.0
2024Q4	2.0	10.7	0.0	1.7	3.8	88.1	89.4
2025Q1	2.0	10.2	0.0	1.7	3.7	89.4	91.8
2025Q2	2.0	9.7	0.0	1.8	3.7	90.7	94.2
2025Q3	1.9	9.1	0.0	1.8	3.6	92.1	96.6
2025Q4	1.9	8.6	0.0	1.8	3.5	93.4	99.0

Appendix Table VIII.3. Sensitivity Scenario 2

	Real GDP Growth *(percent, Q-o-Q annualized)*	Unemployment Rate *(percent)*	3-Month Treasury Rate *(percent)*	10-Year Treasury Bond Yield *(percent)*	BBB Corporate Bond Yield *(percent)*	Stock Market Index *(2019Q4=100)*	House Price Index *(2019Q4=100)*
2019Q4	2.1	3.5	1.6	1.8	3.3	100.0	100.0
2020Q1	-4.8	3.8	1.1	1.4	3.3	96.8	101.2
2020Q2	-66.8	22.8	0.1	0.5	5.8	72.9	88.3
2020Q3	0.0	26.5	0.1	0.7	7.2	62.5	83.9
2020Q4	29.5	24.5	0.1	0.7	7.5	63.0	80.8
2021Q1	21.6	22.2	0.1	0.8	7.4	65.8	77.0
2021Q2	7.3	20.7	0.1	0.8	6.9	67.1	73.2
2021Q3	4.2	19.6	0.1	0.8	6.6	68.4	69.8
2021Q4	3.2	18.8	0.1	0.9	6.3	69.7	66.6
2022Q1	2.8	18.1	0.0	1.0	5.8	70.9	65.0
2022Q2	2.5	17.5	0.0	1.1	5.5	72.2	64.7
2022Q3	2.2	17.0	0.0	1.2	5.2	73.5	65.6
2022Q4	2.2	16.4	0.0	1.4	4.9	74.7	66.6
2023Q1	2.1	15.9	0.0	1.5	4.6	76.0	68.2
2023Q2	2.1	15.4	0.0	1.5	4.5	77.3	70.7
2023Q3	2.1	14.9	0.0	1.5	4.4	78.5	73.3
2023Q4	2.1	14.4	0.0	1.5	4.3	79.8	75.8
2024Q1	2.1	13.9	0.0	1.5	4.2	81.1	78.4
2024Q2	2.0	13.4	0.0	1.6	4.2	82.3	80.9
2024Q3	2.0	12.9	0.0	1.6	4.1	83.6	83.4
2024Q4	2.0	12.4	0.0	1.6	4.0	84.9	86.0
2025Q1	2.0	12.0	0.0	1.6	3.9	86.1	88.5
2025Q2	2.0	11.5	0.0	1.6	3.8	87.4	91.0
2025Q3	1.9	11.1	0.0	1.6	3.7	88.7	93.4
2025Q4	1.9	10.8	0.0	1.6	3.6	89.9	95.8

Appendix Table VIII.4. Sensitivity Scenario 3

	Real GDP Growth *(percent, Q-o-Q annualized)*	Unemployment Rate *(percent)*	3-Month Treasury Rate *(percent)*	10-Year Treasury Bond Yield *(percent)*	BBB Corporate Bond Yield *(percent)*	Stock Market Index *(2019Q4=100)*	House Price Index *(2019Q4=100)*
2019Q4	2.1	3.5	1.6	1.8	3.3	100.0	100.0
2020Q1	-4.8	3.8	1.1	1.4	3.3	96.8	101.2
2020Q2	-66.8	22.8	0.1	0.5	5.8	72.9	83.3
2020Q3	29.5	25.3	0.1	0.6	6.8	66.6	79.1
2020Q4	21.6	23.3	0.1	0.6	7.1	66.1	76.2
2021Q1	-36.4	25.3	0.1	0.6	8.3	58.8	68.3
2021Q2	29.5	22.8	0.1	0.7	7.4	62.8	65.6
2021Q3	21.6	20.5	0.1	0.7	6.8	66.5	63.5
2021Q4	3.2	19.7	0.1	0.8	6.4	67.7	60.4
2022Q1	2.8	19.1	0.0	0.9	6.0	69.0	58.9
2022Q2	2.5	18.5	0.0	1.0	5.6	70.2	58.7
2022Q3	2.2	18.0	0.0	1.1	5.3	71.4	59.8
2022Q4	2.2	17.5	0.0	1.2	5.1	72.7	60.9
2023Q1	2.1	17.0	0.0	1.3	4.7	73.9	62.6
2023Q2	2.1	16.5	0.0	1.3	4.6	75.1	65.3
2023Q3	2.1	16.0	0.0	1.3	4.6	76.4	68.0
2023Q4	2.1	15.5	0.0	1.3	4.5	77.6	70.7
2024Q1	2.1	15.0	0.0	1.3	4.4	78.8	73.4
2024Q2	2.0	14.6	0.0	1.4	4.3	80.1	76.0
2024Q3	2.0	14.1	0.0	1.4	4.2	81.3	78.7
2024Q4	2.0	13.7	0.0	1.4	4.1	82.5	81.3
2025Q1	2.0	13.2	0.0	1.4	4.0	83.8	83.9
2025Q2	2.0	12.9	0.0	1.4	3.9	85.0	86.4
2025Q3	1.9	12.5	0.0	1.4	3.8	86.2	88.9
2025Q4	1.9	12.3	0.0	1.4	3.7	87.5	91.1

Appendix IX. Class: Amendments and Econometric Estimation Results

The FSAP team made the following modifications/extensions to the CLASS model:

a. *Sample size*. The stress testing is adjusted to reflect largest bank holding companies with consolidated assets over $100 billion (35 largest bank holding companies covering about 80 percent of the banking sector is used in the stress testing exercise);

b. *Risks from foreign activities/exposures***.** Geographical segmentation of income: domestic vs. foreign.

c. *Interest income modeling, dynamic balance sheet and changes in assets/liabilities***.** The CLASS model estimates net interest income as one specification, and therefore there is no explicit modeling of funding costs and loan interest rates. This analysis models them separately to be able to capture changes in funding profiles (solvency-liquidity feedback) and composition of balance sheets (i.e., to be able to use dynamic stress tests).

d. *Losses and recoveries.* The CLASS model uses net charge-off, i.e., does not model losses and recoveries separately. To simulate delayed GDP recovery scenario, we model recoveries separately.

The modified model is based on 57 different income statement specifications to improve the quality of stress testing in the absence of access to confidential supervisory data. As illustrated in the figure on the bank solvency stress testing below (Appendix Figure IX.1), we forecast 26 pre-provision net revenue (PPNR)-related ratios separately (8 interest income ratios, 7 interest expense ratios, 8 non-interest income ratios, and 3 non-interest expense ratios). Such granularity in the income statement breakdown provides room to capture solvency-liquidity feedback loop dynamics such as those that are related to changes in funding profiles and other balance sheet components.

The macroeconomic variables used in the regression specifications are chosen based on the economic intuition rather than merely relying on the statistical significance to better capture the economic significance of forecasted variables.[1] The regressions are estimated in a fixed effects panel setting thus controlling for heterogeneity among the 35 banks in the sample (such as various business models) through panel fixed effects. An autoregressive term (AR1) also enters the model, thus implying that the projected ratios will converge to their long-run steady state value. For robustness, in cases where weaker predictive power and weaker relationships with macrofinancial variables exist, specifications are also estimated at industry-level. The following general form of the specification is used:

$$Ratio_{i,t} = \alpha + \beta_1 Ratio_{i,t-1} + \beta_2 Macro_t + \varepsilon_t ,$$

[1] Choice of macrofinancial variables are also conditional on other statistical issues such as multicollinearity (Such statistical properties are assessed before entering the regressors into specifications. For instance, within-correlations are also assessed when choosing variables).

where, *i* stands for bank, and *t* stands for time (in quarters from 1991–2019). The next several paragraphs in this section explain in detail how the income statement and balance sheet line items are estimated.

Net Income Projections

Specifications for pre-provision net revenue, returns on available-for-sale (AFS) securities, and charge-offs and recoveries are modeled using fixed effects panel regressions thus also controlling for heterogeneities among the entities. Interest income and expense variables are modeled as a share of rate sensitive assets, while non-interest income and non-interest expense categories are modeled as a share of total assets. Returns of AFS securities are modeled as a share of AFS securities. Charge-off and recovery specifications are in percent of the respective loan portfolio. Each ratio for the forecasting horizon is predicted for each bank using estimated coefficients from the regressions, forecasted time series from the macrofinancial scenario, and the estimated lagged dependent variable in the previous iteration in the loop. Projected ratios for the forecasting horizon are converted into U.S. dollars by multiplying it with the forecasted growth of the denominator from the balance sheet.

Interest Income

Eight interest income specifications are modeled using a fixed effects panel framework with an AR1 term. As explained previously, separate specifications would allow us to better capture changes related to various segments of income (e.g., geographic segmentation, loan interest rate dynamics, etc.). Modeled variables include interest income on: (i) domestic real estate loans, (ii) other domestic loans, (iii) foreign loans, (iv) U.S. Treasury securities, (v) MBS, (vi) other securities, (vii) trading-related, (viii) other interest income not captured in i through vii. Short-term interest rates and the term spread (10 year minus 3 month) enter as common explanatory variables in most specifications. However, interest income on foreign loans is modeled as a function of foreign GDP growth (calculated as the first principle component of the growth in Euro Area, Japan, and the United Kingdom from the macroeconomic scenario).

Interest Expense

Seven interest expense regressions are estimated using fixed effects panels to project the interest expense categories subsequently mentioned. Estimated categories include interest income on: (i) domestic retail deposits, (ii) domestic wholesale deposits, (iii) other domestic deposits, (iv) foreign office deposits, (v) repo, (vi) trading-related, (vii) other interest expense not included in i through vi. Main explanatory variable common to all specifications in this category is the 3-month treasury yield, except for foreign office deposits where the foreign inflation is used as a predictor. The autoregressive term also enters the specifications to capture the convergence to the long-run steady-state values.

Non-interest Income

Eight non-interest income regressions are estimated to model a diverse set of expense categories, which uses fixed effects terms as well as an AR1 term. Trading revenue is modeled by using the change in BBB spreads (vis-à-vis the 10-year yield). To capture the nonlinearity in BBB spreads during volatile times, an interaction term for the positive values of the BBB spreads was used in a robustness specification, but the interaction term was not statistically significant. Non-interest income related to service charges for deposits is modeled by using real GDP growth. Other non-interest specifications (fees and commissions from securities brokerage, investment banking, fees and commissions from insurance and reinsurance activities, asset sales income, securitization income, and other noninterest income) are explained more by variables such as the change in BBB spreads and the VIX.

Non-interest Expenses

Panel regressions using fixed effects are estimated to model wages, fixed assets, and other non-interest expenses (which typically includes costs related to operational-risk events among others)[2]. Historically, wages and other non-interest expense categories were over 1 percent of total assets. Due to the large size of these line items, PPNR projections are rather sensitive to the behaviors of these two expense items. Wages are therefore modeled as a function of equity price growth with the rationale that equity price movements reflect broader financial conditions and profitability. Thereby financial conditions would affect the size of the business, hence affecting the size of the employee base (i.e., the wages). Our model-based forecasted wages-to-assets ratio shows a decline in the ratio during crisis time (as was the case during the GFC period), alluding cost cutting measures of BHCs such as layoffs. The historical patterns of wages-to-assets ratios of the BHCs in the stress testing sample reveals that sharp decline in the ratio during the GFC period was recovered shortly after. Similarly, the forecasted ratio recovers to its long-run average subsequently. Other non-interest expenses are predicted using real GDP growth controlling for the securities portfolio of the banks, reflecting macroeconomic conditions and banks' capacity to liquidate assets in sudden stress events.

Returns on Available-for-Sale (AFS) Securities

Realized gains on AFS securities are estimated separately. Financial volatilities such as credit and asset price shocks may reflect sudden movements in this variable that is stationary in tranquil times. Therefore, the explanatory variables used for this specification include the change in the 10-year yield and an interaction term between changes in BBB corporate spreads and securities excluding U.S. Treasury and agency securities (i.e., unsafe assets).

[2] Given the structural changes incurred during the GFC period resulted in large adjustments in these ratios that are structural in nature, the long-run convergence to the steady-state is assumed to be similar to the ratios since 2012 (which corresponds to the end of TARP period); thus, these regressions are estimated starting 2012 (about 950 observations).

Allowance for Loan Losses

Provisions are estimated through modeling charge-offs and recoveries on loans. Regressions are estimated separately for charge-offs and recoveries on 3 residential real estate loan categories, 3 commercial real estate loans categories, commercial and industrial loans, credit cards, other consumer loans, other real estate loans, depository institution loans, agriculture loans, leases, foreign government loans, and other loans. These categories are modeled using explanatory variables such as the unemployment rate, house price changes, commercial property price changes, real GDP growth, and BBB spreads in addition to the lagged depended variables.

Loan loss reserves are calculated based on modeled charge-offs and recoveries. This approach is used given that net charge-offs do not directly affect net income according to the U.S. accounting standards, but rather provisions that alter loan loss reserves affect the net income. The model assumes that allowances for loan losses are bounded by an upper and lower bound related to the modeled net charge-offs. Provisions are calculated as the difference between the loan loss reserves of the current period minus the previous period.

Taxes

The tax rate is assumed at 21 percent, which is the current US corporate tax rate. deferred tax assets (DTA) are calculated using data on deferred tax assets and liabilities and disallowed DTA. Allowed DTA above 10 percent of Tier 1 capital is held constant over the forecasting horizon as there are limits on how much DTA can be countered as regulatory capital.[3] Accumulated tax losses are combined with allowed DTA of the future periods as tax losses may be carried forward for regulatory capital purposes.

Dividends

A partial adjustment method is used as the dividend distribution rule. The model assumes that the dividends would converge to its historically observed payout ratio of 45 percent over the forecasting horizon. Sensitivity analyses using different assumptions are also performed as robustness checks. These additional assumptions include dividend payout ratio at 0, 20, and 45, dividend held constant at historical level observed in 2019:Q3.

Other Assumptions

Additional assumptions are used for the following items related to net income projections: realized gains on held-to-maturity securities are assumed at zero. Extraordinary items and other adjustments net of taxes are assumed to be zero. Minority interests are assumed to be as same as the latest historical period. Net sale of common, preferred, and treasury stocks are assumed to be zero. Other comprehensive income and net other are also assumed to be zero.

[3] Any allowed DTA above 10 percent of Tier 1 capital is assumed to be recoverable through loss carry-backs.

Balance Sheet and Risk-Weighted Asset Projections

Balance sheet projections are modeled as a two-step process. First, the growth in total loans, total trading assets, and total other assets are modeled at industry level. Total loans are estimated using the AR1 term, nominal GDP growth, and the 3-month Treasury yield as explanatory variables. Trading asset growth is estimated using the change in BBB spreads and the 3-month Treasury yield as explanatory variables. Other asset growth is estimated using its lagged dependent variable and the 3-month Treasury yield as explanatory variables. The dollar value of total assets is then calculated as the sum of loans, trading assets, and other assets, derived based on the above 3 growth rates for the industry. Firm-level assets are then estimated using the forecasted industry-level projections. This is in line with the U.S. Federal Reserve's goal of helping to ensure that large financial firms remain sufficiently capitalized to accommodate credit demand in a downturn (assumption that the industry will continue to lend using the standards that are consistent with long-run behavior, which is in line with the FRB's goal of helping to ensure that large financial firms remain sufficiently capitalized to accommodate credit demand in a downturn).

Firm-level asset growth is forecasted separately for banks with larger trading books and for those with other business models using fixed effects panel regressions. For the banks in the latter group, firm-level total asset growth is forecasted using industry-level forecasted loans and other asset growth rates. For banks with larger trading books, total asset growth is modeled as a function of industry-level forecasted trading asset growth.

Total risk weighted assets are projected at firm-level in a panel fixed effects framework. Historical data for the 35 BHCs suggests that the RWAs closely follow the path of total assets. Therefore, total risk weighted asset growth is modeled as a function of total asset growth of the firm and the lagged dependent variable.

The growth of the subcomponents of risk weighted assets are forecasted with the following assumptions. Credit risk weighted assets, the largest RWA component, grows at the same rate as the forecasted total asset growth. Operational risk weighted asset growth and market risk weighted asset growth is held constant at their historical growth rates between 2014:Q2[4] through 2019:Q3 due to the high degree of model uncertainty related to the latter.

[4] Risk-weighted assets data for the 3 subcomponents are only available starting 2013:Q2 in FFEIC101.

Regulatory Capital

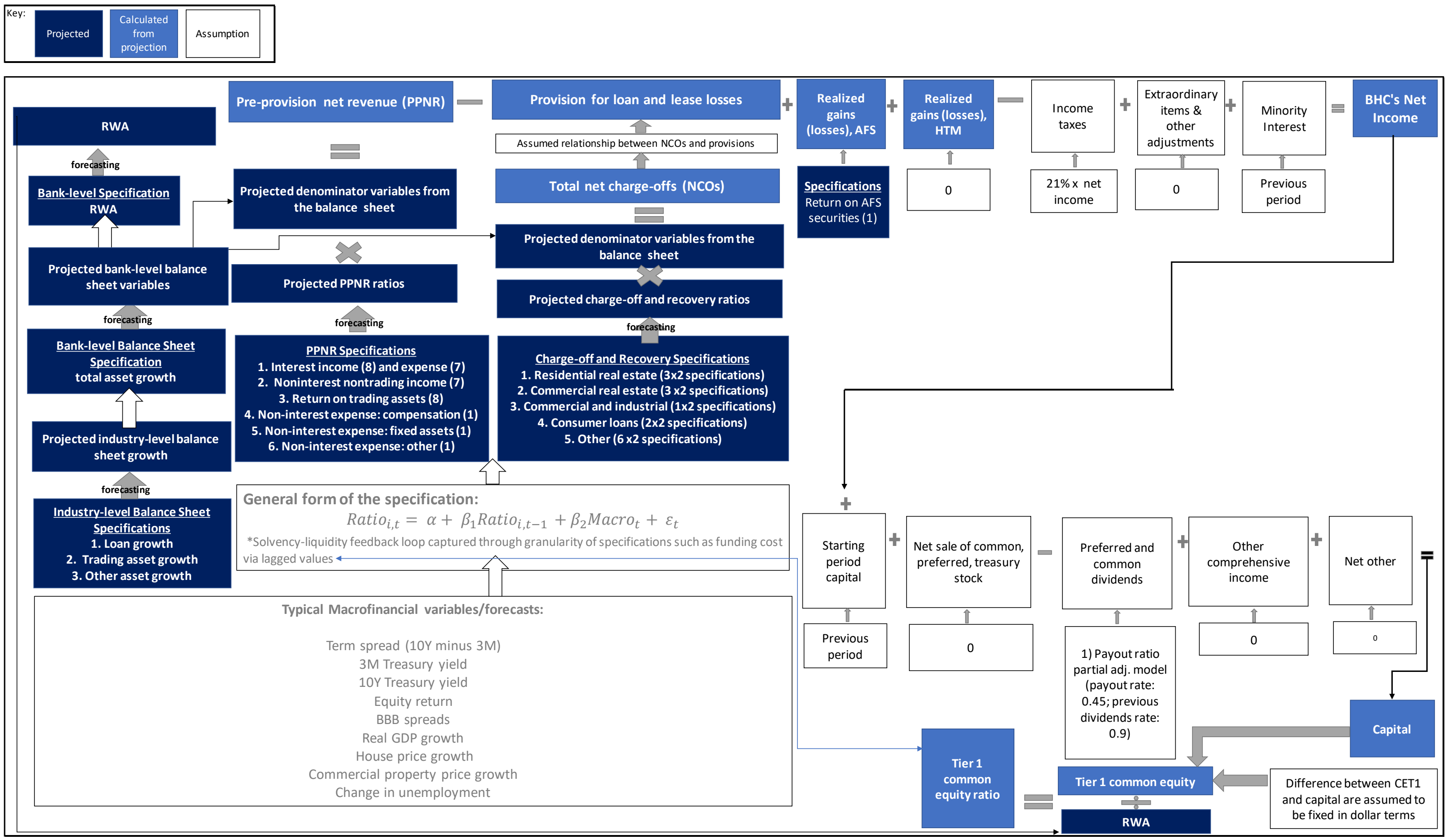
Regulatory capital ratios are calculated by using the net income[5] estimated from the modeled variables above. Regulatory capital is calculated by first calculating the change in equity (which corresponds to net income minus the dividends, as these are the two main factors determining changes in equity and regulatory capital) and adding to the previous period's regulatory capital. Tier 1 capital is calculated by adding the change in the regulatory capital minus the disallowed DTA into the previous period's tier 1 capital. The CET1 level is calculated by assuming the wedge between the CET1 and Tier 1 observed in 2019:Q3 remain fixed in dollar terms throughout the forecasting horizon and adding it to the estimated tier 1 level. CET1 ratio is calculated as the CET1 level in percent of risk-weighted assets.

[5] Net income = PPNR – provisions + realized gains (losses) on AFS and HTM securities – income tax + extraordinary items and other adjustments + minority interest

159 INTERNATIONAL MONETARY FUND

UNITED STATES

Appendix Figure IX.1. IMF Bank Solvency Stress Testing Framework



Source: IMF staff.

Appendix Table IX.1. Estimation Results

Appendix Table IX.1a. Selected PPNR and Return on AFS Items

	Interest income						Non-interest income						
VARIABLES	real estate loans	other loans	US Treasuries	MBS	Other securities	Trading-related	Service charges for deposit accounts in domestic offices	trading revenue	Fees and comissions from securities brokerage	Investment banking and etc.	Fees and comissions from insurance and reinsurance activities	Asset sales income	Securitization income
Lagged dependent variable	0.445***	0.332**	0.836***	0.751***	0.771***	0.656***	0.882***	0.548***	0.809***	0.970***	0.109	0.061	0.793***
	(0.052)	(0.124)	(0.029)	(0.024)	(0.032)	(0.084)	(0.043)	(0.071)	(0.091)	(0.016)	(0.092)	(0.063)	(0.091)
3M T-bill rate	0.263***	0.421***	0.019***	0.050***	0.023***	0.018***							0.003*
	(0.037)	(0.052)	(0.006)	(0.009)	(0.005)	(0.007)							(0.002)
Term spread	0.261***	0.137**			0.016***								
	(0.045)	(0.058)			(0.005)								
Real GDP growth							0.001						
							(0.000)						
change in BBB spreads								-0.074***	-0.006*			-0.058***	-0.013
								(0.026)	(0.004)			(0.015)	(0.009)
Change in equity prices													
Change in VIX										-0.001***	-0.000		
										(0.000)	(0.000)		
Change in 10Y Yield													
Unsafe assets x change in BBB spreads													
Constant	0.310***	1.507***	0.003	0.173***	-0.002	0.072***	0.023**	0.059***	0.018**	0.010***	0.047***	0.108***	0.002
	(0.073)	(0.386)	(0.009)	(0.025)	(0.011)	(0.020)	(0.010)	(0.009)	(0.007)	(0.002)	(0.008)	(0.006)	(0.005)
Observations	1,317	1,372	1,904	1,915	1,926	1,862	2,765	2,765	2,765	2,765	301	1,575	2,765
R-squared	0.447	0.402	0.772	0.690	0.705	0.526	0.772	0.334	0.640	0.883	0.041	0.011	0.631

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: IMF staff.

Appendix Table IX.1a. Selected PPNR and Return on AFS Items (continued)

	Intest Expense					Non-interest expense			Return on AFS assets
VARIABLES	Retail deposits	Wholesale dep	Other dep	Repo	Trading-related	Wages	Fixed assets	Other	
Lagged dependent variable	0.846***	0.772***	0.692***	0.812***	0.681***	0.160	0.213**	0.017	0.060
	(0.023)	(0.049)	(0.053)	(0.035)	(0.035)	(0.140)	(0.098)	(0.030)	(0.087)
3M T-bill rate	0.026***	0.027***	0.061***	0.056***	0.086***				
	(0.004)	(0.005)	(0.012)	(0.010)	(0.012)				
Term spread									
Real GDP growth								-0.044*	
								(0.023)	
change in BBB spreads							-0.026		
							(0.025)		
Change in equity prices						0.010***			
						(0.003)			
Change in VIX									
Change in 10Y Yield									-0.430**
									(0.177)
Unsafe assets x change in BBB spreads									-0.013
									(0.008)
Constant	0.009	0.006	0.035***	0.003	0.187***	1.345***	0.246***	1.732***	0.211***
	(0.007)	(0.005)	(0.007)	(0.012)	(0.021)	(0.251)	(0.037)	(0.114)	(0.055)
Observations	1,925	1,953	2,058	1,961	2,068	950	947	950	2,764
R-squared	0.889	0.823	0.893	0.864	0.791	0.086	0.080	0.012	0.026

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: IMF staff.

Appendix Table IX.1b. Selected Charge-Off Specifications

VARIABLES	Residential real estate: first lien	Residential real estate: junior lien	Residential real estate: HELOC	CRE real estate: construction	CRE real estate: multi family	CRE real estate: NFNR	C&I	Credit cards	Other consumer	Lease	Other Real estate	Depositary corps	Agriculture
Lagged dep variable	0.905***	0.799***	0.885***	0.820***	0.775***	0.856***	0.881***	0.803***	0.707***	0.747***	0.476***	0.371**	0.615***
	(0.098)	(0.102)	(0.057)	(0.066)	(0.143)	(0.094)	(0.085)	(0.077)	(0.100)	(0.079)	(0.142)	(0.161)	(0.137)
House price growth	-0.004	-0.060**	-0.013*										
	(0.005)	(0.026)	(0.007)										
change in unemp	0.078**	0.090	0.088***					0.408***	0.170***	0.075***			-0.000
	(0.035)	(0.100)	(0.032)					(0.111)	(0.035)	(0.013)			(0.038)
Commercial property price growth				-0.040**	-0.011**	-0.009***					-0.008		
				(0.016)	(0.005)	(0.003)					(0.011)		
Real GDP growth				-0.023			-0.032**					-0.009	
				(0.042)			(0.014)					(0.018)	
Change in BBB spreads												0.090	
												(0.127)	
Constant	0.081	0.825***	0.200***	0.436***	0.107**	0.088***	0.181**	1.177**	0.794***	0.126***	0.426***	0.123**	0.231***
	(0.056)	(0.301)	(0.068)	(0.160)	(0.044)	(0.033)	(0.079)	(0.454)	(0.247)	(0.033)	(0.110)	(0.050)	(0.065)
Observations	71	71	78	79	79	79	79	75	79	51	79	59	79
R-squared	0.897	0.804	0.943	0.919	0.811	0.886	0.793	0.871	0.724	0.807	0.240	0.185	0.375

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: IMF staff.

Appendix Table IX.1c. Selected Recoveries Specifications

VARIABLES	Residential real estate: first lien	Residential real estate: junior lien	Residential real estate: HELOC	CRE real estate: construction	CRE real estate: multi family	CRE real estate: NFNR	C&I	Credit cards	Other consumer	Lease	Other Real estate	Depositary corps	Agriculture
Lagged dep variable	0.746***	1.027***	0.960***	0.905***	0.752***	0.782***	0.838***	0.629***	0.811***	0.815***	0.660***	0.145	0.452***
	(0.122)	(0.138)	(0.063)	(0.083)	(0.105)	(0.106)	(0.080)	(0.105)	(0.090)	(0.108)	(0.229)	(0.155)	(0.087)
change in unemp	-0.005									-0.001	-0.004		-0.018***
	(0.003)									(0.003)	(0.010)		(0.007)
House price growth		0.002	0.001					0.003	0.004				
		(0.002)	(0.001)					(0.006)	(0.007)				
Real GDP growth				0.003	0.000	0.002	0.003					0.008	
				(0.004)	(0.001)	(0.001)	(0.003)					(0.007)	
Change in BBB spreads												0.004	
												(0.019)	
Foreign inflation													
Constant	0.015***	0.045	0.019**	0.016	0.009*	0.011**	0.025*	0.328***	0.141*	0.032	0.049*	0.023**	0.097***
	(0.005)	(0.039)	(0.009)	(0.010)	(0.005)	(0.005)	(0.014)	(0.094)	(0.075)	(0.020)	(0.026)	(0.010)	(0.016)
Observations	71	70	78	79	79	79	79	75	79	51	79	57	79
R-squared	0.657	0.687	0.841	0.823	0.562	0.618	0.727	0.580	0.717	0.696	0.436	0.077	0.284

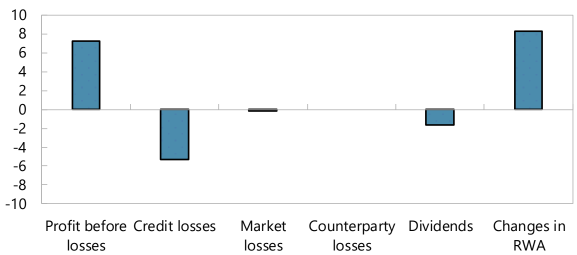
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: IMF staff.

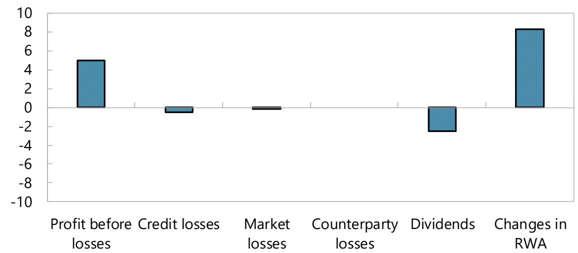
Appendix X. Contribution to Losses in Terms of RWAs

Appendix Figure X.1a. Baseline Scenario

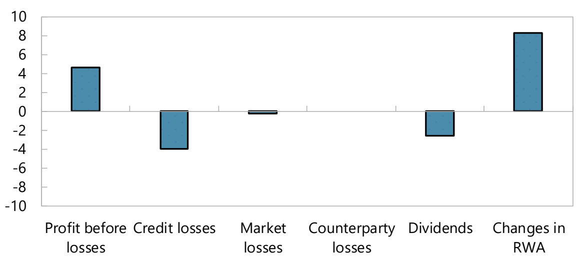
Contribution to Changes in Tier1 Ratio:
GSIBs (In pct pnt of RWA)



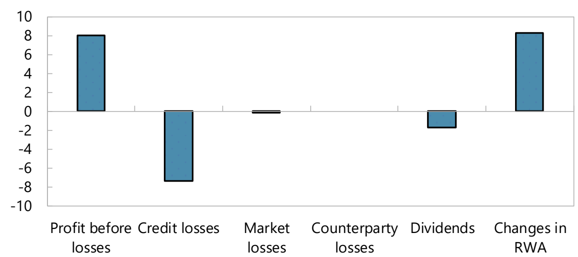
Contribution to Changes in Tier1 Ratio:
Trading Banks (In pct pnt of RWA)



Contribution to Changes in Tier1 Ratio:
Foreign Banks (In pct pnt of RWA)

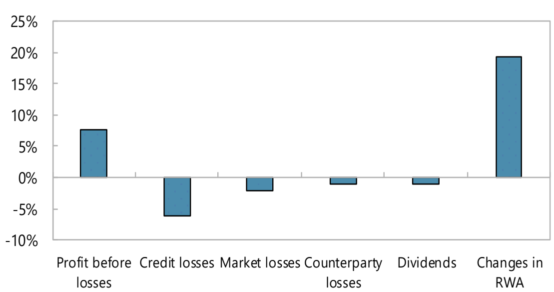


Contribution to Changes in Tier1 Ratio:
Non-GSIBs (In pct pnt of RWA)

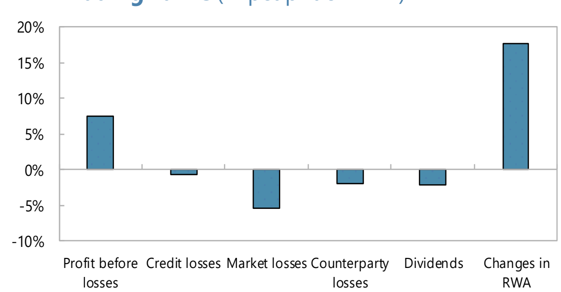


Appendix Figure X.1b. Adverse Scenario

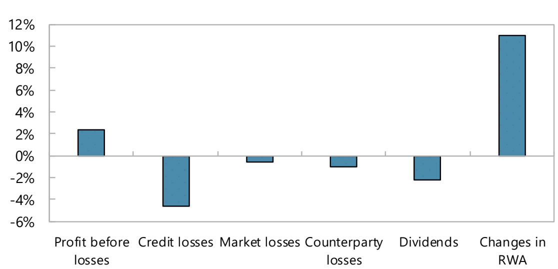
Contribution to Changes in Tier1 Ratio:
GSIBs (In pct pnt of RWA)



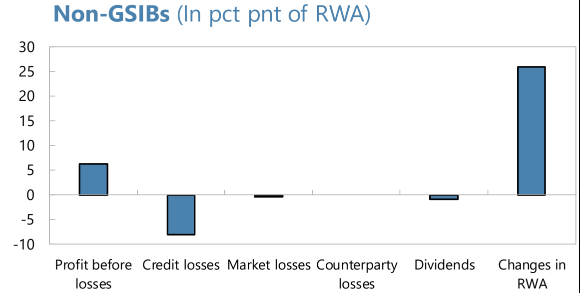
Contribution to Changes in Tier1 Ratio:
Trading Banks (In pct pnt of RWA)



Contribution to Changes in Tier1 Ratio:
Foreign Banks (In pct pnt of RWA)



Contribution to Changes in Tier1 Ratio:
Non-GSIBs (In pct pnt of RWA)



Source: IMF staff.

Appendix XI. Data and Sample of Funds Used in Stress Tests

Sample of Funds

The sample of funds is based on available data from Morningstar. The sample includes all U.S. mutual funds that belong to the following Morningstar global broad category group: Allocation, Taxable Bond and Municipal Bond. Target dates funds are excluded since they are not included in ICI categories. The remaining 2,743 funds were split into 43 fund Morningstar Global categories, which were then mapped into ICI categories using the correspondence table shown in Appendix Table XI.1. For the purpose of the stress tests, nine categories of funds are used, mainly based on the type of assets the funds invest in.

Appendix Table XI.1. Correspondence Table

Global Broad category group	Global category	ICI category	Fund category
Allocation	US Fund Allocation--15% to 30% Equity	Mixed	Mixed
	US Fund Allocation--30% to 50% Equity	Mixed	Mixed
	US Fund Allocation--50% to 70% Equity	Mixed	Mixed
	US Fund Allocation--70% to 85% Equity	Mixed	Mixed
	US Fund Allocation--85%+ Equity	Mixed	Mixed
	US Fund Convertibles	Mixed	Mixed
	US Fund Tactical Allocation	Mixed	Mixed
	US Fund World Allocation	Mixed	Mixed
Municipal	US Fund High Yield Muni	Muni	Muni
	US Fund Muni California Intermediate	Muni	Muni
	US Fund Muni California Long	Muni	Muni
	US Fund Muni Massachusetts	Muni	Muni
	US Fund Muni Minnesota	Muni	Muni
	US Fund Muni National Interm	Muni	Muni
	US Fund Muni National Long	Muni	Muni
	US Fund Muni National Short	Muni	Muni
	US Fund Muni New Jersey	Muni	Muni
	US Fund Muni New York Intermediate	Muni	Muni
	US Fund Muni New York Long	Muni	Muni
	US Fund Muni Ohio	Muni	Muni
	US Fund Muni Pennsylvania	Muni	Muni
	US Fund Muni Single State Interm	Muni	Muni
	US Fund Muni Single State Long	Muni	Muni
	US Fund Muni Single State Short	Muni	Muni
	US Fund Muni Target Maturity	Muni	Muni
Taxable Bond	US Fund Emerging Markets Bond	Global	EM
	US Fund Emerging-Markets Local-Currency Bond	Global	EM
	US Fund World Bond	Global	Global
	US Fund World Bond-USD Hedged	Global	Global
	US Fund Inflation-Protected Bond	Gov	Gov
	US Fund Intermediate Government	Gov	Gov
	US Fund Long Government	Gov	Gov
	US Fund Short Government	Gov	Gov
	US Fund High Yield Bond	HY	HY
	US Fund Bank Loan	HY	Loan
	US Fund Intermediate Core Bond	IG	IG
	US Fund Intermediate Core-Plus Bond	IG	IG
	US Fund Long-Term Bond	IG	IG
	US Fund Preferred Stock	IG	IG
	US Fund Short-Term Bond	IG	IG
	US Fund Ultrashort Bond	IG	IG
	US Fund Corporate Bond	IG	IG
	US Fund Multisector Bond	Multi	Multi
	US Fund Nontraditional Bond	Multi	Multi

The nine categories are mixed, municipal, EM, HY, IG, loan, government, multi-strategy funds and global funds.

Appendix Table XI.2 displays the sample of funds compared to the ICI universe.

Appendix Table XI.2. Sample of Funds

Fund category	Net asset Value (US $ bn)	Number of funds
Corp. IG	2,427	608
Mixed funds	1,752	792
Municipal	799	567
Multisector	432	182
Government	326	161
Corp. HY	257	192
Global	247	87
Loan funds	91	58
EM funds	66	96
Total	6,398	2,743

Sources: Morningstar, ICI, IMF staff calculations

Data

For each fund in the sample, monthly data on flows, net asset value, portfolio composition and returns are retrieved over the 2017–2019 period. The sample of fund is based only on funds that were still alive as of end-2019.

Computation of net flows: For each fund, net flows in percent of NAV (f_t) are computed using the following formula:

$$f_t = \frac{FLOWS_t}{NAV_{t-1}}$$

Net flows whose absolute value is above 50% were excluded as they are likely related to reporting mistakes.

Portfolio composition: For each fund, the latest portfolio composition is retrieved. At the highest level, the portfolio is split into four categories: cash, equities, bonds and other. The fixed income portfolio (cash and bonds) is then split into further categories: government, municipal, corporate, securitized, cash and equivalents, and derivatives (Appendix Table XI.3). Each subcategory is subsequently split into further asset classes as detailed in Morningstar (2016).

Appendix Table XI.3. Morningstar Portfolio Composition

Asset allocation	Fixed income classification
Equities	
Other	
Cash	*Cash and equivalents*
Bonds	*Government*
	Municipal
	Corporate
	Securitized
	Derivatives

Credit quality: For each fund, the latest data on credit quality are retrieved, i.e., the share of the bond portfolio split by credit rating. Morningstar does not provide the credit rating data by type of fixed income instrument (government, corporate bond, etc.). Therefore, credit rating by instrument is estimated by allocating the highest credit rating first to the government portfolio, then to corporate bonds and finally to securitized products.

Treatment of mutual funds using derivatives and leverage: When funds use derivatives and leverage Morningstar asset allocation weights will always add up to 100 percent, but the cash part will have negative values. In those cases, cash is set up equal to 0 percent, and put a 100 percent limit on the other parts of the portfolio. When the funds reports cash allocation above 100 percent, the cash is bounded to 100 percent.

Appendix XII. Mutual Fund Stress Tests Methodology

This appendix outlines the different building blocks of the liquidity stress test.

I. Calibration of the redemption shock

a. Calibration of the redemption shock: historical approach

For each fund in the sample, the shock is calibrated on the distribution of net flows. The shock is an instantaneous shock, i.e., there is no persistence over several periods.

Under *the homogeneity assumption*, each fund within the same category (e.g., Corp. HY) face the same redemption shock. The shock is based on the distribution of all individual fund net flows belonging to this category. The calibration is based on the 3 percent Expected Shortfall (ES), which is equal to the average worst flows (below the 3th percentile) observed in the sample.

As a robustness check, redemption shocks are also calibrated at the 1 percent and 5 percent level for the expected shortfall, and also at the worst 1, 3, and 5 percent net flows observed ("VaR approach").

Under *the heterogeneity assumption*, the redemption shock is calibrated separately for each fund based only on its own historical data. The shock is based on the 3 percent expected shortfall. As a robustness check, the shock is also estimated at 1 percent and 5 percent level as well as using percentiles.

Overall, each fund is subject to 12 different redemption shocks (Appendix Table XII.1). The main focus of the stress test is on the homogeneity assumption—which allows funds to be compared within the same category—calibrated at the 3 percent level, with redemption shocks ranging from 7 percent for Municipal funds to 17 percent for EM bond funds.

Appendix Table XII.1. Calibration of Redemption Shocks

	Homogeneity assumption		Heterogeneity assumption	
	ES	VaR	ES	VaR
	1st percentile			
Municipal	11	7	8	6
Mixed funds	15	8	9	6
Corp. IG	21	13	14	10
Multisector	22	12	13	10
Loan funds	19	13	15	12
Global	23	14	17	12
Government	24	14	15	11
HY	23	15	15	12
EM funds	26	18	19	13
	3rd percentile			
Municipal	7	4	6	4
Mixed funds	9	4	7	4
Corp. IG	13	7	10	6
Multisector	13	7	10	6
Loan funds	13	9	12	8
Global	14	7	12	7
Government	14	7	11	7
HY	15	8	12	8
EM funds	17	10	14	8
	5th percentile			
Municipal	5	3	5	3
Mixed funds	7	3	5	3
Corp. IG	10	5	8	5
Multisector	10	5	8	5
Loan funds	11	7	11	6
Global	11	5	9	5
Government	11	5	9	5
HY	12	6	10	6
EM funds	14	7	11	6

Note: Net outflows in % of NAV. Average flows by fund category for the heterogeneity assumption.
Sources: Morningstar, IMF staff.

b. Calibration of the redemption shock: adverse scenario

The adverse scenario designed for the banking sector stress test is used to project the net flows that funds would face. First, relevant macrofinancial variables are projected under the adverse scenario. Then, returns for each fund are estimated and finally net flows are projected based on the flow-performance relationship.

Step 1: Projection of macrofinancial variables

Since the adverse scenario is over a five-year horizon and at quarterly frequency, it needs to be converted to fit the shorter horizon used for the liquidity stress tests. Monthly projected changes are obtained using the following formula:

$$Monthly\ shock = \frac{\sqrt{20}}{\sqrt{60}} = 0.57$$

Appendix Table XII.2 displays the relevant macrofinancial variables.

Appendix Table XII.2. Projected Macrofinancial Variables

	Quarterly change	Unit	Monthly change	Unit
3-Month Treasury Rate	-78	bps	-45.0	bps
10-Year Treasury Bond yield	-103	bps	-59.5	bps
BBB Corporate Bond Yield	161	bps	93.0	bps
Equities	-30	%	-17.3	%

Sources: IMF staff

Some of the relevant macrofinancial variables such as EM and HY yields along with the term structure of U.S. rates are not used in the adverse scenario and therefore needs to be projected separately.

For EM, HY and securitized yields, the projection is based on the shock to BBB yields multiplied by a conversion factor. The conversion factor is equal to the ratio of the projected change in BBB yields divided by the change observed in October 2008:

$$Conversion = \frac{\Delta BBB_{proj}}{\Delta BBB_{Oct.08}} = \frac{93}{163} = 0.57$$

ICE Bank of America Merrill Lynch indices are used to retrieve yield information and derive the relevant change which is applied in the adverse scenario.

Appendix Table XII.3. Projected Yields for Other Macofinancial Variables

Asset class	Oct.2008 change	Monthly change	Index name	Code	Source
BBB	163	93	US corporate index	C0A0	ICE BoAML
A corp	163	93	US AA corporate index	C0A3	ICE BoAML
AA corp	111	63	US AA corporate index	C0A2	ICE BoAML
HY	550	314	US HY index	H0A0	ICE BoAML
Leveraged loans	486	277	JPM Leveraged loan index	LILI	JPM
EM	416	237	Global EM sovereign and credit index	IM00	ICE BoAML
Municipal	75	43	US Municipal Securities Index	U0A0	ICE BoAML
Securitized Agencies	39	22	US MBS index	M0A0	ICE BoAML
Securitized	164	94	US ABS index	R0A0	ICE BoAML

Sources: IMF staff, Refinitiv Datastream

For the U.S. yield curve, the levels of interest rate are very close in the adverse scenario: 0.79 percent for the 3-Month rate and 0.62 percent for the 10Y rate as of 2020:Q1. This translates into 1.11 percent for the 3-Month rate and 1.06 percent for the 10Y rate over a one-month horizon. Therefore, the yield curve is assumed to be flat and the yield for the relevant maturity are linearly interpolated.

Step 2: Computation of funds' returns

Projected values for macrofinancial variables are combined with fund-level information on the composition of the portfolio by asset class, along with the modified duration to compute the projected returns. For each fund, data on modified duration are retrieved from Morningstar and when data are not available, the average duration of the relevant Morningstar fund category is used.

The table below shows the results obtained for the sample of funds, with large negative returns for EM and HY bond funds (due to the large increase in yields) and for mixed funds (mainly due to the large decline of equity prices). For government and municipal bond funds, most funds experience little change in their returns or positive returns. Loan funds experience relatively low shocks to returns despite the sizeable increase in spreads because of the very short duration of their portfolio (less than 0.5).

Appendix Table XII.4. Impact on Monthly Returns of the Adverse Scenario

	Monthly returns			
Fund category	Average	Median	Min	Max
EM	-11%	-10%	-20%	-1%
Global	-3%	-1%	-27%	4%
Gov	1%	0%	-4%	14%
HY	-7%	-7%	-12%	0%
IG	-2%	-1%	-12%	2%
Loan	-1%	-1%	-2%	0%
Mixed	-10%	-11%	-22%	9%
Multi	-3%	-2%	-24%	2%
Muni	-1%	0%	-16%	3%
Total	-4%	-2%	-27%	14%

Sources: IMF staff calculations

Step 3: Computation of funds' net flows

To assess the net flows from funds following the shocks, the flow-performance relationship is used. At fund category level, the flow performance is estimated following the Fama-McBeth (1973) two-step methodology. For each month, a cross-sectional regression is estimated, with twelve lags for returns and flows, and the lagged size of the fund as a control variable:

$$f_{i,t} = \alpha + \sum_{k=1}^{12} \beta_k f_{i,t-k} + \sum_{h=1}^{12} \gamma_h \, return_{i,t-h} + \log(size_{i,t-1}) + \varepsilon_{i,t}$$

Then the time series average of the coefficient is calculated to get the parameter for the flow-performance relationship. For all fund categories, the parameter for lagged returns is significant at the 5 percent level. Table X shows the corresponding results.

Under the adverse scenario EM and HY funds would experience sizable outflows, Corporate and mixed funds would face more limited outflows and other fund categories would face small outflows (or inflows for government bond funds).

Appendix Table XII.5. Flow-Performance Relationship and Net Flows in the Adverse Scenario

Fund category	Parameter	Net flows in %
EM	0.85	-10.3%
Global	0.25	-0.6%
Gov	0.27	0.5%
HY	0.64	-4.8%
IG	0.71	-1.1%
Loan	0.91	-0.8%
Mixed	0.26	-2.8%
Multi	0.55	-0.9%
Muni	0.53	-0.7%

Sources: IMF staff calculations

II. Ability of funds to withstand shocks: the liquidity bucket approach

The ability of funds to withstand shocks is estimated by comparing the redemptions to the level of high liquid assets. High liquid assets are measured at fund level using the liquidity weights defined in the context of the Liquidity Coverage Ratio for banks. For each asset class, liquidity weights are defined based on the type of assets and for fixed income instruments the credit quality. Liquidity weights are taken from the Basel Committee rather than domestic implementation of the LCR, to allow for comparability.[1]

[1] For example, in the U.S corporate debt securities are not included in Level 2A assets (liquidity weight of 85 percent) but only to Level 2B (liquidity weight of 50 percent).

Appendix Table XII.6: Liquidity Weights

	AAA-AA	A	BBB	Below BBB
Cash		100%		
Equities		50%		
Sovereign bonds	100%	85%	50%	0%
Corporate bonds	85%	50%	50%	0%
Securitized	85%	0%	0%	0%

Source: Basel Committee

As in the 2017 Luxembourg FSAP (IMF, 2017), the ability of funds to withstand redemption shocks is measured by the Redemption Coverage Ratio (RCR) defined as follows:

$$RCR = \frac{Highly\ liquid\ assets}{Redemption\ shock}$$

When the RCR is below 1, the fund does not have enough highly liquid assets to cover redemptions without selling fewer liquid assets. In that case, the liquidity shortfall is defined as the difference between the redemption shock and the stock of highly liquid assets:

$$Liquidity\ shortfall = Redemption\ shock - Highly\ liquid\ assets$$

For funds using derivatives, the adverse scenario is used to estimate potential variation margins. It is assumed that funds can only post cash as margins and for each fund a liquidity shortfall is defined as follows:

$$Liquidity\ shortfall = Variation\ margins - Cash$$

The variation margins are calculated as follows in the case of an interest rate swap:

$$Variation\ margins = shock * DV01 * Exposure$$

The first order approximations are the following for an interest rate swap (Bardoscia et al. (2019)):

$$\Delta V_t^{IRS}(T) \approx -ND_t\Delta\rho_t = -N\left[\frac{1}{2}\sum_{c=1}^{2T} e^{-i_{t,\frac{c}{2}}\frac{c}{2}}\right]\Delta\rho_t$$

And for FX forwards:

$$\Delta V_t^{FXF}(T) \approx -Nd_t^B\Delta S_t = -N\left[e^{-i_{t,T-t}^B(T-t)}\right]\Delta S_t$$

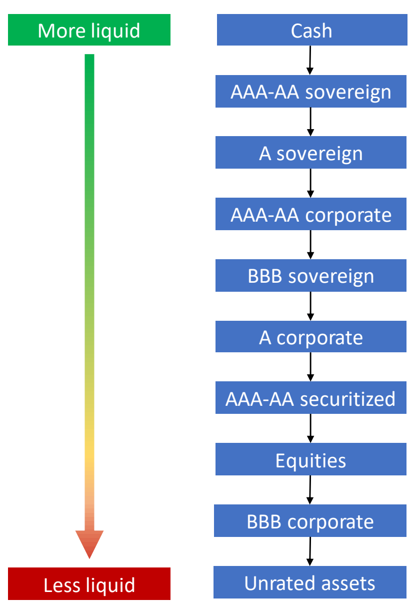
III. Liquidation strategies and price impact of funds sales

Following the redemption shocks, fund managers have to sell some of the fund assets to meet investors' redemptions. Different liquidation strategies can be used: slicing (prorata)—where the manager sells each asset class in proportion of their weight in the fund's portfolio—waterfall (where most liquid assets are sold first), or a mixed approach where cash is used first and then the manager follows a slicing approach.

The choice of the liquidation strategy can have a sizeable impact on remaining investors. Under the slicing approach, the manager maintains the profile of the portfolio, in line with the investment policy, but this might require selling fewer liquid assets which could lead to a high price impact.[2]

Under the waterfall approach, the manager sells the most liquid assets first, which mitigates the price impact of sales but generates costs for remaining investors as they are left with a portfolio which is less liquid than initially. When the waterfall approach is used, the liquidation strategy is based on the ordering stemming from HQLA liquidity weights (cash then AAA-AA sovereign bonds, A sovereign bonds, AAA-AA corporate bonds, BBB sovereign bonds, A corporate bonds, AAA-AA securitized assets, and BBB corporate bonds). When assets with positive liquidity weights have been entirely sold, managers use unrated sovereign bonds, corporate bonds and finally securitized assets.

Appendix Figure XII.1. Waterfall Liquidation Strategy



[2] Using data on U.S. mutual funds, Girardi et al. (2017) show that funds with relatively low levels of cash tend to have worse performance than their peers, due to the price impact of their trades.

Generally, asset managers use the slicing approach, but in some cases the waterfall approach can be better for both redeeming and remaining investors as well as for the market as large (AMIC, 2019; Blackrock, 2019).

In the stress test analysis, liquidity management tools (LMTs) such as in-kind redemptions, swing pricing or suspension of redemptions or credit lines are not taken into account. By design, the objective of the stress test is to analyze the ability of the funds to withstand shocks without resorting to extraordinary measures.

Price impact of funds sales

Given a redemption shock and a liquidation strategy, funds have to sell a given amount of securities across different asset classes. To estimate the price impact of the sales, the volume of sales is compared to market depth. Following Cont and Schaaning (2017), market depth is equal to:

$$MD(\tau) = c\frac{ADV}{\sigma}\sqrt{\tau}$$

The market depth over a time horizon τ is a function of a scaling factor c, times the ratio between the average daily trading volumes and the asset volatility, multiplied by the square root of the time horizon. The price impact is therefore lower, when the time horizon is longer. The estimation of the parameters will follow the approach used by Cont and Schaaning (2017) and Coen et al. (2019), using high-level data on trading volumes and bond indices to estimate the volatility.

For each asset class, the daily volatility is computed over different periods. Appendix Table XII.7 shows the corresponding measures of market liquidity obtained.

Appendix Table XII.7. Price Impact Measures by Asset Class

Asset class	ADV (US$ bn)	Average volatility	2008 Volatility	Market Depth (US$ bn)	Impact of $ 1bn of sale (in bps)	Market Depth (US$ bn)	Impact of $ 1bn of sale (in bps)
UST	545	0.28%	0.55%	77,857	0.1	39,636	0.3
Corp. IG	21	0.30%	0.65%	2,800	3.6	1,292	7.7
Corp. HY	12	0.31%	1.07%	1,548	6.5	449	22.3
Leveraged loans	3	0.18%	0.64%	556	18.0	156	64.0
EM debt	8	0.40%	1.36%	750	13.3	221	45.3
Municipal bonds	11	0.19%	0.64%	2,316	4.3	688	14.5
Securitized Agencies	220	0.19%	0.44%	46,316	0.2	20,000	0.5
Securitized	2	0.11%	0.27%	727	13.8	296	33.8
Equities	320	1.12%	3.60%	11,429	0.9	3,556	2.8

Sources: Refinitiv Datastream, SIFMA, JPMorgan, EMTA, IMF staff
Note: 2008 volatility estimated over September-December 2008

When trading volumes are large, using a linear price impact can lead to inconsistencies. Therefore, the correction suggested by Cont and Schaaning (2017) is used, by setting up a floor on the price impact during fire asset sales. The floor is set at 50 percent, implying that when prices fall that much, opportunistic investors will step in to buy undervalued assets, hence stabilizing the market.

Second-round effects

Once the price impact of sales is estimated, the NAV of each fund is recalculated to reflect the costs due to the liquidation of assets on the remaining portfolio of securities. As a result of negative returns, a second wave of redemption will occur, whose magnitude depends on the flow-performance relationship (as described previously).

Appendix XIII. Mutual Fund Stress Tests Results

The table below outlines the results for the 12 different redemption shocks calibrated on funds net flows based on two set of assumptions: homogeneity approach (same shock for funds within the same category but shocks different across categories) and heterogeneity approach (shock calibrated only on each individual fund net flows). For each approach, six shocks are defined using either the expected shortfall (average of worst net flows below a threshold) or the VaR (percentile of net flows) at three different levels: 1 percent (most conservative), 3 percent, and 5 percent.

Appendix Table XIII.1

	Homogeneity assumption		Heterogeneity assumption	
	ES	VaR	ES	VaR
	1st percentile			
Municipal	0%	0%	0%	0%
Mixed funds	0%	0%	0%	0%
Corp. IG	1%	0%	0%	0%
Multisector	10%	5%	9%	4%
Loan funds	96%	82%	82%	62%
Global	0%	0%	0%	0%
Government	0%	0%	0%	0%
HY	90%	75%	66%	55%
EM funds	20%	6%	11%	3%
	3rd percentile			
Municipal	0%	0%	0%	0%
Mixed funds	0%	0%	0%	0%
Corp. IG	0%	0%	0%	0%
Multisector	5%	2%	4%	2%
Loan funds	82%	42%	64%	42%
Global	0%	0%	0%	0%
Government	0%	0%	0%	0%
HY	75%	48%	56%	37%
EM funds	6%	0%	3%	2%
	5th percentile			
Municipal	0%	0%	0%	0%
Mixed funds	0%	0%	0%	0%
Corp. IG	0%	0%	0%	0%
Multisector	4%	1%	3%	2%
Loan funds	76%	27%	58%	24%
Global	0%	0%	0%	0%
Government	0%	0%	0%	0%
HY	65%	26%	48%	25%
EM funds	0%	0%	2%	0%

Note: Share of funds with RCR<0, in percent.
Sources: Morningstar, IMF staff.

Appendix XIV. Analysis of Vulnerabilities and Interconnectedness (Mutual Funds)

The analysis of vulnerabilities and interconnectedness within mutual funds is based on two concepts of risk. Vulnerable funds are funds that are likely to be in distress when other funds (or the market) are in distress. Spreader funds are institutions for which other funds are likely to be in distress when the spreader fund is in distress.

The identification of vulnerable and spreader funds is based on two methodologies: tail-dependence using copula, and the interconnectedness approach (Diebold and Yilmaz, 2016).

Tail-dependence using copula

For each of the fund categories in the sample, aggregated net flows are computed for each month over the period 2007–2019.

The dependence structure across fund categories is modelled using copulas.

A n-dimensional copula is a function $C: [0,1]^n \rightarrow [0,1]$ which satisfies the following conditions:

- $C(1,1,\ldots,u_{i,},\ldots,1,1) = u_i$ for every $i \leq n$
- $C(u_{1,},\ldots,u_{n,}) = 0$ if $u_i = 0$ for any $i \leq n$
- C is n-increasing

According to Sklar's theorem, given H, a n-dimensional cumulative density function with one-dimensional marginals $F_1, \ldots, F_n$, then there exists a copula C such that

$$H(x_1,\ldots,x_n) = C(F(x_1),\ldots,F(x_n)), \forall(x_1,\ldots,x_n) \in \mathbb{R}^n$$

Therefore, the copula captures the dependence structure of the joint cumulative density function.

The copula framework is applied to net flows by fund categories. This allows the estimation of the expected net flows of a given fund style conditional on another fund-type being in distress. Formally, it is equal to the conditional expectation of net flows for fund category A conditional of fund category B being in distress (net flows below a threshold α):

$$E(f_A|f_B < \alpha) = \int_{-\infty}^{+\infty}\int_{-\infty}^{\alpha} xh(x,y)dxdy$$

The dependence structure between fund flows is modelled using a Student t-copula with ν degrees of freedom, which allows for tail dependence:

$$C_{\nu,\Sigma}^{t}\ (u_{1,},\ldots,u_{n,}) = t_{\nu,\Sigma}\ (t_\nu^{-1}(u_1),\ldots,t_\nu^{-1}(u_n))$$

With $t_{\nu,\Sigma}$ the joint cumulative density function of the multivariate distribution.

The copula requires the input parameter Σ which represents the correlation matrix:

$$\sum = \begin{pmatrix} 1 & \cdots & \rho_{1,n} \\ \vdots & \ddots & \vdots \\ \rho_{n,1} & \cdots & 1 \end{pmatrix}$$

The parameters of the Student copula are estimated by maximum likelihood, using observable correlations among series as input for $\sum$.

In the estimation, a parametric approach for the marginal distribution is first used. The logistic distribution provides the best fit for the distribution of flows by types. The probability density function is given by:

$$f(x; \mu, s) = \frac{e^{-\frac{x-\mu}{s}}}{s\left(1 + e^{-\frac{x-\mu}{s}}\right)^2} \quad (8)$$

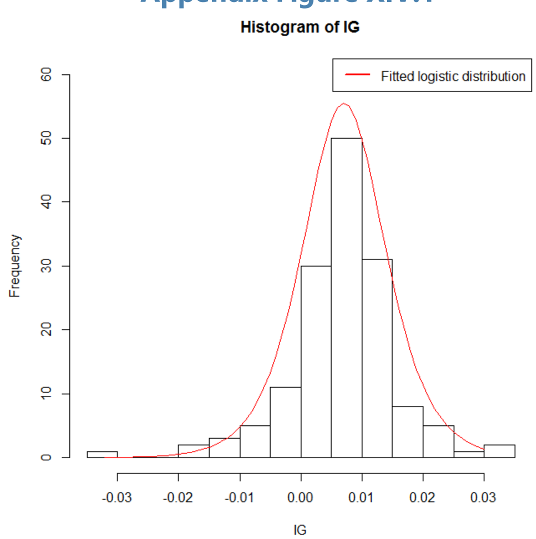
With μ the mean and s the scale parameter. Both parameters are estimated by maximum likelihood.

Finally, the expectation can be calculated using numerical integration or Monte-Carlo simulations.

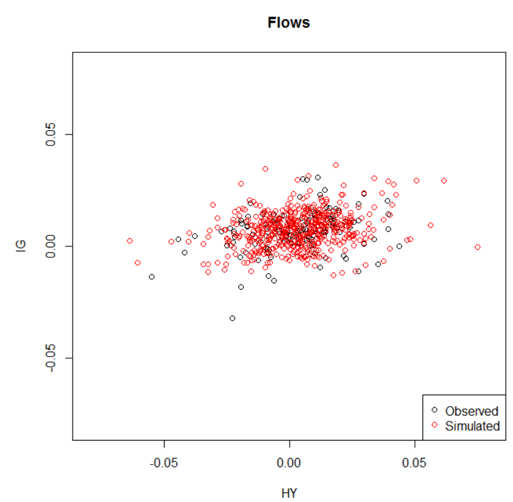
As an example, Appendix Figure XIV.1 shows the histogram of IG fund flows along with the corresponding pdf derived from the logistic distribution.

Appendix Figure XIV.2 illustrates the results by displaying the observed and simulated values (see Yan (2007) for details about the estimation procedure). Appendix Figure XIV.2 illustrates the results by displaying the observed and simulated values (see Yan (2007) for details about the estimation procedure).

Appendix Figure XIV.1



Appendix Figure XIV.2



Appendix Table XIV.1 shows an example of the output. Vulnerable categories can be identified as the categories in the columns, which experience high outflows when other fund categories (in row) are in distress. Spreader categories can be identified in as the categories in row, which are coupled with distress on other categories (in column).

In the example, EM funds are vulnerable since they experience high outflows when IG and MISC categories are in distress. On the opposite, Municipal bond funds are not vulnerable since they do not experience large outflows when other funds are in distress.

IG funds are identified as spreaders: when IG funds are in distress, both HY and EM funds also experience high outflows. On the opposite, HY funds are not identified as spreaders: when HY funds are in distress, other fund categories do not experience large outflows (and some of them such as government bond funds experience inflows due to flight to safety effects).

Interconnectedness approach

The Diebold-Yilmaz interconnectedness approach is applied to funds returns and fund flows. Weekly returns for each individual fund are retrieved from Morningstar. The methodology is the same as the one presented in the section on market-based contagion analysis and is reproduced below.

The interconnectedness approach is based in the spillover analysis of Diebold and Yilmaz (2014). A financial spillover from firm A to firm B is defined as the share of the variation in firm B's equity returns shocks that can be attributed to (contemporaneous or preceding) shocks to firm A's equity returns. The concept stresses idiosyncratic shocks and excludes co-movement across markets that is driven by common factors. The VAR was estimated using a lasso-estimator (see Zou and Hastie 2005).

The VAR model above is used to build a generalized forecast-error variance decomposition (GVD), using Pesaran and Shin's (1998) methodology, to identify uncorrelated structural shocks to FCIs.[1] The GVD for each firm is aggregated in a matrix, with the non-diagonal elements capturing spillovers effects.

The spillover therefore measures the fraction of the H-month ahead forecast error variance of firm j's returns that can be accounted for by innovations in firm i's returns. In this application, the focus is on the 3-week ahead forecast error.

[1] The GVD identification framework is order invariant by construction, hence avoids the ad hoc ordering of structural shocks characteristic of recursive identification.

Appendix XV. Sample Selection for Insurance Stress Tests

a. Starting from the NAIC Market Share Reports 2018, both for life&health[1] and P&C[2] insurers, the Top 25 companies from each sector were identified. In addition, the largest health insurers were identified[3], however, due to the higher concentration in that market segment and the homogeneity in business models, a significantly smaller sample was deemed sufficient. A company or a group is only included in one of the three samples—in case a company writes business in different sectors, it is allocated to that sector for which premiums are highest.

b. Large providers of variable annuities (VA) were identified from a research report by LIMRA Secure Retirement Institute.[4] To be included in the VA sub-sample, premiums written in that respective line must be greater than 30 percent of total life&health premiums. This method excludes some large VA providers, but focuses on those which have a large concentration in VA business.

c. Finally, subsidiaries of foreign insurance groups were identified based on the ultimate ownership.

The three insurance sectors differ significantly in terms of average size and capital position (Table XV.2). Life insurers have much larger balance sheet assets than the other two sectors and lower levels of statutory capital which is a typical characteristic. However, the distinction between life and P&C insurers is not always perfectly clear-cut as some groups are active in both sectors—the allocation of such groups was made based on the split of gross premiums. This results in some rather large companies also in the P&C sample which are also active in life business. The health insurance sample comprises relatively small companies in terms of balance sheet assets, which hold a very high amount of statutory capital—their premium volume, however, is sizable.

[1] Life Insurance Industry; Life/Health and Fraternal Insurers 2018 Market Share Report – Total Premium; Totals Life Insurance, Annuity, Deposit-Type Contracts, Other Considerations, and Accident&Health; States, U.S. Territories, Canada, Aggregate Other Alien.

[2] Property and Casualty Insurance Industry 2018 Market Share Report – Total Premium; States, U.S. Territories, Canada, Aggregate Other Alien; Total All Lines.

[3] Accident and Health Insurance Industry; Property/Casualty, Life/Health, Fraternal and Health Insurers 2018 Market Share Report – Total Premium; States, U.S. Territories, Canada, Aggregate Other Alien.

[4] https://www.limra.com/globalassets/limra/newsroom/fact-tank/sales-data/2018/q4/2018_q4_annuity_company_rankings_total_va_fixed_updated.pdf.

Appendix Table XV.1. Sample for the Insurance Stress Test

Life	P&C (diversified)	Health
Allianz Insurance Group	Aflac Group	Anthem Inc Group
AXA Insurance Group	Allstate Insurance Group	Centene Group
Global Atlantic Group	American Financial Group	Cigna Health Group
Jackson National Group	American International Group	CVS Group
John Hancock Group	Amtrust Financial Services Group	Humana Group
Lincoln National Group	Auto Owners Group	Kaiser Foundation Group
Mass Mutual Life Insurance Group	Berkshire Hathaway Group	UnitedHealth Group
Metropolitan Group	Chubb Ltd Group	
Minnesota Mutual Group	CNA Insurance Group	
Mutual of Omaha Group	Erie Insurance Group	
Nationwide Corp Group	Fairfax Financial Group	
New York Life Group	Farmers Insurance Group	
Northwestern Mutual Group	Hartford Fire&Casualty Group	
Pacific Life Group	Liberty Mutual Group	
Principal Financial Group	Markel Corp Group	
Prudential of America Group	Progressive Group	
Thrivent Financial for Lutherans	State Farm Group	
TIAA Family Group	Tokio Marine Holdings Inc Group	
Transamerica Group	Travelers Group	
Voya Financial Group	USAA Group	
West Southern Group	WR Berkley Corp Group	
	Zurich Insurance Group	
Market share >70 percent	**Market share >70 percent**	**Market share ~45 percent**

Appendix Table XV.2. Sample Characteristics for the Insurance Stress Test

		Life	P&C (diversified)	Health
Number of groups		21	22	7
Balance sheet assets (USD bn.)	Min	3.7	8.9	3.5
	25th percentile	135.6	20.3	9.2
	Median	195.0	36.0	15.2
	75th percentile	254.9	67.0	21.9
	Max	577.9	321.4	34.4
Statutory capital / Assets	Min	2.0%	3.3%	32.5%
	25th percentile	3.3%	23.8%	41.9%
	Median	4.6%	26.8%	46.2%
	75th percentile	6.4%	33.3%	47.2%
	Max	12.1%	56.7%	48.5%

Source: IMF staff calculations.

Appendix XVI. Solvency-Liquidity Network Model

I. Data

FR 2052a: cash flow data	**Stock of HQLA, including cash and CB reserves. FR Y-9C**	**Regulatory capital, assets, liabilities, Risk Weighted Assets. FR Y-9C**
Estimates of trading related data: price impact measures, transaction volumes. TRACES	**Interbank exposure data: secured, unsecured, contingent liabilities**	**Scenarios: funding liquidity shocks, market related haircuts on items in counterbalancing capacity**

FR2052a data on different types of secured financing transactions are aggregated into 4 buckets (HQLA1, HQLA2a, HQLA2b and Non-HQLA). HQLA is further disaggregated into more granular buckets using data from FR Y-9C.

Parameters such as Price Impact, Corwin-Schultz measures are estimated using TRACES data. Estimation methods and models are provided below.

Data for the interbank network is sourced from the bilateral exposures data (i.e., "i-to-i") for the domestic G-SIBs that the FRB has access to via the BIS G-SIB hub database. These exposures enter the interbank network under separate exposure categories (i.e., lending-unsecured, ST money placement, issuer risk (equities and fixed income), and CDS). In addition, a separate category for risk transfers is sourced from DTCC data. Loss-given-default rates and the risk transfer parameter are proxied by the IMF team based on information available through prior research, Moody's defaults and recoveries and CreditEdge databases, etc.

II. Risks and scenarios. Funding shock.

The scenario consists of a set of inflow/outflow/CBC (Counterbalancing capacity) parameters. Each scenario has two types of parameters: (i) fixed (i.e., the ones which remain constant) and (ii) varying, (i.e., the ones which are changing by a 5 percent or 10 percent increment to allow for sensitivity simulation). To simulate a liquidity shock, the user needs to apply the respective scenario embedded in the tabs Scenarios_Flows_LCR (same shocks to flows for all banks) and Scenarios_Flows_All_Repo_CIs (same shocks to flows for all banks). Scenarios_Flows_*BankName* allow to run a customized scenario for each bank (it is not used for the US FSAP purposes). Scenario type and severity, time horizon is embedded in the tabs and depends on data availability. Below is the illustration of shock parameters we suggest running for two main scenarios:

i) LCR
ii) Closure of repo markets for non-Treasury securities.

LCR scenario. In addition to the average, system-wide LCR inflow/outflow rates, the scenario assumes that each bank in the network faces increase in demand for committed facilities, withdrawal of wholesale funding, own credit rating downgrade and subsequent loss of rehypothecation rights, additional margin calls for derivative positions etc. (we do not assume that liquidity is redistributed from bank X to bank Y, in the nutshell this scenario tests what would happen if each of the bank in the network would face shocks and interbank network is not functioning due to a risk aversion of participants). Asset fire-sales prices are applied to balances of other banks which hold same types of securities (marked-to-market accounting). Stylized balance sheet allows to determine CAR and liquidity position after such a shock and simulate second round effects.

Closure of Repo market. Scenario assumes that a bank is not able to repo assets to obtain liquidity, except using HQLA1 treasury securities. All other parameters are same as in the LCR scenario.

The same variable parameters are applied to obtain sub-scenarios:

a) Outstanding Draws on Revolving Credit Facilities (shocks from 100% to 0%);
b) Credit Facilities (shocks from 0% to 100%);
c) Retail Mortgage Commitments (shocks from 0% to 100%)
d) Liquidity Facilities (shocks from 0% to 100%)
e) Federal Home Loan Bank Advances (all types of HQLA) (shocks from 0% to 100%)
f) Draws on committed lines (shocks from 0% to 100%)
g) MTM Impact on Derivative Positions (shocks from 100% to 0%)
h) Loss of Rehypothecation Rights, Total Collateral Required Due to a Notch Downgrade Total Collateral Required Due to a Change in Financial Condition (all types of downgrades). (shocks from 0% to 100%)
i) Combined scenarios: all shocks as above.

III. Network.

The network analysis comprises a system consisting of N entities (i.e., banks operating in the U.S. in the case of the domestic interbank network). A key ingredient in the network analysis is the availability of exposure data between these N financial institutions, forming a NxN matrix of 'interbank exposures.' The analysis then quantifies what are the consequences of a hypothetical 'stress event' (e.g., the default in a given bank on its interbank obligations to other banks in the network), and then assess the potential credit risk and funding risk related losses on other banks of the system.

Decomposition of assets and liabilities. The asset side of a bank is decomposed into the following items: cash and CB reserves, unencumbered securities (available for liquidity purposes), reverse repos, collateral swaps, secured loans ('rehypothecatable'), derivatives receivable, loans and all other assets (residual). The liabilities side of a bank consists of the following items: unsecured and secured wholesale funding, wholesale borrowing on and off-shore, repos, operational and non-operational wholesale deposits, liquidity and credit facilities, derivatives payable and all other liabilities (residual). Assets are decomposed into different types of collateral, namely Level 1, Level 2a, Level 2b, non-HQLA. The decomposition is used to evaluate bank's ability to raise liquidity in times of funding shocks. Non-HQLA securities are further decomposed by issuer/CUSIP number to allow for specific haircuts to be applied.

Counterparty information allows linking of assets and liabilities by different types of counterparties. Information is aggregated by sector using the following broad categories of counterparties: bank; mutual fund; insurance company; hedge fund; pension fund; CCP; other non-bank financial company; nonfinancial entity; other.

The balance sheet information is obtained from FR2052a report and covers three-time horizons: open + Day1; open+Day1….Day 5; Open + Day 1….Day 30. All other contractual inflows and outflows not included into those horizons are treated as other assets/liabilities in the stylized balance sheet.

The following two sub-sections describe the main two types of shocks being assessed in the network analysis, namely credit and funding risk shocks.

Simple Credit risk shock

The stylized balance sheet of a given bank *i* can be expressed as satisfying the following fundamental identity:

$$\sum_{k,j=1}^{N} a_{i,j}^{(k)} + \sum_{k} a_i^{(k)} = c_i + \sum_{k,j=1}^{N} d_{i,j}^{(k)} + \sum_{k} d_i^{(k)}$$

where $a_{i,j}^{(k)}$ and $d_{i,j}^{(k)}$ are the matrices of asset and liabilities exposures according to the different tenors (as in contractual cash flow report), respectively, of type of exposure *k* of bank *i* relative to another bank *j* in the network; $a_i^{(k)}$ and $d_i^{(k)}$ are other type-*k* assets and liabilities, respectively, of bank *i* (which are not direct exposures to other banks); and c_i is the regulatory capital of bank *i*.

The credit risk analysis assesses the impact of a hypothetical simulated 'default' of a given bank *h* in the network. In particular, when bank *h* defaults on its obligations, the direct credit losses of bank *i* can be expressed as $\lambda_{i,h}^{(k)}\, a_{i,h}^{(k)}$ where $a_{i,h}^{(k)}$ is the asset exposure of bank *i* to bank *h*, and $\lambda_{i,h}^{(k)}$ is the expected loss-given-default on that particular asset exposure. The after-shock balance sheet identity then becomes:

$$\sum_{k,j=1,j\neq h}^{N} a_{i,j}^{(k)} + \sum_{k} a_{i}^{(k)} + \sum_{k}\left(1-\lambda_{i,h}^{(k)}\right) a_{i,h}^{(k)} = \underbrace{\left[c_i - \sum_{k} \lambda_{i,h}^{(k)}\, a_{i,h}^{(k)}\right]}_{c_i'} + \sum_{k,j=1}^{N} d_{i,j}^{(k)} + \sum_{k} d_{i}^{(k)}$$

The amount of capital accounting for the direct credit losses is c_i'. This capital is then compared to a minimum threshold level c^*. If the resulting capital is below c^*, then bank i is considered to be 'in default' and the cascade effect continues.

IV. Funding risk shocks

A bank's capital falls below its minimum required solvency ratio and thus the bank experiences funding withdrawals over 1-, 5-, and 30-day period (separate scenarios). The analysis aims to assess how a given set of shocks would affect markets as well as banks and non-bank financial intermediaries. The following parameters were applied: wholesale funding outflows – commercial funding (no ability to borrow; maturing securities must be redeemed); wholesale borrowing (all counterparties) – 50,75,100 percent outflows; repos (non-HQLA) – maturing repos are not renewed; transactional, operational accounts – 2,5,10 percent outflows; non-operational accounts: 25,50,75 percent outflows. Liquidity facilities provided to a bank – not available. Credit facilities provided by bank – granted (to avoid reputational risk). Derivatives payable – 25,50, 100 percent outflows. Because of outflows, bank needs to use cash/CB reserves available as well as to sell or repo securities to meet its liquidity needs due to wholesale funding outflows.

V. Determination of Haircuts[1]

We assume that a bank can use up to the full amount of cash and CB reserves, however haircuts were determined by the amount of assets liquidated. There can be several types of haircuts:

(i) *Scenario based*: term and risk premiums to be in line with macroeconomic stress test scenario (which are also used in the other segments of the FSAP financial stability analysis). We assume that risk and term premiums shocks are realized immediately.

(ii) *Security based*: CB eligible assets. Based on the Fed's collateral framework, we assume that a bank is able to obtain liquidity form the Fed with minimal costs via repos.

(iii) *Security based*: market repos. We assume that a bank is able to repo securities using market haircuts.

[1] For details see Han, F. and M. Leika "Integrating Solvency and Liquidity Stress Tests: The Use of Markov Regime-Switching Models". IMF Working Paper No. 19/250.

(iv) *Security based*: fire-sales. We assume that securities for which repos would not be available (non-HQLA), bank may need to liquidate in the market. Haircuts were determined by the total amount of securities a given bank as well as other banks sell. Calculations could be done assuming 50 percent implementation shortfall (see methodology explained below).

Security-level measures of market liquidity are aggregated for a certain asset class to obtain measures of aggregate market liquidity. Different measures of market liquidity at the security level have been developed in literature. Two widely-used market liquidity measures of price impact in literature (see, for example, IMF, 2015b) are: (i) the Amihud (2002) measure—defined as the ratio between the absolute value of daily returns and daily trading volume of a frequently-traded security, and (ii) the price impact measure (PI)—defined as the slope coefficient of a regression of price change on signed order flow (buyer-initiated trades minus seller-initiated trades). The price impact measure assigns "signs" to trades, making it more suitable for modeling the haircuts for asset fire sales as most fire sales are seller- rather than buyer-initiated trades. As shown by the 2017 Japan FSAP (IMF, 2017), the Amihud measure of the Japanese stock market varies over time and exhibits regime switching. Similarly, IMF (2015) showed that the price impact measure for European sovereign bonds increased rapidly during the global financial crisis and European debt crisis.

IMF team used daily TRACE trading data to construct price impact measures for following security classes: corporate bonds, agency, ABS, CMO, MBS, TBA. The aggregation is needed as data by CUSIP or other higher level of granularity is not available. In general, the higher the aggregation level the higher the PI as diversification effects are lost in the aggregation process.

The following steps are used to estimate a simple regime-switching model for the aggregate market liquidity measure of each asset class:

- Step 1: identify the marketable asset classes and securities that banks hold as CBC and calculate the price impact measure (PI) at the security level using transaction data;[2]

- Step 2: average the security-level price impact measures for all securities in the same asset class to obtain aggregate price impact measure for each asset class;

- Step 3: for each asset class j, estimate the following baseline Markov regime-switching model:[3]

$$PI_t^j = \beta_0^{j,s} + \varepsilon_t^{j,s}, \qquad (1)$$

where PI_t^j is the aggregate price impact measure averaged across all securities in the asset class j, and s denotes the regime of the aggregate price impact measure. For simplicity, two regimes are assumed, notably, a non-stress (or high-liquidity) regime and a stress (or low-liquidity) regime, but one could also choose a different number of regimes based on the estimation results. $\beta_0^{j,s}$ is the

[2] The price impact measure is calculated daily in this paper.

[3] The specification is similar to Flood and others (2015).

constant of interest that varies across regimes and $\varepsilon_t^{j,s}$ is the error term with mean zero and variance σ_s^2. The variance σ_s^2 is also assumed to vary across the two regimes.[4]

The impact of asset sales on the prices depends on the price impact measure of that asset class and the total amount of securities offered to sell in that asset class. To determine the amount of sales for each asset class, one would need to use information or make assumptions about the pecking (liquidation) order of sales. Amount of securities a bank needs to liquidate to offset the negative funding gap is available from liquidity stress test. In other words, one would need the information on how much securities in each asset class will be sold at which order and time horizon for each bank. Since the focus of the analysis is to estimate the haircuts, we do not attempt to model the pecking order and time horizon of sales and simply assume that bank i needs to liquidate Vol_i^j amount of securities that belong to asset class j. [5] Therefore, the total amount of securities in asset class j that will be liquidated by all banks, Vol_{all}^j, can be expressed as:

$Vol_{all}^j \equiv \sum_{i=1}^{N} Vol_i^j$ (2)

where N is the total number of banks in the system.[6]

Based on the baseline Markov regime-switching model, we calculate the price impact for each asset class using the total amount of fire sales. More specifically, since the price impact measure indicates the impact of a one-unit (net) trade on the price, we can assume a linear relationship with a scenario based floor[867] between the price impact of fire sales and the total amount of fire sales.[8] the price impact for each asset class j in regime s can be calculated as $\beta_0^{j,s} \cdot Vol_{all}^j$.[9] Since we assume that market liquidity of an asset class remains in the non-stress regime in idiosyncratic fire-sale events, then the price impact for asset class j in idiosyncratic events could be calculated as:

$\beta_0^{j,non-stress} \cdot Vol_{all}^{j,non-stress}$ (3)

[4] We also consider the case where the variance of the error term is the same across regimes.

[5] Time horizon of sales is implicitly linked with stress testing scenario, i.e., 1,5 30 days.

[6] Given that the time period of liquidation could be longer than one day (e.g., weeks), one could assume different scenarios of liquidation strategies. In this context, the total amount of liquidation on a particular day would depend on the specific liquidation strategy.

[7] The floor is important as without the model which estimates demand of securities it would be possible to have haircuts which would exceed realistic values (i.e., may even become negative). Assumed floors depend on types of securities and can be very high for sovereign bonds and low for illiquid, opaque securities.

[8] This is a simplifying assumption as the actual price impact of a trade could be a nonlinear function of the size of the trade. Moreover, a linear relationship implies that a sufficiently large trade could lead to a price decline of over 100 percent, which would never happen. Having said that, since the price impact measure quantifies the "average" impact of a one-unit trade on prices, one may make the simplified assumption when the size of the trade is not "too" large in the sense that post-trade prices would become negative.

[9] As explained above, the total amount of fire sales is obtained from the liquidity stress test, and a pecking order of fire sales of different asset classes need to be assumed before applying the methodology.

where $Vol_{all}^{j,non-stress}$ represents the total amount of securities in asset class j that are liquidated by all banks in the non-stress regime. Similarly, since we assume that market liquidity of an asset class switches from the non-stress regime to the stress regime when banks start to liquidate this asset class, the price impact should be calculated as:

$$\beta_0^{j,stress} * Vol_{all}^{j,stress} \quad (4)$$

where $Vol_{all}^{j,stress}$ denotes the total liquidation amount by all banks in the stress regime. The price impact can be much larger in the stress regime than in the non-stress regime, depending on the total fire-sale amount and the specific asset class.[10]

VI. Estimated haircuts

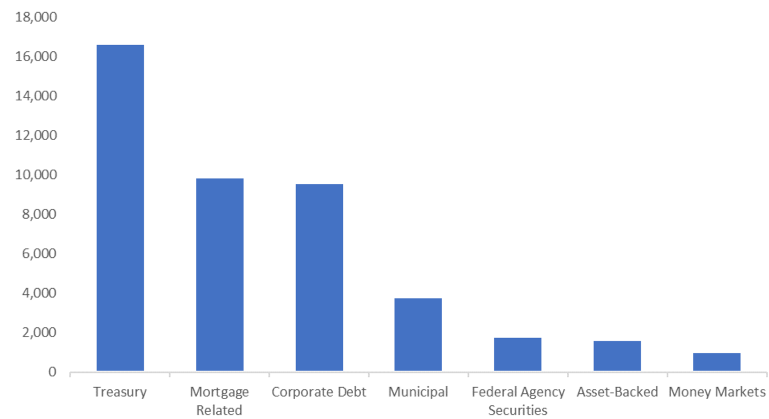
Estimated Price Impact of Securities

	Volume-based (per US$ 100 mil)		Corwin-Schulz	
	Stress regime	Non-stress regime	Stress regime	Non-stress regime
US Treasuries	…	…	0.00097	0.00001
RMBS: pass-through	0.06058	0.01691	0.00159	0.00069
RMBS: other	0.02440	0.00552	0.00117	0.00064
CMBS	0.10874	0.01598	0.00753	0.00045
ABS and other structured products	…	…	0.00053	0.00012
Corporate securities	0.12906	0.03047	0.00336	0.00004

Sources: FINRA, TRACE; Bloomberg LP; IMF staff

[10] It is worth noting here that aggregating security-level price impact measures to the asset class-level is to simplify the calculation, and the calculation could also be conducted at the security level if more granular data of each bank's CBC are available.

Market size of various securities



Sources: SIFMA and IMF calculations.

VII. Network algorithm and cascade effects

The network algorithm comprises of a system consisting of *N* nodes (each node representing a banking system/bank) and with a structure of inter-node (or interbank) loans represented by the *N x N* matrix, *X*, with a generic element denoted by an array of exposures x_{ij}—note that these exposures are direct exposures across nodes. Let F_t be the set of failed institutions and let NF_t be the set of not-failed institutions in round *t* of the simulations.

To initialize the credit shock simulation (simulation 1), assume that institution h fails at t=0, and thus a fraction λ of its debts to the rest of institutions will not be repaid. Then, for each one of the not-failed institutions, $j \in NF_t$, the algorithm checks whether the amount of losses suffered by that institution is larger than the amount of capital of that institution. If that is the case, then that institution is also driven to bankruptcy. That is,

$$\text{if} \sum_{h \in F_t} \lambda x_{ht} > k_j \rightarrow j \text{ defaults too} : j \in F_{t+1}$$

The algorithm is said to converge once there are no further failures: that is, $F_t = F_{t+1}$.

For the credit-plus-funding shock simulations (simulation 2), the previous shock is compounded by the funding-shortfall induced loss, $\delta \rho x_{ih}$. That is, at each stage of the simulation, an institution's capital may be negatively affected by the asset fire sale, and hence the default condition is given by:

$$if \sum_{h \in F_t} \lambda x_{ht} + \sum_{h \in F_t} \delta \rho x_{jh} > k_j \rightarrow j \text{ defaults too} : j \in F_{t+1}$$

We would recalculate banks solvency position after each shock (in terms of shareholders' equity, CET1 ratio, total CAR). There are several thresholds, like illiquidity (inability to maintain positive cash flows after use of available counterbalancing capacity) within 1,5,30 days horizon; inability to maintain CET1 ratio above minimum requirements (4.5 percent); inability to maintain positive shareholders equity.

Shocks are transmitted to banks and other non-bank financial intermediaries via funding, liquidity and solvency channels. Funding channels assume that bank which faces liquidity shortage cancels credit lines to other banks/non-bank financial institutions; liquidity channels – asset fire-sale affects other financial intermediaries via marked-to-market pricing; solvency channel – failing financial institution would not redeem its own securities, deposits held by other banks and non-bank financial institutions. Second/third round effects were calculated.

The FSAP team uses two dimensions of market liquidity—cost and quantity—to measure the impact and the ability to execute sizable securities transactions to fulfill funding gaps incurred by the G-SIBs in the network. These estimates are used to assess the degree of price impact haircuts due to direct liquidation losses as well as marked-to-market losses in fire sale events. The calculations are performed at securities transactions level for seven asset classes (Corporate, ABS, RMBS pass-through, RMBS other, CMBS, Agency, Treasuries) using FINRA TRACE data (with the exception of U.S. treasuries, where the data comes from Bloomberg given lack of access to this asset class in FINRA TRACE subscription).

Following IMF's 2015 October GFSR chapter 2 on market liquidity, we estimate two measures to assess the cost dimension of market liquidity: 1) a regression-based price impact measure; 2) Corwin-Schultz (2012) high-low spread. The first measure (i.e., price impact measure) is calculated as the slope coefficient of a regression that uses price changes and sigh-ordered buy and sell transaction volumes (see the equation below). The estimation is performed at securities transaction level during a given day.

$$\Delta \text{Price}_{s,t} = \alpha + \beta \text{Trading Volume}_{s,t} + \varepsilon,$$

Where:

s = security;

t = time between two transaction within a day (typically in milliseconds).

Given that the size of the coefficient (β) is determined by the size of trades in the sample (i.e., the quantity), simply multiplying these coefficients by the amount of assets needed to fulfill the funding gap may result in erroneous elasticities when the funding gaps are substantially larger than the trading volumes in the securities samples. Therefore, we compliment the cost-based market liquidity measures by incorporating a trading volume parameter, thus also capturing the quantity-dimension of market liquidity. Specifically, we use two volume constrains: 1) amount of assets needed to liquidate are divided into transactions before applying the price impact coefficient, where the number of transactions is based on the maximum per transaction volume in the sample of each asset class and the amount of assets needed to liquidate to cover the gap; 2) total amount of assets that can be liquidated is constrained by a daily total trading volume constrain, where the total trading volume is the total daily trading volume observed in the sample. Given the latter amount is the total liquidity available to all participants in the market, and the G-SIBs in the network may not necessarily be able to use the entire amount, we further refine the constraint by allowing only a share of the total daily trading volume to be available to the 6 G-SIBs (this is proxied based on the banking sector share in the financial sector under relevant instruments in U.S. flow of funds data). To account for the uncertainly associated with the daily total trading volume constrain assumption, we also incorporate a parameter that ranges from half-to 5 times the threshold.

As an additional cost-based market liquidity measure, Corwin-Schultz (2012) high-low spread is used. Spreads (S) are estimated using two-day high and low prices of the securities in the 7 asset classes as a nonlinear function, where:

$$S = \frac{2(e^{\alpha} - 1)}{1 + e^{\alpha}};$$

α is defined as $\frac{\sqrt{2\beta} - \sqrt{\beta}}{3 - 2\sqrt{2}} - \sqrt{\frac{\gamma}{3 - 2\sqrt{2}}}$,
β is defined as $\ln{(H_t/L_t)}^2 + \ln{(H_{t+1}/L_{t+1})}^2$,
γ is defined as $\left[ln\left(\frac{H_{t,t+1}}{L_{t,t+1}}\right)\right]^2$,
H is the daily high price of the security,
L is the daily low price of the security, and
t stands for time (in days).

In line with Corwin-Schultz (2012), we assign a zero value to estimated high-low spreads that are less than zero (i.e., negative values); negative values could particularly occur in the presence of large price fluctuations where the 2-day variance in the prices may exceed the single-day variance. Subsequently,

Appendix XVII. Network Algorithm for Contagion (Cross-Border Interconnectedness)[187]

The network algorithm comprises of a system consisting of *N* nodes (each node representing a banking system/bank) and with a structure of inter-node (or interbank) loans represented by the *N x N* matrix, *X*, with a generic element denoted by x_{ij}—note that these loans are direct exposures across nodes. Let F_t be the set of failed institutions and let NF_t be the set of not-failed institutions in round *t* of the simulations.

To initialize the credit shock simulation (simulation 1), assume that institution h fails at t=0, and thus a fraction λ of its debts to the rest of institutions will not be repaid. Then, for each one of the not-failed institutions, $j \in NF_t$, the algorithm checks whether the amount of losses suffered by that institution is larger than the amount of capital of that particular institution. If that is the case, then that institution is also driven to bankruptcy. That is,

$$\text{if} \sum_{h\,\in F_t} \lambda x_{ht} > k_j \;\rightarrow j \text{ defaults too} : j \;\in F_{t+1}$$

The algorithm is said to converge once there are no further failures: that is, $F_t = F_{t+1}$.

For the credit-plus-funding shock simulations (simulation 2), the previous shock is compounded by the funding-shortfall induced loss, $\delta\rho x_{ih}$. That is, at each stage of the simulation, an institution's capital may be negatively affected by the asset fire sale, and hence the default condition is given by:

$$if \sum_{h\,\in F_t} \lambda x_{ht} + \sum_{h\in F_t} \delta\rho x_{jh} > k_j \;\rightarrow j \text{ defaults too} : j \;\in F_{t+1}$$

[1] Based on Espinosa-Vega and Sole (2010).

References

Antolin-Diaz, J., Petrella, I., and Rubio-Ramirez, J., 2018, "Structural scenario analysis with SVARs," CEPR Discussion Papers 12597, C.E.P.R. Discussion Papers.

Amihud, Y., 2002, "Illiquidity and Stock Returns: Cross-Section and Time-Series Effects, Journal of Financial Markets," 5, pp. 31–56.

Baumeister, C., and Kilian, K., 2014, "Real-time analysis of oil price risks using forecast scenarios", IMF Economic Review (2014) 62:119.

Bernanke, B. S., Gertler, M., and Gilchrist, S., 1999, "The financial accelerator in a quantitative business cycle framework," Handbook of macroeconomics 1: pp. 1341–1393.

Board of Governors of the Federal Reserve System, (2018). Financial Stability Report, https://www.federalreserve.gov/publications/files/financial-stability-report-201811.pdf

Breuer, T., and Summer, M., 2018, "Systematic Systemic Stress Tests," Oesterreichische Nationalbank working paper 225.

Caceres, C., Cerdeiro, D.A., Pan, D., and Tambunlertchai, S., 2020a, "Stress Testing U.S. Leveraged Corporates," IMF Working Paper, 20/XX (forthcoming).

Caceres, C., Cerdeiro, D.A., Pan, D., and Tambunlertchai, S., 2020b, "Collateralized Loan Obligations and the Pricing of Risk," IMF Working Paper, 20/XX (forthcoming).

Caceres, C., M. Leika, D. Seneviratne and E. Yu 2020c. "Keeping It Real": Enhanced Network Analysis in IMF FSAPs." IMF Working paper, 20/XX (forthcoming).

Coen, J., Lepore, C. and Schaanning, E., 2019, "Taking regulation seriously: fire sales under solvency and liquidity constraints," Bank of England Staff Working paper No. 793.

Cont, R. and Schaaning, E., 2017, "Fire sales, indirect contagion and systemic stress testing," Norges Bank Working paper 02/2017.

Christiano, L. J., Motto, R., and Rostagno, M., 2014, "Risk shocks," American Economic Review, American Economic Association, vol. 104(1), pp. 27–56, January.

Deli, D., Hanouna, P., Stahel, C., Tang, Y. and Yost, W., 2015, "Use of Derivatives by Registered Investment Companies," DERA White Paper.

Diebold, F.X. and Yilmaz, K., 2014, "On the Network Topology of Variance Decompositions: Measuring the Connectedness of Financial Firms," Journal of Econometrics, 182, pp. 119–134.

Espinosa-Vega, M. A., and Sole, J., 2010, "Cross-border financial surveillance: a network perspective," IMF Working Paper 10/105, International Monetary Fund.

Girardi Giulio, Christof Stahel, and Youchang Wu, 2017, "Cash Management and Extreme Liquidity Demand of Mutual Funds" DERA Working Paper.

Gourio, F., Kashyap, A. K., & Sim, J. W., 2018, The tradeoffs in Leaning Against the Wind. IMF Economic Review, 66(1), pp. 70–115.

Han, F. and M. Leika, 2019, "Integrating Solvency and Liquidity Stress Tests: The Use of Markov Regime-Switching Models". IMF Working Paper No. 19/250.

Hirtle, B., Kovner, A., Vickery, J., and Bhanot, M. (2015), "Assessing Financial Stability: The Capital and Loss Assessment under Stress Scenarios (CLASS) Model", Federal Reserve Bank of New York Staff Report No. 663, July 2015.

International Monetary Fund, 2015a, "The Asset Management Industry and Financial Stability", Global Financial Stability Report, April issue.

International Monetary Fund (IMF), 2015b, "Market Liquidity—Resilient or Fleeting?" Global Financial Stability Report, October issue.

International Monetary Fund (IMF), 2017, "Is Growth at Risk?" Global Financial Stability Report, October issue.

International Monetary Fund (2017), "Japan—Financial System Stability Assessment," IMF Country Report No. 17/244.

International Monetary Fund (2017), "Technical Note—Risk Analysis," Luxembourg Financial Sector Assessment Program, IMF Country Report No. 17/261.

International Monetary Fund (2018), "Technical Note on Stress Testing and Systemic Risk Analysis," Brazil Financial Sector Assessment Program, IMF Country Report No. 18/344.

Lawrence, C. J., Motto, R., and Rostagno, M., 2014, "Risk Shocks, " American Economic Review, 104 (1): pp. 27–65.

Li, L. and Chen, C., 2018, "The domino effect of credit defaults: test of asymmetric default correlations using realized default data," Applied Economics, 50 (44), pp. 4803–13.

Lucas, D., 1995, “Default Correlation and Credit Analysis,” Journal of Fixed Income, 4 (4), pp. 76–87.

National Association of Insurance Commissioners (2018), “Market Share Report, Accident and Health Insurance Industry.”

National Association of Insurance Commissioners (2018), “Market Share Report, Life Insurance Industry; Life/Health and Fraternal Insurers.”

National Association of Insurance Commissioners (2018), “Market Share Report, Property and Casualty Insurance Industry.”

Nickerson, J. and Griffin, J.M., “Debt correlations in the wake of financial crisis: What are appropriate default correlations for structured products?” Journal of Financial Economics, 125, pp. 454–472.

Pesaran, H. H., and Shin, Y. (1998), “Generalized impulse response analysis in linear multivariate models,” Economics Letters, Elsevier, vol. 58(1), pp. 17–29, January.

Qi, H., Shi, J., and Xie, Y.A., 2019, “Default correlation: rating, industry ripple effect, and business cycle,” Applied Economics, 51 (30), pp. 3256–3273.

Santos Silva, J. M. C., and Tenreyro, S. (2006), “The log of gravity”, The Review of Economics and Statistics, MIT Press, vol. 88(4), pp. 641–658, November.

Securities and Exchange Commission (2015), “Use of Derivatives by Registered Investment Companies and Business Development Companies,” Concept Release, No. IC-31933; File No. S7-24-15.

Securities and Exchange Commission (2016), “Investment Company Liquidity Risk Management Programs,” Final Rule, Release Nos. 33- 10233; IC- 32315; File No. S7-16-15.

Van der Veer, K., Levels, A., Lambert, C., Molestina Vivar, L., Weistroffer, C., Chaudron, R. and de Sousa van Stralen, R. (2017), “Developing macroprudential policy for alternative investment funds,” ECB Occasional Paper Series No. 202.

Zou, H., and Hastie, T. (2005) “Regularization and variable selection via the elastic net,” Journal of The Royal Statistical Society. Series B (Statistical Methodology), Vol. 67, No. 2 (2005), pp. 301-320.