INTERNATIONAL MONETARY FUND

IMF Country Report No. 22/158

COLOMBIA

FINANCIAL SECTOR ASSESSMENT PROGRAM

June 2022

TECHNICAL NOTE ON RISK ANALYSIS

This Technical Note on Risk Analysis was prepared by a staff team of the International Monetary Fund. It is based on the information available at the time it was completed in April 2022.

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International Monetary Fund
Washington, D.C.

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May 24, 2022

TECHNICAL NOTE

RISK ANALYSIS

Prepared By
Monetary and Capital Markets Department

This Technical Note was prepared in the context of a joint IMF-World Bank Financial Sector Assessment Program (FSAP) virtual mission in Colombia during June 2021 led by Ms. Zsofia Arvai, IMF and Ms. Raquel Letelier, World Bank, and overseen by the Monetary and Capital Markets Department, International Monetary Fund, and the Finance and Markets Global Practice, World Bank. The note contains the technical analysis and detailed information underpinning the FSAP assessment'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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AFP	Private Pension Funds (*Administradora de Fondos de Pensiones y de Cesantías*)
AFS	Available for Sale
AUM	Assets Under Management
BCP	Basel Core Principles
BMA	Bayesian Model Averaging
BR	Central Bank of Colombia (*Banco de la República*)
CAR	Capital Adequacy Ratio
CCoB	Capital Conservation Buffer
CET1	Core Equity Tier 1
CF or FC	Financial Conglomerate (*Conglomerado Financiero*)
CI	Credit Institution
CIF	Collective Investment Funds
COP	Colombian Peso
DSIB	Domestic Systemically Important Bank
ELA	Emergency Liquidity Assistance
EWS	Early Warning System
FCL	Flexible Credit Line
FX	Foreign Exchange (Currency)
GDP	Gross Domestic Product
GFC	Global Financial Crisis
HFT	Held for Trading
HTM	Held to Maturity
HQLA	High Quality Liquid Assets
IBR	Interbank Overnight Rate (*Indicador Bancario de Referencia*)
ICR	Interest Coverage Ratio
IFRS	International Financial Reporting Standards
IRL	Liquidity Risk Index (*Índice de Riesgo de Liquidez)*
LCR	Liquidity Coverage Ratio
LTV	Loan to Value
MSME	Micro, Small, and Medium Enterprises
NBFI	Nonbank Financial Institutions
NPL	Nonperforming Loan
NSFR	Net Stable Funding Ratio
PAD	Program to Support Debtors (*Programa de Acompañamiento de Deudores*)
RAM	Risk Assessment Matrix
ROA	Return on Assets
ROE	Return on Equity
RWA	Risk-Weighted Assets
SFC	Financial Superintendency of Colombia (*Superintendencia Financiera de Colombia*)
SIB	Systemically Important Bank
SIC	Superintendency of Industry and Commerce (*Superintendencia de Industria y Comercio)*
SIFI	Systemically Important Financial Institution
SSC	Superintendency of Companies (*Superintendencia de Sociedades*)
TES	Short-Term Treasury Securities (*Títulos de Tesorería*)
URF	Financial Regulation Agency (Unidad de Regulación Financiera)
WEO	World Economic Outlook

EXECUTIVE SUMMARY[1]

1. The Financial Sector Assessment Program (FSAP) risk analysis work was conducted in the aftermath of the initial COVID shock and subsequent lockdowns, and while a strong economic recovery was underway in Colombia during 2021. Given the persistent uncertainty around the evolution of the COVID-19 virus, and for the trajectory of the economic recovery, the outlook remained subject to significant revisions throughout the year. While the workstreams took the latest macroeconomic and supervisory data updates into account as much as possible for the various analyses, the test results and their implications should be interpreted with caution due to high uncertainty around the central projections and downside risks.

2. The banking system entered the COVID-19 pandemic from a position of relative strength, and the authorities mounted a strong policy response to avoid a tightening of credit supply. In addition to substantial fiscal and monetary response, the Financial Superintendency of Colombia (SFC) allowed the release of countercyclical provisions, and banks were allowed to provide temporary grace periods, extensions, and other loan modifications. The SFC launched the Program to Support Debtors (PAD) to support viable borrowers, which was phased out at end-August 2021.

3. The risk indicators for the banking system were broadly sound going into the COVID-19 pandemic, having recovered from the deterioration in asset quality and profitability from the 2014–16 oil price shock and economic slowdown. Despite the impact of the pandemic, banks had strong profitability buffers and had adequate capital, further boosted by several factors, including migration to Basel III. Banks' funding is largely deposit-based, with almost 80 percent of funding coming from the wholesale sources. At large, the financial system is dominated by large and complex financial conglomerates (FC), with increasing cross-border exposures that make the monitoring of intragroup risks and contagion channels essential. Colombian conglomerates have become systemic players in several Central American countries.

4. To gauge the effects of a prolonged contraction and rising risks amidst heightening uncertainties, the FSAP conducted various analyses to assess the system's resilience. To analyze financial stability risks related to banks' solvency and liquidity, the FSAP team conducted bank solvency and liquidity stress tests following standard FSAP methodologies on four domestic systemically important banks (DSIBs) and eight non-systemic banks, which together account for the vast majority of banking system assets. The FSAP team also undertook interconnectedness and contagion risk analyses mapping both intersectoral linkages and cross-border exposures using advanced network models. Given the importance of the bank-nonfinancial corporate (NFC) links, and as a complement, the FSAP conducted a scenario-based corporate vulnerability analysis employing firm-level financial statement data on both corporates and SMEs.

[1] Prepared by Jorge Alvarez, Marco Arena, Aleksandra Babii, and Mehmet Ziya Gorpe (all IMF staff). The work of the risk analysis team was made possible by and benefited from the expertise of staffs of the SFC, the BR, and the SSC, as well as from discussions with financial sector and industry representatives, and other stakeholders who are too numerous to list. The team would like to express deep appreciation for their collegiality and assistance.

5. The FSAP team's assessment of the banking system's capacity to withstand severe shocks suggests broad resilience at the aggregate level, albeit with pockets of vulnerabilities in a few banks. The solvency exercise presents a severe scenario, with a combination of risks arising from global resurgence of the pandemic, tightening of financial conditions, political uncertainty, and fiscal deterioration. High starting levels of system-wide capital and strong profit buffers allow most banks to absorb a large shock under the adverse scenario and to retain substantial buffers, overall resulting in very small capital shortfall in the system. Non-DSIBs and foreign-owned banks are impacted somewhat more than DSIBs and domestically owned banks, respectively. Credit impairments and lower net interest income are the key contributing factors.

6. Banks hold ample liquidity to manage significant liquidity pressures, but some would lack liquid assets to support credit intermediation if faced with long-lasting, very severe liquidity shocks. After the start of the pandemic, the level of liquidity in the banking system had benefited from substantial central bank support, from the reallocation of resources to the banking system due to a flight-to-stability motive, as well as from slower loan growth. Results based on the liquidity stress tests that considered large outflows of retail and wholesale funding showed that the Colombian banks are well positioned to manage significant liquidity pressures, with only modest liquidity shortfalls in the extreme funding shock. However, attention is warranted to the reliance of banks on wholesale unsecured funding.

7. Interbank contagion seems limited, whereas intersectoral linkages and cross-border exposures could lead to substantial losses. The exercise confirms that banks designated as "systemically important" (DSIBs) are sources of heightened contagion risk to the rest of the system. However, cascade effects remain contained. Low vulnerability levels of DSIBs to contagion is a key factor in limiting amplification that could potentially arise from idiosyncratic shocks in the banking system. However, contagion to nonbank financial entities and cross-border exposures reveal important vulnerabilities. Furthermore, the results reveal some vulnerability of insurers due to their exposures to banks.

8. The SFC and the BR conduct extensive analysis on solvency, liquidity, and interconnectedness in the system. To strengthen the authorities' ability to monitor cross-border exposures, it would be important to fill data gaps on the exposures and risk metrics of ultimate subsidiaries, in order to enable the authorities to conduct a fully consolidated stress-testing exercise. To further enhance liquidity monitoring, the FSAP recommends collecting more granular data on sources and uses of funds that would allow for more refined quantitative exercises. In addition, the regulatory parameters used for the computation of local liquidity coverage ratio (IRL) and net stable funding ratio (NSFR) could be readjusted or determined to be further aligned with Basel III liquidity requirements.

9. Although the system is resilient, the financial network's evolving complexity, suggested by the analysis, calls for the further development of monitoring tools to bolster early warning systems (EWS) while vulnerabilities are building up. Certain data coverage and methodology improvements would bolster the mapping of the network and the assessment of contagion risks. These include the development of network analysis tools that improve on the

analysis presented, advancing the identification of foreign creditors to Colombian entities to monitor cross-border funding risks, and gathering further data on the composition of conglomerate subsidiary operations in Central America.

10. The corporate vulnerability analysis shows that while the pandemic shock led to a deterioration in their repayment capacity and profitability in 2020, it did not trigger widespread systemic failures due to policy actions. Under an adverse scenario, there is an increase in the share of firms with lower repayment capacity and in the share of firms with potential borrowing needs, as well as those that go under solvency pressure, though to a lesser extent. The firm-level analysis suggests that the authorities need to continue monitoring the nonfinancial corporate sector, especially the services sector, to identify potential pockets of vulnerability. An important element for such monitoring is the ongoing work on early warnings, which could be broadened to increase the number of firms in the sample.

Table 1. Colombia: Risk Analysis Recommendations

Recommendation	Agency	Time
1. Strengthen the ability to monitor cross-border exposures and conduct a fully consolidated stress-testing by filling data gaps on the exposures and risk metrics of ultimate subsidiaries.	SFC	ST
2. Extend data collection to monitor liquidity risks by currency. Collect more granular data on assets and liabilities generating cashflows, including those related to cross-border exposures.	SFC	ST
3. Readjust or determine some parameters used in the computation of the local LCR and NSFR ratios to further align with Basel III requirements.	SFC	MT
4. Develop network analysis tools and improve data coverage to bolster EWS for domestic and cross-border contagion.	SFC/BR	ST
5. Broaden the sample of firms for the early warning exercise ("Alerta Temprana") for the nonfinancial corporate sector and enhance cross-agency information sharing to reinforce the feedback channel to strengthen the early warning exercise.	SSC/SFC	ST

INTRODUCTION

A. Background and Macrofinancial Context

11. Colombia has a broad financial system dominated by complex financial conglomerates (FCs). Credit institutions' (CIs) assets are equivalent to about 76 percent of GDP, followed by trust companies and private pension funds and, to a lesser extent, insurance companies (Table 2). The five largest financial conglomerates own about 60 percent of the system's assets. The share of pension funds and trusts has increased considerably since the last FSAP. The complexity of conglomerate structures has the potential to hide important vulnerabilities.

Table 2. Colombia: Financial Sector Structure

(At end-2020)

Type of Financial Institution	Assets (billion, Col$)	Assets (% of GDP)	Assets (% of total system)	No. of entities
Credit institutions	**768,724**	**76.2**	**34.9**	**46**
Commercial banks	701,990	69.6	31.9	24
State-owned bank	27,851	2.8	1.3	1
Other	38,883	3.9	1.8	21
Pension funds	**383,761**	**38.1**	**17.4**	**5**
Pension funds	325,138	32.2	14.8	
Other retirement funds	47,927	4.8	2.2	
Prima media	10,696	1.1	0.5	
Mutual funds	**135,027**	**13.4**	**6.1**	**279**
Collective investment funds	76,039	7.5	3.5	
Private equity funds	19,412	1.9	0.9	
Other	39,577	3.9	1.8	
Insurance	**94,820**	**9.4**	**4.3**	**45**
Life	58,358	5.8	2.7	20
General	33,137	3.3	1.5	25
Other	3,326	0.3	0.2	
State-owned Financial Institutions[1]	**88,120**	**8.7**	**4.0**	**11**
Other	**69,191**	**6.9**	**3.1**	
Trust services	**660,546**	**65.5**	**30.0**	**23,680**
Management and Payment	179,000	17.8	8.1	11,986
Social Security Resources	88,000	8.7	4.0	103
Real Estate Development	76,000	7.5	3.5	8,572
Secured Finance and Collateral Mgmt	72,000	7.1	3.3	3,010
Investment	15,000	1.5	0.7	404
Securities custody	222,173	22.0	10.1	
Other	8,373	0.8	0.4	
TOTAL FINANCIAL SYSTEM	**2,200,188**	**218**	**100**	

[1] This category includes only nonbanks and does not include the state-owned bank (Banco Agrario), which is reflected under credit institutions.

Source: SFC.

12. Colombia's financial sector has been operating in an environment of strong macroeconomic policies and policy framework, but in an economy with still relatively high commodity export dependence and high exposure to capital flow shocks. The economy has a high exposure to trade shocks, with commodity exports amounting to about half of total exports. Moreover, Colombia has been exposed to external financial conditions via high nonresident participation in the local bond market at about 8 percent of GDP and close to 23.7 percent of the total holdings before the pandemic. The external vulnerabilities are limited by the country's adequate foreign reserves buffers and access to a flexible credit line (FCL) from the Fund.

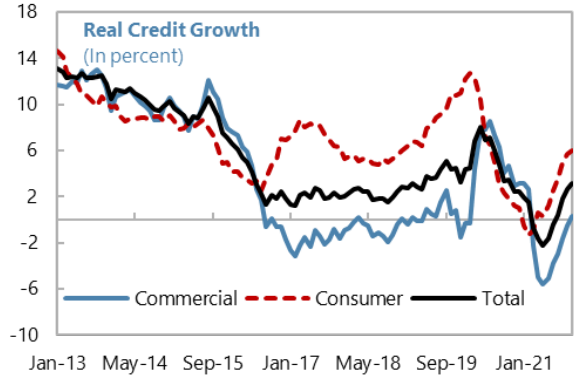
13. The pandemic led to Colombia's first recession in over 20 years, and the largest on record. GDP fell about 7 percent in 2020 in response to lockdowns and spillovers from lower oil prices and the collapse of global growth. The severe downturn and the need to respond to the

pandemic led to a substantial widening of the budget deficit, and the fiscal rule was suspended. The contraction triggered job losses, with unemployment reaching record levels and labor force participation dropping. As restrictions were eased in Q3 2020, activity started to recover, led by manufacturing, retail trade, and public services, but with continued service sector weakness. Economic growth bounced back stronger than expected at about 10.6 percent in 2021.

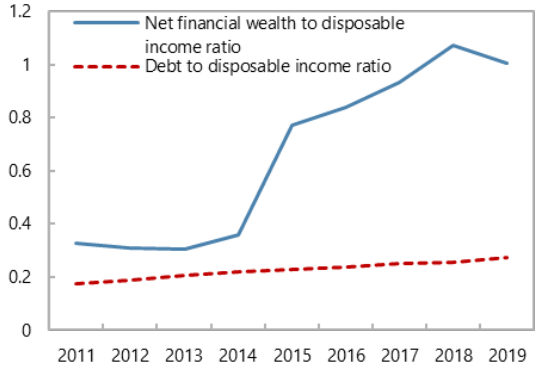
14. Before the pandemic hit, credit had recovered in line with the economic cycle after the 2014–16 oil price shock (Figure 1.a). Increased competition in the banking sector had reduced costs and boosted consumer credit growth (Figure 2). Overall mortgage loan growth was more modest and concentrated in the subsidized housing loan segment, which increased from 24.1 percent of total mortgages at end-2019 to 26.2 percent at end-2020. Consumption (especially unsecured) and microcredit loan growth were hit hard in H1 2020 but started to recover in Q3. During 2021, high-value mortgage was the most dynamic segment and, thus, total mortgage loans surpassed their growth rates observed in the pre-pandemic period. Credit procyclicality also prevailed in commercial credit, ending the year with 3.6 percent in real growth.[1] Foreign exchange (FX) lending by banks is low, and the rise in corporate FX debt relative to GDP in recent years is due mostly to the peso's depreciation following the oil price shock during 2014–16. Rising only gradually, and at about 25 percent of GDP at end-2020, household indebtedness is relatively low (Figure 1.b).[2] Leverage of large corporates increased significantly after 2013, mostly due to the aforementioned depreciation. FX-denominated debt is about 35 percent of the private sector corporate debt. This relatively high level of corporate FX debt makes corporates vulnerable to a potential tightening of global financial conditions and exchange rate risks.

Figure 1. Colombia: Credit Growth and Household Indebtedness

a. Real Credit Growth
(in percent)



b. Household Financial Wealth and Indebtedness
(ratios)



Sources: Superfinanciera; IMF staff calculations.

[1] During the initial stage of the pandemic, commercial credit accelerated sharply as corporates and SMEs increased demand for credit in order to increase liquidity positions amid elevated levels of uncertainty and shutdowns.

[2] There may be shortcomings in the data for household indebtedness as elaborated in the FSAP Technical Note on Macroprudential Policy Framework and Tools. Currently, collected data does not allow for a precise calculation and for a detailed analysis of the total household debt to income and total debt-service-to-income ratios of households.

15. The authorities mounted a strong response to help banks deal with the crisis and avoid a tightening of credit supply. The SFC allowed the release of countercyclical provisions built up in the past.[3] Banks were allowed to provide temporary grace periods, extensions, and other loan modifications on a case-by-case basis, without affecting the debtor's credit rating or leading to a reclassification of the loan as nonperforming, but provisioning rules were not relaxed.[4] The SFC launched PAD to support viable borrowers, which was phased out at end-August 2021. It triaged borrowers according to the degree to which they had been affected by the crisis, with higher provisioning for those debtors who were severely affected by the pandemic.[5] The uptake of relief initiatives in the first phase of the crisis was one of the highest in Latin America, with above 40 percent of all gross loans benefiting from payment deferrals at their peak. While this uptake dropped to about 10 percent in the second phase under a more targeted program, overall NPLs picked up, reaching 5.6 percent by end-2020, and the banks increased provisions. The transition of loans under PAD to the ordinary regulation is expected to be relatively smooth, as by the end of the PAD, loans under this program represented 6.8 percent of total gross loans (Col$37 billion associated with 2.2 million debtors).[6]

B. Financial System

16. Financial conglomerates lie at the core of an interconnected financial system. Domestically, conglomerates own assets of both financial and nonfinancial entities, with the five largest conglomerates controlling 80 percent of banking sector assets (Figure 4). Banks lie at the core of the financial network, providing the main source of financing for households and nonfinancial corporations, while figuring prominently as an asset in the balance sheets of investment funds, insurers, securities firms, and trusts (Figures 5 and 6). Asset concentration in bank securities is due in part to the limited development of domestic capital markets (with market capitalization of about 40 percent of GDP), which restricts domestic investment alternatives beyond government and bank securities for institutional investors.

17. The growing size and complexity of financial conglomerates have come with increasing cross-border exposures in the system. Colombian conglomerates are now present in 14 countries in business lines, including banking, insurance, and asset management services, and have become systemic players in selected Central American markets (Figure 7). Entities abroad increased in number from 46 to 288 from 2009 to 2020, with corresponding exposures rising over eight-fold from US$11 billion to US$93 billion during that period, and have more than doubled since the last FSAP. About 83 percent of these assets are held in Central American countries and,

[3] As of December 2020, only 11 out of 42 CIs have released about 60 percent of their cumulative stock.

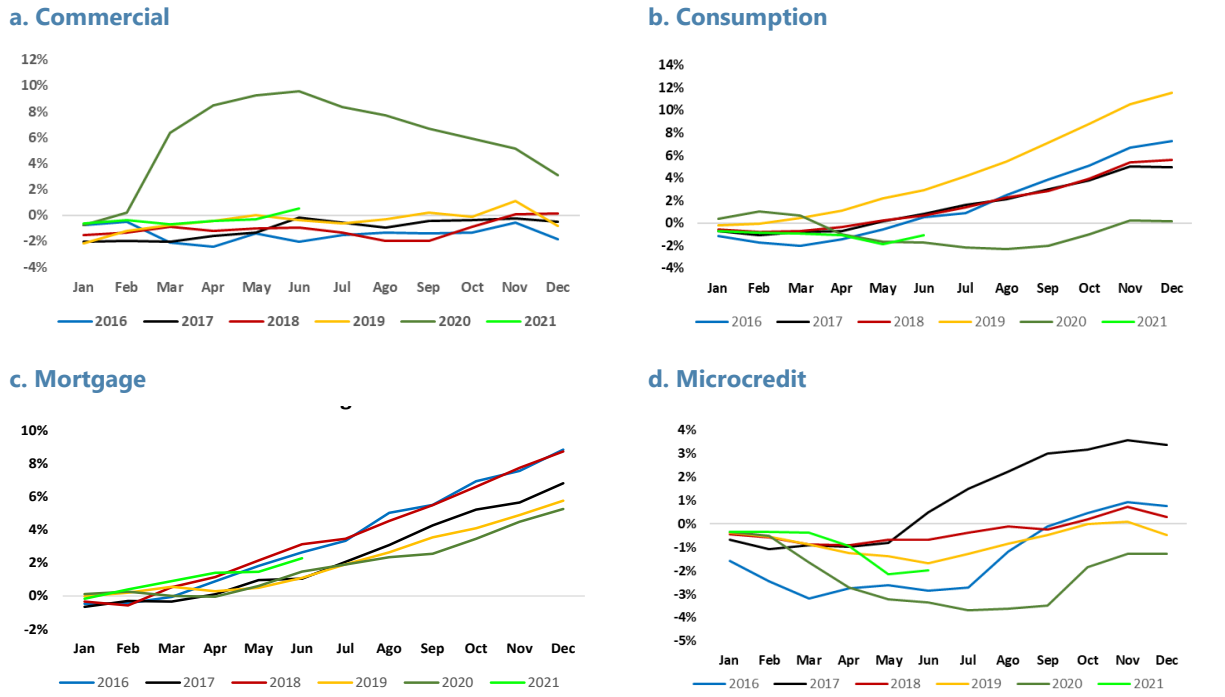
[4] The first wave of measures (mainly grace periods) was targeted at performing loans and loans that were less than 60 days past due.

[5] Two additional regulatory provisions were introduced to account for: (i) accrued but not collected interest from grace periods granted during the first wave of measures; and (ii) the expected losses that may arise from a further deterioration in economic outlook, resembling the IFRS9 forward-looking estimates.

[6] Data as of November 2021 suggests that nearly 0.4 percent of gross loans are still covered by the first wave of measures (EC 007 and 014 of 2020), while the PAD program accounts for 5.3 percent of the total gross loans.

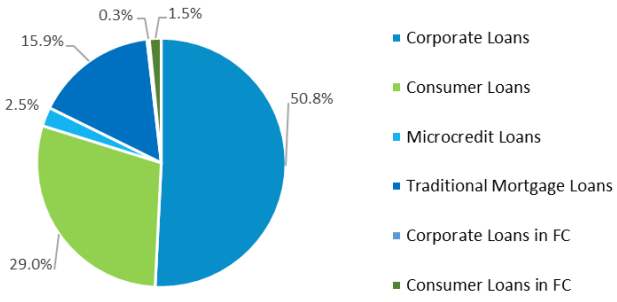
although system-wide geographical concentrations of loans and deposits are moderate, specific entities can be highly exposed to specific countries, such as Panama, Costa Rica, El Salvador, and Guatemala. These concentrated exposures—along with investments in foreign jurisdictions comprising over one-fifth of total banking sector assets—present an important source of cross-border contagion risk, which calls for the intensified monitoring of cross-border vulnerabilities.

Figure 2. Colombia: Real Credit Growth
(Year to date)



Superfinanciera; IMF staff calculations.

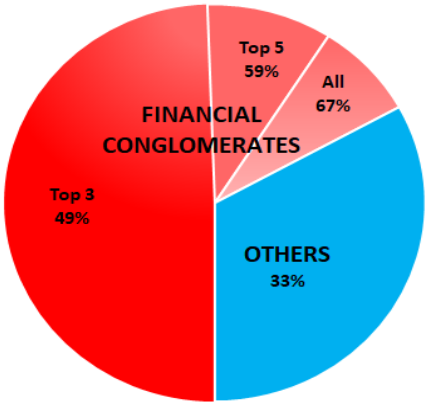
Figure 3. Colombia: Banking Sector Gross Loans by Type
(June 2021)



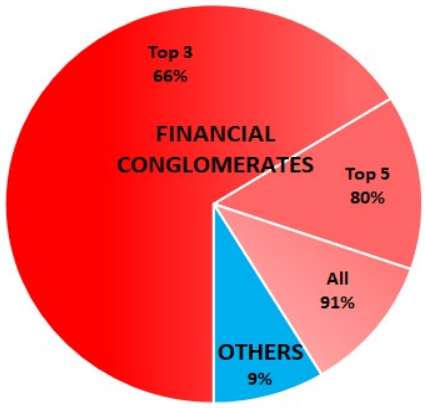
Sources: Superfinanciera; IMF staff calculations.

Figure 4. Colombia: Financial Conglomerates

a. Conglomerate Shares in the Financial System



b. Conglomerate Shares in the Banking Sector



Sources: SFC and IMF staff calculations.

18. The financial system was impacted by the Covid-related economic contraction in 2020, but so far it appears to be resilient. Banking sector soundness indicators already show improvement toward pre-pandemic levels as of June 2021 (Table 11 and Figure 8). Banks entered 2021 with markedly higher capital ratios compared to pre-pandemic levels, due to convergence with Basel III and strengthening of regulatory capital through subordinated debt and retained earnings.[7] In fact, as of August 2021, all but two smaller banks have total capital ratios higher than pre-COVID-19. Bank profitability also bounced back from the previous downturn; thus, banks entered the pandemic with relatively strong buffers.

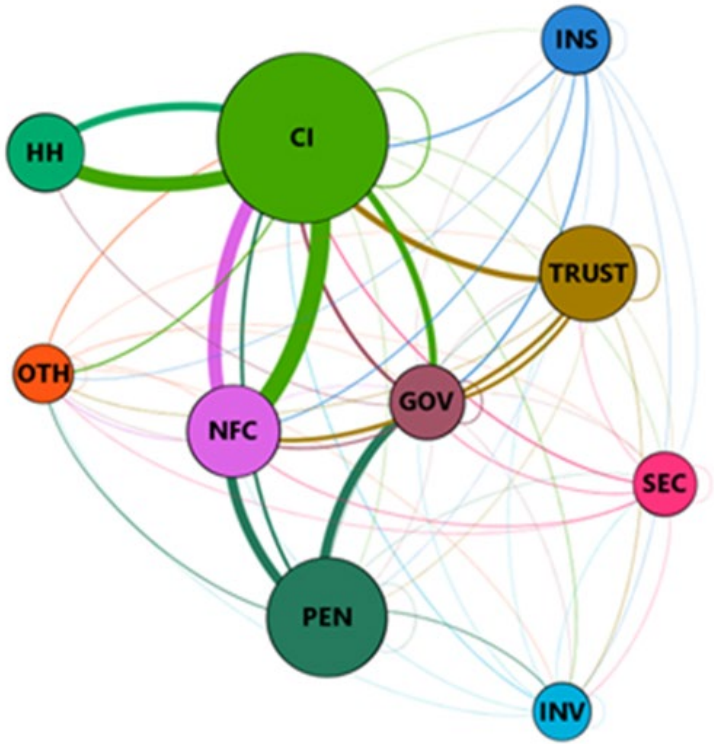
19. The main vulnerability to banks stems from credit risk. Just prior to the pandemic, Colombian banks had almost recovered, both in terms of profitability and asset quality, from the 2014–16 downturn, which mainly impacted the commercial portfolio, coupled with an acceleration of credit growth, particularly in consumer lines. After initially declining, partly due to debtor support and regulatory relief programs, NPLs peaked later in 2020 but started declining again in 2021.[8] However, if growth slows down again—for example, because of a prolonged pandemic—borrowers could come under built-up pressure resulting in larger-than-expected risk revelation, especially for consumer portfolios and sectors that are most affected by the pandemic. Furthermore, although banks have maintained healthy net interest margins so far, they could be compressed if global financial tightening risks were to materialize.

[7] Banks benefited from the inclusion of new items in the CET1 and lower risk-weighted assets. All banks follow the standardized approach for risk weights, which resulted in smaller RWA under Basel III for most banks. Also, the significant increase in provisions for credit losses and additional provisions resulted in reduced RWA for credit risk.

[8] The decline in NPLs can also be attributed to the increasing trends in write-offs (16.2 percent year-on-year increase in June 2021) and loan collection.

Figure 5. Colombia: Interconnectedness of the Colombian Financial System

a. Network Map of Cross-sectoral Interlinkages



b. Heatmap (COP trillions)

CREDITOR \ DEBTOR	Credit institutions	Government	Households	NFCs	Insurers	Pension funds	Investment funds	Securities firms	Trusts	Others	Total
Credit institutions	22.0	114.4	232.1	311.0	0.2	1.9	5.1	0.9	3.1	23.6	714.2
Government	56.8	17.2	8.3	27.3	0.0	0.0	0.2	0.1	0.3	0.9	111.0
Households	135.3					331.1					466.4
NFCs	644.2	1.7								5.3	651.2
Insurers	22.7	25.4		15.8	0.1	0.1	1.7	0.0	1.8	3.8	71.4
Pension funds	50.7	156.3		155.3		0.2	12.3	0.0	4.0	15.6	394.4
Investment funds	5.3	0.4		0.2			0.1	0.0	0.0	0.1	6.1
Securities firms	17.7	8.9		8.4	0.0		2.0	0.4	3.6	3.0	44.0
Trusts	99.1	55.7		62.4	0.0	1.1	5.5	0.1	15.9	5.9	245.7
Others	12.2	0.3		1.0			0.3	0.0	0.0	0.7	14.5
Total	**1,065.9**	**380.2**	**240.3**	**581.3**	**0.3**	**334.3**	**27.3**	**1.6**	**28.8**	**58.8**	**2,718.9**

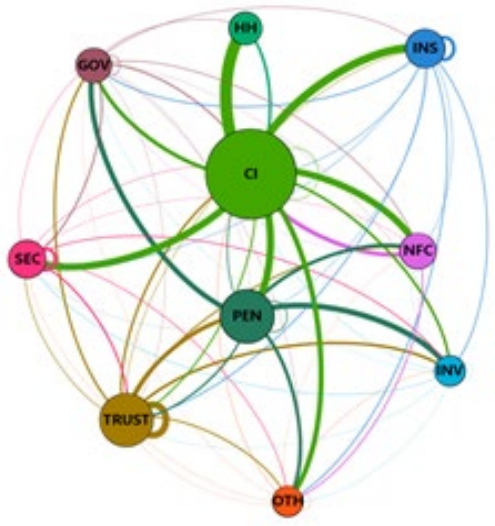
Sources: SFC and IMF staff calculations.

Legend: CI: Credit institutions; HH: Households; NFC: Nonfinancial corporates; INS: Insurance firms; PEN: Pension funds; INV: Investment funds; GOV: Government; TRUST: Trust companies; SEC: Securities firms; OTH: Others.

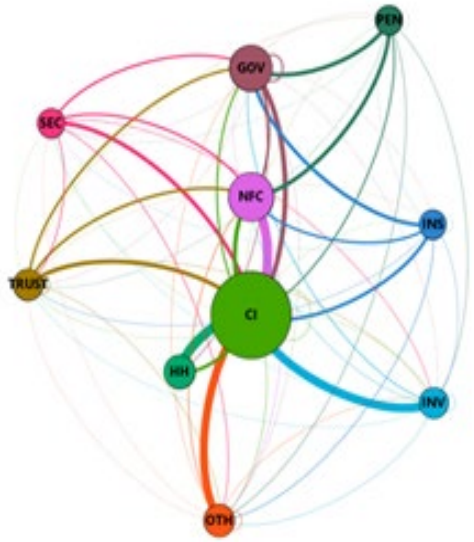
Notes: December 2020 data. Edges in network map indicate exposures between sectors (including short-term debt, long-term debt, equities, and derivatives), with their color corresponding to the creditor's color. Thickness of edges indicates total exposure size and bubble-size indicate total sector assets. Trusts and securities firms include assets from on their own positions and those under management.

Figure 6. Colombia: Sectoral Importance of Asset and Liability Exposures

a. Concentration of Funding Sources (debtor perspective)



b. Concentration of Asset Exposures (creditor perspective)



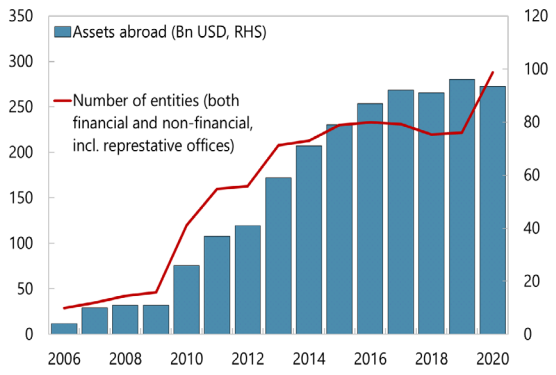
Sources: SFC and IMF staff calculations.

Legend: CI: Credit institutions; HH: Households; NFC: Nonfinancial corporates; INS: Insurance firms; PEN: Pension funds; INV: Investment funds; GOV: Government; TRUST: Trust companies; SEC: Securities firms; OTH: Others.

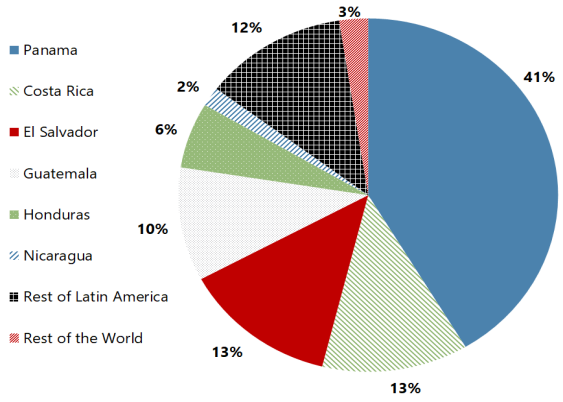
Notes: December 2020 data. Edges in network map indicate exposures between sectors (including short-term debt, long-term debt, equities, and derivatives), with their color corresponding to the creditor's color. For Figure 6a, thickness of edges indicates total exposure size relative to liabilities of debtor, and bubble-size indicate weighted out-degree measure of the node in the network. The larger the size, the more important is the sector as a source of funding for other sectors in the system. For Figure 6b, thickness of edges indicates total exposure size relative to total assets of creditor, and bubble-size indicates weighted in-degree measure of the node in the network. The larger the size, the more important is the sector as an asset issuer for other sectors in the system.

Figure 7. Colombia: Conglomerates' Cross-Border Exposures

a. Evolution of Conglomerates' Foreign Exposures
(foreign exposures of conglomerates)



b. Conglomerates' Foreign Exposures by Geography
(share of subsidiaries' total assets, unconsolidated)



Sources: Superfinanciera; IMF staff calculations.

20. Almost 80 percent of funding comes from wholesale (nonfinancial corporates and financial institutions) sources with the unsecured portion accounting for the vast majority (Figure 16.e). The latter consists of demand deposits (41 percent), term deposits (17 percent), bonds (9 percent), and bank credits and other financial obligations (8 percent). Retail demand and term deposits comprise about 16 percent and 7 percent of total funding. The national liquidity indices, the NSFR[9] and—even more so—the Liquidity Coverage Index (IRL, for its initials in Spanish) increased during 2020, mainly due to higher banks' holdings of liquid assets, with IRL stabilizing around the pre-pandemic level in the middle of 2021 (Figure 9).

21. The impact of COVID-19 on nonbank financial institutions (NBFIs) has been mixed. Most notably, collective investment funds (CIFs) faced significant investor withdrawals of Col$24.6 trillion during March 2020, resulting in 32 percent decline in total assets. The fire sale pressure on CIFs was subsequently alleviated by extraordinary liquidity facilities provided by the central bank. This led to an increase in retail deposits at banks and CIFs' AUM returned to pre-pandemic levels by end-2020.

C. Scope

22. The forward-looking risk assessment for Colombia has four components: (i) solvency; (ii) liquidity risk analysis for the banking system; (iii) domestic and cross-border inter-connectedness and contagion analysis for the financial system, and (partly) other sectors of the economy; and (iv) corporate stress test (Figure 10).

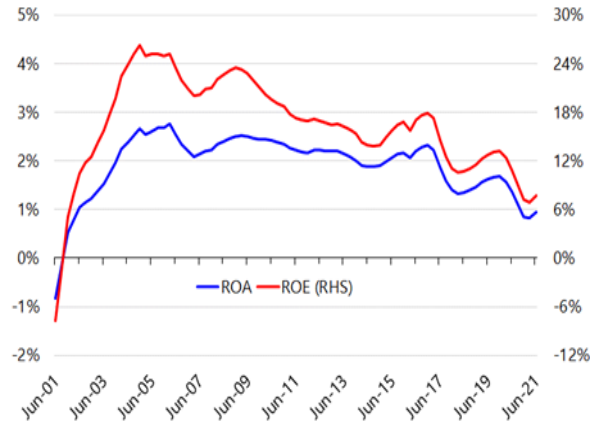
SOLVENCY STRESS TEST

23. The solvency stress test comprises a top-down assessment of whether banks have sufficient capital to withstand a range of economic and financial shocks. The team used the IMF's internally developed technical assessment tools to assess the effects of the shocks on individual bank profitability and capitalization. These tools include a core balance sheet and capital engine used to generate forward-looking projection of profit and loss (P&L) and balance sheet items under specific macroeconomic scenarios, and a set of satellite models for the projection of scenario-dependent paths for banks' parameters, focusing mainly on credit risk, market risk, and interest rate risk. In addition, a sensitivity test assessed banking system vulnerabilities to individual shocks as part of a concentration risk analysis.

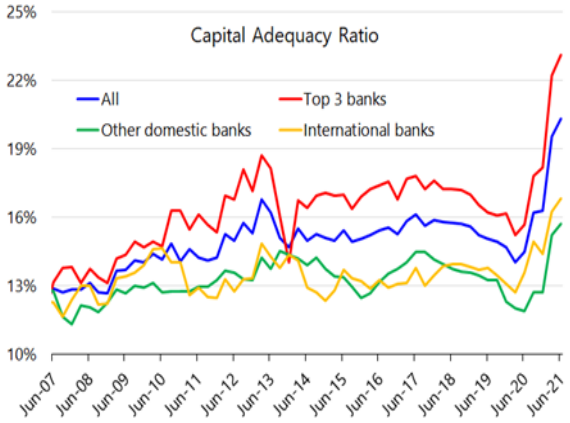
[9] CFEN stands for an acronym of this longer-term liquidity indicator in Spanish.

Figure 8. Colombia: Selected Banking Indicators

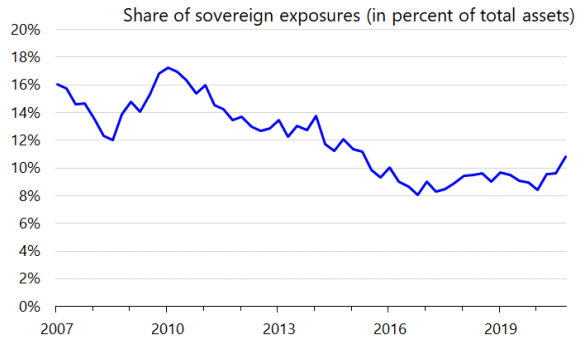
a. Profitability



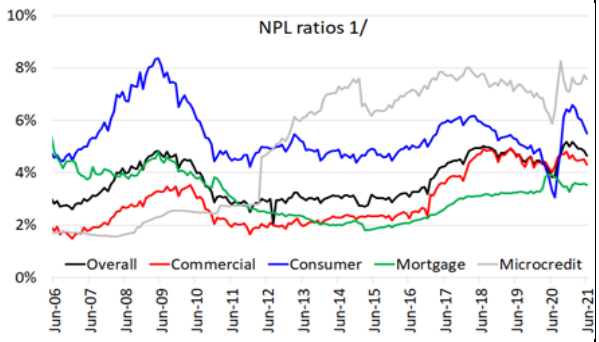
b. Solvency



c. Sovereign Exposures



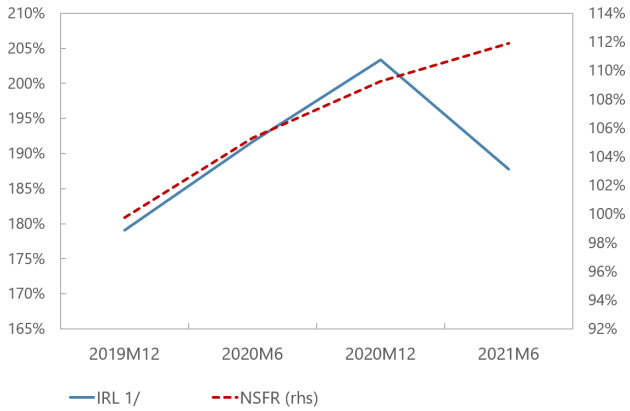
d. Credit Quality



Source: SFC; IMF staff calculations.
1/ NPL ratios for consumer, commercial, and microcredit segments reflect 30 days or more past due and for mortgages 120 days or more past due.

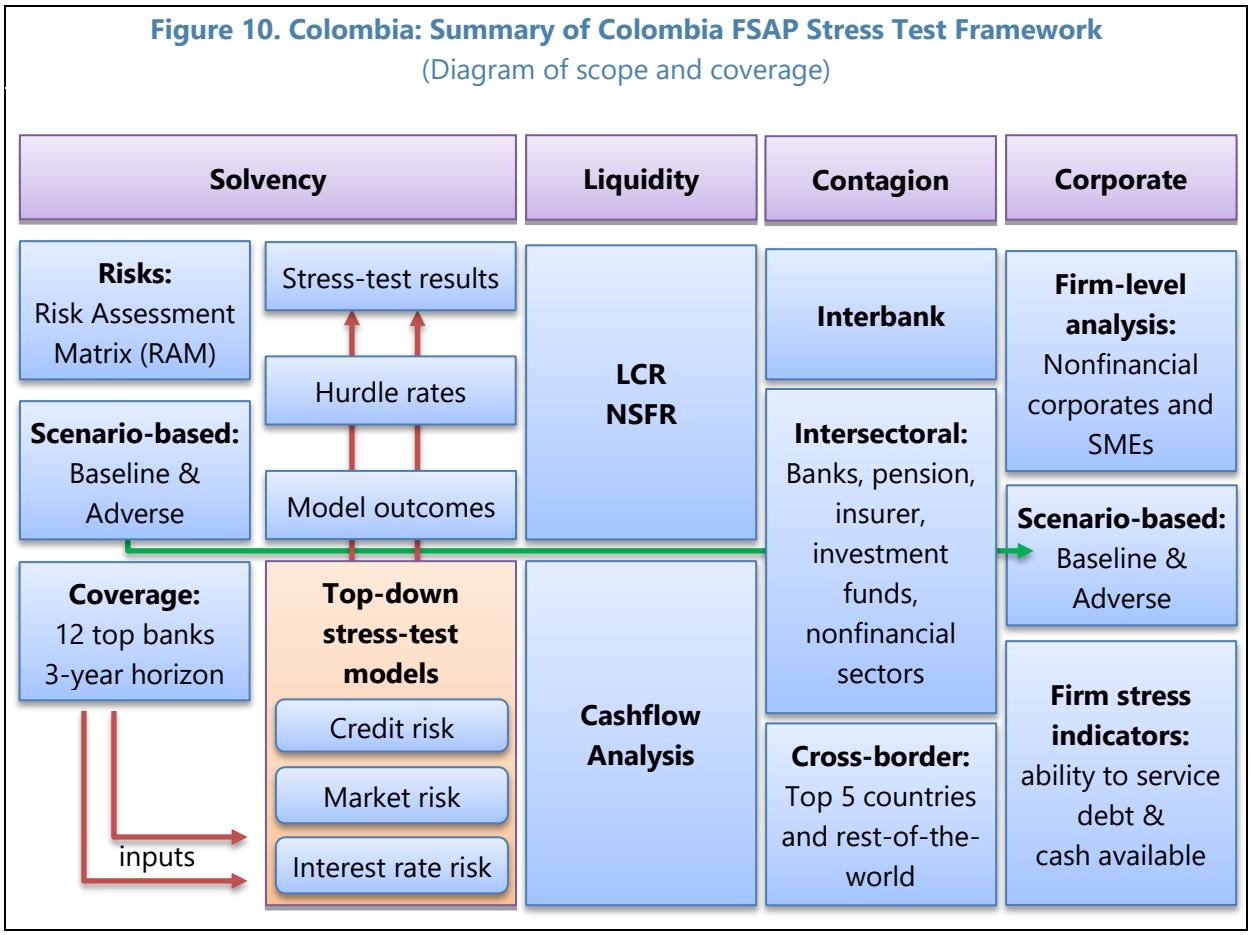
Figure 9. Colombia: Banking Liquidity Indices

(top 12 banks)



Source: SFC; IMF staff calculations.
1/ IRL is a national implementation of BASEL III Liquidity Coverage Ratio focusing on the short-term liquidity risks.

Figure 10. Colombia: Summary of Colombia FSAP Stress Test Framework
(Diagram of scope and coverage)



24. The exercise focuses on 12 banks, covering 93.8 percent of banking sector assets. The sample includes all four (DSIBs), five non-systemic domestically owned banks, and three non-systemic foreign-owned banks.[10] The exercise was conducted on a solo-reporting basis, as the FSAP team had limited data to enable modeling consolidated risks with respect to banking subsidiaries abroad. To account for the relevant cross-border exposures and risks, two complementary approaches are used. For the solvency exercise, the potential stress on exposures abroad is incorporated via a shock factor on gains/losses from associated entities on the income statement. Furthermore, the interconnectedness and contagion analysis maps the intra-group exposures within financial conglomerates and assesses the magnitude and path of contagion through these linkages.

25. The stress test is based on the applicable international and national frameworks. It was conducted mainly with reference to the national implementation of the Basel III framework. Basel III standards came into force in Colombia in January 1, 2021. Specifically, (i) definitions of capital (Common Equity Tier 1 (CET1), Tier 1 and total capital) were aligned with Basel III; (ii) credit risk weights were aligned with the latest standardized approach; and (iii) leverage ratio with a minimum of 3 percent was incorporated. All banks had to comply with these as of January 2021. The remaining items under transitional arrangements relate to (iv) the internal loss indicator for the

[10] One D-SIB is foreign-owned.

calculation of operational risk; (v) phasing in the capital conservation and systemically important bank buffers; and (vi) phasing in the Tier 1 ratio. There is no applicable countercyclical capital buffer in Colombia, as banks are required to build up countercyclical provisions instead. Regarding the risk weights, all banks use the same risk weights according to the standardized model given by the Financial Regulation Agency (URF) through a decree.

26. It should be noted that standard FSAP stress test assumptions may produce more pessimistic results relative to actual results during the stress-test horizon. To begin with, the FSAP stress test is not a forecasting exercise, even for the baseline. It does not aim at minimizing forecast errors. Rather, it targets assessing the system's resilience in tail events, with "neutral behaviors" to ensure cross-country comparability of exercises. For instance, stress test results depend on the banks' behavior—e.g., balance sheet deleveraging. If banks aggressively shrink their loan portfolio, shift to safer creditors/assets, or write-off NPLs, the resulting bank soundness indicators could improve. However, it is hard to pin down such bank behaviors adequately. Therefore, stress tests typically assume certain behaviors to neutralize any mitigating effects from bank management's actions.

A. Macrofinancial Risks and Macroeconomic Scenarios

27. The solvency risk analysis is based on the assessment of current conditions, characterized by continuing pandemic-related risks and other external and domestic risks exacerbated by the impact of the pandemic. Risks to the ongoing recovery include: (i) uncontrolled COVID-19 local outbreaks and global resurgence of the pandemic; (ii) de-anchoring of U.S. inflation expectations and rise in global risk premia; (iii) disorderly structural transformations triggered by COVID-19; and (iv) increasing fiscal pressures. These risks can individually or collectively lead to a downturn in economic activity, higher risk premia and financing difficulties for leveraged firms and banks, capital outflows, depreciation and inflation pressures, higher cost for sovereign financing, and a sharp fall in asset prices.

28. The stress testing exercise was based on full-fledged macroeconomic scenarios comprising a baseline and a severe adverse scenario. The scenarios stretch over a three-year horizon from mid-2021 to mid-2024.

- The **baseline** scenario is aligned with the October 2021 World Economic Outlook (WEO) projections for a set macrofinancial variables for Colombia. The baseline projections reflect a strong 2021 rebound from the largest recession on record followed by a more gradual recovery. This recovery is accompanied by declining unemployment through 2022, and inflation remaining within target as the policy rate is steadily raised.

- The **adverse scenario** features protracted recession forming a U-shaped GDP level profile. This scenario incorporates key macrofinancial risks from both global and Colombia-specific factors identified by the Risk Assessment Matrix (Appendix 1). Averaging 0.5 percent real GDP growth over three years, it is characterized by contraction continuing into the second year before phasing into near-full recovery, with GDP growth at -1.2 percent, -1.3 percent, and 4 percent in

the first, second, and third years of the horizon, respectively (see Appendix III. Figure 1.a). The projections under the adverse scenario are also expressed in terms of deviations from the baseline. The cumulative GDP decline under adverse over three (two) years is equivalent to a 1.8 (2.5) standard deviation shock (see Appendix III. Figure 1.b). This scenario reflects the realization of shocks that are very severe in relation to the baseline scenario. Other key variables show significant deterioration with a drop in housing prices by 21 percent, a depreciation in the exchange rate by about 25 percent, a rise in long-term sovereign yields by 190 basis points, and interbank spread widening by 125 basis points (see Figure 11 and Table 15 in Appendix III for full set of projections).[11]

29. In Colombia, the main transmission channels of the external shocks would go through external demand, capital flows, and sovereign distress. A global resurgence of the pandemic can disrupt economic activity and depress growth prospects globally. A weak external demand, including for oil, would have an adverse effect on domestic confidence, public finances, and growth prospects for Colombia. In parallel, signals of policy tightening by the U.S. Fed can result in repositioning by market participants and, thus, tightening of financial conditions and higher risk premia for credit and equities, as well as the Colombian peso. Increased reliance on external financing makes Colombia especially vulnerable to additional financial tightening, as these conditions could trigger capital outflows, depreciations, and sovereign distress. The persistent decline in economic confidence would hit housing prices. Moreover, the stress in global and domestic funding markets would affect corporates, with rising interest rates and reduced income negatively hurting banks' asset quality and profitability. The financial cycle downturn would add to the pressures on housing prices due to increases in mortgage rates and a drop in income growth. A negative consumer confidence transmission channel would then operate, as the decline in property prices in turn triggers adverse wealth-effects, creating a negative feedback loop with domestic demand and a deflationary process.

30. The adverse scenario incorporates Colombia-specific shocks, assuming further weakening of the fiscal outlook related to political uncertainty and a weakening debt profile. This can lead to further downgrades and trigger a sell-off event by foreign investors.[12] Stress in public finances would have an impact on sovereign exposures of financial entities, given the strong home bias. In the meantime, heightening of political and social tensions imply the risk of capital flights and have the potential to slow down economic activity and delay reforms. With the expiration of regulatory measures and prolonged period of unfavorable economic conditions, borrowers' repayment capacity may not be fully restored, resulting in a larger-than-expected share of NPLs, as well as a wave of bankruptcies due to deep scarring of firms' balance sheets and labor markets. The spillovers from the region would exacerbate the financial conditions, as Colombian financial conglomerates have significant exposures to several Central American countries facing similar risks

[11] See Appendix III for detailed description of the macro scenario and the relevant assumptions and calibrations.

[12] In the first half of 2021, Colombia was downgraded to below investment grade by two rating agencies, given weaker-than-expected fiscal adjustment and a weaker outlook for public debt, with an increase in long-term bonds by about 160 basis points during this period, part of which could be attributed to the increase in U.S. long-term yields early in 2021.

at the current juncture. With profits sliding and risks materializing, the affected banks, which collectively account for a high share of Colombia's banking system, would face additional stress from cross-border exposures, exacerbating an already precarious situation domestically under the adverse scenario.

B. Stress Test Methodology

Balance Sheet, Income Projections, and Hurdle Rates

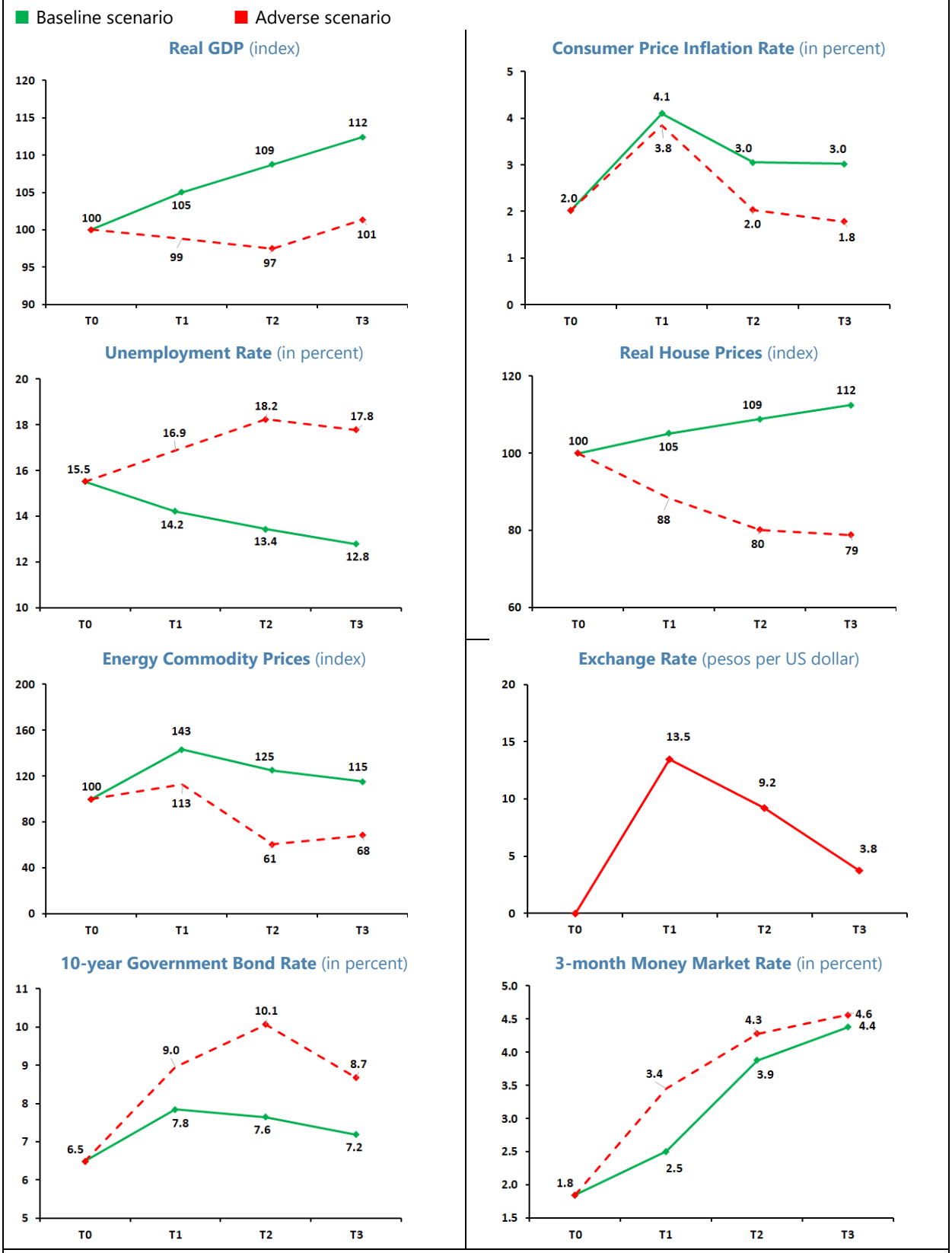
31. The balance sheet projection followed the "quasi-static" approach. The approach, typical for FSAP stress testing, assumes that the balance sheet grows proportionally with nominal GDP under baseline and adverse scenarios; however, with a lower bound of zero. Therefore, in the first two years of the adverse scenario with nominal GDP contraction, the size of a bank's balance sheets remains constant. While the balance sheets can grow in line with nominal GDP, the structure and composition of assets and liabilities are assumed to remain unchanged ex ante before stress factors are applied. However, an ex-post adjustment is made to overnight retail deposits to cover the funding gap.

32. The projection of RWAs accounted for balance sheet growth, impairments, and changes in exchange rates and triggered credit lines. RWAs adjust due to the balance sheet growth, accounting for new provisions for credit losses and exchange rate movements for foreign currency exposures, and a triggered portion of undisbursed credit lines (off-balance sheet). Furthermore, RWAs for operational risks increase by 5 percent per year in the first two years of the adverse scenario.

33. Income (profit or loss) was projected using all the risk factors in the stress test. Most of the noninterest income items were projected in line with the growth of each bank's balance sheet. This included the projection of net fee and commission income, other noninterest income, and noninterest expenses. Extraordinary income and losses were assumed not to incur during the projection period. The income tax was reflected in the profit/loss calculations, calibrated as the median of historical tax expense ratios per bank (with a sample average of 20 percent).

34. Distribution of income was also incorporated per the following dividend policy. After-tax income was assumed to be distributed only if the bank's net income was positive. The baseline scenario applied the historical averages of dividend payout ratios per bank, excluding years with greater than 100 percent in the calculation, resulting with a sample average of about 48 percent. The adverse scenario used the historical non-zero minimum ratios during the first two years (with a sample average of about 37 percent) reverting to the baseline assumption in year 3.

Figure 11. Colombia: FSAP Macro Projections



Source: World Economic Outlook; IMF staff calculations.

35. Banks' indirect exposures through subsidiaries were also taken into account. As the FSAP team did not have access to data that would allow for conducting a solvency stress test on a fully consolidated basis, the exercise covered banks on a solo basis while capturing shocks on the income of their subsidiaries through gains/losses from associated entities.[13] This P&L item was shocked by 50 percent and 25 percent in the first and second years, respectively, of the adverse scenario.

36. The stress test hurdle rates were based on minimum capital requirements applicable to banks in Colombia. The stress test results were benchmarked against the current capital adequacy framework accounting for the phase-in of several components during the projection period (Table 3). Accordingly, a total capital adequacy ratio (CAR) of 9 percent applies, which includes an additional 1 percent above what is required by Basel III. A minimum of 4.5 percent CET1 is required, which has been in effect since 2013. As for the Tier 1 (T1) ratio, the hurdle rate is currently 4.9 percent and is gradually increased to 6 percent by January 2024 according to the phase-in schedule during the transition period. Given that the additional T1 component is a small fraction or non-existent for many of the banks, a higher minimum requirement for T1 is a more binding constraint. Also, a minimum leverage ratio (Tier 1 capital to total assets) of 3 percent applies throughout. The capital conservation buffer (CCoB) and the DSIB buffer would be phased in gradually to reach 1.5 percent and 1 percent of RWAs by January 2024. The capital projection path also incorporates the gradual phase-out of eligible capital instruments from additional Tier 2, which has the identical impact under both the baseline and the adverse scenarios.

Credit Risk

37. Credit risk in the loan book is the most important risk for the banking system. This is a direct consequence of the high share (69 percent) of credit exposures in total banking assets (see Figure 12.a). In terms of composition, the vast majority of these exposures are domestic and, therefore, credit risk is modeled at a single geography level. Of the credit exposures, commercial (54 percent), consumer (29 percent), and mortgage (15 percent) portfolios collectively account for 98 percent of bank lending. The credit risk satellite models focus on these portfolios given their materiality.

38. The stress test made use of satellite models to estimate the credit losses in the banking system. Given that all banks fall under the standardized regulatory framework and the availability of long time-series data by bank on a quarterly basis go back to 2002, NPL ratios were modeled for each portfolio segment. They were estimated based on a Bayesian Model Averaging (BMA)

[13] Currently, both the BR and the SFC perform stress tests on an individual bank basis but conduct different tests to analyze Colombian banks' foreign exposures. The SFC has access to a variety of information, most of which is reported by supervised entities through standard templates, while access to more specific information can be handled (e.g., through Supervisory Colleges, etc.) based on the criteria established in the Memoranda of Understanding with other jurisdictions. Moreover, the SFC plans on leading a consolidated stress test exercise on financial conglomerates with banking subordinates in Central America, to be developed in coordination with the host supervisors.

methodology subject to sign constraints on the long-run multipliers.[14] The approach adopts panel fixed effect regression and operates on a pool of equations per dependent variable. The NPL models were used to derive projections of NPLs conditional on the macrofinancial variables under the baseline and adverse scenarios. The models, as well as the methodology, are explained in greater detail in Appendix IV.

Table 3. Colombia: FSAP Solvency Stress Test Hurdle Rates and Current Capital Ratios

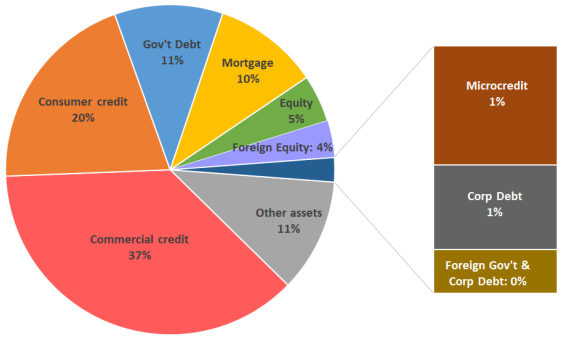
Criteria	Stress test hurdle rate (minimum requirement in percent)				Actual ratio before stress (June 2021)				
	2021 (T0)	2022 (T1)	2023 (T2)	2024 (T3)	12 banks (FSAP sample)	(by systemicity) *DSIBs*	*Non-DSIBs*	(by ownership) *Domestic*	*Foreign*
Total CAR ratio	9.0	9.0	9.0	9.0	20.2	21.8	16.2	21.3	16.2
Tier 1 capital ratio	4.9	5.3	5.6	6.0	15.1	16.4	11.9	16.4	10.2
CET1 capital ratio	4.5	4.5	4.5	4.5	14.7	15.9	11.9	16.0	10.2
Leverage ratio	3.0	3.0	3.0	3.0	10.5	12.2	7.2	11.8	6.4
CCoB	0.4	0.8	1.1	1.5	-	-	-	-	-
Systemic risk buffer	0.3	0.5	0.8	1.0	-	-	-	-	-

Sources: Superfinanciera; IMF staff calculations.

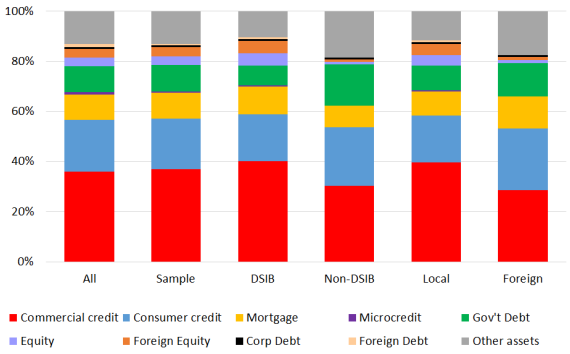
Note: Total CAR, Tier 1 and Common Equity Tier 1 (CET1) ratios are expressed in percent of RWAs. Leverage ratio is calculated as Tier 1 capital to total assets in percent. The applicable hurdle rates and capital buffers are based on the phase-in schedule that is in place.

Figure 12. Colombia: Bank Assets
(December 2020)

a. Sample Banks' Asset Composition
(loans and securities in percent of total assets)



b. Asset Decomposition by Bank Groups
(loans and securities in percent of total assets)



Sources: Superfinanciera; IMF staff calculations.

39. Provisioning ratios for NPLs were calculated based on the historical data for each portfolio segment. Banks in Colombia have historically had high provisioning coverage for NPLs

[14] See Gross, M. and Poblacion, J. (2017), "Implications of model uncertainty for bank stress testing," Journal of Financial Services Research, Vol. 55, pp. 31–58.

(see Figure 13.d) with both procyclical and countercyclical components. In the baseline scenario, the aggregate ratio at the cut-off date is used. To be conservative, in the adverse scenario, the ninetieth and ninety-fifth percentiles of aggregate provisioning coverage ratios are applied for each portfolio type. In order to account for the jump in provisioning coverage ratios from the cut-off date, the new provisions are calculated based on applying the year 1 (T1) provisioning coverage ratio in year 1 (T1) to the starting point data at the cut-off date (T0). To be conservative, the procyclical provisions, which would generate an additional layer of buffer, are not utilized in the exercise.

40. Expected losses in the adverse scenario are driven by all three loan portfolios (see Figure 13). The NPL ratio in the commercial portfolio rise from about 3.7 percent to 4.8 percent at the peak in response to adverse shocks, gradually improving afterwards. The starting point NPLs in the commercial segment already reflect the deterioration in this portfolio during the 2016–17 downturn. NPLs in the consumer portfolio climb from 3 percent to 5 percent at the peak, and mortgage NPLs rise significantly from 3.4 percent to a little over 10 percent at the peak. In the baseline scenario, all portfolio segments experience improvement in NPLs, in line with the macroeconomic recovery in the post-COVID period.

41. Held-to-maturity (HTM) debt securities are treated under the credit risk module, albeit, using the haircut approach to determine the loss provisions. The haircut for each asset class is linked to the shocks on the respective portfolio durations and credit spreads under the scenarios. However, this component is a very small fraction of credit loss provisions.

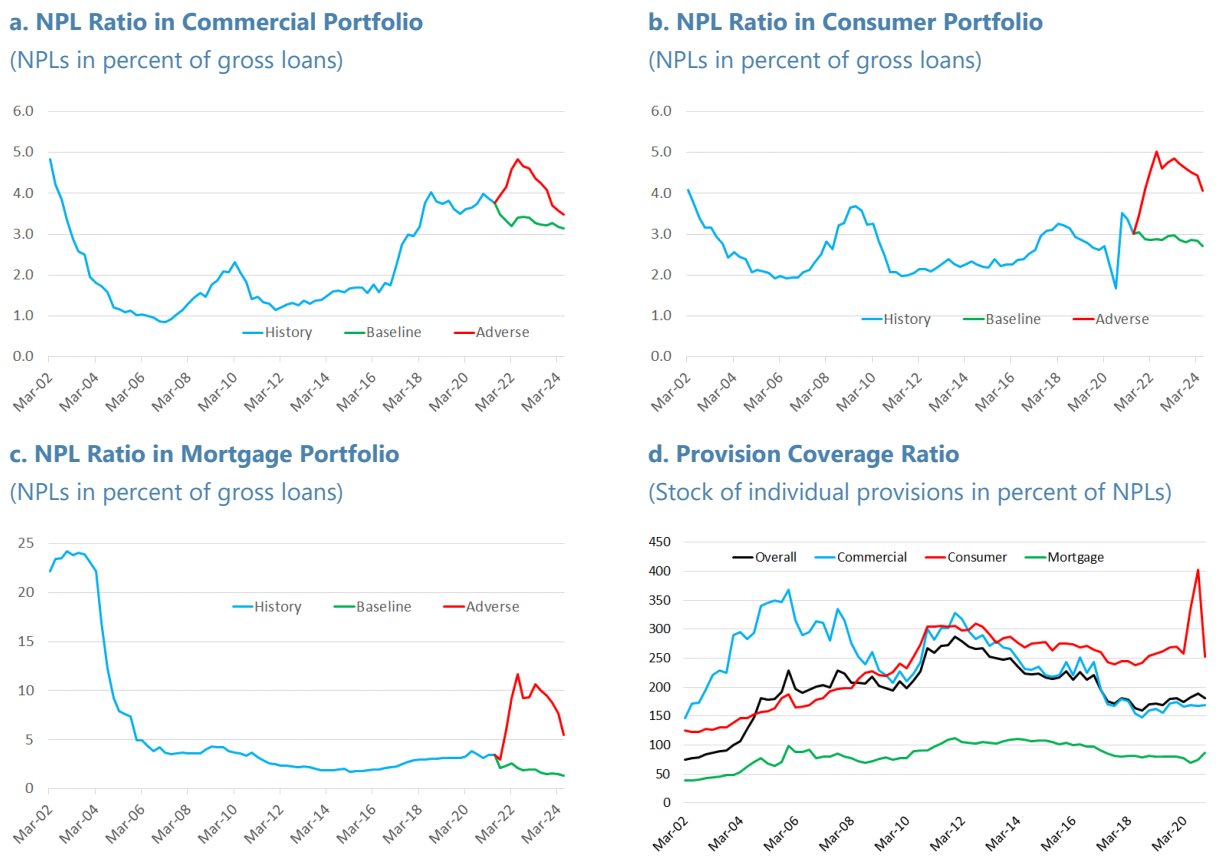
42. The rise in NPLs requires additional provisions that worsen banks' profitability in the adverse scenario. Credit losses over the first two years amount to 3 percent of total banking system assets (similar ratios for DSIBs and non-DSIBs) in the adverse scenario caused by severe macro-economic and financial conditions, recovering somewhat in year 3. In the baseline scenario, due to improvement in NPL ratios, banks register overall provision reimbursements over three years of about 0.7 percent of total banking system assets.

Market Risk

43. The stress test also assessed banks' resilience when facing different sources of market risk, making no allowance for macro hedges. In addition to credit-risk-related losses due to credit spreads, banks experience losses due to changes in market variables: risk-free interest rates, exchange rates, and equity prices.

44. The methodologies applied to exposures subject to marked-to-market valuation depend on the exposure type. For sovereign and corporate debt security exposures that are classified under available for sale (AFS) or held for trading (HFT), a modified-duration formula was used to revalue exposure as a function of their residual duration and the relevant bond yield assumptions under the scenarios. Foreign exchange risk and equity risk were estimated based on their respective net open positions and the paths of the equity index and exchange rate under the scenarios.

Figure 13. Colombia: NPL Projections and Provisioning[1]



Sources: Superfinanciera; IMF staff calculations.

Net Interest Income Analysis (Interest Rate Risk)

45. The impact of interest rate risk on net interest income was assessed using time-to-repricing buckets. The impact of funding and lending rate shocks on net interest income is estimated by measuring the gap between interest sensitive assets and liabilities, and by making use time-to-repricing buckets for different asset and liability segments.

46. Regulatory reports were used to establish the outstanding volumes by asset and liability segments at the cut-off date and the effective repricing schedule for each segment. For assets, a combination of breakdown by portfolio (commercial, consumer, mortgage, and microcredit) and rate type (fixed, money-market-linked, and deposit-linked) were used. On the liability side, a more granular breakdown was used by rates for overnight and term, retail and wholesale deposit, repos, unsecured, government, and other.

47. Effective interest rates were estimated using satellite models and pass-through assumptions. Given the availability of historical time-series data on deposit rates, satellite models

were estimated for 3 different deposit groups: less than 3 months, between 3 and 12 months, and longer than 1 year. Accordingly, the paths of deposit rates per bank was projected under baseline and adverse scenarios. For the other liability segments that could not be modeled, shocks on corporate credit spreads were used under each scenario. Shifts in the effective interest rates for loans were then calculated using assumptions on the pass-through rates, distinguishing between the baseline and adverse scenarios. The details of the funding cost satellite models and pass-through rates can be found in Appendix IV.

48. The projection of net interest income (NII) was, accordingly, based on a semi-structural approach. The impact of new business repricing was consequently calculated under the assumption that maturing instruments were replaced by identical new instruments (of the same segment and with the same initial maturity) but at reference and margin rates implied by the scenario and the pass-through assumptions. The NII projection is the result of measuring the difference in interest income and expense for each segment after accounting for the repricing impact for the new business each year, and accounting for changes in the amount of performing interest-bearing assets due to credit risk.

C. Stress Test Results

49. The FSAP team's assessment of the banking system's capacity to withstand severe shocks suggests broad resilience at the aggregate level, albeit with pockets of vulnerabilities in a few banks. High starting levels of system-wide capital and strong profit buffers allow most banks to absorb a large shock under the adverse scenario and to retain substantial buffers, with non-DSIB banks and foreign-owned banks impacted somewhat more than DSIBs, and domestically owned banks, respectively. Key findings are as follows (Table 4 and Figure 14):

- Using full Basel III regulatory requirements, the ratio of banks' Tier 1 capital relative to their total RWAs (the aggregate Tier 1 ratio) would drop from 15.1 percent to 12.8 percent with a minor improvement in year 2 to 13.0 percent before almost fully recovering in year 3. As for the total CAR, it would decline from 20.2 percent to 17.6 percent in year 1 and to 17.4 percent in year 2, before returning to 19.1 percent after year 3 recovery.

- DSIBs as a group have a much stronger absorption capacity, experiencing only about 180 basis points drop in the Tier 1 ratio compared to 360 basis points for non-DSIBs, allowing DSIBs to keep comfortable buffers in the adverse scenario, given a much higher Tier 1 ratio at the outset. Also, while the capital adequacy of DSIBs would recover by year 3, for non-DSIBS it remains at significantly lower levels, never fully recovering within the projection period. For two small banks, the Tier 1 ratio and CAR ratio, respectively, would be lower than the minimum requirements, resulting in a very small capital shortfall (0.01 percent of GDP) under the adverse scenario. For one of these banks the leverage ratio would fall below the regulatory minimum.

- In terms of contributions to the change in capital, credit impairments and interest rate risk are the key factors (see Figure 15), with a cumulative impact of -4.1 and -2.1 percentage points, respectively, by year 2. Market valuation losses on all portfolios lead to a further -0.7 percentage

points fall by year 2, followed by 0.5 percentage point drop that can be attributed to the sharp decline in profit shares from subsidiaries, which mostly impact one DSIB and two small banks.

Table 4. Colombia: Results of the Solvency Stress Test Exercise

	Tier 1 *(year 1)*	Total CAR *(year 2)*	Leverage ratio *(year 1)*	Number of banks depleting buffers 1/	Number of undercapitalized banks	Number of over-leveraged banks	Maximum capital shortfall (in % of GDP)
Before stress	15.1%	20.2%	10.5%	0	0	0	0
Baseline scenario	15.8%	20.5%	11.0%	0	0	0	0
Adverse scenario	12.8%	17.4%	9.4%	3	2	1	0.01%

Source: IMF staff calculations.

Notes: Banks's depleting buffers refer to those banks that are still above their minimum requirements but within the range when applicable capital buffers are added to the respective minimum thresholds. For DSIBs, capital buffers include both the capital conservation buffer (CCoB) and the systemic risk buffer, whereas, while only the CCoB applies to smaller banks. Both buffers are currently being phased in, and the exercise considers only the phased-in portion of respective buffers at each point in time.

D. Sensitivity Analysis

50. With respect to concentration risk, sensitivity tests show that some banks would be vulnerable to the default of their largest nonfinancial corporate exposures (Table 4). The default of the 10 largest exposures (after application of financial guarantees) would lead 5 banks to be undercapitalized by about 0.2 percent of GDP collectively with regard to the Tier 1 or CAR minimum requirements. However, without considering the financial guarantees, a very conservative assumption, the overall impact would be undercapitalization by about 0.7 percent of GDP, involving nine banks in the sample. Notably, above 40 percent of the 10 largest exposures among banks involve the same counterparty across multiple banks (up to 7 banks).

LIQUIDITY STRESS TESTS

A. Overview

51. To assess current banking system liquidity risks, top-down LCR-based and cashflow-based tests covered 95 percent of the banking system. The SFC imposes two liquidity risk requirements: the Liquidity Risk Index (IRL, for its initials in Spanish), which is based on the Basel III LCR, and the NSFR, both implemented on an individual basis and for all currencies combined.[15,16] The IRL requires the level of liquid assets to be above the net liquidity requirements for the 7- and 30-day horizons. The NSFR ratio estimates the ratio of available stable funding relative to the amount of required stable funding. The FSAP team conducted the LCR-based test in line with the regulatory framework embedded in the IRL over the period of 30 days, and the cashflow based test

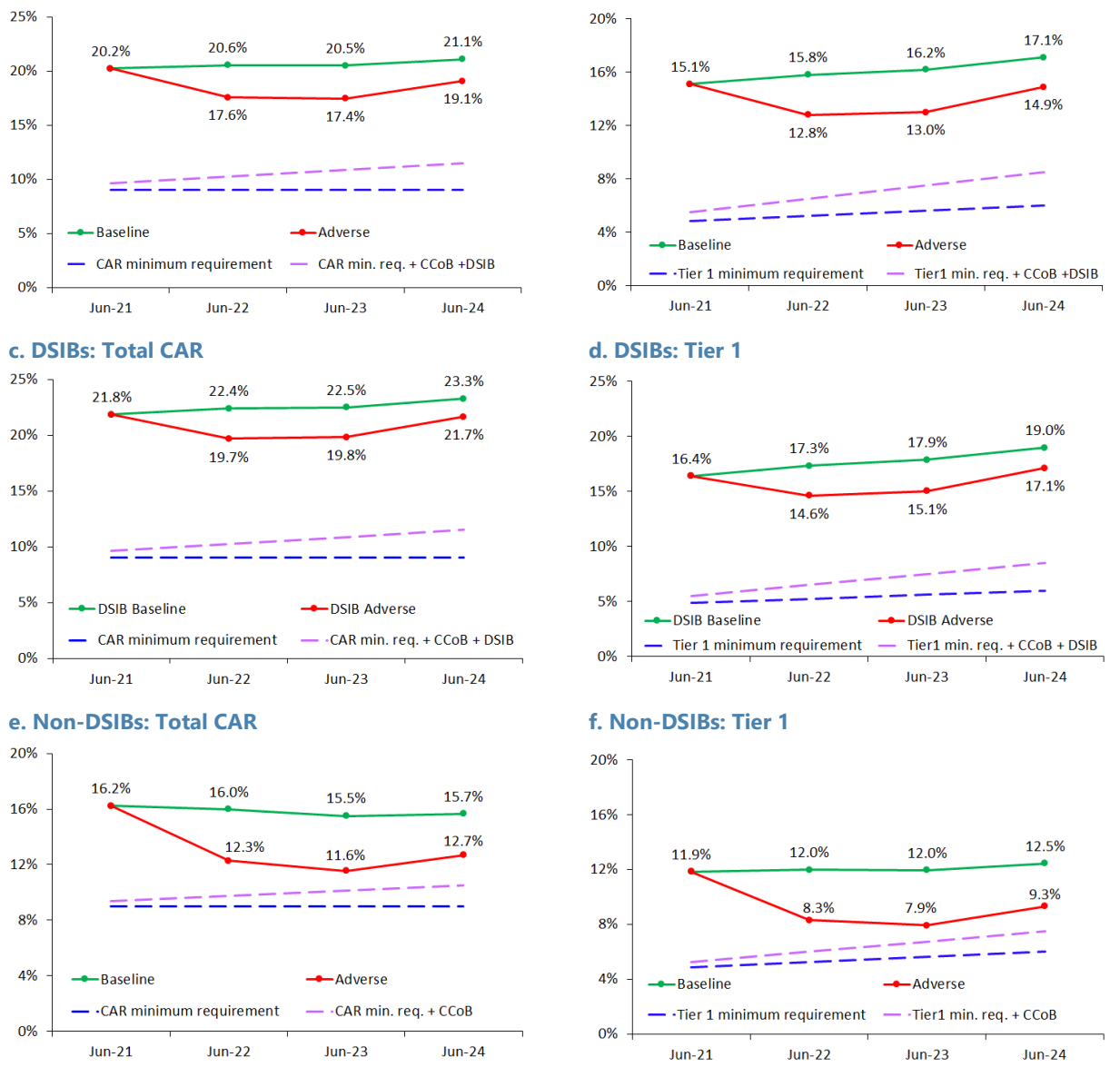
[15] In addition to the IRL, the BR imposes a liquidity metric aimed at capturing foreign exchange risk at individual and consolidated levels.

[16] See Colombia: FSAP– Basel Core Principles for Effective Banking Supervision for a detailed description of differences between Basel III standards and national implementations of the LCR and the NSFR.

over the 3-month period on the individual basis for all currencies combined, using data as of end-June 2021, available through regulatory reporting for liquidity monitoring. An exploratory analysis based on the NSFR was also conducted.

52. The liquidity stress tests covered a sample of 12 banks with total assets of Col$708 trillion. This sample covers about 95 percent of the total assets of banks in Colombia and includes four DSIBs and eight non-DSIBs, one of which is a state-owned bank. One DSIB and three non-DSIBs are foreign headquartered, while the rest are local.

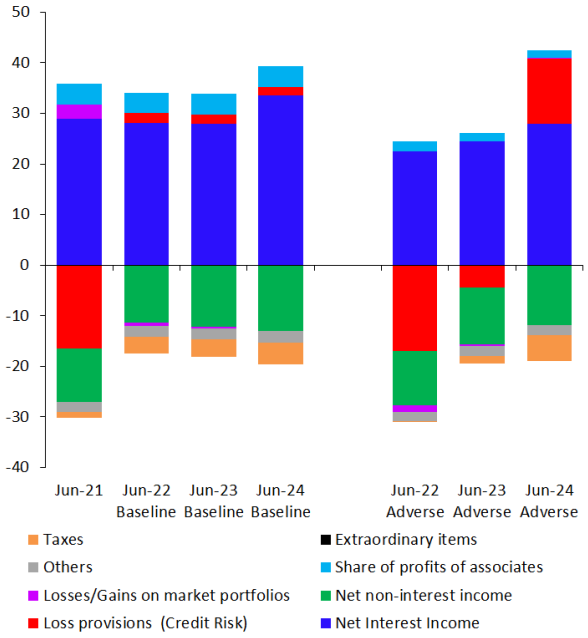
Figure 14. Colombia: Main Results of the Solvency Stress Test



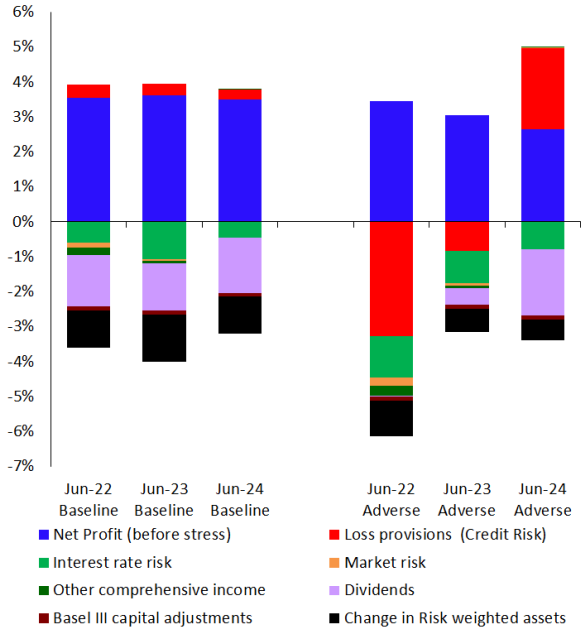
Sources: SFC; IMF staff calculations.

Figure 15. Colombia: Solvency Stress Test Detailed Results

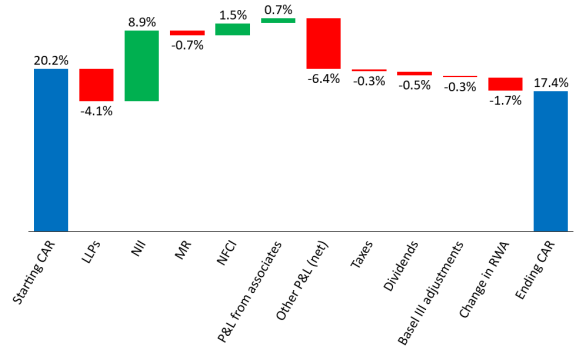
a. Net Income Components



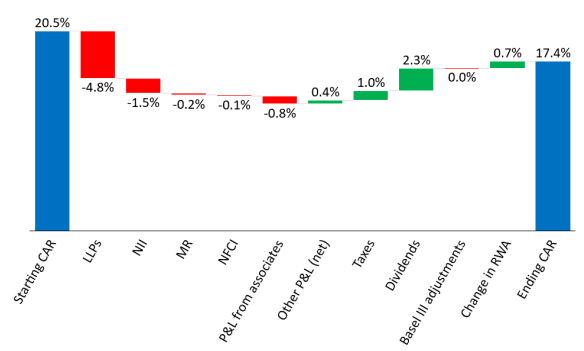
b. Contribution to Change in Capitalization Ratio



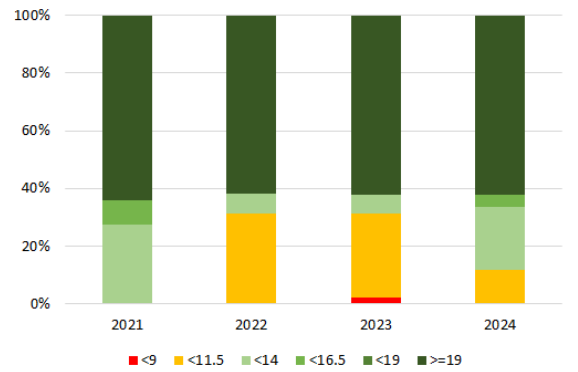
c. Drivers of Change in Total CAR: Under Adverse at the Low Point



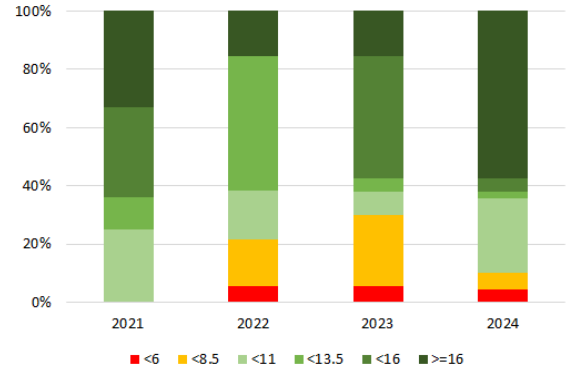
d. Drivers of Change in Total CAR: Delta with Respect to Baseline at the Low Point



e. Banks' Total CAR Distribution: Adverse



f. Banks' Tier 1 Ratio Distribution: Adverse



Sources: SFC; IMF staff calculations.

Table 5. Colombia: Results of the Concentration Risk Sensitivity Analysis (December 2020)

	Exposures net of financial guarantees				Exposures before financial guarantees			
	Tier 1	Total CAR	Number of undercapitalized banks	Maximum capital shortfall (in % of GDP)	Tier 1	Total CAR	Number of undercapitalized banks	Maximum capital shortfall (in % of GDP)
Before stress	11.5%	16.3%	0	0	11.5%	16.3%	0	0
Top 1	10.8%	15.5%	0	0.00%	10.4%	15.2%	1	0.00%
Top 5	9.0%	13.8%	2	0.03%	8.1%	12.8%	5	0.28%
Top 10	7.4%	12.2%	5	0.21%	6.0%	10.8%	9	0.71%
Minimum requirement	*4.9%*	*9.0%*			*4.9%*	*9.0%*		

Source: SFC; IMF staff calculations.
Notes: The sensitivity analysis used December 2020 data on counterparty-level exposures data as well as the corresponding data on banks' capital adequacy ratios at end-2020.

B. Current Liquidity Conditions and Banks' Liquidity Profiles

53. Banks hold ample liquidity, as measured by liquidity indexes, despite the hit of the COVID-19 pandemic. The level of liquidity had benefited from the BR's substantial liquidity support, and from the reallocation of resources to the banking system due to a flight-to-stability motive, as well as from slower loan growth. The aggregate IRL for the top 12 banks was well above the regulatory minimum requirement of 100 percent pre-COVID-19 and increased even more after the start of the pandemic and returned close to the pre-pandemic level of 188 percent at end-June 2021 (Figure 16.a). Similarly, the NSFR increased since the start to the pandemic and reached 112 percent (Figure 16.b). Both liquidity indicators are higher for foreign headquartered banks relative to local banks and for DSIBs relative to non-DSIBs (Figure 16.c).

54. Liquid assets are largely composed of Level 1 securities (HQLA). According to the IRL methodology, liquid assets consist of HQLA and other liquid assets, where the latter are equivalent to Level 2 assets under the LCR standard. Level 1 securities constitute 96 percent of liquid assets and consist of required reserves (26 percent of liquid assets), other cash items (16 percent), and of securities admitted by the BR, mainly Colombian sovereign debt (54 percent) (see Figure 16.d). Most of the banks hold a relatively small share of foreign currency-denominated liquid assets (about 13 percent) that are subject to additional haircuts capturing foreign exchange risk, according to the IRL methodology. An exception is one DSIB that has 41 percent of liquid assets denominated in foreign currency. Overall, liquid assets comprise 16 percent of total assets. Non-DSIBs and foreign headquartered banks hold relatively larger share of liquid assets, which contributes to higher IRL for these groups of banks relative to DSIBs and local banks.

55. Almost 80 percent of commercial banks' funding comes from wholesale sources (nonfinancial corporates and financial institutions, Figure 16.e). As of end-of March 2021, unsecured wholesale funding of the 12 largest banks constitutes 75 percent of total funding and consists of demand deposits (41 percent of total funding), term deposits (17 percent), bonds (9 percent), and bank credit and other financial obligations (8 percent). Remaining wholesale funding (3 percent) comes from passive money market operations with the BR and financial entities, with public debt (TES) being the dominating type of collateral followed by equity. Retail demand and

terms deposits comprise about 16 percent and 7 percent of total funding, respectively.[17] Overall, demand and term deposits constitute the main source of funding, which is 57 percent and 24 percent respectively. The main holders of deposits are nonfinancial companies, followed by natural persons, and non-credit-institutions financial entities (Figure 16.f).

56. There are significant counterparties among deposits holders that hold more than 1 percent of total liabilities. With deposits being the main source of funding, the high deposit concentration may impose a liquidity risk on the bank. For the top 12 banks, on average, the top 1 depositor holds about 4 percent of total liabilities, and the top 20 depositors hold about 15 percent (Figure 17.a). Top depositors hold mainly current and savings deposits that might be withdrawn immediately, and most of them do not belong to related counterparties, which also points to higher instability of this source of funding.[18] Both the SFC and the BR monitor risks associated with large depositors' withdrawals.

57. Relative to the pre-pandemic situation, banks increased their holding of HQLA supported by funding coming from demand deposits across all types of counterparties. The amount of demand deposits in the top 12 banks increased by 31 percent between end-2019 and June 2021. The inflow of demand deposits was higher for DSIBs (33 percent) relative to non-DSIBs (28 percent), which reflects, among other things, higher confidence in bigger institutions. An increase in banks' holdings of liquid assets is the main contributor to the rise in the IRL, which was partially offset by (predicted) cash outflows attributed to higher balances of demand deposits (Figure 18.a). At the same time, a decrease in contractual outflows, due to maturing passive money market operations and other contractual outflows, also contributed positively to the IRL. The stability of loan repayments despite the pandemic is reflected in stable contractual inflows, due to maturing loans, that had only a modest negative impact on the IRL.

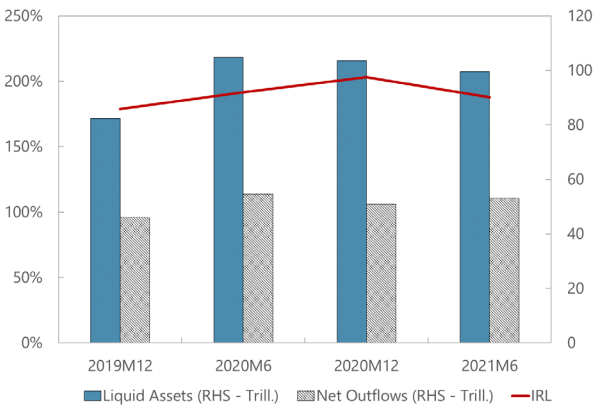
58. Increase in total regulatory capital and demand deposits resulted in the rise of the NSFR after the start of the pandemic. Available stable funding (ASF) mainly consists of total regulatory capital (20 percent), demand deposits (50 percent), and term deposits (49 percent). An increase in total regulatory capital, due to early convergence to Basel III standards and capitalization of retained earnings, and the increase in demand deposits, especially held by clients with high ASF factors, contributed to an increase in ASF from 422 at end-December 2019 to Col$498 trillion at end-June 2021 (Figures 18.b and 18.c). On the other hand, a decrease in the share of term deposits with maturity over a year negatively affected the amount of ASF. Required Stable Funding (RSF) has increased slightly by 5.6 percent, due to a rise in holdings of assets with the highest RSF factor, such as non-exchange-traded equities. However, it benefited from a slower pace in loan growth driven by lower credit demand and increased credit risk.

[17] Here, retail deposits are defined as all deposits held by natural persons and the wholesale funding is the funding provided by all counterparties, except natural persons. Nonfinancial companies refer to legal persons. Note that the IRL methodology incorporates different classifications of demand deposits by their estimated riskiness.

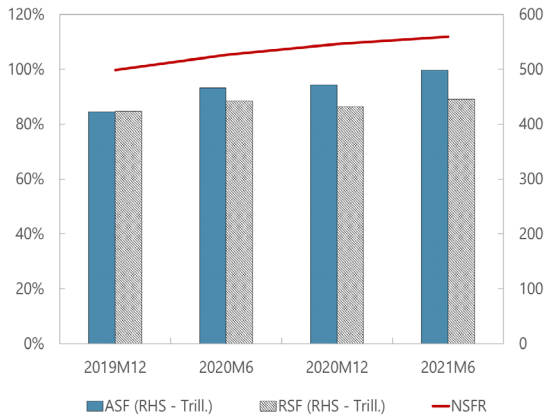
[18] According to data used for interconnectedness analysis as of end-of-2020.

Figure 16. Colombia: Selected Banking Liquidity Indicators
(Top 12 banks)

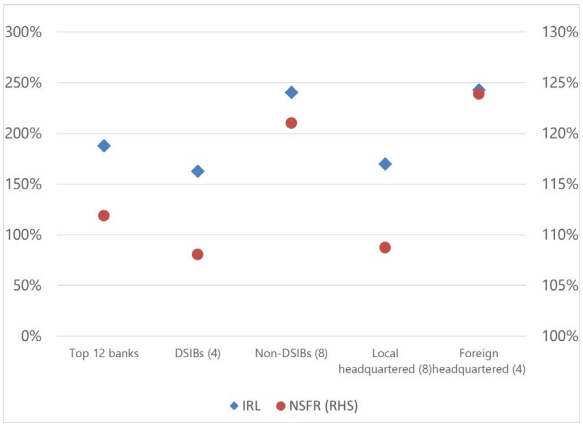
a. Liquidity Coverage Ratio Index[1]



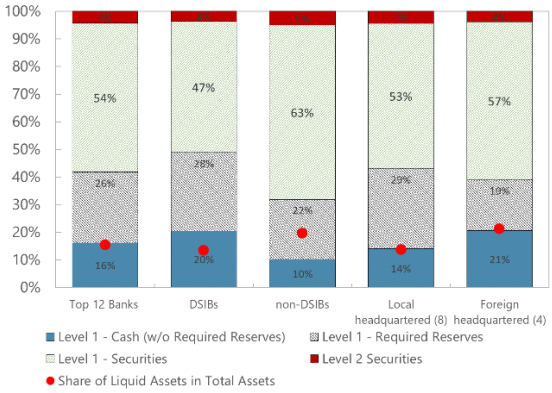
b. Net Stable Funding Ratio



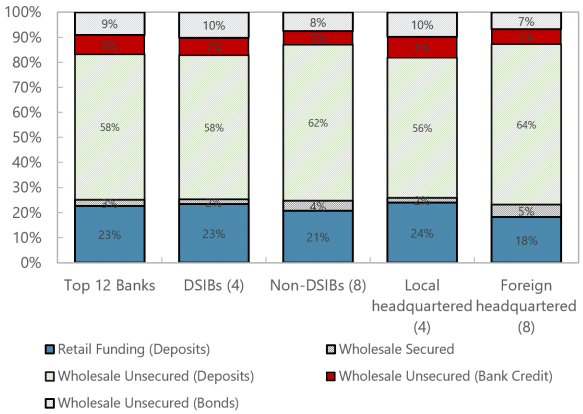
c. Liquidity Indicators across Banks



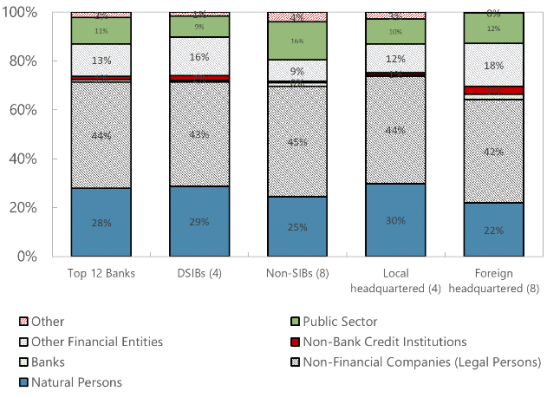
d. Composition of Liquid Assets
(in percent of liquid assets)



e. Sources of Funding by Bank Type
(2021M3, in percent of total funding)



f. Deposits by Counterparty
(2021M3, in percent)

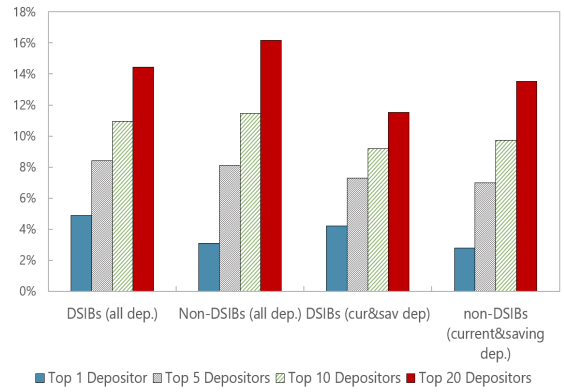


Source: SFC; IMF staff calculations.

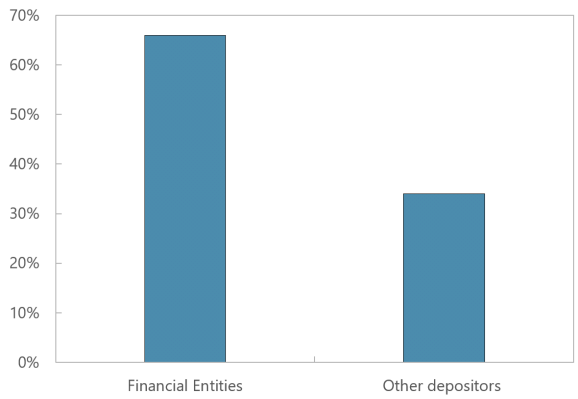
[1] IRL is a national implementation of BASEL III Liquidity Coverage Ratio focusing on the short-term liquidity risks.

Figure 17. Colombia: Deposit Concentration

a. Share of Top Depositors
(in percent of total liabilities)



b. Share by Depositor Type
(in percent of five largest deposits)



Source: SFC; IMF staff calculations.

59. Banks do not demonstrate significant exposures to the exchange rate risks. To complement the IRL, the BR imposes an additional liquidity metric aimed at capturing foreign exchange risk.[19] This indicator estimates the difference between liquid assets and net liquidity requirements, both expressed in US dollars, for each currency. The net liquidity requirements (NLR) in foreign currency comprise only 11 percent of total NLR and are dominated by NLR in US dollars (97 percent). At the aggregate level of the top 12 banks, liquid assets in US dollars comfortably exceed NLR, even for some non-DSIBs, liquid assets in US dollars were significantly below NRL (as a percent of US dollar NRL) in June 2021 (Figure 19). However, excess liquidity in COL compensates for this shortage of US dollar liquidity even after the application of 11 percent regulatory haircut.

C. LCR-based Stress Tests

60. The LCR-based test was conducted in line with the national implementation of the Basel III regulatory framework. The LCR-based test assesses banks' ability to manage potential liquidity pressures by using a stock of unencumbered liquid assets for a period of 30 days.

61. To assess the banks' short-term resilience to an abrupt withdrawal of funding, the LCR-based stress test included more severe scenarios in addition to regulatory scenario:

- A *Baseline scenario* reflects the scenario embedded in the IRL. Under this scenario, the cash outflows consist of contractual outflows, with maturities within the reporting period that are subject to 100 percent run-off factors, and noncontractual outflows related to demand deposits segmented by the type of client. Run-off rates corresponding to demand deposits take into account the bank-level historical run-off rates from 2011 up to the latest month, as well as regulatory estimates based on data between 2011 and 2017 (Figure 20.a). Cash inflows include contractual inflows, with maturities within the reporting period that are subject to 100 percent

[19] The metric is implemented on individual and consolidated bases; however, this technical note covers the individual level data that is only consistent with the IRL coverage.

factors (or 0 percent roll-over rates), except for inflows related to loan portfolios, which include only performing loans and are adjusted by half of the latest past-due portfolio index. Liquid assets include reserves and are subject to haircuts, including those that aim to capture the foreign exchange risk.

- *Adverse scenarios* simulate more abrupt withdrawal of funding (see Appendix V, Table 1 for the full set of assumptions). All three adverse scenarios incorporate more severe assumptions on run-off rates for demand deposits. All other assumptions remained the same as in the baseline scenario. The *retail funding stress scenario* simulates elevated levels of retail demand deposit withdrawals by increasing run-off rates from levels of about 3 percent to 13 percent on average across banks to 5 percent to 20 percent.[20,21] The *wholesale funding stress scenario* simulates abrupt withdrawal of wholesale demand deposits, especially those of the institutional investors. The *severe scenario* combines the stressed run-off parameters of these two scenarios.[22] As the large share of Colombian banks' funding comes from demand deposits, the adverse scenarios result in significant liquidity outflows once aggregated across all banks. As it is unlikely for such a large amount of liquidity to leave the banking sector, the adverse scenarios are considered to simulate idiosyncratic shocks.

62. The results of the baseline (regulatory) scenario show that Colombian banks have significant liquidity. The aggregate IRL is at the level of 188 percent, and all individual banks pass the 100 percent hurdle rate by a comfortable margin. The level of liquidity is higher for non-DSIBs than for DSIBs (241 percent vs. 163 percent). As for the components that constitute this level of the IRL, cash outflows account for 15 percent of total assets, which is above the level of liquid assets after the application of haircuts (Figure 20.b). Cash outflows are counterbalanced by contractual inflows of 8 percent of total assets, one-fourth of which are inflows due to maturing loans. Consistent with the funding structure of banks, a large amount of cash outflows is due to demand deposits, with wholesale demand deposit outflows playing a more important role for DSIBs. While net cash outflows are at about the same level for DSIBs and non-DSIBs, DSIBs hold a smaller amount of liquid assets, which implies that they might be more strongly impacted in the event of very severe liquidity shocks. The aggregated IRL for foreign headquartered banks of 243 percent is higher than the aggregate IRL for local banks of 170 percent. This might be related to the fact that a sample of foreign headquartered banks are subject to Basel III LCR standards, which differ from the IRL

[20] Retail deposits which are deposits of natural persons are included in the categories of *judicial deposits*, *retail depositors (covered by deposit insurance)*, *small and medium-sized clients* (medium natural persons), *local private wholesale funding* (large natural persons) (see Appendix V, Table 1).

[21] The IRL methodology implies that the run-off rates differ across banks, so the adverse scenarios take the maximum between the adverse scenario run-off rate and regulatory run-off rate for each bank. The text and assumptions are described in Appendix V; Table 6 refers to average regulatory run-off rates across banks as of end-June 2021.

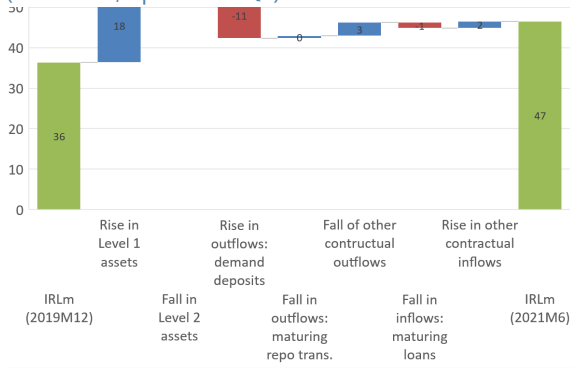
[22] Parameters embedded in the adverse scenarios were chosen based on expert judgement, international benchmarks, and the regulatory parameters that represent the fifth percentile of historical changes in balances of demand deposits for some banks (see Figure 20.a). The absence of historical data on the evolution of demand deposits, as classified in the IRL methodology, was a constraint for the direct calibration of run-off rates based on historical events.

methodology in several dimensions, and also that the parent companies requested their subsidiaries to contain the activation of liquidity contingency plans.[23]

Figure 18. Colombia: Developments During the Pandemic

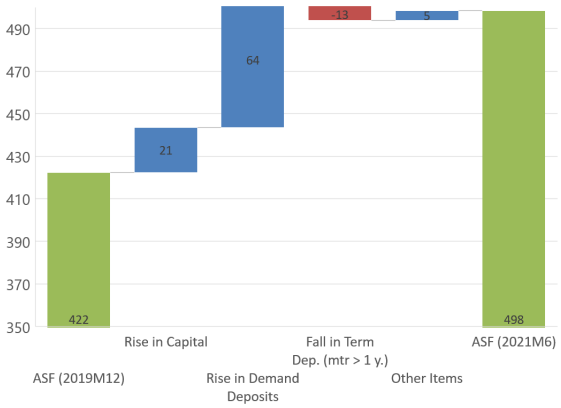
a. Contribution to Changes in IRL

(in trillions; up to 2021Q2)



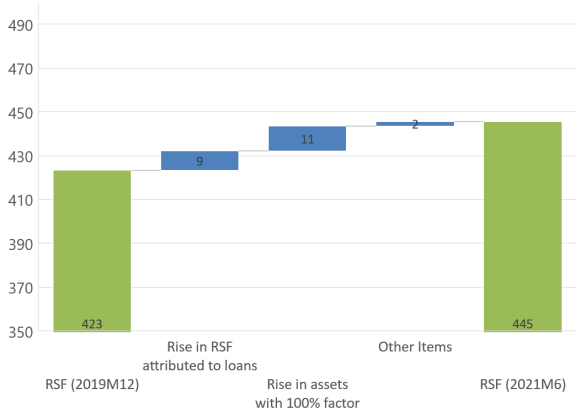
b. Contribution to Changes in ASF

(in trillions; up to 2021Q2)



c. Contribution to Changes in RSF

(in trillions; up to 2021Q2)



Source: SFC and IMF staff calculations.
Note: IRLm = Liquid Assets – Net Cash Outflows

63. The "retail" adverse scenario tests the banks' resilience to retail demand deposits withdrawal. The results indicate that banks are resilient to the retail funding shock, with the aggregate IRL decreasing to143 percent and all banks maintaining IRL above 100 percent (Table 6).

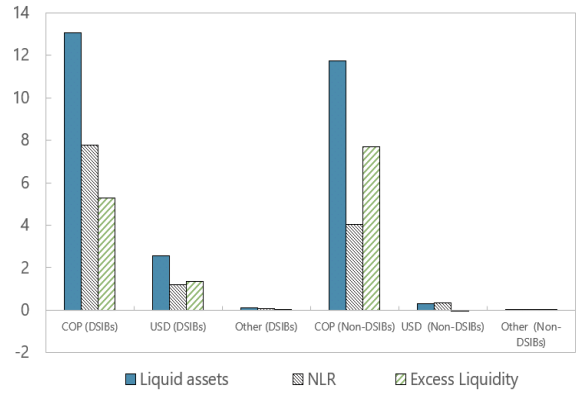
[23] See Colombia FSAP "Detailed Assessment of Observance of the Basel Core Principles for Effective Banking Supervision" for the detailed description of differences between Basel III standards and the IRL standards. The granularity of data reported through regulatory reporting for liquidity monitoring is limited to making a precise comparison of Basel III LCR and IRL. However, there are some elements of the two standards that are more prudent in Basel III LCR than in the IRL, such as the treatment of cash inflows due to maturing loans and lower run-off rates for investment funds under the IRL.

Even though banks rely significantly on retail funding, the regulatory run-off rates are already high for these types of deposits relative to those in the adverse retail scenario.

Figure 19. Colombia: Liquidity by Currency

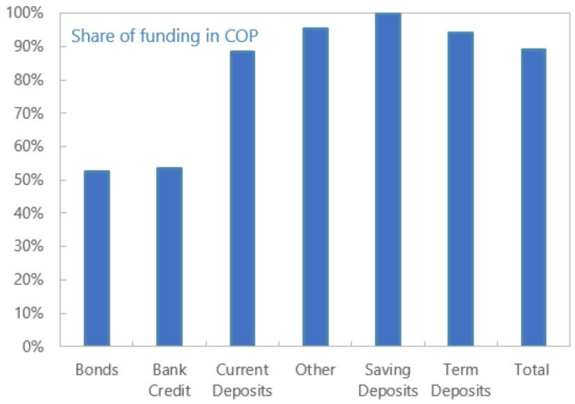
a. Liquidity by Currency

(in billions; 2021Q2)



b. Funding in Local Currency

(in percent of total funding; 2021Q1)

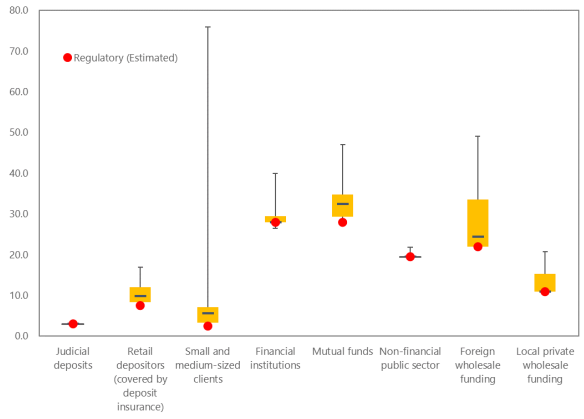


Source: SFC and IMF staff calculations.

Figure 20. Colombia: LCR-Based Test: Regulatory Scenario

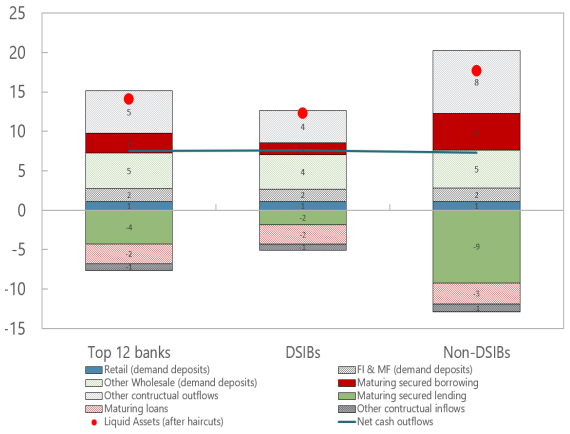
a. Regulatory Run-off Rates across Banks

(in percent; distribution across banks)



b. Composition of Cashflows and Liquid Assets

(in percent of total assets)



Sources: SFC and IMF staff calculations.

Note: According to the IRL methodology, for each bank, run-off rates for demand deposits are computed as the median from: (i) the zero percentile of historical changes in balances of demand deposits for each client category for that bank up to the previous month; (ii) the fifth percentile of the same series; and (iii) regulatory estimates on the historical data up to between 2011 and 2017 (red dots).

64. The "wholesale" and combined adverse scenarios reveal some weaknesses in the event of very large deposit withdrawals. In the scenario that simulates a dry-up of wholesale funding, the aggregate IRL falls to 123 percent, with two banks falling below the 100 percent hurdle rate. In the scenario combining withdrawal of both retail and wholesale funding, the aggregate IRL decreases to 102 percent with five banks' IRL falling below 100 percent. DSIBs are more strongly impacted than the smaller banks under the same adverse scenario, with the aggregate IRL falling

from 163 percent in the regulatory scenario to 88 percent. The stronger impact of simulated funding shocks on DSIBs reflects the fact that even though their reliance on wholesale deposit funding is similar to non-DSIBs measured as a share of total assets, DSIBs hold relatively lower amount of liquid assets. However, even in the very extreme scenario, the aggregate liquidity shortfall is of manageable magnitude of 1.7 percent of total assets of banks in the sample, and liquidity shortfalls for the individual banks do not exceed 3 percent of total assets. The aggregate IRL for foreign headquartered banks declines from 243 percent in the baseline scenario to 141 percent in the severe scenario, while it declines from 170 percent to 91 percent for local banks.

Table 6. Colombia: Results of the LCR-Based Test

	Regulatory			Retail Shock			Wholesale Shock			Severe Shock		
	Top 12	DSIBs (4)	Non-DSIBs	Top 12	DSIBs (4)	Non-DSIBs	Top 12	DSIBs (4)	Non-DSIBs	Top 12	DSIBs (4)	Non-DSIBs
Agregate LCR	188%	163%	241%	143%	123%	186%	123%	107%	156%	102%	88%	131%
No. of banks with LCR<100	0	0	0	0	0	0	2	1	1	5	3	2
Liquidity shortfall												
COL Trillion	0	0	0	0	0	0	2.3	2.2	0	11.9	10.5	1
Percent of GDP	0	0	0	0	0	0	0.2%	0.1%	0.1%	0.5%	0.3%	0.2%
Percent of bank's assets in sample	0	0	0	0	0	0	0.3%	0.3%	0.0%	1.7%	1.5%	0.2%

Note: Liquidity shortfall is the amount of liquid assets needed to restore IRL at 100 percent. Even though the adverse scenarios simulate idiosyncratic shocks, only the aggregated liquidity shortfall is reported due to data confidentiality agreement.

Sources: SFC and IMF staff calculations.

D. Cashflow Analysis

65. The cashflow-based analysis assesses risks from the maturity structure of banks' cash inflows and outflows up to a three-month horizon. The analysis simulates a longer duration of stressed liquidity conditions, with large funding outflows affecting all funding sources, restrictions on contractual inflows, and on the use of assets for the counterbalancing capacity. It uses information from the contractual maturity ladder for banks' assets and liabilities over the following buckets: 1 to 7 days, 8 to 15 days, 16 to 30 days, and 30 to 90 days. For each maturity bucket, the net cash balance is computed as the existing cash position, the counterbalancing capacity (i.e., the ability to obtain additional liquidity), and the amount of net funding inflows. If some banks had a negative net cash balance after utilizing their counterbalancing capacity in the simulation, they would experience a liquidity shortfall.

66. Funding pressure was captured through specific time profiles of run-off rates for different funding sources (see Appendix V, Tables 2–4 for the full set of the assumptions). The choice of run-off rates is consistent with general principles, guided by historical experience and empirical studies of different depositor and investor behavior in extreme but plausible conditions. The first principle is that more informed and sophisticated investors withdraw a larger amount of funding than those that are less informed. Second, run-off rates on secured funding sources are lower than those applied to unsecured funding sources. Third, the liquidity pressure is assumed to

be protracted and lasts for up to three months; however, run-off rates are assumed to decline for the longer maturity bucket (after 30 days). Partial utilization of existing off-balance sheet credit or liquidity commitments by banks' clients is also taken into account. For the cash inflows, 100 percent roll-off rates were applied to all maturing assets, except for maturing loans and maturing secured lending. Banks can counterbalance negative funding gaps by using their cash, unencumbered holdings of debt securities and required reserves.[1] Another possibility for Colombian banks to obtain additional liquidity is to use banks' credit lines with foreign entities. However, this might be challenging in the extreme system-wide funding shock in the cashflow analysis. Given this caution, the analysis treats this item of counterbalancing capacity separately.[2]

67. The cashflow analysis identifies small liquidity shortfalls for some banks under severely adverse conditions. The results summarized in Table 7 and Figure 21 show that banks do not experience liquidity shortfalls at the short-term horizon up to 15 days. However, as banks utilize their counterbalancing capacity over time to cover cash outflows, three DSIBs and three non-DSIBs experience liquidity shortfalls over the longer horizon. Even in the very extreme case, the combined shortfall of 1.6 percent of assets for banks in the sample is of a modest magnitude and should be manageable, given the BR's ability to provide liquidity to the system.[3] Moreover, if a drawdown of 15 percent of foreign credit lines by banks experiencing liquidity shortfall is exercised, one non-DSIB covers its liquidity shortfall, and the cumulative liquidity shortfall decreases to 0.6 percent of total assets of banks in the sample. The liquidity shortfall could also be potentially covered by a reduction in loan extension. The cashflow analysis supports the results of the LCR-based test, revealing greater impact of adverse funding conditions on DSIBs due to their reliance on the wholesale unsecured funding and relatively lower holdings of liquid assets.

Table 7. Colombia: Results of the Cashflow Analysis[1]

	Up to 7 Days	Up to 15 Days	Up to 30 Days	Up to 90 Days
Total	0	0	2	6
DSIBs	0	0	2	3
Non-SIBs	0	0	0	3
Liquidity Shortfall				
Percent of banks' assets in sample	0.0	0.0	0.2	1.6

[1] If drawdown of 15% of credit lines in foreign entities of banks experiencing liquidity shortfall is exercised in the case of the extreme funding shock, one non-DSIB covers liquidity shortfall, and the cumulative liquidity shortfall decreases to 0.6 percent of banks' assets in sample.

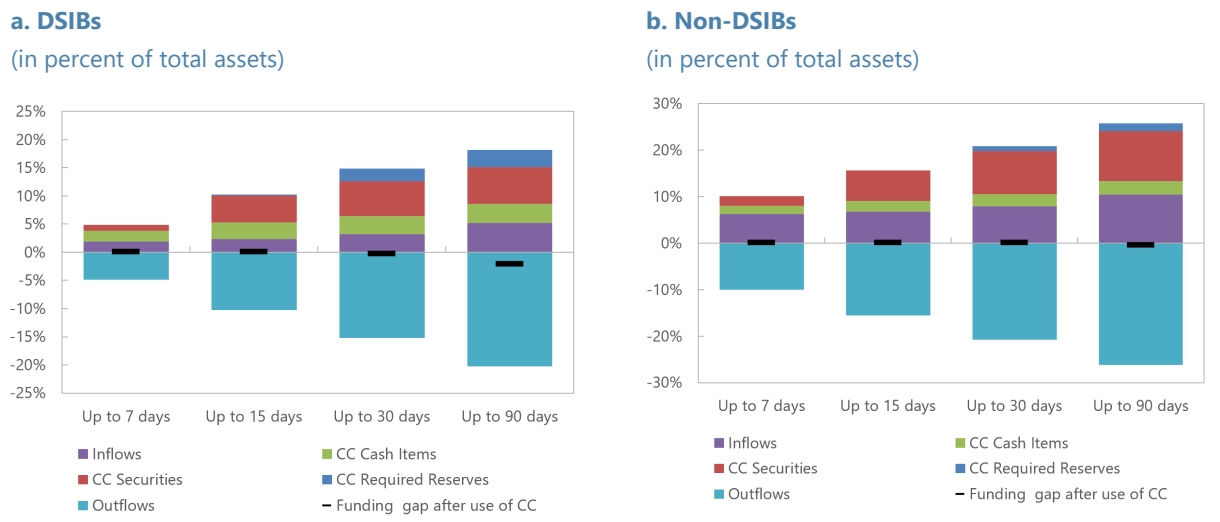
Source: SFC and IMF staff calculations.

[1] According to the regulation, the Colombian banks can only have structural equity investments that correspond to their subordinated entities. It is assumed that banks do not decrease their participation in subordinated entities in the adverse scenario. This assumption is equivalent to the assumption of 100 percent haircuts on equities.

[2] In particular, the analysis includes the possibility of drawdown of 15 percent of banks' credit lines with foreign entities.

[3] Extraordinary liquidity support measures (the lender-of-last-resort facilities) include dematerialized promissory notes with the loan portfolio admitted as collateral.

Figure 21. Colombia: Cash Inflows and Outflows and Use of Counterbalancing Capacity
(CC)



Sources: SFC and IMF staff calculations.

E. Exploratory NSFR-Based Analysis

68. The NSFR was already above 100 percent for most of the banks at end-June 2021. The authorities have started gradual implementation of NSFR requirements, with the level of the requirement depending on the systemic importance of the entity, with 100 percent limit for banks with assets greater than 2 percent of total system assets. The implementation of the NSFR is scheduled to be finalized by end-March 2022; however, by June 2021, the NSFR was already above 100 percent for all except one bank in the sample (Table 8).[4]

F. Conclusions and Recommendations

69. Although the SFC and the BR conduct an extensive liquidity monitoring analysis, it could be augmented by additional data collection. Data collection for liquidity risk monitoring could be enhanced to ensure availability of more granular data to reflect the diversity of sources and uses of funds, which would allow conducting more refined quantitative exercises. More detailed data collection might cover data on term deposit inflows by counterparty, on operational demand deposits and parent funding in unsecured wholesale funding, and on secured funding and lending by type of security, as well as data on off-balance sheet commitments. Additional data on the time structure of cashflows beyond 90 days would allow assessing the effects of more protracted liquidity

[4] The implementation schedule is the following: (i) Group 1: March 31, 2020: 80 percent, March 31, 2021: 90 percent, March 31, 2022: 100 percent; (ii) Group 2: March 31, 2020: 60 percent, March 31, 2021: 70 percent, March 31, 2022: 80 percent. Group 1 includes banks with assets greater than 2 percent of total system assets and group 2 includes other institutions with credit portfolio being primary activity. All top 12 banks in the sample have assets greater than 2 percent of total system assets.

shocks. Given large foreign exposures of some Colombian banks, extended data collection should ensure the availability of data on assets and liabilities generating cashflows by significant currency, as well as related to cross-border exposures.

Table 8. Colombia: NSFR

	2019M12	2020M6	2020M12	2021M3	2021M6
			(In percent)		
Minimum value	87	89	93	95	97
First quantile	96	99	103	104	105
Median value	105	107	112	111	109
Third quantile	114	121	128	129	133
Maximum value	193	179	183	189	198
No. of banks with NSFR < 100 percent	5	4	2	1	1
No. of banks with NSFR < 90 percent	2	1	0	0	0
No. of banks with NSFR < 80 percent	0	0	0	0	0

Sources: SFC and IMF staff calculations.

70. The regulatory parameters used for the computation of the IRL and the NSFR could be re-adjusted or determined to be further aligned with Basel III requirements. Closer convergence of national regulation to Basel III standards would allow for the international comparability of liquidity indexes, including those of the subsidiaries of financial conglomerates. Higher values of liquidity indexes for foreign headquartered banks relative to local banks could reflect the fact that IRL standards are less stringent than Basel III LCR standards. Extension of data collection for liquidity monitoring would allow for more informed analyses of these differences, as well as assessment of the consequences of possible adjustments in regulatory parameters.

INTERCONNECTEDNESS ANALYSIS

71. To evaluate the interconnectedness of Colombia's financial system and potential stress transmission channels, a network and contagion risk analysis was conducted. The analysis is presented in the sections below in three stages. First, a mapping of the Colombian financial system at both the sectoral and entity level is presented. Second, the role of conglomerates and cross-border exposures is discussed. Once the network is mapped, contagion is evaluated through the lens of a contagion risk model.

A. Mapping the Structure of Colombia's Financial System

72. A wide dataset of sectoral and entity-level financial exposures was used to map the structure of the financial network. The anonymized data used covered exposures in equities, short-term debt, long-term debt, loans, deposits, derivatives, interbank exposures, and money

market operations across banks, pension funds, insurers, investment funds, trusts, securities firms, nonfinancial corporates, households, and government entities. For those transactions where a foreign debtor counterpart could be identified, these were mapped as well to assess potential foreign contagion channels. The dataset covers entities supervised directly by SFC, as well as the counterparts for all identifiable exposures.

73. Banks lie at the core of the Colombian financial network. Figure 22 shows the mapping of the network at the sectoral level through the lens of network and heat maps. The size of the sectoral nodes in the network represents the total positions of the sector entities as creditors, while the width of the connecting lines represents the magnitude of total exposures connected at the sectoral level. The color of the connecting lines corresponds to the creditor sector. As expected, large exposures are dominated by credit institutions (including banks), with significant exposures to households and NFCs, both as creditors (mainly through loans) and as debtors (through deposits). Pension funds, and to a lesser degree insurers and investment funds, play a prominent role as asset holders, with significant exposures to government securities. Other sectors play a lesser role, but their interconnectivity to multiple sectors present potential contagion transmission channels.

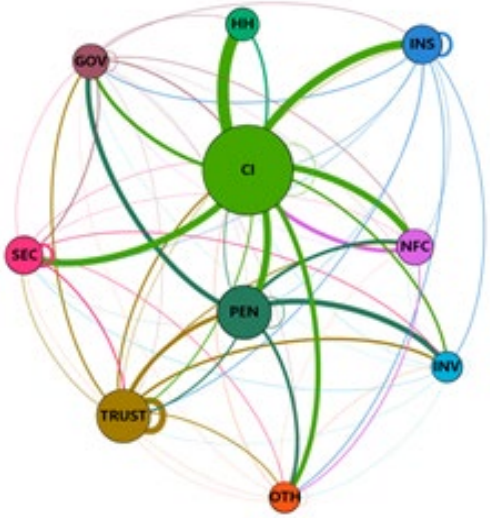
74. Banks provide the leading role as a source of both funding and balance sheet asset exposures of counterparts. Figure 22 shows the network, in relative terms, from two perspectives. Figure 22.a shows the debtor perspective, where the thickness of the lines equals the size of the exposure in gross terms divided by all liabilities in the dataset of the debtor sector. The size of each sector node corresponds to the weighted out-degree measure—roughly a measure of how important each sector is as a source of funding in the system. Conversely, Figure 22.b shows the creditor perspective, where the thickness of the lines equals the size of the exposure divided by the total assets in the dataset of the creditor sector. The figures show that creditor institutions (dominated by banks) provide the main source of financing for households and nonfinancial corporations, while figuring prominently as an asset in the balance sheets of investment funds, insurers, securities firms, and trusts. As a result, they can serve either as a shock source or as a shock transmission mechanism to other nodes in the network.

75. At the entity level, banks stand connected to all of the main entities and economic sectors in the system, comprising a complex web of inter-bank and cross-sectoral inter-entity contagion channels. Similar to Figure 22 described above, Figure 23 shows the network at the entity level from asset concentration (creditor) perspective—showing all links, as well as only the large ones under different minimum importance thresholds. All individual banks are shown in the center circle, with outer nodes including individual large pension funds, investment funds, and insurers. Entities from other sectors are aggregated for tractability, including all government entities, households, and nonfinancial corporates (at the industry level). The figure shows a complex network, although one with dominating exposure channels. In particular, most banks have significant loan exposures to households while being exposed to the government through the holding of government securities. With nonfinancial corporates holding deposits at banks and pension funds, investment funds and trusts being exposed to banks through deposits and equity positions, this presents a potential transmission channel. In contrast, there appears to be limited concentration of

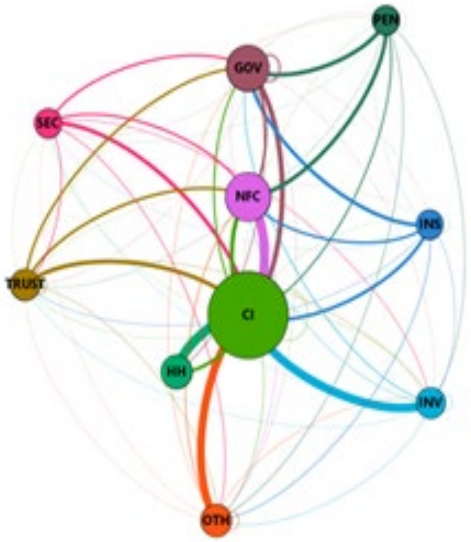
bank exposures to specific nonfinancial industries, and households—by their inherent diversity—provide some resilience to idiosyncratic shocks. Pension funds and investment funds exhibit some concentration to government securities and to a lesser degree banks, which, though understandable given the limited capital market development in Colombia (with market capitalization about 40 percent of GDP), leads to concentrated domestic currency exposures to local government securities.

Figure 22. Colombia: Sectoral Importance of Asset and Liability Exposures

a. Concentration of Funding Sources (debtor perspective)



b. Concentration of Asset Exposures (creditor perspective)



Sources: SFC and IMF staff calculations.

Legend: CI: Credit institutions; HH: Households; NFC: Nonfinancial corporates; INS: Insurance firms; PEN: Pension funds; INV: Investment funds; GOV: Government; TRUST: Trust companies; SEC: Securities firms; OTH: Others.

Notes: December 2020 data. Edges in network map indicate exposures between sectors (including short-term debt, long-term debt, equities, and derivatives), with their color corresponding to the creditor's color. For Figure 6a, thickness of edges indicates total exposure size relative to liabilities of debtor, and bubble-size indicate weighted out-degree measure of the node in the network. The larger the size, the more important is the sector as a source of funding for other sectors in the system. For Figure 6b, thickness of edges indicates total exposure size relative to total assets of creditor, and bubble-size indicate weighted in-degree measure of the node in the network. The larger the size, the more important is the sector as an asset issuer for other sectors in the system.

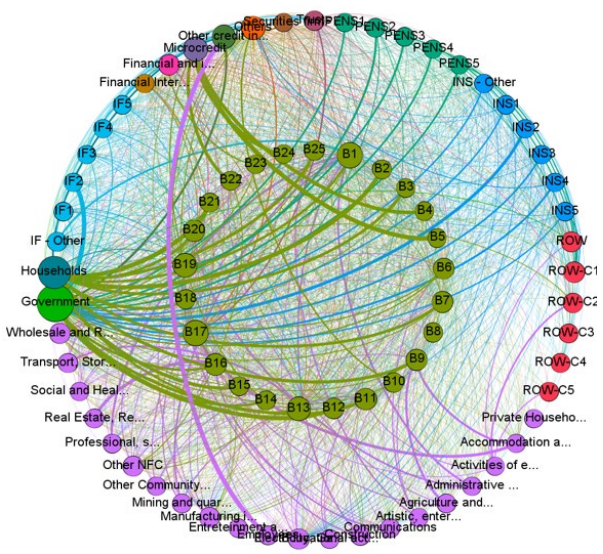
B. The Role of Conglomerates and Cross-Border Exposures

76. Financial conglomerates stand at the center of the interbank network. Domestically, conglomerates own assets of both financial and nonfinancial entities, with the three largest conglomerates controlling about half of the assets in the financial system and two-thirds of the assets in the banking sector. When mapping inter-connectivity of banks in the system (Figure 24.a), conglomerate banks appear at the core of the network and provide multiple transmission channels across the system. Moreover, conglomerates consist of complex, interconnected networks of not only banks, but also trusts, insurers, pension funds, securities firms, and other institution types. Thus, they not only provide networks of contagion within their own structure, but also multiple potential

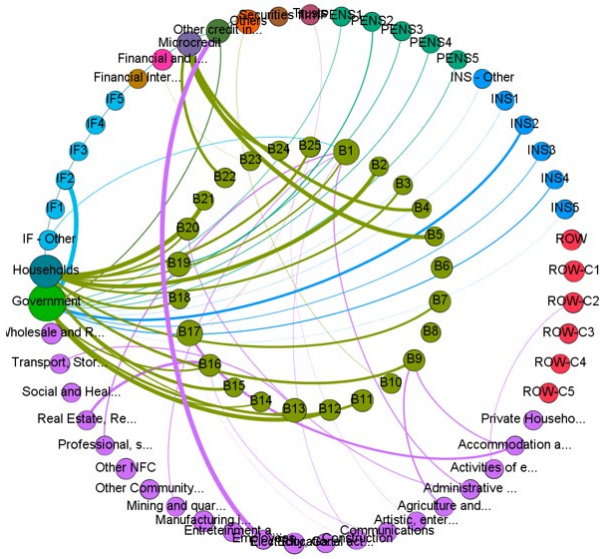
contagion routes between conglomerates through nonbank entities, as shown in Figure 24.b. This complexity motivates the need not only of a holistic approach to conglomerate supervision, but also the proper understanding of inter-conglomerate contagion channels.

Figure 23. Colombia: Network Asset Concentration Map

a. All Exposures



b. Exposures Representing More than 25 percent of Creditor Exposure

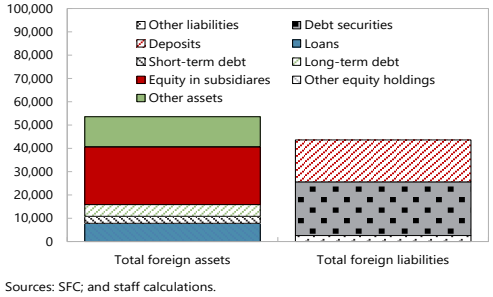


Sources: SFC and IMF staff calculations.

Notes: December 2020 data. Nodes include pension funds, large insurers and investment funds, and other aggregated sectors and nonfinancial industries. Aggregated country categories of foreign counterparts are labeled ROW (Rest of the World). Edges in network map indicate exposures between nodes (including short-term debt, long-term debt, equities, and derivatives), with their color corresponding to the creditor's color. Thickness of edges indicates total exposure size relative to total assets of creditor, and bubble-size indicate weighted in-degree measure of the node in the network. Figure A shows all exposures, while Figure B shows exposures representing more than 25 percent of creditor exposures.

77. The composition of conglomerate exposures—particularly in Central America—is dominated by equity positions in subsidiaries. From a total of Col$54 trillion in bank foreign assets, Col$25 trillion (46 percent) are equity exposures in subsidiaries. There are Col$8 trillion (15 percent) in loans directly, although indirectly loan exposures, on a consolidated basis, are higher, as some loan exposures in non-Panama Central American countries happen through equity exposures in Panama. Although it is harder to identify the universe of foreign liabilities and the network analysis below excludes this channel, these appear to be dominated by debt securities (Col$23 trillion) and deposits (Col$18 trillion), indicating a more dispersed but still viable foreign funding transmission channel.

Cross-border bank exposures by type
(Total foreign assets in COL bn)

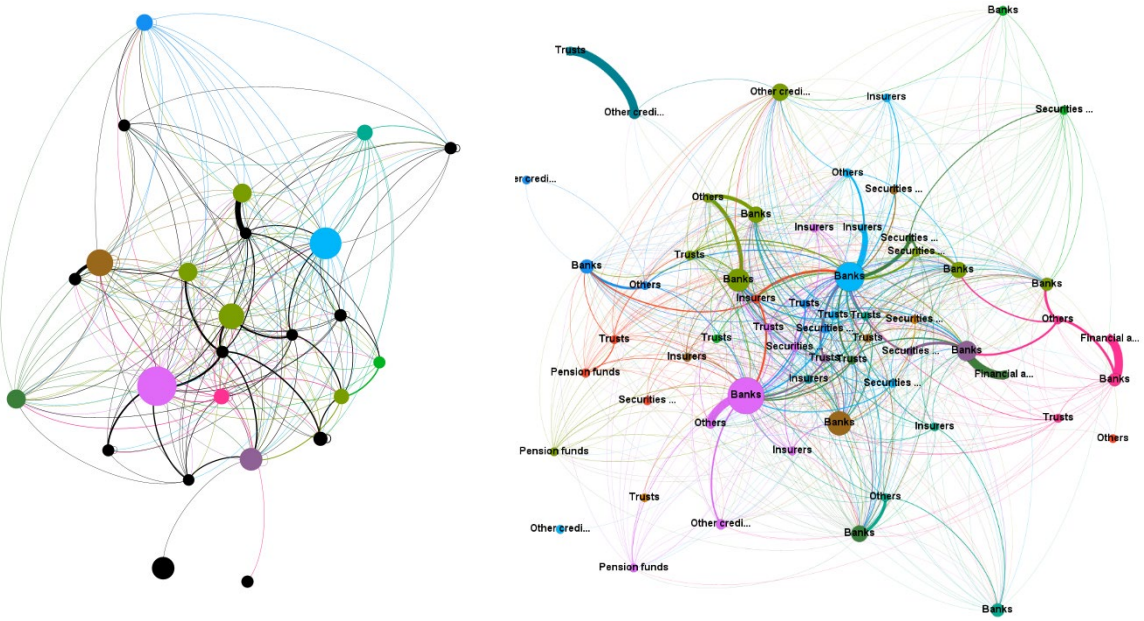


Sources: SFC; and staff calculations.

Figure 24. Colombia: Conglomerate Structures (December 2020)

a. **Banks Only**

b. **All Institution Types**



Sources: SFC and IMF staff calculations.

Notes: Edges indicate exposures linking entities (including short-term debt, long-term debt, equities, and derivatives), with their color corresponding to the creditor's associated conglomerates. Thickness of edges indicates total exposure size relative to total assets of creditor, and bubble-size indicate weighted in-degree measure of the node in the network. Labels identify entity types. Figure a shows banks only with non-conglomerate banks shown in black. Figure b shows all entity types.

78. Beyond conglomerate bank exposures to Central America, significant holdings of U.S. and other foreign securities in the balance sheets of banks, pension funds, investment funds, and other entities present another potential foreign contagion route. Figure 25.a shows the banks' exposures from the asset concentration perspective (creditor) to foreign entities. Consistent with the conglomerate cross-border exposures described, there are at least two banks with significant relative positions in Central America, while several more hold other exposures to other countries. Figure 25.b shows the equivalent mapping for NBFIs, where exposures are dominated by asset exposures to U.S. and other international securities—a preferred method of foreign investment. The figure also shows some exposures through trusts and other types of connecting financial entities—again emphasizing the need for a holistic monitoring of the network.

C. Contagion Risk Analysis

79. The complexity of the interlinkages calls for the exploration of contagion risks through the lens of an agent-based network model. For this exercise, we assess contagion risk using an expanded version of the CoMap model from Covi, Gorpe, and Kok (2019). In particular, it advances the simple interbank exposure model with credit and funding shocks by incorporating bank- and exposure-specific parameters and liquidity dynamics that reflect parametric

heterogeneity across entities. Given the richness of the Colombian dataset, the model has been extended to incorporate nonbank financials, non-financials, and selected foreign counterparts.

80. The contagion risk exercise models how both credit and funding shocks can spread throughout the entity network. The model has a stylized shock transmission framework, where entities or aggregated sectors default one at a time at the beginning of a simulation, and this in turn produces either credit- or liquidity-induced defaults in other entities in the system. On the credit channel, the default of an entity induces a default on its obligations, which are then reflected as losses in the balance sheet of its creditors. On the liquidity channel, the framework models the liquidity dynamics by allowing entities to conduct a "fire sale" dependent on each entity's surplus, liquidity constraints, and asset quality composition—with haircuts applied depending on the exposure types. Importantly, the default of an entity can induce contagion defaults by making other entities in the network either insolvent or illiquid. By iterating the contagion effects across the network, the model informs of potential cascade effects and capital losses across the network. The full methodology is described in Appendix VI.

81. Using available data, the exercise covers all sectors, but only selected entities are allowed to be shock absorbers or amplifiers in the network. The appropriate modeling of an entity's solvency and liquidity positions, and their response to another entity's defaults, requires data on its cross-entity exposures, as well as balance sheet positions. Given available data, we are able to model 25 banks, 5 pension funds, the largest 5 investment funds, and the largest 5 insurers as both entities subject to capital losses and potential amplifiers of shocks in the network.[5] Other entities are aggregated by industry as described in Appendix VI, Table 1. For these aggregated entities, as well as the aggregated foreign counterpart nodes, we trace these nodes as sources of shocks in the network, but not shock amplifiers. The exercises do not consider their capital losses or assess their vulnerability, but we are able to assess their potential contagiousness.

82. As expected, systemic banks are the most contagious in the system—although the network's structure is such that others can induce entity failures as well. To summarize how contagious is an entity in the system, a contagion index is computed broadly reflecting the aggregate losses to other entities in the network relative to the capital of affected entities (see Appendix VI for details). Figure 26 shows this index for banks and other financial institutions, with circles indicating the entities that are able to induce subsequent failures in the system. For banks, two versions of the model are shown: one estimated with banks only and the other a full model with all entities. Several points are worth noting:

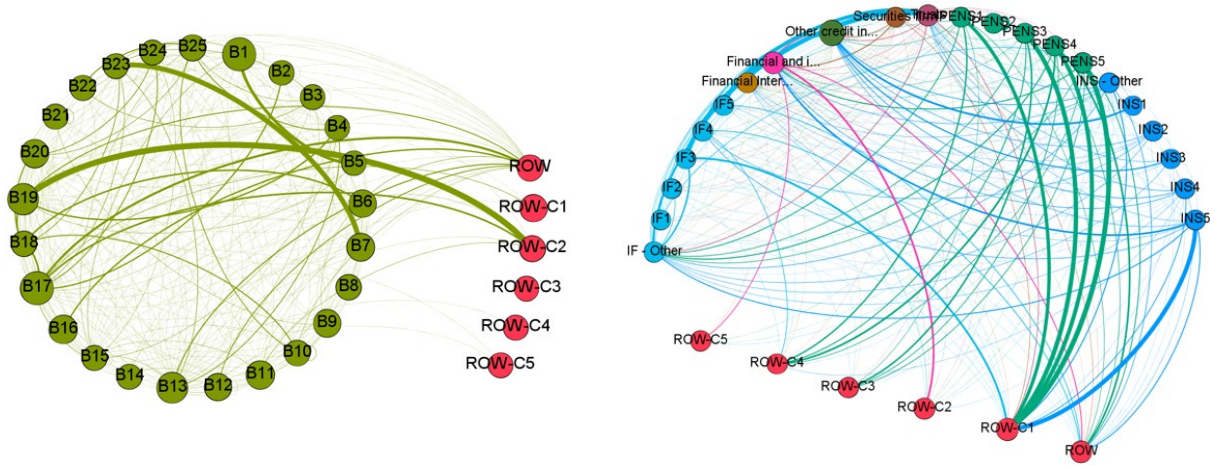
- Bank-only network effects understate total potential losses in the system. This is primarily because bank's induce liabilities in pension funds, investment funds, and other financial entities exposed to banks.

[5]Individual investment funds are combined at asset manager level.

Figure 25. Colombia: Cross-Border Exposures

a. Bank Cross-Border Exposures

b. Other Financial Institutions Cross-Border Exposures



Sources: SFC and IMF staff calculations.

Notes: December 2020 data. Edges in network map indicate exposures between nodes (including short-term debt, long-term debt, equities, and derivatives), with their color corresponding to the creditor's color. Aggregated country categories of foreign counterparts are labeled ROW (Rest of the World). Thickness of edges indicates total exposure size relative to total assets of creditor, and bubble-size indicate weighted in-degree measure of the node in the network. Figure a shows exposures between banks and foreign counterparts (ROW), while Figure b shows exposures between nonbank financial entities and foreign counterparts (ROW).

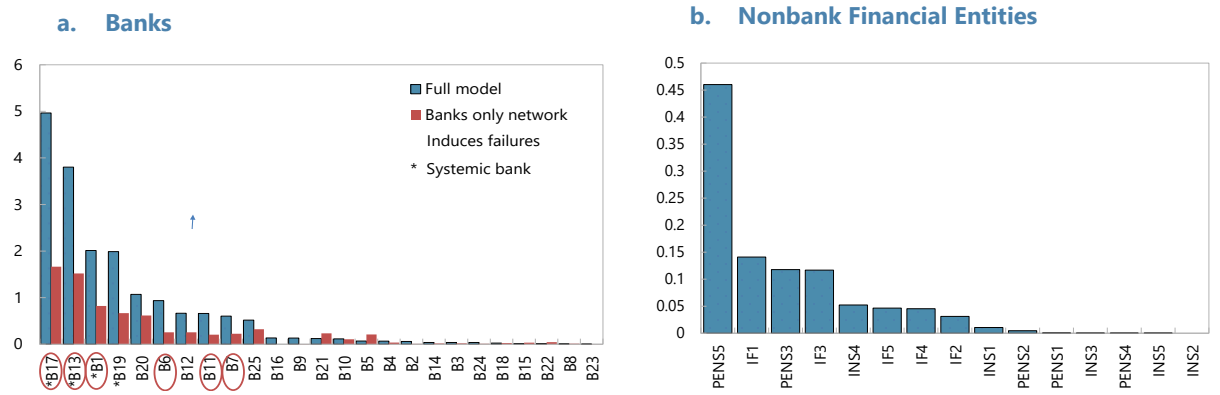
- Systemic banks are the ones identified as most contagious by the model, indicating that the current identification of systemic banks is consistent with the network interpretation of contagion potential.

- Overall, bank failures can lead to three contagion failures in other banks, and six failures in nonbank entities. Importantly, because of the network's structure, certain entities that are not identified as systemic, can induce failures on other entities. As shown in Figure 26, banks B6, B11, and B7 can induce entity failures without inducing the largest system-wide capital losses.

- No bank failure scenarios led, by themselves, to second-round failures. Although some banks might directly induce the failure of a subset of banks in the network, the structure of exposures in the network is such that those entities do not spread further failures forward.

- Pension funds, investment funds, and insurers do not induce failures in the model. As discussed below, this should be viewed in the context of the data limitations of the exercise. Since the liabilities of these entities are not all identified in the network and, due to the nature of their operations, their failure would induce losses in households and investors whose behavior is not modelled, all potential transmission mechanisms from their failure are not considered.

Figure 26. Colombia: Contagion Index by Entity



Sources: SFC and IMF staff calculations.

Note: Contagion index from CoMap model calibrated to December 2020 data. Banks only network refers to the results of a model where only banks are considered. Full model includes all sectors. Red circles indicate banks that induce failures of other bank or nonbank entities in the network.

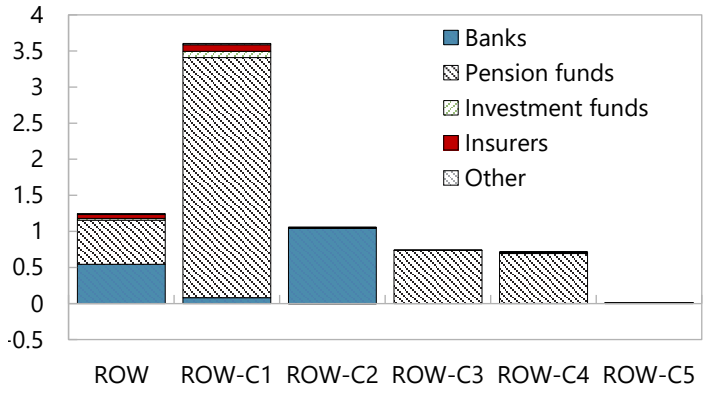
83. Cross-border exposures can lead to substantial losses, but no entity failures are produced by the model. Shocks from aggregated foreign corporates are assumed to involve a loss-given default of 25 percent for equities, 20 percent for short-term debt, long-term debt, other non-loan exposures, and a default of the upper quartile of riskiest loans. Figure 27 shows a decomposition of the contagion risks induced by each country entity and reveals that composition of stress transmission channels varies significantly between countries. For instance, while C1, C3, and C4 shocks expand mainly through the balance sheets of pension funds who hold significant positions in foreign securities, C2's contagion happens mainly through banks and through equity exposures on a concentrated set of conglomerate entities. Concentrated losses notwithstanding, none of the cross-border stress scenarios induced the failure of any entity modelled in the network.

84. Stress scenarios stemming from household and government risk produce the most contagion, while other sectors do not produce failures in the system. Shocks are simulated for each aggregated nonfinancial industrial node, financial intermediation and insurance activities sector, securities firms, trusts, microcredit entities, and nonbank credit institutions as described for aggregated foreign corporates above. For the government, to simulate the effects of a partial default or sharp yield movements, we assumed a loss-given default parameter of 20 percent. For households, the shock is the default of the riskiest quartile of loans. Figure 28 depicts failures induced by these shocks along with those from the failure of disaggregated banks, pension funds, investment funds, and insurer entities. From the shock experiments conducted, the government and household default scenarios produce 16 and 8 entity failures, respectively. The strong government shock induces the failure of 11 entities (8 banks) in the first round, and 5 entities (4 banks) in the second round due to cascade effects from first-round failures. The household shock leads to failures of four entities (four banks) in the first round, two entities (one systemic bank) in the second round, and it is the only shock that lasts a third round with two entities (one bank) failing. In addition, the microcredit shock induces the failure of three banks with large microcredit exposures. Of course, these results should be viewed as the mapping of potential cascade effects from shocks that are

intentionally extreme in nature. Interestingly, no individual NFC industrial sector (other than the residual "other" category) produces failures, indicating the lack of high concentration of bank loan exposures to particular nonfinancial industries.

Figure 27. Colombia: Contagion from Cross-Border Exposures

(contagion index decomposition by affected counterparty sector)



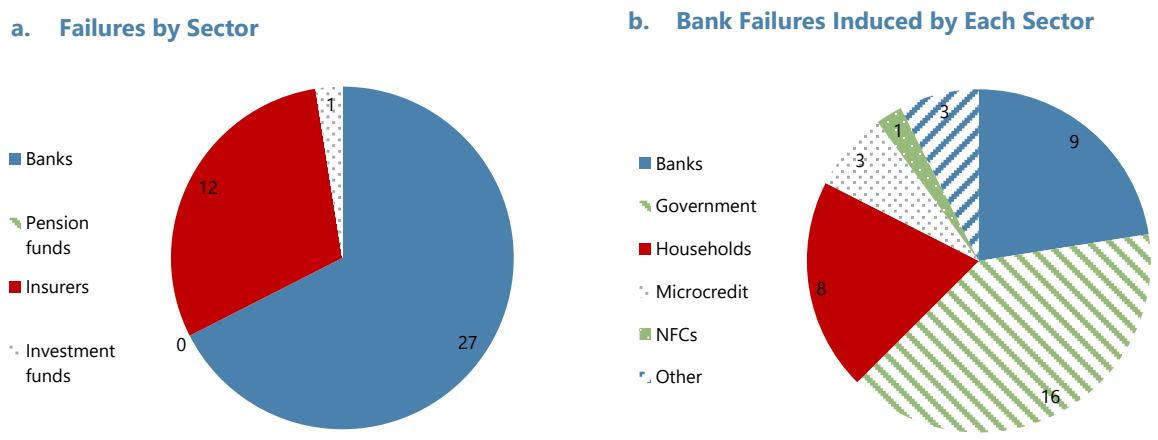
Sources: SFC and IMF staff calculations.

Note: Contagion index from CoMap model calibrated to December 2020 data. Shown for five aggregated foreign categories and a rest of the world (ROW) residual category. The contribution index is decomposed based on capital losses induced on other entities, by sector.

85. There is significant heterogeneity in the composition of network vulnerabilities across banks. As a measure of how vulnerable an entity is to the different shock scenarios conducted, a vulnerability index is computed reflecting aggregate losses of an entity to the failures of other entities in the network divided by a scaled measure of their own capital (see Appendix VI for details). Figure 29 provides a decomposition of this index, showing the composition of vulnerabilities for each entity. This shows significant heterogeneity in both levels and composition between entities—and banks in particular. While some banks (e.g., B12, B14, B23, and B6) are vulnerable to the government, others (e.g., B2, B20) are more vulnerable to the household shocks and certain banks (e.g., B18 and B23) present significant vulnerability to other banks. Importantly, none of the systemic banks appear particularly vulnerable, with only B1 failing to the household shock in the second round after the joint failures of other institutions in the network.

86. The results reveal some vulnerability of insurers and investment funds to idiosyncratic bank failures. Across simulations, there are 12 failures from insurers (mainly 2 firms failing in multiple simulations) and 1 investment fund failure. When decomposing the vulnerability index for the modeled nonbank entities (Figure 29), it is revealed that a significant source of vulnerability comes from their exposure (as creditors) to banks. The high degree of exposures vis-à-vis the banking sector relative to their excess solvency capital makes them vulnerable to idiosyncratic bank failures and, to a lesser degree, government-induced shocks.

Figure 28. Colombia: Failures Induced by Model



Sources: SFC and IMF staff calculations.

Note: Total failures across all simulations from CoMap model. NFCs refer to nonfinancial industries.

87. The correlation of contagion and vulnerability measures reveals entities that merit particular attention. A monitoring tool to detect potential tipping points in the system is to look at the correlation of vulnerabilities and contagion measures. Figure 30 shows how the two measures compared across entities, with three banks (B11, B12, B20) and one insurer (INS2), appearing as both significantly more contagious and vulnerable than the median entity. Their careful monitoring is therefore warranted. Importantly, although systemic banks are more contagious than the median, their lower vulnerability does not make them a particular source of concern.

Caveats

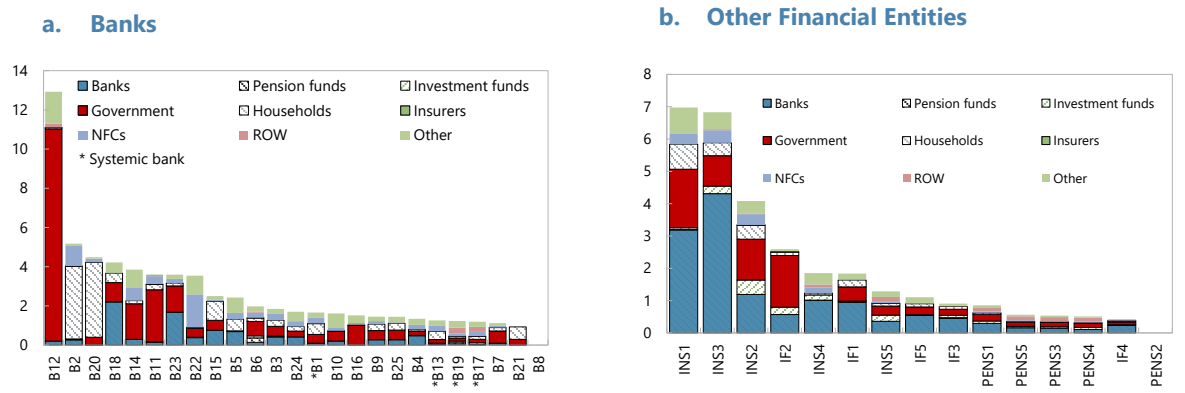
88. Although the Colombian supervisory data is remarkably rich, the analysis above is still subject to modeling and data limitations caveats that need to be taken into account in the interpretation of the results:

- On the modeling side, the CoMap framework does not account for market perceptions around exposure composition. The contagion could potentially spread faster and wider if the model considered additional losses due to a shift in perceptions. On the other hand, by assuming a single solvency threshold and full defaults scenarios, the model can overstate capital losses induced on other entities. Banks could indeed be supported either by policies to remain liquid or solvent, or react to depleting capital basis.

- On the data side, data availability limits the modeling of all contagion channels identified in the network maps above. On the one hand, this exercise explicitly rules out amplification of shocks through NFCs, government entities, households, large investors, trusts, securities firms, nonfinancial corporates, and foreign entities. Given that the structure of conglomerate interconnectivity relies on some of these nonbank entities, we are not modeling all contagion routes either within conglomerate structures or outside of them. Data limitations also prevent us from modeling potential foreign contagion through the funding channel, as detailed information

on foreign holdings of Colombian obligations is limited. Overall, the results should be viewed as the consequences of contagion through a subset of all contagion routes mapped in the network.

Figure 29. Colombia: Vulnerability Index by Entity



Sources: SFC and IMF staff calculations.

Note: Vulnerability index from CoMap model calibrated to December 2020 data. The index is decomposed based on the source of capital losses of each affected entity, classified by sector. ROW refers to Rest of the World nodes. NFCs refer to the combined contributions of nonfinancial industries.

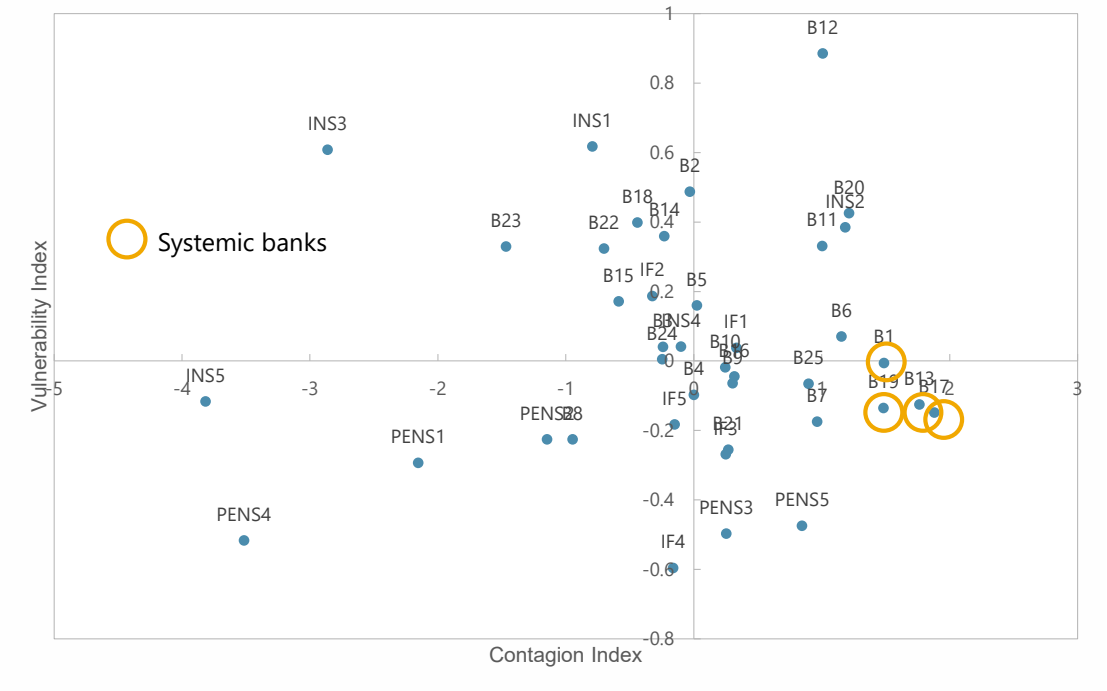
D. Summary and Policy Implications

89. Altogether, the results suggest that contagion risks are concentrated around large domestic exposures to households and government entities, with cross-border risks being relatively contained. Nonetheless, there is some vulnerability to government securities (producing 12 bank failures and 16 entity failures in total) and households (producing 6 bank failures and 8 entities in total). The network structure is such that household stress can cause a systemic bank to fail as the result of second-round effects. There are also some vulnerabilities to insurers, given their concentrated exposure to banks relative to their solvency capitals. The existing link between banks and insurers is one that merits special attention.

90. Although the system is resilient, the financial network's evolving complexity suggested by the analysis calls for the further development of monitoring tools. The network mapping exercise identified multiple potential contagion channels that can spread stress within and across conglomerates through trusts, securities firms, or other financial institutions. Even though some of these contagion channels might be currently small, they have the potential to grow rapidly and have complex implications, so there is need for monitoring. In this vein, there are data coverage and methodology improvements that would bolster the mapping of the network and the assessment of contagion risks. These include the development of network analysis tools that improve on the analysis conducted during this FSAP (e.g., through the incorporation of individual trusts and securities firms in the contagion risk analysis), advancing the identification of foreign creditors on Colombian claims to monitor cross-border funding risks, and gathering further data on the composition of conglomerate subsidiary operations in Central America. The goal should be to bolster EWS while vulnerabilities are building up. While the task of improving data coverage lies with the SFC, the BR's ability to improve network analysis tools depends crucially on having access to

such data. In this respect, the FSAP Technical Note on Macroprudential Framework and Tools recommends improved coordination in systemic risks monitoring and leveraging the BR's technical expertise, including the criticality of access to the necessary data needed to perform those tasks.

Figure 30. Colombia: Contagion and Vulnerability by Entity



Sources: SFC and IMF staff calculations.

Note: Contagiousness and vulnerability indexes, by entity, produced by the CoMap model. Systemic banks as classified by SFC are identified by circles.

CORPORATE RISK ANALYSIS

A. Stylized Facts: Overview of the Corporate Sector Through the Lens of Micro-Data

91. This analysis is conducted using firm-level data on Colombian firms from the Superintendency of Companies (SSC, *Supersociedades*). The analysis uses annual financial (end-December) and income statements of corporates and SMEs for the period 2016–2020, which comprises 21 industries (SIC classification) and represents about 80 percent of GDP. In the database used, the number of corporates ranges between 3,000 and 4,000 per year and between 16,000 and 23,000 per year for SMEs (Table 8). For the period of analysis, about 60 percent of the total number of corporates appear for four or five years compared to 40 percent in the case of SMEs. Moreover, above 40 percent of SMEs appear only one or two years. The latter reflects the known characteristic of a higher degree of market entry and exit from SMEs relative to corporates. The sample entities capture altogether 38 percent (25 percent by corporates and 13 percent by SMEs) of gross loan portfolio of banks.

Table 9. Colombia: Description of Firm-Level Data

Number of firms in database			Percentage of firms that appear across the sample period		
Year	Corporates	SMEs	Years	Corporates	SMEs
2016	3,469	19,681	5 years	56	33
2017	3,3,97	16,410	4 years	13	7
2018	3,556	15,938	3 years	8	8
2019	3,706	21,638	2 years	12	28
2020	3,346	22,720	1 year[1]	7	16

Source: Supersociedades; IMF staff calculations.

[1] Excluding 2020.

Note: The SSC uses a definition based on financial accounting (IFRS or NIIF in Colombia) to classify the firms as corporates (plenas) or SMEs (pymes).

92. Corporates are mainly concentrated in similar sectors in terms of total assets and numbers but with some differences for SMEs. In terms of numbers, corporates are concentrated in the sectors of industry, wholesale and retail, and construction (Figure 31). However, in terms of assets, corporates are concentrated in the sectors of industry, wholesale and retail, other financial services, and construction. Regarding SMEs, in terms of numbers, they are concentrated in the sectors of wholesale and retail, real estate activities, industry, and construction. In terms of assets, SMEs are mainly concentrated in the sectors of construction and real estate activities.

93. Both corporates and SMEs exhibited a relatively stable level of liquidity, leverage, solvency, and profitability during the pre-pandemic years (2017–2019). Moreover, the median firm showed increases in liquidity and profitability in 2019, which was in tandem with economic activity, and the leverage ratios (debt-to-assets and debt-to-equity) showed a slight decline (Figure 32).

94. Regarding the interest coverage ratio (ICR), while above 1, corporates have exhibited a lower ratio compared to SMEs (Figure 33). However, corporates appear to have exhibited a higher debt share associated with an ICR below 1, which showed a slight decline in 2019. With respect to the cash available ratio,[6] which proxies for external (to the firm) borrowing needs, it was also relatively stable before the pandemic. The share of debt of firms with a cash available ratio below zero has shown a relative stability between 2017 and 2019. For the group of corporates, before the pandemic, the sectors with the largest debt shares of firms with an ICR below 1 were real estate, wholesale and retail, other financial services, and energy. For SMEs, the sectors were transport and energy.

95. The pandemic shock worsened the indicators of repayment capacity and profitability for both corporates and SMEs in 2020 (Figure 33). Due to the nature of the shock, both corporates and SMEs accumulated more cash, which pushed up their cash available ratio. Leverage

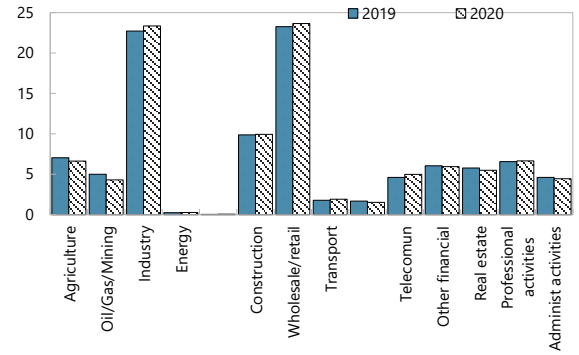
[6] This ratio is defined as cash and equivalent plus receivables minus short-term liabilities (excluding short-term debt). Data limitations did not allow to exclude the portion of long-term debt paid in the current year.

indicators (debt-to-assets and debt-to-equity) exhibited a slight decline. Profitability (return on assets and return on equity) showed a decline due to the impact on firm revenues.[7] At the sectoral level, some financial indicators (e.g., repayment capacity and profitability) showed a deterioration across many sectors, especially the ones related to the services sector.[8] At the same time, the debt share of firms with an ICR of less than 1 increased across most economic sectors for both corporates and SMEs.

Figure 31. Colombia: Distribution of Firms by Sector

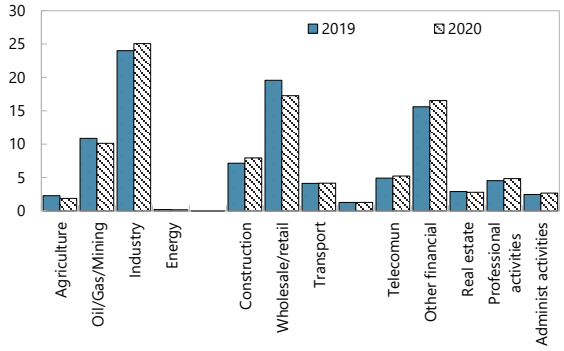
a. Corporates: Proportion by Economic Sectors

(in percent of total number of firms)



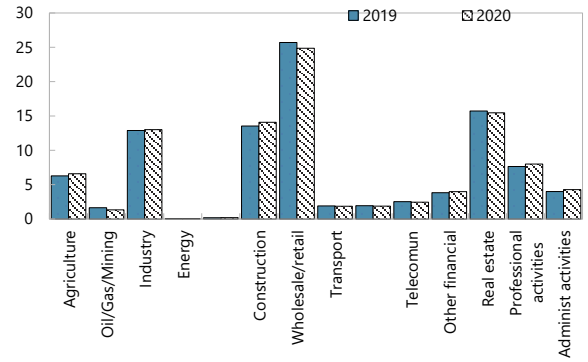
b. Corporates: Proportion by Economic Sectors

(in percent of total assets of firms)



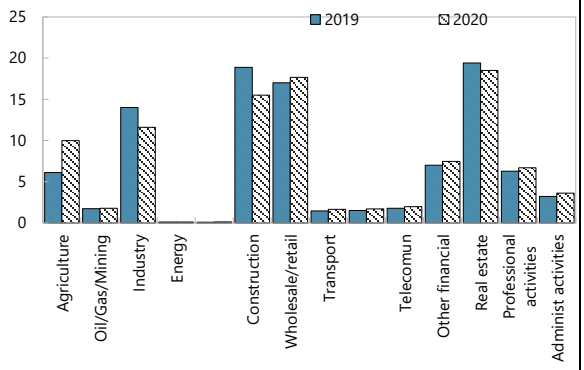
c. SMEs: Proportion by Economic Sectors

(in percent of total number of firms)



d. SMEs: Proportion by Economic Sectors

(in percent of total assets of firms)



Sources: Supersociedades and IMF staff calculations.

[7] Data limitations do not allow us to distinguish firms that were able to obtain COVID-related support measures.

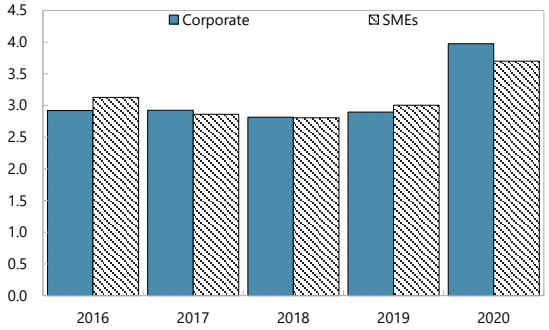
[8] For the oil sector, besides the effects of the pandemic, the ratios also exhibit the effects of the sharp oil price decline (dual shock).

Figure 32. Colombia: Firms' Financial Ratios

Firms increased their liquidity positions in 2020…

Cash-to-Total Assets Ratio

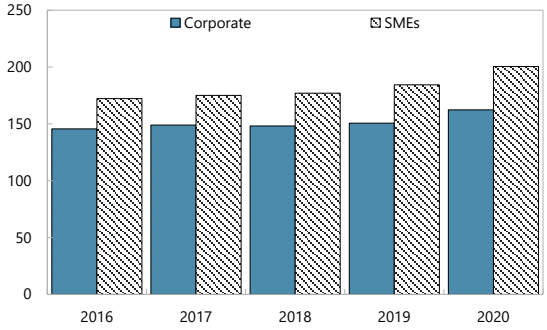
(Median of the distribution; in percent)



… given the nature of the shock.

Current Assets-to-Current Liabilities Ratio

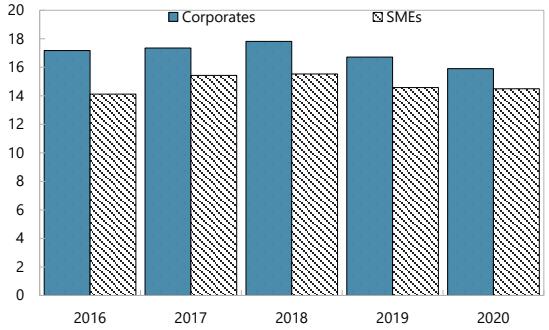
(Median of the distribution; in perecent)



A slight decline of the debt-to-assets ratio in 2020 for corporates but almost similar levels for SMEs

Debt-to-Assets Ratio

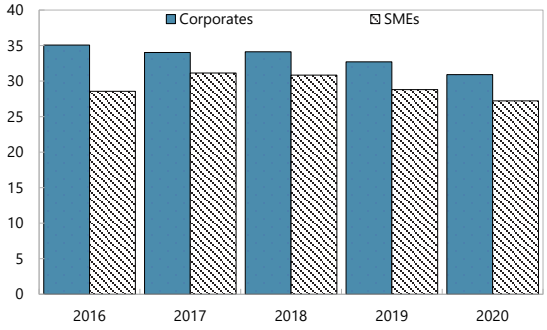
(Median of the distribution; in percent)



A slight decline of the debt-to-equity ratio for both corporates and SMEs

Debt-to-Equity Ratio

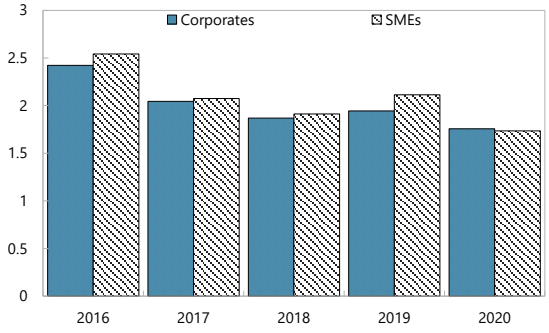
(In percent. Median of the distribution after exlcuding extreme values)



Return-on-assets declined in 2020 for both groups…

ROA

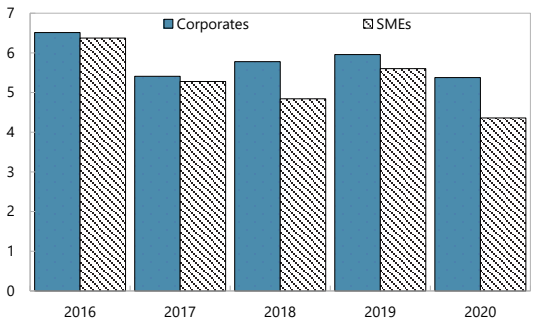
(Median of the distribution; in percent)



… as it was also the case for return-on-equity

ROE

(Median of the distribution; in percent)

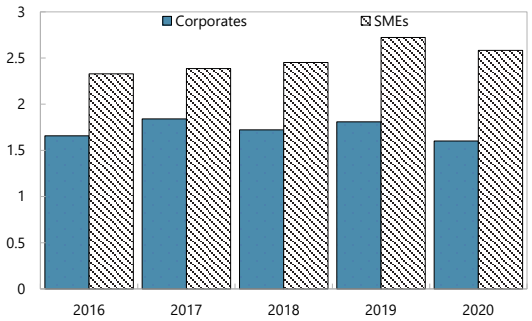


Source: Supersociedades and IMF staff calculations.

Figure 33. Colombia: Indicators of Repayment Capacity and Cash Available

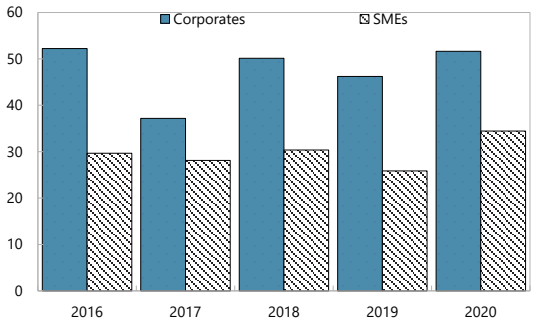
SMEs have exhibited a higher ICR ratio than corporates.

ICR
(In percent. Median of the distribution after excluding extreme values)



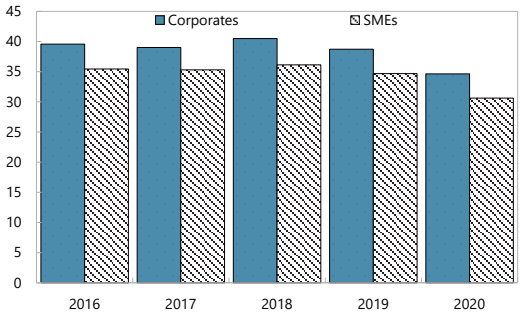
However, corporates have exhibited a higher debt share associated with an ICR<1.

Debt Share of Firms with ICR<1
(In percent. Shares calculated after excluding extreme values of ICR)



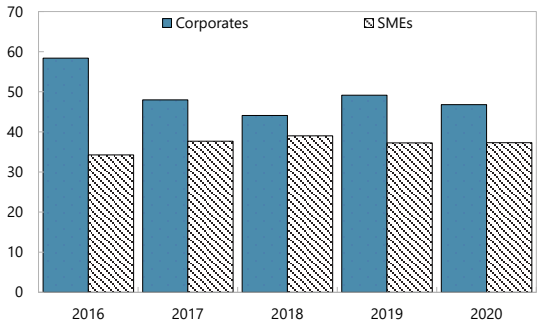
Corporates have exhibited a slightly higher negative cash available ratio compared to SMEs…

Share of Firms with Cash Available Ratio<0
(In percent; shares calculated after excluding extreme values)



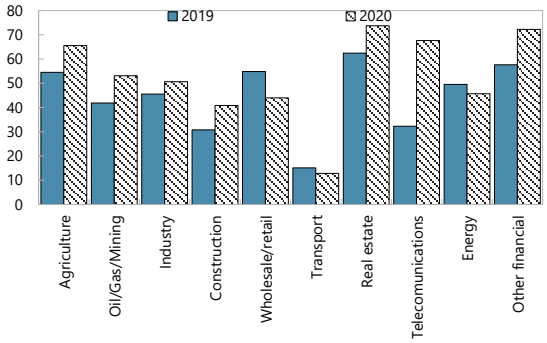
…and a higher debt share.

Debt Share of Firms with Cash Available Ratio<0
(In percent; shares calculated after excluding extreme values)



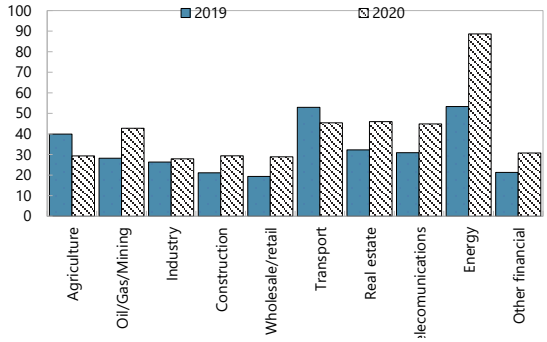
Debt share increased in most sectors for corporates…

Debt Share of Firms with ICR<1: Corporates
(By economic sector, in percent)



…as well as for SMEs.

Debt Share of Firms with ICR<1: SMEs
(By economic sector; in percent)



Sources: Supersociedades and IMF staff calculations.

Table 10. Colombia: Change in Indicators from 2019 to 2020

Corporates: Change of the indicator between 2020 and 2019

	Cash	ICR	Debt-to-assets	ROA	ROE
Agriculture	0.3	0.1	1.8	0.6	1.1
Oil/Gas/Mining	-0.1	-2.6	0.4	-1.6	-4.8
Industry	1.6	-0.1	-1.6	0.0	-0.4
Construction	-0.5	-0.5	0.0	-0.3	-0.7
Wholesale/retail	2.0	-0.1	-1.9	0.1	0.0
Transport	4.6	0.8	-0.9	0.5	-2.4
Real estate	0.3	-0.3	-1.3	0.2	-0.1
Telecomunications	3.0	-0.8	-0.8	-0.9	-6.9
Energy	-0.7	-0.3	4.9	-3.0	-2.6
Other financial	0.6	-1.0	1.5	-0.7	-0.4

Source: Supersociedades; IMF staff calculations.

SMEs: Change of the indicator between 2020 and 2019

	Cash	ICR	Debt-to-assets	ROA	ROE
Agriculture	0.6	0.3	-0.4	0.3	0.4
Oil/Gas/Mining	0.2	-1.1	2.0	-0.6	-1.1
Industry	1.1	-0.1	0.3	-0.4	-1.2
Construction	0.5	0.1	-0.3	-0.3	-1.4
Wholesale/retail	1.4	-0.1	-0.2	-0.1	-0.7
Transport	1.4	-1.0	-0.6	-0.7	-1.8
Real estate	0.2	-0.5	0.4	-0.3	-0.6
Telecomunications	1.1	0.8	0.4	-0.7	-1.7
Energy	4.2	1.1	5.7	-1.2	-0.7
Other financial	0.3	-1.1	-0.8	-0.3	-0.7

Source: Supersociedades; IMF staff calculations.

B. Stress Test: Impact from the Adverse Scenario

96. The analysis uses a dynamic scenario-based analysis to assess the impact of an adverse scenario.[9] The methodology developed by Tressel and Ding (2021, forthcoming) focuses on a set of firm-level indicators to assess the ability to service debt (ICR) and external (to the firm) borrowing needs, based on the cash balance (cash available ratio), given shocks to macrofinancial variables such as GDP growth and an index of financial conditions (see Annex I). The adverse scenario implies a moderate two-year recession and a two-year increase of the index of financial conditions.[10]

97. Profitability and leverage measures are key variables that explain the ability to service debt (ICR) and external (to the firm) borrowing needs. The probability that a firm is unable to pay for its interest expenses from earnings is negatively correlated with profitability, and is positively correlated with leverage, as expected. The likelihood that a firm does not generate sufficient earnings to pay for interest expenses is negatively correlated with GDP growth. With respect to the probability of the cash available ratio to be below zero, the sign of the coefficients for profitability and leverage are as expected. Higher profits generate higher retained earnings, everything else equal, and therefore higher cash buffers, while higher leverage being associated with higher interest expenses may result in lower cash buffers. Also, in this case, the probability is negatively correlated with GDP growth (see Appendix VII).

98. Under the adverse scenario, there is an increase in the share of firms with lower repayment capacity (ICR<1). By the second year of the adverse scenario, the share of corporates with an ICR of less than 1 increases by 3 percentage points (from 39 percent to 42 percent) to then decline by the third year of the shock as GDP growth and financial conditions recover. In the case of SMEs, the share of firms with an ICR of less than 1 also increases by 3 percentage points (from 25 percent to 28 percent) and then it shows a decline by the third year of the adverse scenario. For corporates and SMEs, in 2020, the share increases by about 5 percentage points. However, that

[9] The adverse scenario used of this analysis is the same as the one use for the bank solvency stress test.

[10] The calculation of the financial conditions index follows the methodology used in the Global Financial Stability Report (IMF, 2017). For Colombia, the index uses the following variables: Spread of local currency sovereign debt, spread of US dollar sovereign debt, spread of US dollar corporate debt, equity prices, exchange rate, and house prices.

outcome included the implementation of pandemic-related support policies. The impacts from the adverse scenario do not account for the potential implementation of support policies that could ameliorate the negative impact on firms (Figure 34).

99. The share of firms with potential borrowing needs also increase under the adverse scenario. For both corporates and SMEs, by the second year of the adverse scenario, the share of firms with a negative cash available ratio increases by about 9 percentage points to 45 percent and 42 percent, respectively. For corporates and SMEs, in 2020, the share declined between 4 and 5 percentage points. The latter is associated with the nature of the shock where firms increase their cash positions at the beginning of the pandemic. However, the adverse scenario resembles a more "typical" or "usual" recession. For this reason, the shares increase with the decline in GDP growth. As mentioned above, these impacts do not account for the potential implementation of support measures to firms (Figure 34).

C. Conclusions

100. The firm-level analysis suggests that the authorities need to continue monitoring the nonfinancial corporate sector, especially the services sector, to identify potential pockets of vulnerability. An important element for such monitoring is the ongoing work on early warnings ("Alerta Temprana"), which could be broadened, to increase the number of firms in the sample.[11] In addition, continued assessment of firms in sectors that are benefitting from the strong economic rebound is also warranted to identify potential firms for which the 2020 shock would not be temporary in nature.

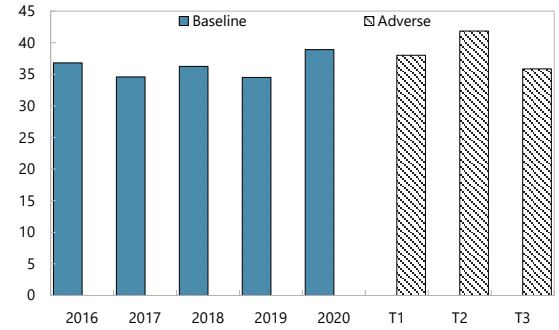
101. An assessment of whether the information provided by early warning could help inform the preparation of potential contingency (policy) plans by supervisory authorities is warranted, given the sensitivity of key firms' indicators as their repayment capacity, cash available ratio, and solvency to adverse shocks. To the extent that is legally feasible, sharing (part of) the information provided by the early warning analysis with other supervisory institutions would be useful to complement their monitoring efforts and receive feedback that could also help to further strengthen the early warning exercise.

[11] Alerta Temprana is a newly implemented project by the SSC to monitor risk levels of firms through the use of descriptive and predictive analytics based on granular firm-level data.

Figure 34. Colombia: Impact of the Adverse Scenario

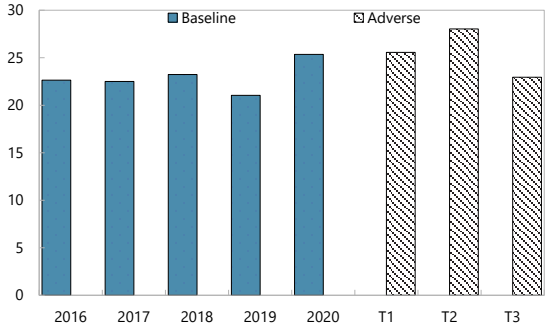
a. ICR<1: Corporates

(share of firms; in percent)



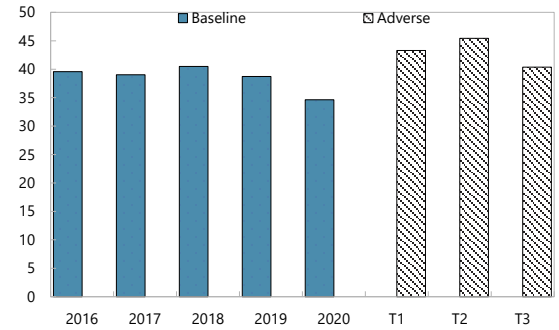
b. ICR<1: SMEs

(share of firms; in percent)



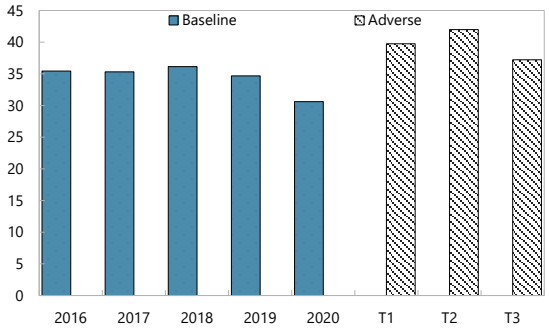
c. Cash Available<0: Corporates

(share of firms; in percent)



d. Cash Available<0: SMEs

(share of firms; in percent)



Source: Supersociedades and IMF staff calculations.

Appendix I. Risk Assessment Matrix[1]

Nature (Source) of Main Threats	Overall Level of Concern	
	Likelihood of Realization of Threat in the Next 1–3 Years *(high, medium, or low)*	**Expected Impact on Financial Stability if Threat is Realized** *(high, medium, or low)*
Uncontrolled Covid-19 local outbreaks and global resurgence of the pandemic	**High/Medium** • Outbreaks of lethal and highly contagious Covid-19 variants lead to subpar/volatile growth, with increased divergence across countries. Rapidly increasing hospitalizations and deaths, due to low vaccination rates or caused by vaccine-resistant variants force new lockdowns and increase uncertainty about the course of the pandemic. • Policies to cushion the economic impact are prematurely withdrawn or for many EMDEs, constrained by lack of policy space. In addition to declines in external demand, a reassessment of growth prospects triggers capital outflows, financial tightening, currency depreciations, and debt distress in some EMDEs, with spillovers to AEs, leading to growing divergence of economic recovery paths.	**High** • Renewed or more stringent containment efforts and resulting uncertainty jeopardize economic recovery, reducing growth, and straining government resources. • With limited policy space, further extension of relief initiatives to support the economy is either impossible or insufficient, triggering capital outflows, depreciation, and inflation pressures. • Household and corporate vulnerabilities worsen, affecting banks' asset quality.
De-anchoring of U.S. inflation expectations and/or advanced European economies	**Medium** • A fast recovery in demand amid a lagging supply-side response leads to a rapid de-anchoring of inflation expectations, which prompts central banks to tighten policies abruptly. • The resulting sharp tightening of global financial conditions and spiking risk premia lead to currency depreciations, asset market sell-offs, bankruptcies, sovereign defaults, and knock-on effects (e.g., lower commodity prices and possible contagion across EMDEs).	**High** • Risk asset prices fall sharply and volatility spikes, leading to significant losses in major NBFIs. • Higher risk premia generate financing difficulties for leveraged firms (including those operating in unviable activities) and households, and a wave of bankruptcies erode banks' capital buffers. • Increased cost of sovereign financing further raises the stakes for continuing the support programs to mitigate the impact of pandemic on the economy at the expense of fiscal sustainability.
Widespread social	**Medium** • Social tensions erupt as a withdrawal of pandemic-related policy support results in	**Medium** • Rising unemployment and re-imposition of lockdown measures could increase public

[1] The Risk Assessment Matrix (RAM) shows events that could materially alter the baseline path (the scenario most likely to materialize in the view of IMF staff). The relative likelihood is the staff's subjective assessment of the risks surrounding the baseline ("low" is meant to indicate a probability below 10 percent, "medium" a probability between 10 and 30 percent, and "high" a probability between 30 percent and 50 percent). Non-mutually exclusive risks may interact and materialize jointly.

Nature (Source) of Main Threats	Overall Level of Concern	
	Likelihood of Realization of Threat in the Next 1–3 Years *(high, medium, or low)*	**Expected Impact on Financial Stability if Threat is Realized** *(high, medium, or low)*
discontent and political instability, including from the region	unemployment, and amid increasing prices of essentials, hurts vulnerable groups (often exacerbating pre-existing inequities). • Spillovers from regional social tensions reduce capital inflows to Latin America for a sustained period.	discontent, amplifying the negative impacts of the pandemic on labor markets and firms. • Economic activity is disrupted. Growing political polarization and instability weaken policymaking and confidence. • Reversals of capital flows, exchange rate depreciation and fragile recovery would adversely impact banking system through rise in funding costs, liquidity shortfalls, and declining asset quality.
Disorderly transformations	**Medium** • Covid-19 triggers structural transformations, albeit facing labor market rigidities, debt overhangs, and inadequate bankruptcy resolution frameworks. • This, coupled with a withdrawal of Covid-19-related policy support, undermines growth prospects, and increases unemployment, with adverse social/political consequences. Significant uptake of relief initiatives by borrowers indicates reliance on these temporary measures and make policy exit risky. • Financial conglomerates' sizeable cross-country exposures similarly impacted by scarring and policy reversals in host states.	**High** • Weak economic activity and high unemployment as well as sizeable labor force exit hinder repayment capacity when support programs are withdrawn. • Banks face a surge in NPLs, especially those exposed more to vulnerable sectors, eroding bank capital. • Profitability and solvency of banks come under significant distress, tightening lending conditions and making it difficult to support the economic recovery. • Corporate credit spreads widen further. Regional spillovers further weaken the balance sheet of financial conglomerates.
Increasing fiscal pressures and/or loss of fiscal credibility	**High** • Lack of confidence about structural and fiscal sustainability and weakening of debt profile leads to further downgrades triggering a major sell-off event for sovereign bonds and Investment Grade corporates. **Medium** • Shortfalls in mobilizing revenue leads to large cuts in public investment and social spending, adversely affecting growth and poverty reduction.	**High** • Stress in public finances spill over into the financial system given the strong home bias. • Banks are negatively impacted through higher funding costs and valuation losses on government debt holdings. • Valuation losses on other financial institutions' assets, in particular pension funds.

Nature (Source) of Main Threats	Overall Level of Concern	
	Likelihood of Realization of Threat in the Next 1–3 Years *(high, medium, or low)*	**Expected Impact on Financial Stability if Threat is Realized** *(high, medium, or low)*
Build-up of climate-related risks	**Medium/Low** • As the effects of climate change become more visible and frequent, stronger policy responses are needed for transitioning towards a low-carbon economy (carbon prices/taxes, change in subsidies, etc.).	**Medium** • Increase in carbon tax affects profits and balance sheets of nonfinancial corporates. • Banks are negatively affected since the asset quality suffers (higher NPLs) due to financial health of corporate borrowers.

Appendix II. Stress Test Matrix

Domain	Top-Down by FSAP Team	
Banking Sector: Solvency Risk		
1. Institutional perimeter	Institutions included	• The top 12 commercial and retail banks.
	Market share	• Nearly 93.8 percent of total assets in the banking system.
	Data and baseline date	• Cut-off date: June 2021. • SFC bank-by-bank supervisory data including credit risk-sensitive exposures, market risk-sensitive exposures, and interest rate sensitive assets and liabilities, as well as historical information on NPLs by portfolio, and details of lending and funding rates. • Other market and publicly available data. • Scope of consolidation: banking activities on an individual basis.
2. Channels of risk propagation	Methodology	• FSAP team satellite models and methodologies. • Balance-sheet approach with quasi-static balance sheet assumption. • All banks follow the standardized approach.
	Satellite models for macrofinancial linkages	• FSAP team's own model for credit losses from bank lending portfolios. NPL models for each loan segment (commercial, consumer, and mortgage) with bank-specific fixed effects. • Models for funding costs with bank-specific fixed effects.
	Stress test horizon	• Three years (mid-2021-mid-2024).
3. Tail shocks	Scenario analysis	• Macrofinancial scenario analysis. • Baseline scenario based on the projections of October 2021 WEO. • The adverse stress scenario is designed as a deviation from baseline forecasts, triggered by a series of global and domestic shocks, capturing the key risks in the RAM.
	Sensitivity analysis	• Single-factor sensitivity test for concentrations risk, where the banks' top single, five and ten largest exposures are assumed to fail simultaneously.
4. Risks and buffers	Risks/factors assessed (how each element is derived, assumptions)	• Credit losses from lending: modeled NPLs for three different portfolios (commercial, consumer, and mortgage) at a single geography level. Estimated panel regression coefficients with fixed effects using the Bayesian Model Averaging (BMA) approach subject to sign constraints. Provisioning ratios for the NPLs were calculated based on the historical data for each portfolio segment, where specific procyclical and countercyclical were treated uniformly due to data limitations. Therefore, effectively, the team took the conservative approach by not treating countercyclical provisions as additional buffer in the FSAP stress-test exercise. • Market risk: losses due to changes in market variables: risk-free interest rates, exchange rate and equity prices, making no allowance for macro hedges. For sovereign and corporate debt securities (under AFS or HFT), a modified-duration formula was used to revalue exposure as function of their residual duration and the relevant bond yield assumptions under the scenarios. Foreign

Domain	Top-Down by FSAP Team	
		exchange risk and equity based on respective net open positions and the paths of equity index and exchange rate under the scenarios. • Non-interest income: the impact of funding and lending interest rate shocks on net interest income is estimated by measuring the gap between interest sensitive assets and liabilities by making use time-to-repricing buckets for different asset and liability segments. Effective interest rates were estimated using satellite models and pass-through assumptions. • Other P&L components: Net fee and commission income, other non-interest income and non-interest expenses projected in line with the growth of each bank's balance sheet. Extraordinary income and losses were assumed not to incur during the projection period. • Banks' indirect exposures through subsidiaries: shocked by 50 percent and 25 percent in the first and second years, respectively, of the adverse scenario (as data limitations didn't allow for modeling various risks on a consolidated basis, the exercise captured shocks on the income of their subsidiaries), • Income tax: calibrated as the median of historical tax expense ratios per bank. • Counterparty concentration risk: losses from simultaneous failure of top 1, 5, and 10 largest single-counterparty exposures.
	Behavioral adjustments	• Quasi-static balance sheet assumption: The approach assumes that balance sheet grows proportionally with nominal GDP under baseline and adverse scenarios, however, with a lower zero-bound (no ex ante deleveraging is allowed). • Dividends can only be paid out by banks that remain adequately capitalized and have positive profits. • The impact of new business repricing was consequently calculated under the assumption that maturing instruments were replaced by identical new instruments (of the same segment and with the same initial maturity) but at reference and margin rates implied by the scenario and the pass-through assumptions. • The stress test did not take into account loan write-offs and cures due to data unavailability.
5. Regulatory and market-based standards and parameters	Calibration of risk parameters	• Based on credit models estimated by IMF staff. • Given that all banks are the standardized regulatory framework, NPL ratios were projected using panel regression techniques.
	Regulatory/ accounting and market-based standards	• The hurdle rate based on the current capital adequacy framework accounting for the phase-in of several components during the projection period. • A minimum total CAR of 9 percent applies. As for the tier 1 (T1) ratio, the hurdle rate is currently 4.9 percent (in 2021) and is gradually increased to 6 percent by January 2024 until full

Domain	Top-Down by FSAP Team	
		convergence. Also, a minimum leverage ratio (tier 1 capital to total assets) of 3 percent applies throughout. • The capital conservation buffer (CCoB) and systemically important bank buffer (SIB) would be phased in gradually to reach 1.5 percent and 1 percent of RWAs by January 2024. The capital projection path also incorporates gradual phase-out of eligible capital instruments from additional tier 2, which has the identical impact under both baseline and adverse scenarios.
6. Reporting format for results	Output presentation	• Capital ratio decline of the banking system. • Number of banks and the percentage of banking assets (or GDP) in the system that fall below a hurdle rate. • Decomposition of the reduction in capital ratio in terms of drivers (credit risk, market risk, interest rate risk, etc.).
Banking Sector: Liquidity Risk		
1. Institutional perimeter	Institutions included	• The top 12 commercial and retail banks.
	Market share	• Nearly 93.8 percent of total assets in the banking system.
	Debt and baseline date	• Baseline date: June 2021. Data for December 2019, June 2020 and December 2020 will be used for comparing against before and during COVID-19 crisis. • Source: Data compiled based on national reporting templates 458, 531, and 238, that are regulatory returns monitoring the LCR and the NSFR, additional off-balance sheet data capturing balance of credit/liquidity facilities. Additional data compiled based on reporting template 474 covering the biggest depositors. • Scope of consolidation: individual bank basis.
2. Channels of risk propagation	Methodology	• The exercise is based on LCR-based and NSFR-based tests, and cash-flow analysis. • The LCR-based test is in line with IRL—the SFR's implementation of Basel's LCR—on individual basis and for all currencies combined. It might be complimented by analysis based on CB's liquidity metric (IEI) that focuses on exchange rate risk at individual level. • A set of scenarios will be used to produce stressed LCR, exploring retail and wholesale funding shocks, complemented large depositors' concentration analysis. • Cashflow analysis will be conducted based on data corrected by the SFC for IRL for the period up-to 90 days on individual basis and for all currencies combined. Scenarios consisting of run-off and roll-over rates, liquid assets haircuts will be implemented. • NSFR requirements are gradually implemented by the authorities with 100 percent limit for banks with assets greater than 2 percent of total system assets and 80 percent limit for other institutions with credit portfolio being primary activity by March 31, 2022, and informative for the rest of institutions. NSFR-based test will rely on national regulatory parameters, on individual basis and for all currencies combined, with the hurdle at 100 percent.

Domain	Top-Down by FSAP Team	
3. Risks and buffers	Risks	• Funding liquidity. • Market liquidity. • Depositor concentration risk, i.e., withdrawal of largest depositors.
	Buffer	• The counterbalancing capacity, including liquidity obtained from markets and/or regular central bank facilities (excluding the central bank's emergency liquidity assistance (ELA) or other temporary measures). • Expected cash inflows are also included in the cashflow based and LCR-based analysis.
4. Tail shocks	Scenario analysis	• Stress scenarios on liability outflows reflecting retail outflows, wholesale funding outflows, and large depositors' withdrawals, and scenarios on liquid assets shock.
5. Regulatory and market-based standards and parameters	Regulatory standards	• LCR per Basel III—the hurdle at 100 percent. • NSFR per Basel III—the hurdle at 100 percent. • Cashflow analysis—a non-negative net cash balance, where the balance reflects net funding outflows and counterbalancing capacity.
	Calibration of risk parameters	• Run-off rates, roll-over rates, and asset haircuts are calibrated based on historical events, empirical evidence, and IMF expert judgment.
6. Reporting format for results	Output presentation	• Distribution of liquidity positions by groups of banks and aggregated (system wide). • Number of institutions with LCR/NSFR below 100 percent and/or negative net cash balance • Amount of liquidity shortfalls
Banking Sector: Interconnectedness Analysis and Contagion Risk		
1. Institutional perimeter	Institutions included	Active nodes: • All 25 banks (DSIBs and non-DSIBs); • Top five pension funds; • Top five insurance companies; • Top five investment funds; Passive nodes: • Residual pension funds aggregated; • Residual insurance companies aggregated; • Residual investment funds aggregated; • Other financial sectors aggregated: trusts, securities firms, and other financial intermediaries; • Nonfinancial corporates aggregated at industry level (20 industries); • Other aggregated sectors: government (Colombia), households (Colombia), top five countries aggregated at country level, rest of the world foreign counterparts
	Market share	• Active nodes account for 100 percent of total assets in the banking system.
	Data and baseline date	• Date: December 2020. • Source: supervisory data on bilateral linkages within the banking system and with other entities to construct a large-exposures matrix,

Domain	Top-Down by FSAP Team	
		and solvency and liquidity related reports to calibrate model parameters. • Scope of consolidation: active nodes (banks and other financial entities) on individual basis. Sector residuals and nonfinancial entities are aggregated at sector level. However, exposures among members of a conglomerate are mapped in the network, allowing for the analysis of intra-conglomerate linkages.
2. Channels of risk Propagation	Methodology	• Application of CoMap framework (Covi, Gorpe and Kok, 2019), with extensions to model contagion through nonbank financial entities.
	Risks/factors assessed	• Credit default channel: impact of an entity defaulting on its obligations to other entities. As a result, a creditor entity incurs losses on a share of its claims depending on the nature and counterparty of its exposures. Exposure-specific loss-given default rates reflect the precise risk mitigation and collateralization that an entity has accounted for in its claims vis-à-vis each counterparty. • Funding shock and liquidity dynamics: impact of a funding withdrawal or non-rolling over by a failed entity. An entity that is facing such a funding shock can meet immediate liquidity needs by using its surplus high-quality liquid assets as collateral to borrow. Once depleted, it must deleverage by selling marketable securities at discount incurring haircut losses. • Cascading defaults due to insolvency and/or illiquidity failures. Insolvency default happens when an entity's solvency threshold is compromised and illiquidity-driven default when an entity runs out of marketable assets that can be sold.
3. Tail shocks	Scenario analysis	• Idiosyncratic shocks: hypothetical failure of each entity as a potential trigger event. Exercise comprises as many simulations as there are nodes in the network, where each simulation considers the hypothetical failure of a single node.
4. Reporting format for results	Output presentation	• Number of cascade defaults and amplification effects. • Contagion losses induced (contagion index) and experienced (vulnerability index) by each node. • Decomposition of losses by entity types.
Nonfinancial Corporate Stress Test		
1. Institutional perimeter	Institutions included	• 26,066 firms in cut-off year: 3,346 corporates and 22,720 SMEs. • Covers 21 industries.
	Market share	• Represent about 80 percent of GDP.
	Data and baseline date	• Cut-off date: December 2020. • Source: firm-level time-series balance sheet and income statement data from the Superintendency of Companies (SS, Supersociedades). • Scope of consolidation: individual reporting basis (unconsolidated).
2. Channels of risk Propagation	Methodology	• Following the methodology developed by Tressel and Ding (2021) in Global Corporate Stress Test: COVID-19 Impact and Medium-term Implications (forthcoming). • Assessment of (i) the ability to service debt (ICR); (ii) external borrowing needs based on cash balance (cash available); and (iii) solvency position.

Domain	Top-Down by FSAP Team	
	Models	• Dynamic regressions for return on assets (ROA) and leverage • Probit models for cash balance (cash available) and ICR.
	Stress test horizon	• Three years (mid-2021-mid-2024).
3. Tail shocks	Scenario analysis	• Macrofinancial scenario analysis: the same scenario as the bank solvency stress-test. • Baseline scenario based on the projections of October 2021 WEO. • The adverse stress scenario is designed as a deviation from baseline forecasts, triggered by a series of global and domestic shocks, capturing the key risks in the RAM.
4. Reporting format for results	Output presentation	• Share of firms with lower repayment capacity (ICR<1) • Share of firms with potential borrowing needs (Cash Available<0)

Appendix III. Technical Details of the Stress Test Macro Scenario Calibration

1. **The adverse scenario projections were simulated using the IMF's Global Macrofinancial Model (GFM).** This dynamic stochastic general equilibrium model of the world economy disaggregated into forty national economies features a range of nominal and real rigidities, extensive macrofinancial linkages, and diverse spillover transmission channels (Vitek. 2018).[1] Colombia is included in the sample of advanced and emerging market economies under consideration. GFM was used to simulate global shocks and their transmission to Colombia in tandem with Colombia-specific shocks. The parameterization of the GFM is based on a mix of calibration and estimation. In particular, subsets of the parameters and variables of the GFM are jointly estimated by full information maximum likelihood, conditional on calibrated values of its other parameters and observed values of its other variables.

2. **The adverse scenario was designed to reflect a deterioration of key macroeconomic factors in Colombia and was benchmarked against historic data.** The projected path of Colombia's GDP growth was found to be very severe with respect to the baseline scenario—albeit consistent with other FSAPs—with an average real GDP growth of **0.5** percent per annum over 2021Q3–2023Q3. It is characterized by GDP contraction continuing into the second year before phasing into near-full recovery by end-2023 with GDP growth -1.2 percent, -1.3 percent, and 4 percent in the first, second, and third years of the horizon, respectively (see Figure 1.a). The projections under the adverse scenario are also expressed in deviations from the baseline. The cumulative decline of GDP relative to the baseline over three (two) years would be about **11** (11.3) percentage points, equivalent to a **1.8** (2.5) standard deviation shock taking the 1995–2020 period as the benchmark for calculations (see Figure 1.b).[2] This scenario reflects realization of shocks that are very severe in relation to the baseline scenario, which accounts for a significant bounce-back from the 2020 recession induced by Covid-19. The sharp deviation from this baseline in the first year would require a shock similar in nature to the one experienced at the height of the Covid-19 outbreak last year, albeit to a lesser degree. Effectively, under the adverse scenario, the recession would be more prolonged due to the continuing outbreaks, social unrest and tightening of financial conditions. See main text for projections of other macro variables. In terms of contribution of global vis-à-vis domestic shocks to the deviation from baseline, the global factors have a slightly heavier weight.

3. **The adverse scenario for Colombia, while more severe than the scenarios considered in the 2021 stress test exercise conducted by the Colombian authorities, is consistent with FSAP protocols**. The 2.5 standard deviation shock in the first two years is significantly higher than the 1.6 standard deviation shock applied in the June 2021 BR stress test. The FSAP adverse scenario

[1] Vitek, Francis. (2018). The Global Macrofinancial Model. IMF Working Paper 18/81, International Monetary Fund.

[2] Utilization of the entire 1995–2020 period for the calculation of the standard deviation was aimed at capturing the full economic impact of the twin crisis, which was the last recession in Colombia prior to Covid, that was also followed by a slower recovery.

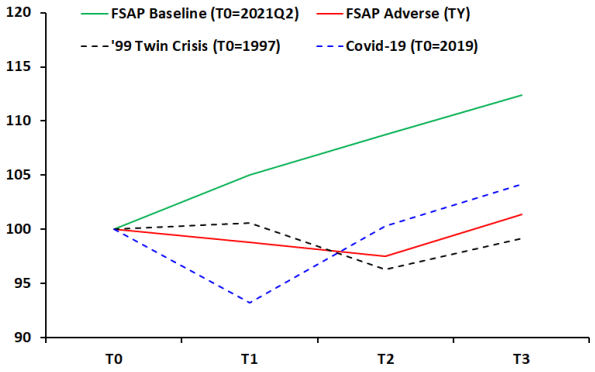
reflects the cumulative impact from the realization of downside risks to the baseline, and is within the range of standard deviation shocks used in other countries (Figure 4). While this deviation is in the higher range of shocks used in FSAPs and historically unprecedented for Colombia, several other concurrent or past FSAPs implemented similar sharp downturn scenarios. The state-dependent nature of adverse scenario can explain larger deviations in light of relatively stronger WEO baseline projections.

4. **Historical data formed the basis for calibrating market and asset price shocks as tail events.** The shock to the Colombia 10-year government bond yields in the first year has been aligned with the largest change in recent history, corresponding to the nearly 190 basis points average increase in 2008. Real housing prices fall by 21 percent over the three-year horizon based on the fifth percentile of three-year cumulative changes in residential real estate prices. The Colombian peso depreciates bilaterally against the US dollar by about 25 percent over the stress-test horizon, amounting to a one-standard-deviation shock based on historical exchange rate movements. Equity prices, as measured by the COLCAP stock price index, drops by 18 percent in the first year of the exercise, corresponding to the fifth percentile of single-year changes in the stock index. at the peak of the tapering episode. Lastly, the interbank rate diverges from the policy rate with the spread reaching 125 basis points in year 2 of the horizon as liquidity dries up and counterparty risks heighten.

Appendix III. Figure 1. Colombia: Adverse Scenario Severity

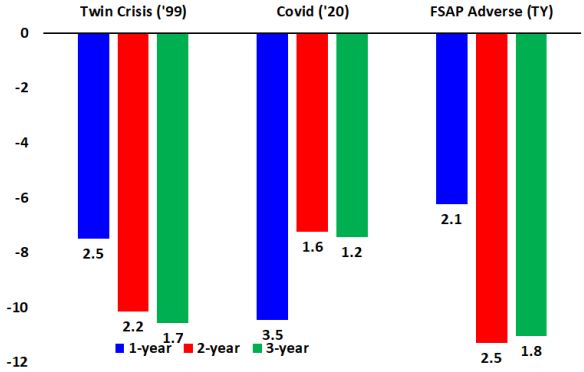
a. Scenario Severity from Historic Perspective

(Real GDP (T0=100)



b. Cumulative Deviation from Baseline in Percent

(equivalent standard deviations next to columns)



Sources: World Economic Outlook; IMF staff calculations.

Appendix III. Table.1. Colombia: FSAP Macro Projections—Baseline and Adverse Scenarios (in percent)					
		2020Q3-2021Q2 (T0)	2021Q3-2022Q2 (T1)	2022Q3-2023Q2 (T2)	2023Q3-2024Q2 (T3)
Real GDP growth	*Baseline*	*1.2*	*5.0*	*3.6*	*3.3*
(percent)	*Adverse*		*-1.2*	*-1.3*	*4.0*
Nominal GDP growth	*Baseline*	*4.2*	*6.3*	*8.1*	*6.1*
(percent)	*Adverse*		*-1.1*	*-0.4*	*3.7*
Inflation rate	*Baseline*	*2.0*	*4.1*	*3.0*	*3.0*
(percent)	*Adverse*		*3.8*	*2.0*	*1.8*
Unemployment rate	*Baseline*	*15.5*	*14.2*	*13.4*	*12.8*
(percent)	*Adverse*		*16.9*	*18.2*	*17.8*
Interbank lending rate	*Baseline*	*1.8*	*2.5*	*3.9*	*4.4*
(percent)	*Adverse*		*3.4*	*4.3*	*4.6*
1-year government bond yield	*Baseline*	*2.3*	*3.8*	*4.7*	*5.0*
(percent)	*Adverse*		*4.2*	*4.8*	*4.7*
10-year government bond yield	*Baseline*	*6.5*	*7.8*	*7.6*	*7.2*
(percent)	*Adverse*		*9.0*	*10.1*	*8.7*
Housing price	*Baseline*	*100.0*	*105.1*	*108.9*	*112.5*
(index)	*Adverse*		*88.2*	*80.2*	*78.8*
Equity price	*Baseline*	*100.0*	*106.3*	*114.9*	*121.9*
(index)	*Adverse*		*83.0*	*79.0*	*87.7*
Energy commodity prices	*Baseline*	*100.0*	*143.0*	*124.9*	*115.3*
(index)	*Adverse*		*112.9*	*60.6*	*68.3*
Non-energy commodity prices	*Baseline*	*100.0*	*110.3*	*107.7*	*107.2*
(index)	*Adverse*		*100.9*	*79.5*	*81.9*

Appendix IV. Satellite Models for Credit Risk and Interest Rate Risk—Technical Details

Credit Risk

1. **In Colombia, the longest available time-series for all loan portfolios was the stock of NPLs.** Therefore, the satellite models focused on estimating elasticities of NPLs to macrofinancial variables using quarterly data going back to 2002. The estimations exclude the pandemic period (2020), given the large scale of relief measures (e.g., moratoria, restructuring, etc.) and their significant impact on loan quality. For consumer and commercial portfolios, NPLs capture loans 90 days due or longer and for mortgage loans, 120 days due and longer.

2. **Bayesian Model Averaging (BMA) was used to develop satellite models.** Credit risk satellite models are estimated for each portfolio using panel regression with fixed effects. As such, the left-hand side (LHS) variables are NPLs for commercial loans, consumer loans, and mortgages. Since microcredit accounts for a tiny fraction of bank credit, it is not modeled in this exercise. No autoregressive lags of the LHS variables were allowed to maximize the content that could be extracted from the variation of the predictor variables on the right-hand side (RHS). The potential RHS variables include GDP growth, unemployment rate, exchange rate, lending rate, VIX, term premium, consumer price index, and real housing price index depending on the portfolio. The models contained the lags of the RHS variables to account for lagged effects. The benefit of the BMA is its ability to rank and weigh a large set of potential model specifications, constructed via all possible combinations of RHS variables. The information criteria to determine the selection and weight of models include sign criteria, R-square, AIC, and the size of the impact in the forecasting period (adverse-baseline gap). The resulting specifications reflect the weight of each coefficient determined through this process. The RHS variables that have posterior inclusion probabilities equal or higher than their prior inclusion probabilities are indicated with the asterisk symbol.

3. **The estimations suggest that NPL ratios are generally more sensitive to unemployment rate and GDP (Appendix IV. Table 1).** Unemployment rate plays the most significant role for consumer and mortgage NPLs, followed by housing prices for mortgages and lending rates for consumer loans. As for the commercial portfolio, while GDP contributes more strongly to NPL projections in year 1, terms spreads and, to a lesser degree, VIX have heavier weight in year 2.

4. **Expected losses were calculated based on historically calibrated provisioning ratios.** Since the historical portfolio-level data was available for loan provision stocks, the provisioning ratio was calculated as the loan provision stocks divided by NPLs per portfolio. Provision stocks used in this calculation include both procyclical and countercyclical individual provisions. Given that there was no breakdown available of historical time-series, countercyclical provisions were treated uniformly with procyclical provisions, and a single ratio was used to estimate credit losses without considering countercyclical buffers, as explained in the main text.

Appendix IV. Table 1. Colombia: NPL Models

	Commercial	Consumer	Mortgage
GDP growth, qoq, percent	-0.150*	-0.084*	-0.127*
GDP growth, qoq, percent [-1]	-0.259*	-0.125*	...
Unemployment rate, percent	...	0.245*	0.687*
Unemployment rate, percent [-1]	...	0.035*	0.312*
Exchange rate, qoq, percent	0.008*	0.002*	...
Exchange rate, qoq, percent [-1]	0.009*	0.002*	...
Lending rate, percent	...	0.068*	0.009
Lending rate, percent [-1]	...	0.078*	0.008
VIX	0.234*	...	...
VIX [-1]	0.245*	...	...
Term premium, percentage point	0.240*	...	0.061*
Term premium, percentage point [-1]	-0.047*	...	0.059*
Consumer price index, qoq, percent	0.049	...	0.048
Consumer price index, qoq, percent [-1]	0.047	...	0.046
Housing price index, qoq, percent	...	...	-0.045*
Housing price index, qoq, percent [-1]	...	...	-0.102*
Individual bank with fixed effects	Yes	Yes	Yes
R-square	0.364	0.301	0.453
Observations	900	908	818

Sources: SFC; IMF staff calculations.

Notes: * indicate the RHS variables that have posterior inclusion probabilities equal or higher than their prior inclusion probabilities are indicated with the asterisk symbol.

Interest Rate Risk on Banking Book (Net Interest Income Analysis)

5. **Projections of net income followed a two-pronged approach.** In this approach, funding costs were estimated using satellite models for different liability segments. There was granular data on bank-specific deposit rates for different maturities from 2014 onwards on a quarterly frequency. Given the availability of historical data, satellite models were developed for the following three segments: deposits with less than 3 months of maturity, deposits, with maturity between 3 months and 12 months, and deposits with maturities over 1 year (Appendix IV. Table 2). These rates were explained by their own lag to an extent, but the interbank rate was consistently significant for all deposit rates as well as long-term risk-free rates for longer maturities. For the other liability segments that could not be modeled, shocks on corporate credit spreads were used under each scenario. Shifts in the effective interest rates for loans were then calculated using pass-through rates, which were somewhat lower under the adverse scenario, given the less favorable environment. Effective pass-through rates for each bank depended on their proportion of fixed vs. floating loans,

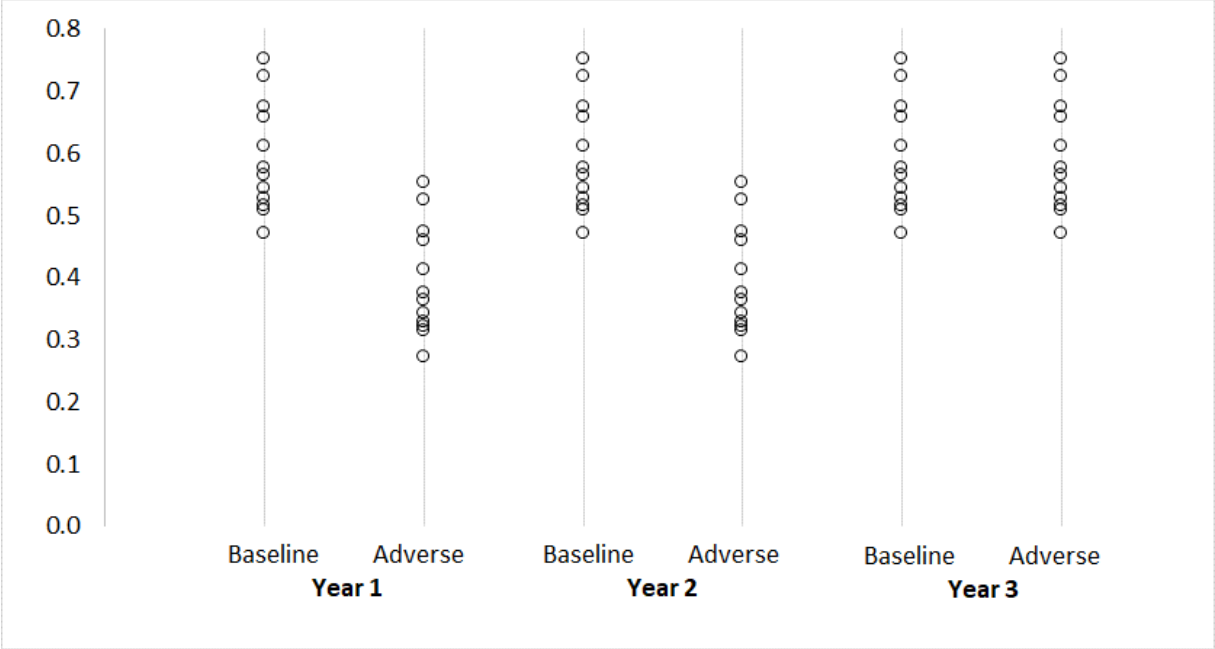
which also reflect the portfolio composition as well as time-to-repricing (see distribution in Figure 1).

Appendix IV. Table 2. Colombia: Funding Cost Models

	0-3 month deposits (dep3m)	3-12 month deposits (dep3-12m)	1-year or longer deposits (dep1y)
dep3m[-1]	0.390***	...	...
dep3-12m[-1]	...	0.328***	...
dep1y[-1]	...	...	0.296***
interbank rate	0.526***	0.570***	0.590***
long-term rate	...	...	0.067*
GDP growth	...	-0.015***	...
Number of obs	336	336	336
Number of groups	12	12	12
Time periods	28	28	28

Sources: SFC; and IMF staff calculations.

Appendix IV. Figure 1. Colombia: Pass-through Rates



Sources: SFC; and IMF staff calculations.

Appendix V. Technical Details of the Liquidity Stress Tests

Appendix V. Table 1. Colombia: LCR-Based Tests Assumptions

	Regulatory (average across banks)	Retail shock	Wholesale shock	Severe shock
Retail demand deposits				
Judicial deposits	3%	**5%**	3%	**5%**
Retail depositors (covered by deposit insurance)	11%	**15%**	11%	**15%**
Small and medium-sized clients	12%	**15%**	12%	**15%**
Wholesale demand deposits				
Financial institutions	30%	30%	**60%**	**60%**
Mutual funds	33%	33%	**60%**	**60%**
Non-financial public sector	20%	20%	**35%**	**35%**
Foreign wholesale funding	29%	29%	**60%**	**60%**
Local private wholesale funding	13%	**15%**	**20%**	**20%**
Contractual outflows	100%	100%	100%	100%
Contractual inflows	100%	100%	100%	100%
Liquid assets				
Level 1 assets				
Cash (local currency)	100%	100%	100%	100%
Cash (foreign currency)	80%	80%	80%	80%
Other Assets (local currency)	90%	90%	90%	90%
Other Assets (foreign currency)	71%	71%	71%	71%
Level 2 assets				
Local currency	90%	90%	90%	90%
Foreign currency	71%	71%	71%	71%

Appendix V. Table 2. Colombia: Run-off Rates for Cashflow Analysis

	Time Bucket			
	1 to 7 days	8 to 15 days	16 to 30 days	30 to 90 days
Retail demand deposits				
Judicial deposits	1	1	1	1
Retail depositors (covered by deposit insurance)	3	4	4	3
Small and medium-sized clients	3	5	4	3
Wholesale demand deposits				
Financial institutions	13	20	18	10
Mutual funds	14	22	19	12
Non-financial public sector	5	8	7	5
Foreign wholesale funding	12	19	16	7
Local private wholesale funding	4	6	5	4
Term deposits				
Retail (natural persons)	5	5	5	3
Non-financial companies (legal persons)	10	10	10	7
Financial entities	50	50	50	40
Public sector	10	10	10	7
Other	10	10	10	7
Outstanding bonds	80	80	80	60
Other unsecured wholesale funding				
Interbank funds	100	100	100	100
Financial obligations (bank credits)	100	100	100	100
Payables (debts to pay)	100	100	100	100
Maturing secured borrowing	60	60	60	60
Outflows from derivatives	100	100	100	100
Unused portion of credit lines and revolving facilities	3	7	5	0
Other countractual outflows	100	100	100	100

Note: A run-off rate indicates the fraction of the liability amount maturing in each time bucket that is withdrawn (and not rolled over) by the claim holders. Run-off rates for demand deposits and credit lines and revolving facilities are defined as the fraction of the initial outstanding balance that is withdrawn in each time bucket. Reported data on cash outflows due to maturing term deposits are not disaggregated by client type and disaggregation in the adverse scenario is approximated using data on balances of term deposits held by different counterparties.

Appendix V. Table 3. Colombia: Roll-off Rates for Cash Inflows

	Time Bucket			
	1 to 7 days	8 to 15 days	16 to 30 days	30 to 90 days
Maturing Loans				
Comercial credits	50	50	50	30
Consumption credits	50	50	50	30
Microcredits	50	50	50	30
Mortgages	50	50	50	30
Inflows from derivatives	100	100	100	100
Interbank funds	100	100	100	100
Inflows from investments	100	100	100	100
Maturing secured lending	60	60	60	60
Other contractual inflows	100	100	100	100

Note: For every type of asset and maturity bucket, the roll-off rates indicate the fraction of the amount maturing that is converted into a cash inflow (and not rolled over) by the bank.

Appendix V. Table 4. Colombia: Haircuts for Cashflow Analysis

	Haircuts
Cash items (incl.required reserves)	0
Level 1 investment	5
Level 2 investment	20
Non Encumbered Equity	100

Appendix VI. Technical Details of the Interconnectedness and Contagion Analysis

This appendix provides an overview of the methodology used to quantify contagion risks, as well as further information on data and implementation.

Methodology

1. The balance sheet-based network analysis follows the CoMap framework (Covi, Gorpe, and Kok 2019), which extends the simple bank network model of Espinosa-Vega and Sole (2011). This advances the simple interbank exposure model, with credit and funding shocks by incorporating entity and exposure-specific parameters and liquidity dynamics that reflect heterogeneity across entities. It also incorporates nonbank financials, nonfinancials, and selected foreign counterparts.

Credit shock

2. The credit shock captures the impact of an entity defaulting on its obligations to other entities. As a result, an entity incurs losses on a share of its claims depending on the nature and counterparty of its exposures. Exposure-specific loss-given default rates reflect the precise risk mitigation and collateralization that an entity has accounted for in its claims vis-à-vis each counterparty. More precisely, assume $\mathcal{Z}$ is the complete set of all entities in the network. Should a subset of entities ($\mathcal{Y} \subset \mathcal{Z}$) default on their obligations, *entity i*'s losses are summed across all entities $j \in \mathcal{Y}$ and claim types k using exposure-specific loss-given default rates, λ_{ij}^{k}, corresponding to its claim of *type k* on *entity j*, x_{ij}^{k}:

$$\sum_{j\in\mathcal{Y}}\sum_{k}\lambda_{ij}^{k}x_{ij}^{k}, where\ \lambda_{ij}^{k} \in [0,1]\ and\ i \notin \mathcal{Y} \qquad (2)$$

Funding shock and liquidity dynamics

3. The funding shock represents how an entity's withdrawal of funding from other entities forces them to deleverage by selling assets at a "fire sale" discount. In response to a subset of entities defaulting or getting into distress ($\mathcal{Y} \subset \mathcal{Z}$), and thereby withdrawing funding from other counterparties, *entity i* faces a funding shortfall summed across all entities $j \in \mathcal{Y}$ using its specific funding shortfall rate, ρ_i:

$$\sum_{j\in\mathcal{Y}}\rho_i x_{ji}, where\ \rho_i \in [0,1] \qquad (5)$$

4. In practice, for immediate liquidity needs, entities can pledge HQLA as collateral to the central bank for overnight borrowing. From a modeling perspective, this implies that *entity i* can offset funding its shortfall with the new credit line up to its liquidity surplus (HQLA in excess of net liquidity outflows), γ_i, with the remaining liquidity shortage computed as:

$$max\left\{0, \sum_{j\in y} \rho_i x_{ji} - \gamma_i\right\} \qquad (7)$$

5. A constraint on the amount of remaining pool of assets available to the entity, θ_i, sets an upper threshold to how much of the remaining liquidity shortage can be sustained with the fire sale proceeds after accounting for haircuts proportional to a discount rate, δ_i. As a result, the deleveraging amounts to the sale of assets equivalent to:

$$min\left\{\frac{1}{1-\delta_i} max\left\{0, \sum_{j\in y} \rho_i x_{ji} - \gamma_i\right\}, \theta_i\right\}, where\ \delta_i \in [0,1] \qquad (8)$$

6. While credit shocks translate directly to a weakening of an entity's capital, funding shocks lead to depletion of its liquidity and to capital losses via fire sales. In a distress event, the capital of exposed counterparties, such as *entity i*, must absorb the losses on impact. Then, *entity i* is said to become insolvent if its capital falls below a certain threshold c_i^d, which may be defined as the entity's minimum capital requirements with or without capital buffers. In other words, *entity i* is said to fail if its capital surplus ($c_i - c_i^d$) is insufficient to fully cover the combined credit and fire-sale losses:

$$c_i - c_i^d < \sum_{j\in y}\sum_k \lambda_{ij}^k x_{ij}^k + \delta_i min\left\{\frac{1}{1-\delta_i} max\left\{0, \sum_{j\in y} \rho_i x_{ji} - \gamma_i\right\}, \theta_i\right\} \qquad (12)$$

7. In terms of the impact through the liquidity channel, *entity i*'s liquidity surplus serves as the first line of defense. However, the remaining liquidity shortages might require a large-scale fire sale operation relative to its financial assets. Having already exhausted its liquidity surplus, *entity i* becomes illiquid if its remaining assets are insufficient to match the liquidity shortage:

$$\theta_i < \frac{1}{1-\delta_i} max\left\{0, \sum_{j\in y} \rho_i x_{ji} - \gamma_i\right\} \qquad (13)$$

8. Bringing the full network of entities into the picture, in each simulation the exercise tests the system for a given entity's default. The initial default of entity 1 is triggered by design in order to study the cascade effects and contagion path it causes through the network. The exercise moves to subsequent rounds if there are additional failures in the system and stops when there are no other failures. The exercise repeats this sequence to simulate for each entity as the trigger default event.

9. In terms of results, this exercise generates a selection of outputs:

- **Contagion index**: This indicator captures each entity's potential contagion (i.e., systemic impact) by taking a weighted average of losses of all other entities in percent of their capital;

$$CI_i = 100\frac{\sum_{j\neq i} L_{ji}}{\sum_{j\neq i} k_j},$$

where L_{ji} is the loss experienced by *entity j* due to the triggered default of *entity i*. This indicator then can be used to compare entities in the network in terms of how much contagion each entity causes to the system if it was to experience severe distress (a tail event).

- **Vulnerability index**: This indicator gauges each entity's degree of vulnerability, averaged across all individual default events with identical probability:

$$VI_i = 100\frac{\sum_{j\neq i} L_{ij}}{(N-1)k_i},$$

where L_{ij} is the loss experienced by entity i due to the triggered default of *entity j*. This indicator can be used to compare fragility of entities to systemic events. Entities that on average incur greater losses due to their exposures are deemed more vulnerable. The average losses take into account both the magnitude of an entity's losses (in response to each default event) and the frequency with which it experiences losses (by treating each default with equal probability).

- **Contagion default**: This indicator tracks the number of entities that experience severe distress associated with the triggered default of *entity i*. Whereas the contagion index measures the degree of losses within a continuous range associated with a default event, contagion default is a discreet indicator based on a binary "pass or fail" outcome. It gauges how many other entities in the network become undercapitalized.

- **Default frequency**: This indicator tallies the total number of simulations under which *entity i* falls below the capital distress threshold. Similarly, whereas the vulnerability index measures the degree of losses within a continuum, default frequency is a discreet indicator, gauging the binary outcomes.

Data Calibration and Implementation

10. Contagion analysis for both the cross-border and cross-sectoral financial network relies on the CoMap methodology and used exposure-level data provided by the supervisory authorities. The data sources and calibration are briefly summarized here:

- **Scope** of the data included individual exposures as of December 2020, at the entity level, connecting banks, pension funds, insurers, investment funds, trusts, securities firms, nonfinancial corporates, households, and public entities. The exposure types included listed and unlisted equities, short-term debt, long-term debt, loans, deposits, derivatives, interbank exposures, and money market operations. For supervised banks, pension funds, insurers, investment funds, and trusts, balance sheet data was also obtained and linked to the exposures identifying the network. Network nodes for aggregated sectors and smaller entities were aggregated. The final list of domestic network nodes included all 25 banks operating in Colombia, 5 pension funds, the largest 5 insurers (plus an additional node aggregating small insurers), the largest 5 investment funds (plus an additional aggregated node for small investment funds),

20 nonfinancial aggregated industries, and aggregated sectoral nodes for trusts, securities firms, financial intermediation, public government entities, and households

- **Cross-border exposures** were identified in three ways. First, for loan exposures linked to foreign debtor identifiers, debtors were labeled as foreign. Second, exposures to entities classified as foreign subsidiaries were also labeled as foreign. Third, entities associated to a foreign conglomerate were identified by country. Country-specific labelling was only available for entities that appeared in the latter two identification methods. From these, country categories were created including one aggregate for non-Panama Central America. The top five debtor country categories were included as separate network nodes with an additional one, labeled ROW (Rest of the World), including all other foreign debtors (and those whose country was not identified). The limitations of this foreign counterpart identification strategy implies that only part of all potential foreign debtor shock channels is considered in this study.

- ***Loss-given-default rate*** (λ_{ij}^{k}) is calibrated at the exposure level by exposure type. For loans, this is based on risk classification and information on impaired assets. For short-term and long-term debt, the parameter is calibrated to .8, while for equities it is calibrated to 1 (listed or unlisted shares). For interbank exposures, money market operations, derivatives, and deposits, this is set to the ratio of net vs gross exposures. In addition, for aggregated sectors, only partial defaults are considered. Thus, default parameter of .2 is set for public entities, motivated by a partial default scenario or a sharp increase in yields. For other aggregated sectors, including nonfinancial industries and households, only top quartile loan exposures, in terms of the loss-given default rate, are considered.

- ***Funding shortfall rate*** (ρ_i) is calibrated based on data on remaining maturity and set to 1 for maturities below 30 days.

- ***Liquidity surplus*** (γ_i) is defined by entity type based on available data. For banks, it is defined as HQLA minus net outflows. For pension funds and insurers, it is defined as total cash liquidity. For investment funds, this is set to HQLA or equivalent assets.

- ***Liquidity constraint*** (θ_i) is the pool of financial assets available for fire-sale. It is calibrated as the total amount of unencumbered eligible assets.

- ***Fire-sale discount rate*** (δ_i) is estimated for each entity based on the portfolio of its assets classified under unencumbered non-central bank eligible assets weighted by relevant haircuts. Respective haircut rates for each asset are applied.

- ***Default/distress threshold*** (c_i^d) is defined by entity type. For banks, this is based on total CAR minimum requirement plus the *systemically important institutions* buffer (applicable to DSIBs). For insurance companies, it is based on available solvency capital (own funds) and the respective minimum capital requirement. For pension and investment funds, it is based on the difference between their total assets and total liabilities with the minimum set at zero.

Appendix VI. Table 1. Sectors Included in Network Analysis

Financial sectors at entity level
Banks (25)
Pension funds (Top five, others aggregated)
Insurers (Top five, others aggregated)
Investment funds (Top five, others aggregated)

Financial aggregated sectors
Trusts
Securities firms
Other financial Intermediation

Other aggregates
Government
Households
Foreign counterparts
(Five aggregated country categories)

Aggregated nonfinancial industries
Accommodation and meal services
Activities of extraterritorial organizations
Administration and support services
Agriculture and livestock
Art and entertainment
Communications
Construction
Education
Employees
Manufacturing
Microcredit debtors
Mining and quarrying
Other community, social and personal services
Professional, scientific, and technical services
Private Household Activities
Real estate, rental, and business activities
Social and health services
Transport, storage, and communication
Wholesale and retail
Other nonfinancial corporates

Note: Aggregated nodes are sources of shocks in the model, but not shock transmitters.

Appendix VI. Table 2. Summary Statistics of Calibrated Model Parameters

	Loss-given default	Funding shortfall	Discount rate
Banks			
Average	0.17	0.36	0.48
Min	0.00	0.06	0.08
Max	0.54	0.99	0.67
Pension funds			
Average	0.47	0.00	0.22
Min	0.32	0.00	0.21
Max	1.00	0.00	0.22
Investment funds			
Average	0.52	0.13	0.27
Min	0.27	0.00	0.22
Max	0.72	0.56	0.33
Insurers			
Average	0.39	0.46	0.20
min	0.32	0.00	0.18
Max	0.46	1.00	0.27

Appendix VII. Corporate Risk Analysis—Technical Details

1. The methodology developed by Tressel and Ding (2021, forthcoming)[1] focuses on a set of firm-level indicators to assess: (i) the ability to service debt (ICR); (ii) external borrowing needs based on the cash balance (cash available); and (iii) the solvency position. The scenario-based stress tests models are built from a battery of firm-level regressions that could also be combined with accounting identities. Specifically, it relies on dynamic regressions for the variables return on assets (ROA) and leverage, and Probit models for the cash balance (cash available) and ICR.

2. The dependent variables of the OLS regressions include ROA and the leverage ratio. The dependent variables of the Probit regressions are indicator variables (i) equal to 1 if the ICR is below one and 0 otherwise; and (ii) equal to 1 if cash available is zero or negative, and 0 otherwise. The dependent variables are projected dynamically from firm-level variables in the previous year, including time varying and time invariant structural characteristics, and macrofinancial variables.

3. The basic firm-level regression specification is a dynamic OLS regression including a set of industry level fixed effects:

$$Y_{i,s,t} = \alpha \cdot Y_{i,s,t-1} + \Delta \cdot firm\_char_{ist-1} + \Phi \cdot Macrofinancial_t + d_s + \nu_{ist}$$

Where $Y_{i,s,t}$ is the variable to be projected for firm i, in industry s and year t, $firm\_char_{ist-1}$ is a set of firm-level explanatory variables, $Macro\_financial_t$ is a set of macro variables for year t, d_s is a full set of industry fixed effects and ν_{ist} is a residual which is clustered at the industry-year level.

4. Firm-level Probit regressions where the dependent variables are indicator variables (i) equal to 1 if the ICR is below one and 0 otherwise; and (ii) equal to 1 if cash available is zero or negative, and 0 otherwise.

$$P[Risk_{i,s,t} = 1] = \beta \cdot firm\_char_{ist-1} + \delta \cdot Macrofinancial_t + d_s + \varepsilon_{ist}$$

Where the indicator $Risk_{i,s,t} = 1$ if the firm is assessed to be risky if the variable considered is below the risk threshold, or $= 0$ if it is above the threshold.

5. Firm-level explanatory variables are lagged by one period and include profitability (return on assets), leverage (the debt-to-asset ratio), size (measured by total assets), tangibility of assets (the ratio of fixed assets to total assets), and the ability to generate cashflows (the ratio of sales to total assets). These variables are considered standard determinants of firms' indebtedness and maturity structure.[2]

[1]Global Corporate Stress Test: COVID-19 Impact and Medium-term Implications.

[2] See, for instance, A. Demirguc-Kunt, M. Martinez-Peria, and T. Tressel, 2015. *"The Impact of the Global Financial Crisis on Firms' Capital Structure,"* World Bank Policy Research Working Paper No. 7522.

6. To construct firm-level projections of the dependent variables considered, the authors assume that some of these explanatory variables reflect structural characteristics of firms and will be time invariant (the size indicator, the tangibility ratio and the cashflow generation ratio) and kept at their 2019 value.[3] Other variables (ROA and leverage) will be projected in a consistent manner and will vary over time given the macro-scenarios considered. Macrofinancial determinants of firm-level profitability and leverage are the annual real GDP growth and an index of financial conditions, which follows the methodology used in the Global Financial Stability Report (IMF, 2017). For Colombia, the index uses the following variables: Spread of local currency sovereign debt, spread of US dollar sovereign debt, spread of US dollar corporate debt, equity prices, exchange rate, and house prices. (IMF, GFSR 2017).

7. The dependent variables are projected dynamically from firm-level variables in the previous year, including time-varying and *structural* characteristics, and the regression estimated coefficients $\tilde{\alpha}$, $\tilde{\Delta}$, $\tilde{\Phi}$, and fixed effects $\tilde{d}_s$:

$$\hat{Y}_{i,s,2021} = \tilde{\alpha} \cdot Y_{i,s,2020} + \tilde{\Delta} \cdot firm\_char_{i,s,2019} + \tilde{\Phi} \cdot Macrofinancial_{2021} + \tilde{d}_s$$

For 2022 and 2023, the estimations are done based on the following equation.

$$\hat{Y}_{i,s,T} = \tilde{\alpha} \cdot \hat{Y}_{i,s,T-1} + \tilde{\Delta} \cdot \left[\_struct\_char_{i,s,2019}, \widehat{\_other\_char}_{i,s,T-1}\right] + \tilde{\Phi} \cdot Macro\_financial_T + \tilde{d}_s$$

Estimation

8. Dynamic OLS regressions for ROA and leverage are estimated for the period 2016–2020, pooling together the data for both corporates and SMEs after excluding the extreme values of the used variables for each group of firms.4 Test are conducted to assess whether the estimated coefficients are statistically different between corporates and SMEs. It was identified that for the specification of ROA, the coefficient of size was different and for the specification of leverage the coefficients for leverage (one period lagged) and turnover were different. To account for this result, specific coefficients for these variables (for SMEs) were incorporated in the specifications.

9. In OLS regressions, there exists a good persistence of leverage (with a coefficient of close to 0.8 on the lagged dependent variable). As explained by Tressel and Ding (2021, forthcoming), this implies that shocks to the firm's capital structure would tend to be persistent over time and feed-through over time, with medium-term impacts larger than the contemporaneous effects. In the case of specification for ROA, the degree of persistence is smaller, implying that the impact of shocks on profits would be more immediate than the impact on leverage.

10. After controlling for country and industry fixed characteristics and persistence of the dependent variable, firms that are less profitable, larger in size tend to be more indebted. No statistically significant effects are found for turnover and tangibility. Firms that have higher turnover

[3] See the discussion in Demirguc-Kunt et al. (2015).

[4] 10 percent of the variable distribution is eliminated (5 percent in each tail of the distribution).

and less indebted are more profitable. In the case of Colombia, the results suggest that firms with a larger share of fixed assets tend to be less profitable. The R-squared is relatively high for leverage, but relatively low for ROA. The latter could reflect the need of additional explanatory variables like, for example, the growth rate of sales. While available, its inclusion reduces the time-series dimension of the sample by two years. For this reason, it was not included. The results suggest that profitability is strongly positively correlated with real GDP growth, but leverage is not correlated with the index of financial conditions. The latter could be related to the shorter time-series or the need to have a more economic sector specific financial condition index.

11. Probit regressions show that the likelihood that a firm does not generate enough earnings to pay for expenses without additional net borrowing is negatively correlated with profitability, and positively correlated with leverage, tangibility of assets, the turnover ratio and size. Higher return on assets (profits) generates higher retained earnings, everything else equal, and therefore higher cash buffers, while higher leverage being associated with higher interest expenses that may result in lower cash buffers. Higher GDP growth rates tend to reduce the likelihood that firms may lack sufficient cash buffers and so may have to resort to external borrowing to fund their operations.

12. The probability that a firm is unable to pay for its interest expenses from earnings is negatively correlated with profitability, turnover, and the tangibility ratio and is positively correlated with leverage, as expected. Also, the results suggest that the likelihood that a firm does not generate sufficient earnings to pay for interest expenses is negatively correlated with GDP growth.

13. Based on the estimated specifications, the ex post prediction for 2020 provides results close to the actual values.

Appendix VII. Table 1. Colombia: Actual and Projected Average Values for 2020

	Corporate		SMEs	
	Actual	Projected	Actual	Projected
ROA	2.1	2.2	2.7	3.1
Leverage (debt to assets)	19.1	20.4	18.0	18.5
ICR < 1 (share)	0.39	0.37	0.25	0.23
Cash availability <0 (share)	0.34	0.34	0.30	0.31

Appendix VII. Table 2. Colombia: Estimation Results

VARIABLES	(1) ROA	(2) Leverage	(4) ICR Risk	(5) Cash Available Risk
ROA (t-1)	0.508***	-0.0573***	-0.103***	-0.0475***
	(0.0338)	(0.00726)	(0.00757)	(0.00565)
Leverage (t-1)	-0.0132***	0.806***	0.00343***	-0.00270
	(0.00247)	(0.00930)	(0.000648)	(0.00240)
Tangibility (t-1)	-0.00478***	0.00384	-0.00235***	0.00573**
	(0.00130)	(0.00290)	(0.000736)	(0.00242)
Size (t-1)	0.0225	0.243***	0.0287**	0.0608***
	(0.0324)	(0.0350)	(0.0118)	(0.00770)
Turnover (t-1)	0.00673***	0.00110	-0.000551***	0.00107*
	(0.000864)	(0.00133)	(0.000133)	(0.000643)
Financial conditions		1.640		
		(1.284)		
GDP growth	0.342***		-0.0444***	-0.0299***
	(0.0680)		(0.0171)	(0.00967)
Year2020	2.912***	-1.175	-0.183	-0.392***
	(0.733)	(1.185)	(0.168)	(0.0891)
Constant	-0.387	-0.775	-0.629**	-1.148***
	(0.728)	(0.696)	(0.251)	(0.143)
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	32,815	30,977	26,101	32,494
R-squared	0.298	0.633		

Note: Standard errors in parentheses (clustered by industry-year); *** p<0.01, ** p<0.05, * p<0.1.