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Not-so-magical realism: A climate stress test of the Colombian banking system

sfc Superintendencia Financiera de Colombia

FIRST initiative

WORLD BANK GROUP

1818 H Street NW, Washington DC 20433
Telephone: 202-473-1000; Internet: www.worldbank.org

Cover photography: Santiago La Rotta
Cover design and typesetting: Diego Catto / www.diegocatto.com

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Acknowledgments

Report prepared by Henk Jan Reinders, Martijn Regelink, Pietro Calice, and Mariana Escobar Uribe. We are grateful to the Superintendencia Financiera de Colombia and the Banco de la República for fruitful discussions and for providing the data needed to perform the analyses. We are furthermore grateful to the Departamento Nacional de Planeación for providing estimates of the economic effects of abrupt climate policy scenarios and to the Instituto de Hidrología, Meteorología y Estudios Ambientales for sharing data on climate change and flood risk. We also thank three peer reviewers for their comments and suggestions: Stephane Hallegatte (World Bank), Guan Schellekens (European Central Bank), and Edo Schets (Bank of England). The vulnerability modeling was developed with input from Nepomuk Dunz, Faruk Miguel Liriano, Oliver Masetti, Carolina Rogelis, Hugo Alexander Rojas Romagosa, Jose Angel Villalobos, and Dieter Wang.

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Acronyms

BCBS	Basel Committee on Banking Supervision
BR	Central Bank of Colombia
CAR	capital adequacy ratio
CEPAL	Economic Commission for Latin America and the Caribbean
CGE	computable general equilibrium
Col$	Colombian peso
DANE	National Administrative Department of Statistics
DID	difference-in-difference
DNB	Dutch Central Bank
DNP	National Planning Department
ESG	environmental, social, and governance
ETS	emission trading system
FSB	Financial Stability Board
G20	Group of Twenty
IDEAM	Institute of Hydrology, Meteorology and Environmental Studies
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
GDP	gross domestic product
GHG	greenhouse gas
LAC	Latin America and the Caribbean
MT	medium term
NDC	nationally determined contribution
NGFS	Network of Central Banks and Supervisors for Greening the Financial System
NPL	nonperforming loan
RCP	representative concentration pathway
RP	return period
S&P	Standard & Poor's
SDG	Sustainable Development Goal
SFC	Financial Superintendence of Colombia
SSP	shared socioeconomic pathway
ST	short term
US$	United States dollar
WRI	World Resources Institute

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Executive Summary

Losses associated with the materialization of climate-related risks are increasingly affecting economies and financial sectors globally, and Colombia is no exception. The Colombian banking sector is hence potentially exposed to climate-related financial risks, particularly from floods and strong climate mitigation targets. Large scale riverine floods are the main climate-related disaster risk (that is, physical risk) in Colombia. In the past few decades, such events have led to major damages to real estate and other capital goods, with the 2010 and 2011 floods leading to combined damages of US$7.0 billion (equivalent to 2.0 percent of the 2011 gross domestic product [GDP]).[1] Approximately 6.5 percent of banks' total loan exposures are in municipalities that face high flood risk.[2] Moreover, the flood hazard is expected to increase between 25 and 65 percent between 1980 and 2080 because of climate change. In general, only a minor fraction (between 2 to 4 percent) of economic damages after disaster events are insured, leaving a large share of the burden on government, households, and firms, thereby increasing the credit risk on banks that finance them. Furthermore, to prevent further climate change, a broad-based change in the Colombian economy would be needed to achieve its greenhouse gas (GHG) emission reduction targets. Recently, the Colombian government increased its GHG emission reduction targets from 20 percent to 51 percent by 2030, constituting one of the most ambitious targets in the Latin America and the Caribbean (LAC) region. About 20 percent of Colombian banks' corporate loans are in sectors that are highly sensitive to transitions, whereas a broader set of sectors and assets is vulnerable through value-chain effects (that is, links between sectors). Besides domestic climate policies, transition risks also originate from climate regulation abroad, technological change, and shifting consumer preferences. Colombia is also exposed to transition risks from abroad, due to relatively high fossil fuel export revenues and a high carbon intensity of manufacturing exports compared to other countries in the region.

This report identifies and assesses climate-related risks in the banking sector and develops two innovative approaches to conduct basic climate risk stress tests in emerging markets. For physical risks, we develop a stress test at the municipal level to investigate the vulnerability of banks toward severe riverine floods. We introduce three innovations (a) to model climate risk in absence of nationwide probabilistic disaster scenarios; (b) to estimate the effects of flood-related economic damages on banks using spatial panel data on loan provisions; and (c) to extend a basic stress test model with spatially disaggregated credit risk and sovereign credit risk channels. These innovations allow us to make first estimates on the impacts of floods on banks' profitability and solvency. For transition risks, we develop a stress test at the two-digit sectoral level using a locally available computable general equilibrium (CGE) model to estimate the effects of severe but plau-

1 Figures for flood damages and insurance penetration based on EM-DAT.
2 High flood risk based on more than 10 percent of the land area flooded during flood events in the past.

sible transition scenarios on value added in 83 economic sectors. This approach allows us to account for interdependencies between sectors as well as for the partial compensation of firms through increased government revenues.[3] Transition scenarios are tailored to Colombia and in line with the recently updated GHG reduction targets as part of the Colombian nationally determined contribution (NDC). We finally estimate the impact on banks, through non-performing loans, using a credit risk model of the Central Bank of Colombia (BR).

Our flood risk assessment shows that severe flood scenarios can lead to declines in capital adequacy that could moreover coincide with other shocks. We look at riverine floods occurring owing to heavy rainfall, which in the most extreme cases has historically been related to La Niña.[4] We investigate three flood scenarios, one based on the 2010 and 2011 floods related to La Niña and two more severe floods with return periods of once in 500 years. For those three scenarios we find an average decline in the capital adequacy ratio (CAR) for Colombian banks between 0.3 and 1.1 percentage points. A fourth scenario, investigating a severe flood coinciding with a recession, finds an average decline in the CAR of 3.2 percentage points. Results differ strongly per bank, with loan losses for individual banks ranging between 0.2 percent of total assets for the least vulnerable bank to 2.2 percent for the most vulnerable one in the most severe flood scenario. Finally, we find that a worst-case climate change scenario (RCP 8.5) could add an additional 0.1 to 0.6 percentage points in CAR impact—per severe flood event—compared with a scenario with limited climate change (RCP 2.6) depending on the bank.[5]

Our transition risk assessment shows that severe decarbonization scenarios can lead to substantial losses in the banking sector. However, the most severe scenarios can be avoided by managing the transition well. Relevant decarbonization scenarios can already materialize in the medium run given Colombia's high GHG reduction targets for 2030. We estimate that in an adverse scenario, with a high GHG reduction target and delayed implementation of policies, aggregated loan losses for Colombian banks may range between 0.2 percent of total assets for the least vulnerable banks to 2.7 percent for the most vulnerable ones. This scenario could materialize when climate policies are introduced late (from 2026) and no other measures are taken to allow the Colombian economy to timely adapt. The estimates may be conservative since they cover a two-year time frame and consider only credit risk, with more losses that could accumulate before and after the shock period and through other risk channels. The possibility of substantial losses warrants action to be taken in the short term to align the banking sector's risk management and capital allocation with the national NDC targets.

Results show differences in climate-related vulnerabilities in credit portfolios between banks, underscoring the importance of risk-based supervision. Three banks are substantially (about two to three times) more vulnerable to flood hazards than most others owing to high exposures in the more rural areas or relatively large sovereign exposures. Also, there is significant heterogeneity in the exposure of individual banks to sectors that are highly sensitive to transitions, ranging between 1 and 26 percent of their credit portfolios. These banks could suffer relatively high losses in the broad set of potentially affected sectors compared with their total assets. They also have relatively high loan concentrations in the sectors that are most vulnerable in our transition scenarios: fossil fuels, waste collection, agriculture, and electricity supply. These observations support a risk-based approach to addressing climate-related risks in microprudential supervision while also noting that the banks with the highest vulnerability potentially have a high potential to contribute to greening the Colombian economy by stimulating GHG mitigation in these sectors. This contribution could, for example, be achieved by engaging with current clients and by including green considerations into a bank's origination practices or by increasing the offering of green products (for example, green corporate loans and green mortgages).

Our analysis is explorative and often based on aggregated data, hence the results of our assessment should be interpreted with caution. Several limitations in data and model availability require us to make assumptions that lead to potential over- or underestimation of outcomes. For example, we improve on macroeconomic approaches by disaggregating exposures into sectors and municipalities but do not have detailed information at firm and household level. Limitations are described throughout the report and should guide the interpretation of results. Specifically, we note that estimates for the effects of transition risks on value added per sector are obtained under adverse or stressed conditions and do not represent a forecast of any kind. The employed scenario does not account for all potential adaptive processes, including technological change, and hence may overestimate effects on the economy—especially in cases where the economy has more time to adjust, that is, the "smooth" transition scenarios. When climate policies are introduced gradually, the economy is expected to adjust and adverse effects are more likely limited than estimated in this study. Given the explorative nature of the stress testing, results are not intended to identify capital shortfalls or to provide pass or fail outcomes for banks.

3 Hence, we are not only looking at direct emissions from owned sources (scope 1 emissions), but also at emissions from the generation of purchased electricity and other emissions that occur in the value chain (scope 2 and 3 emissions), and we account for revenue recycling to alleviate macroeconomic effects.
4 La Niña refers to a recurring weather phenomenon in the Pacific Ocean that causes heavy rainfall, flooding, and landslides in Colombia.
5 A Representative Concentration Pathway (RCP) is a greenhouse gas concentration trajectory adopted by the Intergovernmental Panel on Climate Change (IPCC).

> > World Bank Recommendations:

This report is a collaboration between the World Bank and the Financial Superintendence of Colombia (SFC). Based on this report, the World Bank has identified several short-term (ST) and medium-term (MT) actions that the SFC can consider to improve climate risk identification and mitigation in the banking sector. These actions include that the SFC could adopt risk-based supervision for climate-related risks and continuously improve information disclosures (both by nonfinancial corporates and by financial institutions) and data availability. The latter is also important to assess exposures through affiliated entities abroad, for which the SFC could collaborate with host supervisors to conduct a cross-country climate vulnerability assessment. For physical risks, the SFC could perform deep dives at the most vulnerable institutions, promote capacity building throughout the sector, and encourage the further development of insurance markets since increased disaster insurance penetration mitigates risks for banks. Regarding transition risks, the SFC can work with the banking sector and other authorities to address risks in a timely and forward-looking manner. Such action requires dialogue between public and private stakeholders on how climate mitigation and adaptation measures will take shape, so that banks can address them early on (for example, in engagement with customers, origination practices, and pricing). It also requires capacity building in the banking sector, potentially including new tools such as scenario analysis and full bottom-up stress testing. This capacity building is particularly urgent with respect to domestic transition risks, as substantial efforts to decarbonize the Colombian economy can already be expected this decade. See table ES.1 for an overview of recommendations.

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TABLE ES.1. - World Bank recommendations to the SFC and other stakeholders

Recommendation	Timing	Agency
General		
Issue guidelines on governance, risk management, and climate risk disclosure to the banking sector.	ST	SFC
Promote the development of forward-looking climate risk tools in the banking sector, including scenario analysis and stress testing.	ST/MT	SFC
Incorporate climate risks as part of the risk-based supervision of banks.[a]	MT	SFC
Continue to encourage climate risk disclosure by nonfinancial firms in Colombia, and support the improvement and use of climate-risk data at the firm level.	MT	SFC
Conduct a cross-country climate vulnerability assessment with host supervisors, including improving data collection on spatial and sectoral exposures through related entities.	MT	SFC, host supervisors
Physical risks		
Identify the information and data needed to carry out physical risk assessments tailored to individual institutions' exposure.	ST/MT	SFC
Promote technical capacity building in the banking sector to understand and manage physical risks, covering both disaster risks and gradual changes in climatic conditions (for example, through a platform).	ST/MT	SFC
Promote the development and implementation of mechanisms to mitigate physical risks and their impacts, such as disaster risk insurance.[b]	MT	SFC, Government
Transition risks		
Promote capacity building in the banking sector to understand and manage transition risks, specifically focusing on ST and MT transition risks (that is, 2030 NDC targets).	ST	SFC
Promote further dialogue between climate policy makers and the financial sector including banks, other investors, and financial authorities.	ST/MT	SFC, BR, Government
Provide more detailed guidance to the financial sector on how de-carbonization policies will be implemented and on what is the time line for implementation (for example, a road map until 2030 to allow banks to better align their portfolios).	ST/MT	Government, SFC
Encourage better data collection to perform firm-level stress tests by authorities and banks. Specifically, this would require firm-level GHG emission data for nonfinancial firms in Colombia.	ST/MT	SFC

Note: BR = Central Bank of Colombia; NDC = nationally determined contribution; SFC = Financial Superintendence of Colombia; ST = short term (within one year) and MT = medium term (within one to three years).

a. This could include requiring increased supervisory reporting, addressing the risk in the banks' Internal Capital Adequacy and Assessment Process, and addressing the risk in on-site supervision (including in board-level conversations).

b. We note that sometimes the most cost-effective adaptation lies in preventing the creation of new risks by ensuring that land-use planning and infrastructure regulations take disaster risks into account. Banks could play a role here by integrating disaster and flood risks into their loan origination process (and requiring alignment with land-use plans and infrastructure regulations). Development of insurance markets could include (a) strengthening the legal framework including on the use of parametric insurance and (b) improving the availability of disaster insurance data.

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Introduction

Globally, increasing attention is being paid to the effects of climate change and environmental risks and opportunities on financial sectors. Regulators and central banks—through the Network for Greening the Financial System (NGFS) among others—are warning on the effects of climate change and environmental risks on the stability and soundness of financial sectors. These calls follow attention paid to this topic by the Financial Stability Board (FSB), its Task Force on Climate-Related Financial Disclosures, and the G20 (Group of Twenty) Green Finance Study Group. At the same time, there is global recognition of the importance of financial sectors in mobilizing capital for green objectives, including those related to the Paris Agreement and the Sustainable Development Goals (SDGs). Several global financial bodies have recently stepped up their work on climate-related financial risks, including reports by the Basel Committee on Banking Supervision (BCBS) and the FSB (BCBS 2021; FSB 2020). Sustainable finance is also one of the priorities of the Italian G20 presidency in 2021.

Within the Colombian banking sector, there is an emerging awareness of climate-related risks, but the understanding of the risks and their management are still at an early stage.[6] Although the industry has a broad awareness of risks related to climate and sustainability, relatively little attention is paid to the financial risks that climate change trends pose to the Colombian banking system. Some banks have a management system that takes into account environmental, social, and governance (ESG) risks, which is typically focused on limiting any negative effects of bank activities on ESG-related factors. The financial risk side is explored to a lesser extent, including the effects of climate on credit risk, market risk, and other financial indicators. Also, the financial sector, including a group of Colombian banks, has been seeking to develop strategies to support sustainable development in Colombia through the Protocolo Verde Ampliado (the expanded Green Protocol).

The Financial Superintendence of Colombia (SFC) identified the better understanding of climate-related financial risk as a priority in its 2019 action plan related to climate change (SFC 2019). The SFC action plan focuses on four key areas, including (a) taxonomy, (b) ESG integration, (c) transparency on climate risks, and (d) capacity building. This report contributes to the third and fourth areas by expanding the knowledge base to identify, assess, and manage climate-related financial risks in Colombia. It also provides a foundation for future, more detailed risk assessments and aligns with activities of the Colombian financial authorities who are increasingly involved in the NGFS and other international forums.

6 Based on interviews and an SFC survey amongst banks.

This report identifies and assesses relevant physical and transition risks with focus on the banking sector. Banks constitute the largest segment of the Colombian financial sector with asset holdings of Colombian peso (Col$) 720 trillion (US$209 billion or 78 percent of gross domestic product [GDP]) in 2020.[7] This includes both foreign and domestic banks. Some banks are parts of larger conglomerates in which the related entities could be exposed to similar climate-related financial risks, such as foreign banks, insurance companies, and asset managers. Insurance companies and asset managers are, however, not part of this report. The scope of our analysis includes both physical risks (that is, those emanating from weather-related events and gradual changes in climatic conditions) and transition risks (that is, those emanating from decarbonization of the global economy in line with targets in the Paris Agreement). We note that we use a broad definition of physical risks, covering both climate-related disaster risks and the effects of climate change on their probability distribution. In the remainder of the report, we refer to the collection of these risks as climate-related financial risks, or climate-related risks in short.

The report also builds on quantitative data from a range of sources to explore the vulnerability of banks in specific scenarios. The report bases its analysis on data provided by the SFC, the Central Bank of Colombia (BR), the National Planning Department (DNP), and the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), and further desk research.[8] In general, the report focuses on three main channels through which climate-related risks affect Colombian banks' balance sheet: the effects on credit risk in the loan portfolio, the effects on the market value of government bonds, and the effects on exposures through investments in other financial institutions. These three channels represent the most important asset classes, covering 79 percent of total assets in the Colombian banking sector. However, in some of our quantitative assessments, we limit our scope further owing to data limitations, including investments in related entities and noncorporate loans (the latter only for transition risk).[9] Because data are not available for all potential channels that affect the financial sector, our outcomes can be conservative and lead to an underestimation of the total effect of climate risks on banks.

We investigate a set of scenarios specific to the Colombian context that are designed to investigate events in the tail of the probability distribution. The scenarios that we use for the analysis investigate events that are specifically relevant in Colombia, including a relatively high greenhouse gas (GHG) emission reduction target in the medium term (that is, by 2030) and high and increasing flood risk. For both transition and physical risks, we investigate orderly scenarios but also events that are less likely to occur but that would potentially cause more stress to the Colombian banking sector. Looking at such severe but plausible scenarios is commensurate with common practice in analysis of financial sector scenarios and stress testing but should not be interpreted as investigating the most likely outcome. For floods, the report investigates the full disaster risk—which includes both the baseline risk and potential impacts from climate change. Figure I.1 provides a mapping of the investigated scenarios to the NGFS classification that are relative to the new set of NGFS scenarios.[10]

7 US$1 = Col$3,439 on December 31, 2020.
8 IDEAM is Colombia's national meteorological institute.
9 For the effect of climate-related risks through foreign subsidiary and affiliate exposures, we provide a separate and more high-level analysis in the section titled "Cross-border risks," in chapter 1.
10 The new NGFS scenarios are expected to be published in May 2021 and provide more variables for a wider set of scenarios than those currently available. To our understanding, no specific data will be available for Colombia, but aggregates will be provided for the Latin America and the Caribbean region and a few of its larger countries.

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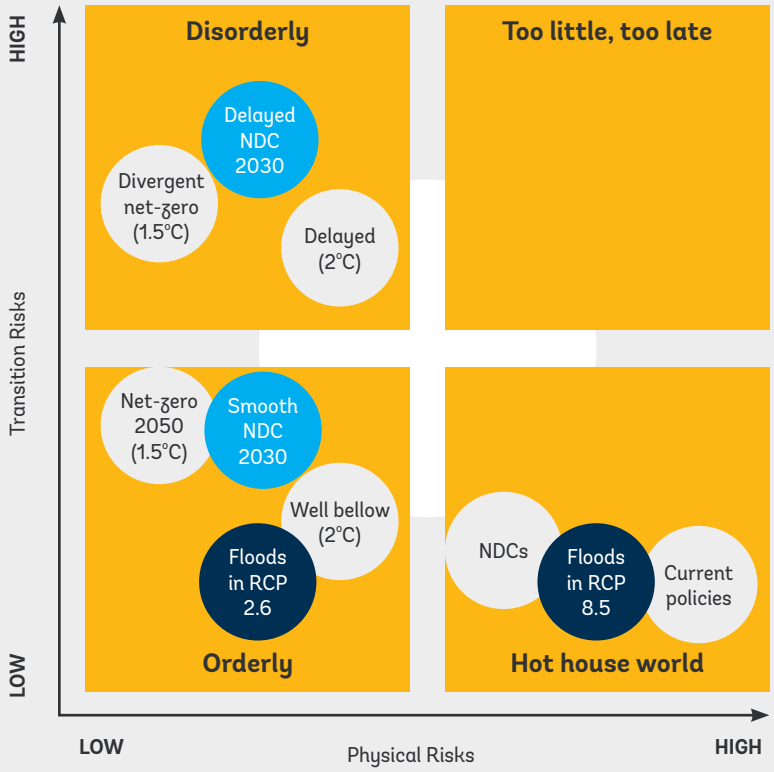
FIGURE I.1. - Mapping of investigated scenarios to the NGFS classification



Source: Staff illustration based on NGFS (2020b).
Note: NDC = nationally determined contribution; RCP = representative concentration pathway.

The exercise is aimed to explore and improve the understanding of the impact of climate-related financial risks to the banking sector, both on an aggregated and per bank level. Globally, central banks and financial supervisors are developing methodologies and tools to identify and mitigate climate-related financial risks. These practices are however emerging and under continuous development. Our analysis is the first of its kind in Colombia and is explorative, based on the available data in the country. Results should be interpreted with some caution because both our analyses and the data used for their input are based on different types of modeling (for example, climate, macroeconomic, financial), hence, leading to the potential compounding model error. Our results, therefore, should be interpreted in their order of magnitude and are not intended to identify capital shortfalls or to provide pass or fail outcomes for banks. Besides aggregate results, we also provide outcomes for individual banks to inform microprudential supervision. With respect to this, we stress the need to perform further deep dives at the institution to confirm the initial hypothesis and to get a more detailed understanding of the specific bank's exposure.

The report is structured in four chapters. The first chapter presents an overview of the climate change in Colombia, the structure of the Colombian banking sector, and the main climate-related risks that are relevant for banks. It also provides a high-level analysis of climate-related risks to countries that the Colombian banking sector has (indirect) exposures to. The second chapter focuses on physical risks, setting out a vulnerability analysis related to severe riverine floods that are in severe cases often linked to La Niña episodes. The third chapter focuses on transition risks, estimating the potential impact of delayed decarbonization scenarios on the Colombian economy and banking sector. Finally, the fourth chapter concludes and puts forward policy recommendations to the SFC and other public stakeholders.

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Climate Change and Financial Risks in Colombia

Natural disasters and climate change

The most economically damaging natural disaster events that occurred in Colombia in the past decades were earthquakes and floods. Colombia suffers from both geophysical and hydrological disasters, which led to economic damages following earthquakes, volcanic activity, floods, insect infestations, and landslides. In today's currency, those that were most damaging were volcanic activity in 1985 (Col$7.8 trillion), earthquakes in 1999 (Col$9.4 trillion), and the floods resulting from the strong La Niña in 2010 and 2011 (combined damages of Col$12.6 trillion). Of those damages, only a minor fraction of losses was insured. See table 1.1. According to estimates provided by IDEAM, the sectors most affected by the floods in 2010 and 2011 include agriculture (37 percent of total damages), mining (29 percent of total damages), and transport (20 percent of total damages). See CEPAL (2012).

> > >

TABLE 1.1. - Most damaging natural disasters in Colombia between 1970 and 2020

Type	Date	Damage	Damage	Insured damage	People affected
		US$ thousand	Col$ million	Col$ million	
Earthquake	January 1999	2,850,664	9,407,193	506,480	1,205,933
Volcanic activity	November 1985	2,376,735	7,843,225	—	12,700
Flood	September 2011	1,466,166	4,838,347	—	498,924
Flood	April 2010	1,172,442	3,869,059	54,167	2,791,999
Flood	April 2011	1,170,659	3,863,176	153,777	988,599
Earthquake	March 1983	1,054,715	3,480,561	—	36,200
Flood	November 1970	913,980	3,016,133	—	5,105,000
Insect infestation	May 1995	174,483	575,796	—	—
Landslide	March 2017	104,299	344,187	—	45,360
Flood	March 2012	69,038	227,826	—	8,000

Source: EM-DAT database
Note: Damages have been adjusted to reflect the 2019 consumer price index, using an exchange rate of US$1 = Col$3,300; — = not available..

Climate change over time alters the underlying probability distribution of losses emanating from natural disasters caused by the weather, which could lead to stronger La Niña events, increased precipitation, and increased flood hazard. In general, IDEAM expects heavy rains, droughts, and hailstorms in places where these did not occur before, as well as changes in the properties of these events (for example, mean, modal values, and dispersion measures). Increased precipitation is especially expected in the center and west of the country, and it could lead to a substantial (25 to 65 percent between 1980 and 2080) increase in flood hazard over time (Winsemius and others 2013). Moreover, the recurring weather phenomena El Niño and La Niña may increase in severity owing to a changing global climate, thereby making episodes of extreme drought (El Niño) and precipitation (La Niña) more likely (Cai and others 2015). Finally, sea level rise may affect the value of real-estate assets and disrupt supply chains of businesses in coastal areas.

Colombia will likely get substantially hotter during the coming decades, with consequences for business activity and labor productivity. IDEAM has created a number of scenarios for the effects of climate change in Colombia. These scenarios include predictions for three time frames, that is, changes between 2011–2040, changes between 2041–2070, and changes between 2071–2100. Scenarios cover temperature and precipitation and are available not only at national but also regional levels (figure 1.1). The International Monetary Fund (IMF) has estimated that a 1 degree increase in temperature in Colombia can lead to a decline in real per capita output of 1.0 to 1.5 percent (IMF 2017). A warmer climate also implies that the glaciers in Colombia will retreat further, after already losing 62 percent of the area present in the country before 2017 compared with the mid 20th century (Rabatel and others 2018).

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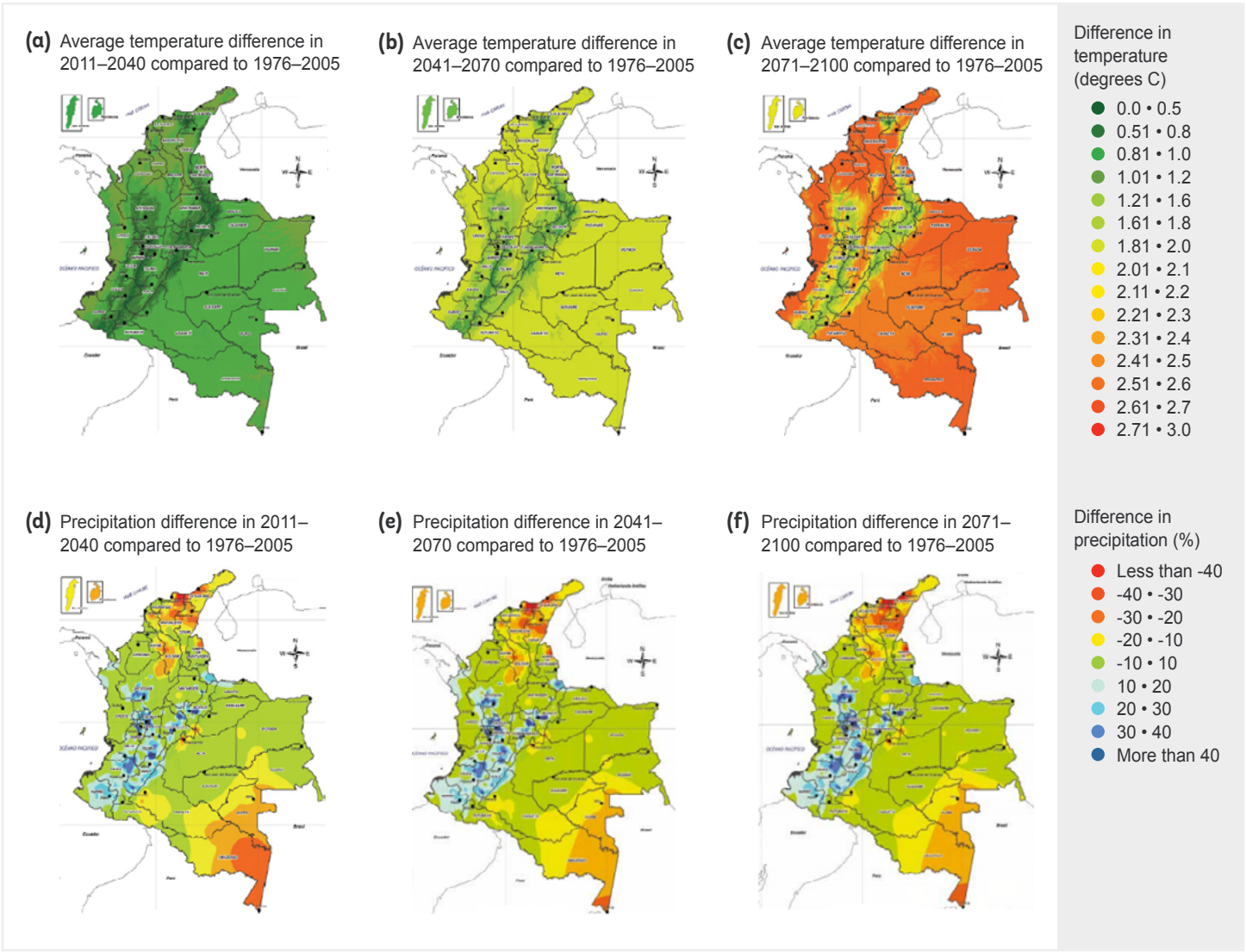
FIGURE 1.1. - IDEAM 2015 climate scenarios



Source: IDEAM 2015.
Note: IDEAM = Institute of Hydrology, Meteorology and Environmental Studies.

The measures for climate mitigation and adaptation are taking shape. In 2016, the authorities introduced a carbon tax of US$5 per ton of carbon dioxide emissions, which is expected to reduce emissions by more than 4.3 million tons over 13 years. Substantial future efforts to reduce emissions can furthermore be expected in Colombia during the coming decade owing to the Colombian government's ambitions to reduce GHG emissions. The Colombian government has long recognized the challenges posed by climate change, starting with its approval of the United Nations Framework Convention on Climate Change in 1994. Since then, the government has included climate change in the National Development Plans since 2002, signed and ratified the Paris Agreement in 2015, established the nationally determined contribution (NDC), the creation of the National System of Climate Change and the formation of an intersectoral commission in charge of coordinating in this area. In December 2020, the Colombian government signed a new NDC with a GHG reduction target of 51 percent below a business-as-usual scenario by 2030 (NDC Colombia 2020). This NDC represents one of the most ambitious targets in the Latin America and the Caribbean region and is aligned with the country's long-term objective of achieving carbon neutrality by 2050.[11] To achieve this goal, a broad-based change in the Colombian economy can be expected during the coming decade. Finally, the DNP estimated that until 2030 about Col$3.1 trillion (US$0.9 billion) is needed annually to reach the Colombian mitigation goals. DNP published a national climate change adaptation plan in 2016, providing guidelines and tools to prioritize adaptation action to reduce risks.

The Colombian banking sector

Colombia has a relatively large banking sector with total assets in 2020 amounting to Col$730 trillion (US$209 billion or 78 percent of GDP).[12] Three national financial groups own the majority of assets (66 percent). The biggest group in bank assets is Grupo Aval, which holds about a quarter of all banking assets and consists of four banks: Banco de Bogotá, Banco de Occidente, Banco Popular, and Banco AV Villas. The second and third largest groups are Grupo Empresarial Antioqueño (Bancolombia) and Grupo Bolívar (Davivienda). Bancolombia is the largest bank in Colombia covering 25.4 percent of bank assets followed by Banco de Bogotá (14.5 percent) and Davivienda (14.6 percent). Larger banks that do not belong to these three groups include BBVA, owned by the international Grupo BBVA, and the government-owned Banco Agrario de Colombia, respectively holding 9.4 percent and 3.8 percent of bank assets.

The majority of bank assets in Colombia are related to lending, with a substantial fraction of the assets invested in debt and equity securities. In 2020, about two-thirds (63 percent) of the assets in Colombian banks were in the credit portfolio, which consists primarily of corporate and consumer loans. Nearly a quarter of all assets (22 percent) is invested in tradable securities, including sovereign debt and corporate debt and equity. About half (47 percent) of the investment portfolio is invested in government-related securities, whereas another third (33 percent) is in other financial institutions and groups (consisting of subsidiaries, branches, and associated entities). The remainder of the investments in local securities (10 percent), foreign securities (2 percent), and others (7 percent). Of all investments in subsidiaries, branches, and associated entities most are toward entities outside Colombia (71 percent). See figure 1.2.

Banks in Colombia vary in the way that they address climate-related financial risks in their strategy and operations. A recent survey conducted by the SFC shows that 64 percent of all banks has some policies or strategies to explicitly incorporate climate change or is developing one. Most banks furthermore report that they identify and address climate risks and opportunities in their operational and administrative activities and as part of their credit operations. The way in which banks do this, however, varies: for some banks it is part of their corporate social responsibility policies and has not yet been integrated into financial risk management, whereas others also identify and take measures for vulnerable sectors and regions to manage financial risks. Some banks approach climate-risk management from a business continuity perspective specifically looking at natural disasters. Finally, some banks have publicly communicated that they will reduce their exposure to coal-related activities to zero over the coming decades.[13]

11 The 2015 NDC commitments for Colombia aimed for a reduction of GHG emissions by 20 percent below the business-as-usual scenario in 2030.
12 Figures are for December 2020. Bank assets excluding other credit institutions (corporaciones financieras [financial corporations], compañías de financiamiento [trade finance companies], and cooperativas financieras [financial cooperatives]).
13 See https://www.elperiodico.com/es/economia/20210305/bbva-dejara-financiar-actividades-relacionadas-11559688?utm_source=mail&utm_medium=social&utm_campaign=btn-share.

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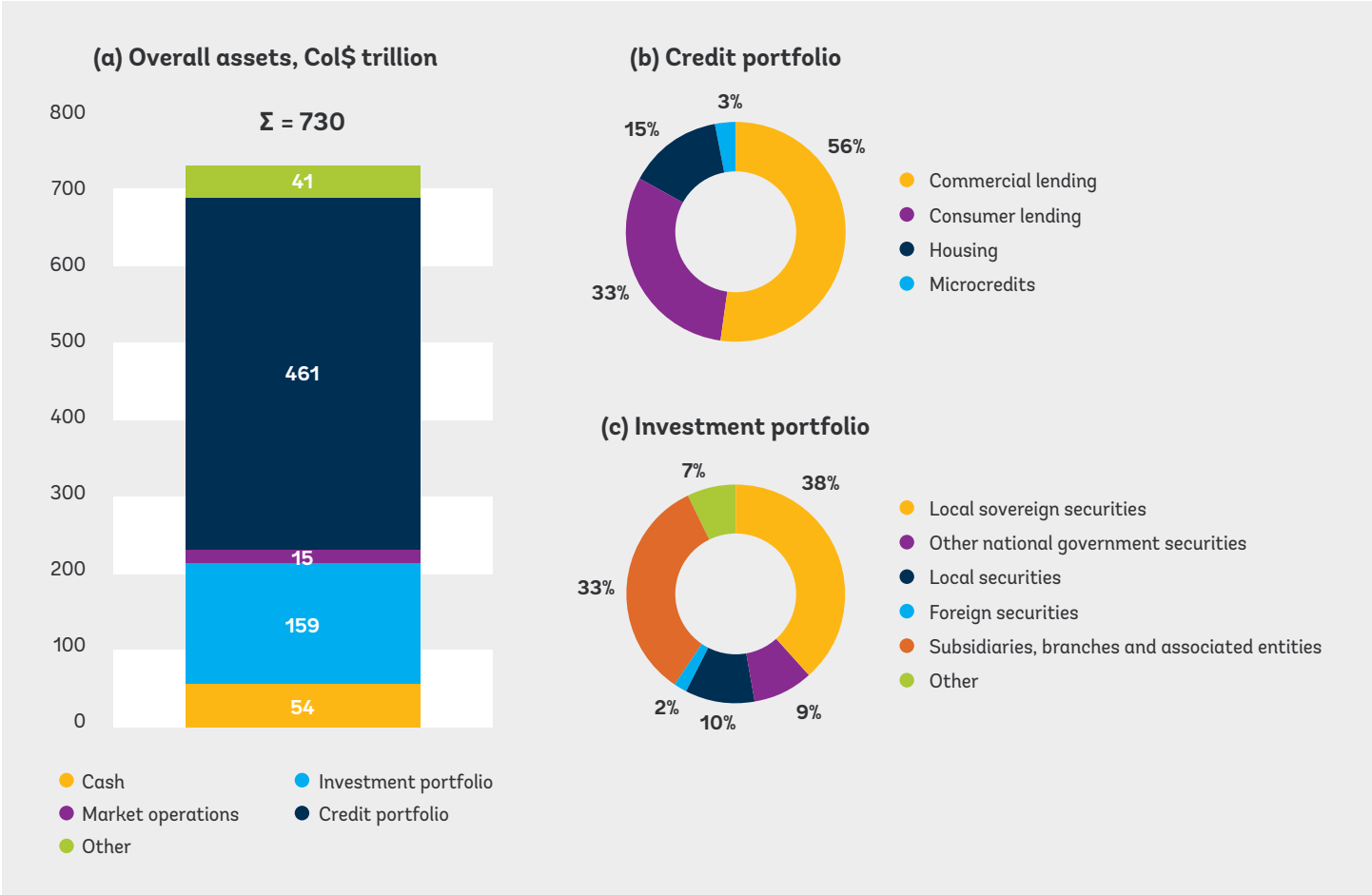
FIGURE 1.2. - Breakdown of assets in the Colombian banking sector in 2020



Sources: SFC, data for December 2020; staff calculations.
Note: Σ = sum.

In the nonfinancial corporate credit portfolio of Colombian banks, about 20 percent of total assets are toward transition-sensitive industries, however, with large differences between individual banks.[14] See figure 1.3. The highest aggregate exposures in the credit portfolio are toward energy generation (7.9 percent) and transport (6.5 percent), which is on the high end compared with countries in a similar position. At the same time, exposures to fossil fuels (0.8 percent) are low. Individual banks vary substantially in their exposures to transition-sensitive sectors, ranging between 1 percent and 26 percent of the corporate credit risk portfolio.

14 Transition-sensitive industries include fossil fuels, energy generation, heavy industry, transport, and agriculture. This description is in line with the classification by Battiston and others (2017), except that we define heavy industries instead of energy-intensive firms. See https://www.finexus.uzh.ch/en/projects/CPRS.html.

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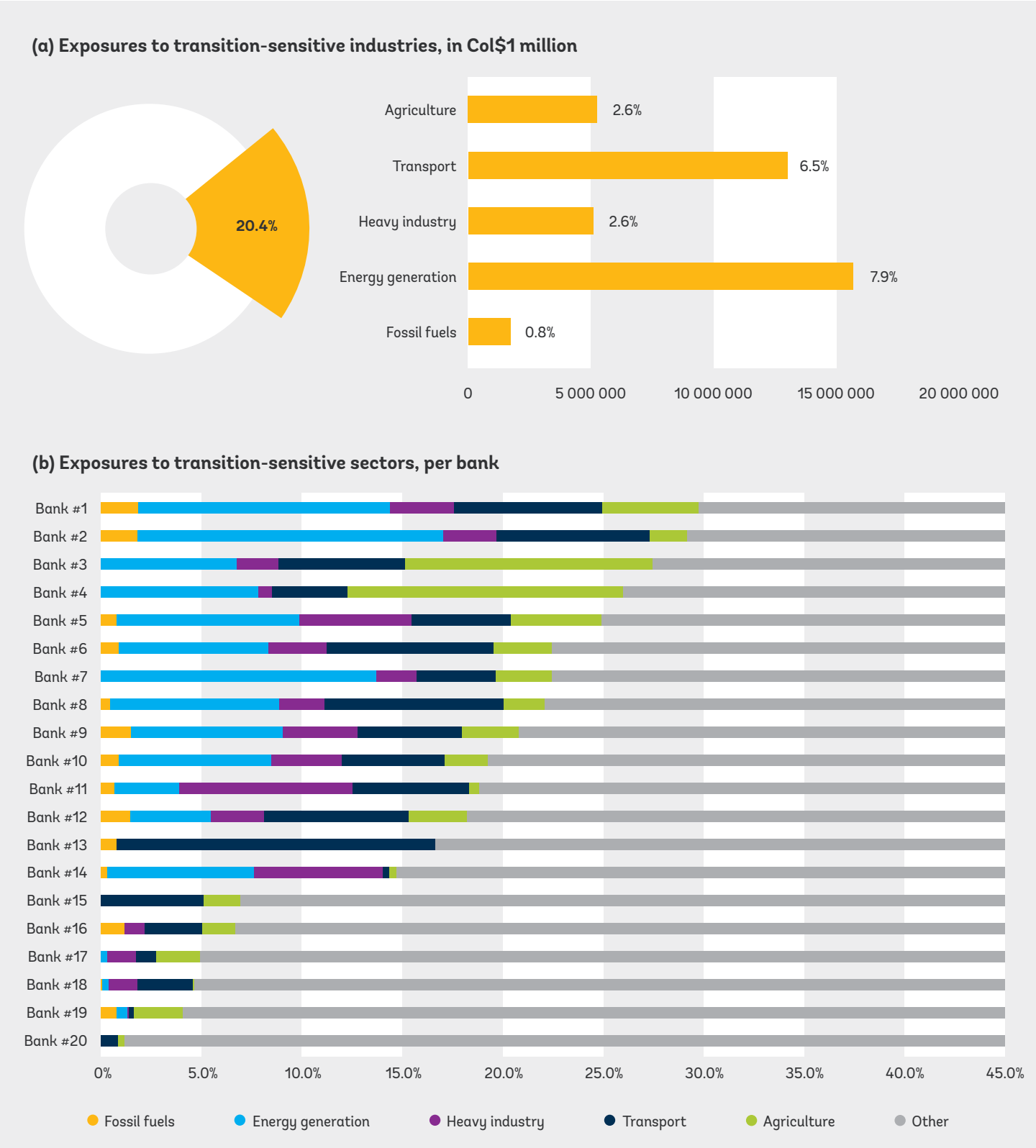
FIGURE 1.3. - Sectoral breakdown of commercial lending portfolio (percentage of total)



Source: SFC, data for December 2020; staff calculations.
Note: Based on a subset of 20 large Colombian banks covering most of the banking assets. Based on sectors 1, 2, 3, 5, 6, 9, 16, 17, 19, 20, 24, 29, 30, 35, 49, 50, 51, 52, and 53.

Main climate-related risks to the banking sector

Climate change and its mitigation lead to economic and financial impacts on traditional financial risks such as credit and market risk, through different channels. Physical risks originate from natural disasters and climate change that can lead to economic costs and financial losses. Physical sources of risk can either be chronic (gradual) in nature, such as rising temperatures and sea levels and changes in precipitation; or acute, such as in the case of extreme weather. Transition risks are related to economic adjustment during the transition toward a greener, carbon-neutral economy. These risks can be related to climate mitigation efforts, whereby abrupt policies to reduce carbon dioxide emissions and thereby limit global warming could have significant impacts on the economy. However, policy pressure to tackle environmental pollution and improve livelihoods can also lead to significant adjustment costs for companies and households. Disruptive technological change, for example, in alternative and cleaner sources of energy as well as changing consumer and market behaviors toward greener products and services can also result in structural economic shifts. In this process toward a greener and carbon-neutral economy, particularly when happening abruptly, revaluations of underlying financial assets are likely. Climate risks and their transmission channels are summarized in figure 1.4.

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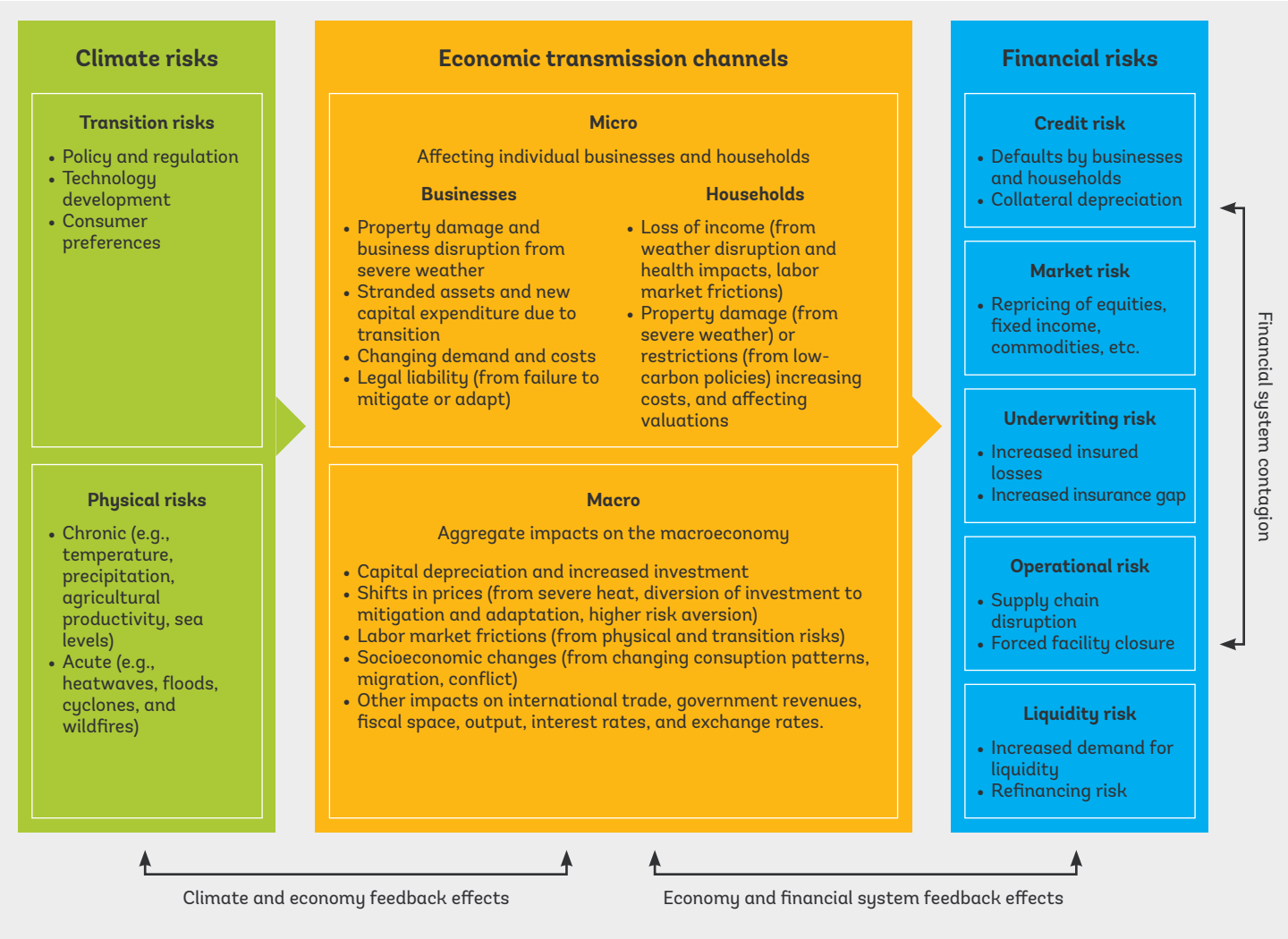
FIGURE 1.4. - Transmission channels for physical and transition risks



Source: NGFS 2020a.

The Colombian banking sector is to some extent exposed to climate-related natural disasters through assets in vulnerable areas and through substantial exposure to the official sector. Floods are the main climate-related disaster risk in Colombia, leading to business interruption, damages to real estate, and damages to other capital goods. This directly affects the creditworthiness of affected businesses and households. Corporate loans make up an important part of the aggregated banking portfolio, amounting to 33 percent of total assets. Historically, floods have affected the Colombian banking negatively owing to increased credit losses and related provisions. Only a minor fraction of economic damages after major flood events are insured (between 2 to 4 percent), hence, the impact on underwriting risks is likely low.[15] A low degree of insurance penetration, however, leaves a burden on the government budget and affects the creditworthiness of firms in case of a large natural disaster. Besides firm defaults, a large climate-related disaster could also affect the creditworthiness of the Colombian government, leading to a downgrade of official sector debt. Such a downgrade may be particularly worrisome if disaster strikes during an economic downturn (that is, a double shock). Government exposures make up about 8 percent of assets. Finally, natural disasters can lead to operational and liquidity risks for banks when branches and payment infrastructure are affected by a disaster and in case households and firms draw on their deposits to finance a recovery.

Furthermore, climate change may affect the underlying economics of businesses in a more gradual way, thereby affecting credit risk, market risk, and potentially affecting macroeconomic variables over time. Changes in temperature, precipitation, and droughts can have an important impact on the market value and creditworthiness of the agricultural and energy sectors, as well as increase the frequency and severity of natural disasters. Agriculture is an important sector in Colombia, representing 6.3 percent of GDP in 2018 and generating more than half of the employment (59.7 percent) of the rural population (Melo and others 2019). Regional changes in temperature, rainfall, and the amount of sun affect agricultural output and may require a shift in crops and techniques to mitigate the effects of a changing climate. Furthermore, the reliance of the Colombian energy sector on hydropower makes it vulnerable to changes in precipitation patterns (and increasing uncertainty surrounding them). For hydropower in particular, an early assessment or risks is important because of the long lifespan of the plant. Colombian banks should closely monitor their exposures to these sectors. Relatively high impacts of changes in temperature and precipitation are expected in the Andean region as well as in the Amazon foothills and in the Orinoquia region (IDEAM and others 2017). Changes in temperature may affect macroeconomic variables such as labor productivity and thereby GDP growth over time. Several banks have indicated that they consider agriculture to be specifically vulnerable and intend to work on insurance solutions to manage this risk. We note that it is already certain that some degree of climate change will occur over the coming decades, regardless of emission scenarios.

Transition risks affect a substantial portion of the corporate loan portfolio of Colombian banks, as well as other asset classes. Specifically, decarbonization trends can lead to increased credit and market risk for corporates that are in transition-sensitive sectors. The Colombian banking sector is mainly exposed to nonfinancial corporates through their credit portfolio, as most investments (bonds and equity) are in the public sector and toward financial entities. Nevertheless, Colombian banks may have indirect exposures to transition-sensitive corporates through their investment portfolio and through investments in subsidiaries and associated entities that make up one-third of the investment portfolio. Furthermore, Colombian banks are vulnerable to potential macroeconomic impacts because of a broad adjustment of the economic structure in stronger transition scenarios. Stress testing by the Dutch Central Bank (DNB) has shown that in sudden transition scenarios, wider macroeconomic effects may lead to losses in the financial sector (Vermeulen and others 2019).[16] Besides direct impacts on transition-sensitive sectors, these macroeconomic impacts can lead to credit losses on other corporate and household loans (for example, because of growth and higher unemployment) as well as losses caused by changing interest rates. Also, the collateral value of real estate loans may decrease for energy inefficient buildings. We note that transition policies may not only originate in Colombia but also abroad. Impacts on the Colombian banking system may then manifest themselves through cross-border exposures through foreign subsidiaries and associated entities and trade channels (for example, exports of GHG-intensive products such as coal and oil). Transition risks in Colombia are high compared with most other countries in the region, because of a combination of a high carbon intensity of the economy, fossil fuel exports, and high policy targets for GHG emission reduction.

High-level sectors that are most relevant for banks to consider for transition risks include agriculture, energy generation, and transport. All these sectors contribute substantially to GHG emissions and are substantially represented in the banks' corporate loan portfolios. The highest aggregate transition-sensitive exposures in the credit portfolio are toward

15 Insurance penetration based on data from EM-DAT.
16 DNB, among others, investigates an overnight application of a US$100 carbon tax.

energy generation (about 6 percent) and transport (around 4 percent). At the same time, the direct exposures to fossil fuels (about 1 percent) are low, although that sector is the most vulnerable to an energy transition. Some banks have indicated that they focus on specific sectors with respect to transition risks, including agriculture (specifically cattle breeding), mining projects, the manufacturing industry, electricity generation, the construction sector, the waste management sector, road transport, plastic and rubber production, and tourism.[17] Further exploration of vulnerable sectors to transition risks is carried out as part of the analysis in chapter 3.

In sum, the Colombian banking sector is vulnerable to gradual and more acute risks that stem from both transition and physical risks. We summarize the main risks in table 1.2. On the one hand, risks I and II are mostly gradual in nature that are expected to play out over a relative long time. These risks are primarily relevant from the perspective of a business model, where banks that do not adjust to changing circumstances (for example, in pricing and loan origination practices) could become less profitable over time, eroding their capacity to replenish financial buffers when needed. In these scenarios, there also could be more abrupt shocks when prices of certain assets rapidly change because of better market understanding (for example, rapid decreasing real estate prices in coastal areas). On the other hand, more acute risks could play out over a shorter time, including natural disasters and sudden tightening of climate policies in the coming decade (until 2030). These more acute risks are the risks that have the highest potential for banking sector stress in the next decade.

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TABLE 1.2. - Summary of main climate-related risks for the Colombian banking sector

Risk		Likelihood	Potential for banking sector stress	Channels
I.	Gradually increasing carbon price and climate policies	Medium	Low	• Increasing loan losses in transition-sensitive sectors • Value of commercial real estate
II.	Gradually increasing temperature and changing weather-patterns	High	Low/medium	• Increasing loan losses in vulnerable sectors (e.g., agriculture)
III.	A sudden tightening of climate policies	Low/medium	Medium/Large	• Increasing loan losses in transition-sensitive sectors • Value of commercial real estate • Macroeconomic effects
IV.	Severe flood	Medium	Medium	• Real estate, corporates, households in affected areas • Sovereign credit downgrades
V.	Severe flood plus recession (double shock)	Low/medium	Large	• Real estate, corporates, households in affected areas • Sovereign credit downgrades • Macroeconomic effects

Source: World Bank staff.

17 Based on the second climate risk and opportunities survey, conducted by the SFC amongst Colombian financial institutions.

Cross-border risks

One specific feature of the Colombian banking system is that climate-related risks may manifest through substantial cross-border exposures, which are significant in highly climate-sensitive economies in Central America. The banks' investment portfolio contains almost no exposure to nonfinancial corporates but may experience indirect losses owing to investments in other financial institutions. In total, more than 7 percent of total assets in the Colombian sector are toward subsidiaries, branches, and affiliated entities. Most of these exposures are part of the investment portfolio and toward entities that are located mainly in Central America, Paraguay, and Peru. In the investment portfolio, a third of affiliated exposures are toward entities in Colombia (29 percent), whereas more than two-thirds (71 percent) are toward entities abroad. This exposes the banking sector to indirect climate risks (both physical and transition). This section provides a first analysis of cross-border risks based on high-level indicators of climate risks in countries that the Colombian banking sector has exposures to.

High-level country indicators show that physical risks could be relatively high, and transition risks more limited, in foreign exposures compared with domestic exposures. See table 1.3. Compared with the main countries where the Colombian banking system has exposures, Colombia scores relatively high on transition risk indicators (fossil fuel exports, carbon dioxide intensity, and NDC goals for 2030), whereas it scores relatively low on physical risk indicators (natural disasters and vulnerability to climate change). Despite detailed data not being available, these indicators imply that foreign exposures of Colombian banks are relatively vulnerable to physical risks. Some of these physical risks may be correlated to domestic risks, in as far as they are caused by the same weather phenomena (for example, El Niño and La Niña). Transition risks may also be correlated across countries, owing to concerted efforts to achieve NDC targets related to the 2015 Paris Agreement.

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TABLE 1.3. - Climate-risk vulnerability indicators per country

	Fossil fuel exports	CO_2 intensity exports	CO_2 intensity domestic	NDC goals for 2030	Natural disasters	Climate change
	Fossil fuel export revenue (normalized)	CO2 intensity of manufacturing export (normalized)	Carbon intensity (kg CO2 per US$ of GDP)	Emissions reduction compared with BAU	Average weather-related losses (% of GDP)	ND GAIN vulnerability index
Colombia	0.26	0.37	0.17	51%	0.16	39
Costa Rica	0.14	0.28	0.12	44%	0.13	39
El Salvador	0.11	0.33	0.13	NA	0.67	45
Guatemala	0.13	0.32	0.15	NA	0.50	46
Honduras	0.09	0.33	0.24	NA	0.47	46
Nicaragua	0.10	0.29	0.19	10%*	0.65	45
Panama	0.19	0.30	0.13	11.5%*	0.01	41
Paraguay	0.22	0.25	0.12	NA	0.78	38
Peru	0.18	0.38	0.15	30%	0.14	43

Sources: World Bank; Global Carbon Project; World Resources Institute; Germanwatch; Notre Dame GAIN; staff calculations.
*Note: BAU = business as usual; CO2 = carbon dioxide; GDP = gross domestic product; kg = kilogram; NA = not available. ND-GAIN = Notre Dame Global Adaptation Initiative; * = target applies to specific sectors, hence providing an upper bound. No data available for the Cayman Islands and Barbados.*

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Physical risk assessment

In this chapter we take a more detailed look at the vulnerability of Colombian banks to severe flood scenarios. Riverine floods are the main climate-related disaster risk in Colombia, leading to business interruption, damages to real estate, and damages to other capital goods. The La Niña–related floods in 2010 and 2011 resulted in economic damages of US$8.6 billion, making it the costliest climate-related disaster in recent history in Colombia.[18] Moreover, the economic damage of floods is expected to increase owing to a combination of socioeconomic development and climate change. The flood hazard (measured in flood volumes with a 100-year return period) is expected to increase in many regions globally during the coming decades because of climate change, with estimates suggesting that the flood hazard in Colombia could increase between 25 and 65 percent between 1980 and 2080 because of climate change alone.[19]

We explore the impact of riverine floods on Colombian banks by modeling bank stress in three steps (figure 2.1). In a first step, we estimate economic damages per municipality in different scenarios. These scenarios vary on the basis of their return period (that is, the frequency with which they occur) and the year in which they occur (with later years experiencing a larger effect of climate change). Because probabilistic flood risk scenarios are not available in Colombia for economic damages per municipality, we downscale national-level flood risk estimates by the World Resources Institute (WRI) using a relative economic flood risk indicator at a municipal level. In a second step, we estimate financial losses through two channels: (a) an increase in loan loss provisions and (b) an increase in the sovereign credit spread. In a third step we combine our estimates of financial losses per unit of exposure with data on municipal loan exposures, sovereign bond exposures, and balance sheets per bank to obtain a first estimate of the effect of each scenario on the capital position of banks. A detailed description of data and variables used is provided in figure 2.5.

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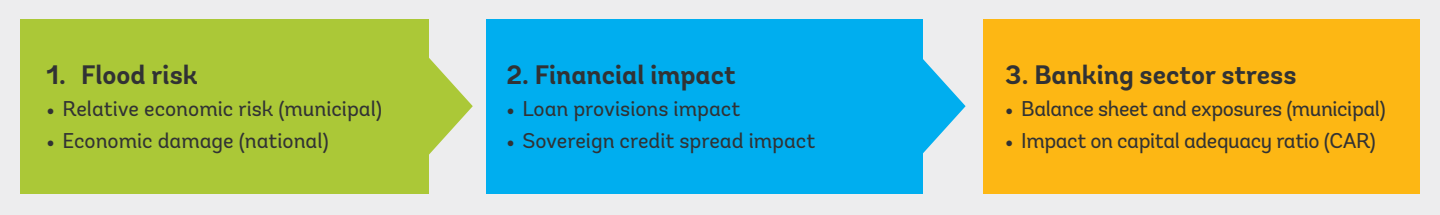
FIGURE 2.1. - Main elements of the flood vulnerability assessment



Source: Staff illustration.

18 We note that earthquakes also could cause substantial damages in Colombia but are out of scope of this climate-risk assessment.
19 See Winsemius and others (2013). Presented estimates represent the average of flood hazard simulations by five Global Climate Models for the representative concentration pathway (RCP) 2.6 and RCP 8.5 scenarios.

Flood risk

Floods in Colombia can inundate substantial areas throughout the country, with the highest levels of inundation historically observed during strong La Niña episodes. According to data by IDEAM, floods can occur throughout the country but especially in the northwest (dark blue areas in figure 2.2), among others covering the Sucre, Bolívar, Antioquia, and Magdalena departments. The north and west areas of the country have also seen the most damaging floods during La Niña, a recurring weather phenomenon in the Pacific Ocean causing heavy rainfall (IDEAM 2012). Periodical and less severe floods are observed in the east and south of the country (light blue areas in figure 2.2), specifically in the Arauca and Casanare departments. The flood maps from IDEAM include the areas that were flooded during La Niña of 1988–1989 (strong event), 1999–2000 (moderate event), and 2010–2012 (strong event). We aggregate this data to the municipal level to create an indicator of flood susceptibility to use as a starting point for further analysis. See panel a in figure 2.3.

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FIGURE 2.2. - Areas with high, medium, and low susceptibility to floods in Colombia

Source: IDEAM. Note: map depicts outer limits for extreme events. The areas covered do not provide an exhaustive mapping of potentially floodable areas. Some scenarios lead to additional areas being flooded, for example, when specific water defense infrastructure fails. See, for example, Cardona and others (2017).

A relative economic risk indicator shows that economic losses are highest in the north, center, and west of the country and are geared toward the rural areas. We create an indicator for the relative economic flood risk per municipality by combining flood hazard with economic exposure data. Throughout our further analysis we aggregate or disaggregate all data to the municipal level, which is needed to link our estimates to available financial sector exposure data. We create an economic flood risk indicator (figure 2.3, panel c) by combining the IDEAM data on the fraction of a municipality that is susceptible to flood (panel a) with the value added in that same municipality, obtained from the National Administrative Department of Statistics (DANE) in panel b.[20] We calculate the relative economic risk by multiplying the flood hazard with the economic exposure ($C = A \times B$). This gives an indication of the fraction of value added that is at risk per municipality. Larger cities tend to be less vulnerable to floods and, hence, pose a lower risk despite the high concentration of economic activity (for example, in Bogotá, Medellín, and Cali). Departments that are at a relatively high economic risk include Antioquia, Cundinamarca, and Bolívar.

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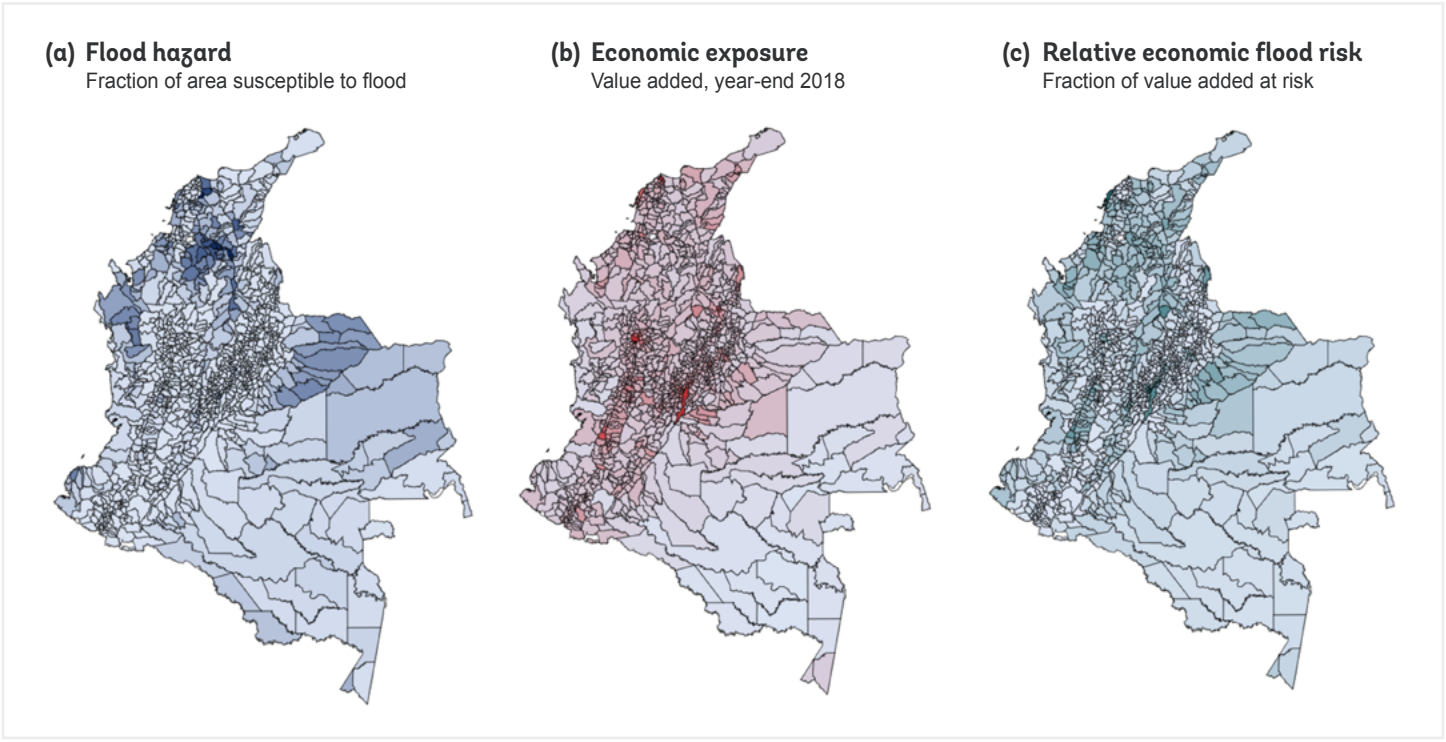
FIGURE 2.3. - Relative economic risk to severe riverine flood events



Sources: Data obtained from IDEAM and DANE; staff calculations.
Note: Darker shades indicate a higher value for the variable.

20 In taking this approach, we assume that economic activity is spread equally across each municipality. We have to make this assumption because we do not have data on the precise location of the assets of Colombian banks. However, municipalities are reasonably small, and our analysis uses a total of 1,122 municipalities. We use weight 1 for areas with high susceptibility to floods and weight 0.5 for areas with medium susceptibility to floods. These weights align with flood depths that occur once every 50 years as calculated by Ingeniar in UNGDR (2018). UNGDR is Colombia's National Unit for Disaster Risk Management. See appendix B on Colombia's flood vulnerability.

Global probabilistic riverine flood models estimate total economic damages in Colombia of up to US$23 billion to US$25 billion in 2030 in severe but plausible scenarios. The WRI Aqueduct database provides probabilistic estimates on economic damages at a national level from riverine flooding in Colombia, based on the average of a set of five global climate models (Ward and others 2020). Economic damages are estimated as a function of the return period (RP), with lower return periods indicating more likely events. For example, an event with an RP of 500 years is expected to occur with a probability of 1 in 500 in each single year. Looking at longer time spans, however, it is increasingly likely that such events will occur at least once during that period. An event with an RP of 500 years is expected to occur within the next 50 years with a probability close to 10 percent. The WRI estimates that an RP 500 event in 2030 could cause US$23 billion in economic damages, on the basis of an intermediate climate change scenario (representative concentration pathway [RCP] 4.5) and intermediate socioeconomic developments (shared socioeconomic pathway [SSP] 2). This amount increases to US$25 billion in an RP 1,000 scenario and reduces to US$13 billion in an RP 25 scenario. See figure 2.4, the blue lines (2030). Using these estimates, riverine flooding of the magnitude of the 2010–2011 La Niña floods would occur roughly every eight to nine years in 2030.

Climate change could increase economic damages of riverine floods with 25–65 percent between 1980 and 2080. This calculation is based on an increase in flood hazard as a result of changes in precipitation patterns, according to an averaging of five global climate models (Winsemius and others 2013) and assuming economic damages proportionally grow with flood volumes. Although estimates are subject to a relative high degree of model uncertainty, all five models for Colombia point to a substantial increase in flood hazard until 2080. Estimates range from a 25 percent increase between 1980 and 2080 in RCP 2.6 (declining emissions from 2020 and net-zero by 2100) to a 65 percent increase in RCP 8.5 (worst-case scenario with a continued rise of GHG emissions throughout the 21st century).[21] To illustrate, these estimates imply that an RP 250 event in 2030 may turn into an RP 50 event in 2080. It also underscores the point that events in the past decades may already have been more severe owing to climate change that has already occurred. We note that economic damages may increase more than 25–65 percent until 2080 because of economic development (and, hence, higher exposures). We exclude this from our analysis, however, because balance sheets of banks can be expected to grow in line with economic development, and we take the 2030 estimates by the WRI as our baseline.[22] We also note that adaptation investments (for example, additional flood management infrastructure) and disaster-resilient planning for new economic activity can reduce overall economic damages as well as the effect on Colombian banks. Estimates for 2050 and 2080 are shown in figure 2.4, under RCP 2.6 (panel a) and RCP 8.5 (panel b).

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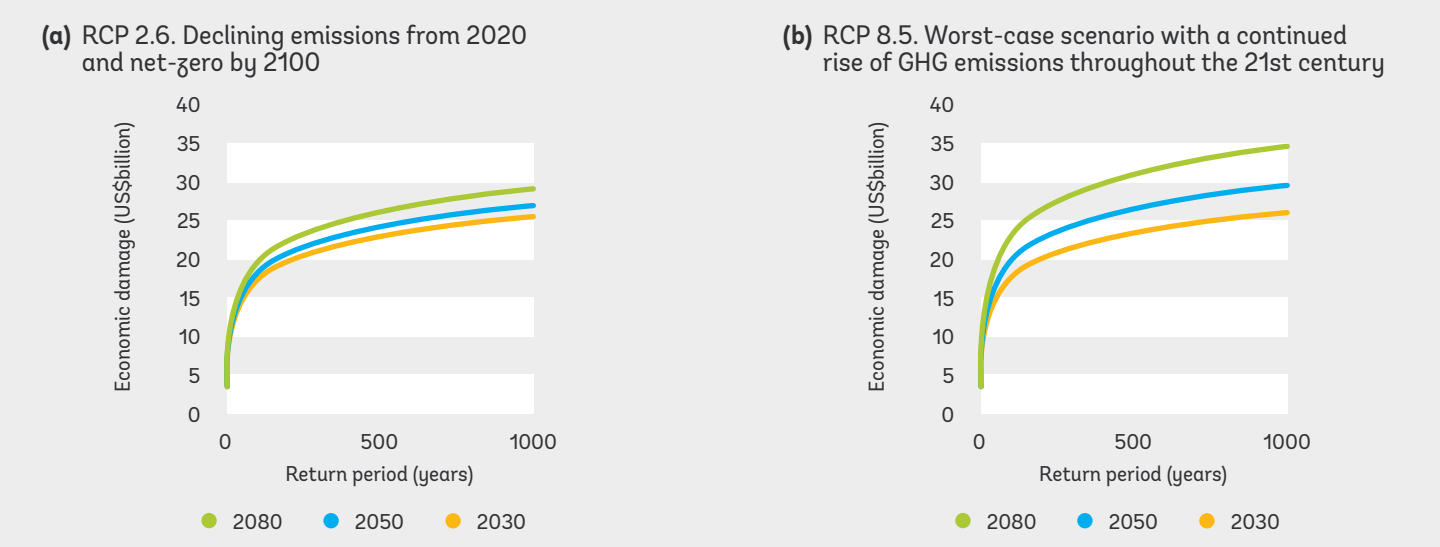
FIGURE 2.4. - Projected economic damages for riverine flood in Colombia in 2030 and increases over time because of climate change



Sources: World Resources Institute Aqueduct Database; Winsemius and others 2013; staff calculations.
Note: RCP = representative concentration pathway; SSP = shared socioeconomic pathway. Estimates for 2030 based on RCP 4.5 and SSP 2; estimates for 2050 and 2080 show the effect of climate change only, based on RCP 2.6 (panel a) and RCP 8.5 (panel b). All estimates are in today's currency (no inflation).

21 For our analysis we also assume that increases in economic damages owing to climate change grow constantly over time and that flood hazard scales linearly with economic damages.

22 Estimates were obtained while holding the level of socioeconomic development constant. Socioeconomic development is less relevant for our analysis as an increase in socioeconomic activity would likely also lead to an increase in banking activity (including available capital). In doing so, we assume that balance sheets of Colombian banks grow in line with socioeconomic activity but otherwise remain similar in structure (semistatic balance sheet).

Financial impact

Historically, natural disasters have led to higher loan losses for banks as well as credit rating downgrades to the debt of national governments (Klomp 2014 and Standard & Poor's 2015). To link disaster risks to losses on financial assets, we obtain empirical estimates for the elasticity of loan loss provisions and the sovereign credit rating to economic damages owing to natural disasters. For loan loss provisions, we make our own estimates based on historical provisioning data available at the SFC. For sovereign credit ratings, these national data are not sufficient to make a comparable estimate. Hence, we base ourselves on data from the credit rating agency Standard & Poor's (S&P) that estimates the relationship between losses from natural disasters and credit ratings from a global sample of countries, including several in Latin America.

a. Based on historical data available for Colombia, we estimate that every 1 percentage point of GDP lost owing to flood damages causes a 0.12 percentage point increase in loan loss provisions.[23] Using a difference-in-difference (DID) panel model specification and SFC spatial credit data, we estimate excess credit provisions in affected areas that cannot be attributed to other cyclical and bank-specific factors (for example, interest rate changes, national policies, differences between bank business models, and so forth). Our model estimates that the La Niña floods of 2010 and 2011 led to excess provisions of 0.12 percentage point of the loan portfolio per 1 percentage point of departmental GDP in economic damages.[24] This is equivalent to total excess provisions of Col$1.5 trillion for the entire banking sector (0.3 percent of the total credit portfolio). Our estimates furthermore imply that provisions that were made over the shock period amounted to 11.9 percent of total assets in flooded areas.[25]

b. Furthermore, S&P data show that every 1 percentage point of GDP lost owing to natural disasters on average leads to a downgrade of sovereign debt by 0.28 notch. Sovereign credit rating downgrades occur regularly because of major natural disasters. Based on S&P data on disaster events that occurred in other countries, we estimate that every percentage point of GDP in economic damages leads to a downgrade of Colombian sovereign debt by 0.28 notch (Standard & Poor's 2015). Downgrades of sovereign debt affect the balance sheets of banks mainly through their holdings of sovereign bonds, through their impact on the credit spread that investors require to hold the debt. A decrease in a sovereign's credit rating on average leads to an increase in the credit spread and hence a decrease in the market value of the debt. This decrease has an immediate impact on sovereign bonds that are held at market value. Moreover, from a prudential perspective it would also be important to consider bonds that are not held at market value to estimate the potential losses that a bank would incur in case of insolvency and sale of its assets. To that end, we provide a comparison between stress results under accounting rules and stress results where we value the whole sovereign debt portfolio at market value. We use an estimated 49 basis points change in credit risk spread per rating notch, obtained from S&P (Standard & Poor's 2019). This calculation is based on the average of the five rating categories around Colombia's 2019 credit rating (BBB-).

23 A loan loss provision is an income statement expense set aside to cover for anticipated uncollected loan payments.
24 Further details on the regression specification are in appendix A. We use this parameter to estimate the total amount of excess provisions based on economic damages as modeled by the WRI. We then allocate excess provisions to municipalities using the relative economic flood risk indicator (figure 2.3, panel c).
25 This calculation is under the assumption that losses occurred in flooded areas only (that is, no spillovers) and that exposures in affected areas are a good representation of total exposure within a municipality.

Banking sector stress

We investigate four scenarios using a basic stress testing model, based on the strongest flood to date and plausibly more severe scenarios. To gauge the effects of severe floods, we link the disaster risk and financial impact estimates to an accounting-based stress test framework as developed by Čihák (2014). See figure 2.5. The Čihák model uses balance sheet and profit and loss data from banks to determine the effect of traditional financial sector shocks on the bank's capital adequacy ratio (CAR) and other profitability and solvency metrics. We adapt this model to allow for the use of granular spatial and sectoral credit exposure data and to include a sovereign credit spread channel. We calibrate the model using projected losses by WRI and estimates for the relationship between economic damages and financial sector outcomes (that is, credit provisions and sovereign credit ratings). We then investigate severe flood events by (a) allocating estimated excess provisions in the loan portfolio based on the relative economic risk per municipality and (b) determining market-value losses to sovereign exposures. We finally distribute loan losses proportionally to banks with exposures in those municipalities and market-value losses on sovereign bonds in line with banks' sovereign exposures. This gives us an estimate per bank of the impact of severe flood events. The four scenarios that we investigate are (A) floods with the severity of the 2010–2011 La Niña occurring in 2020; (B) severe floods, using a 500-year return period, based on estimates of flood risk in 2030 obtained from the WRI Aqueduct database; (C) severe floods occurring in 2080 distinguishing between a low (RCP 2.6) and high (RCP 8.5) climate change scenario based on Winsemius and others (2013), and (D) severe floods occurring in 2030 (similar to scenario B) at the same time as a recession. The recession is calibrated to reflect loan losses during the 1998–2000 banking crisis in Colombia.

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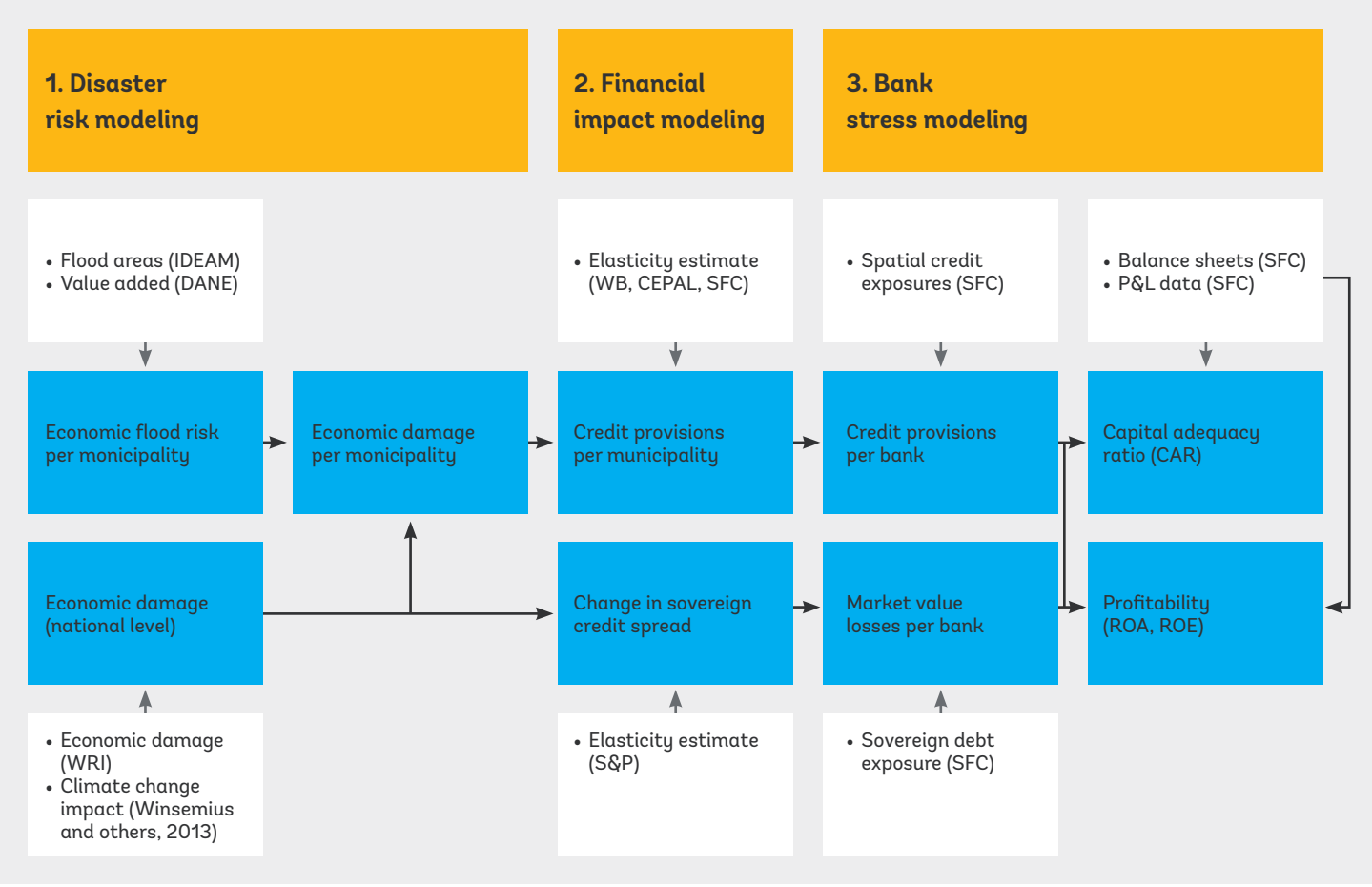
FIGURE 2.5. - Overview of the flood vulnerability model



Source: Staff illustration.
Note: CEPAL = Economic Commission for Latin America and the Caribbean; DANE = National Administrative Department of Statistics; IDEAM = Institute of Hydrology, Meteorology and Environmental Studies; P&L = profit and loss; ROA = return on assets; ROE = return on equity; SFC = Financial Superintendence of Colombia; S&P = Standard & Poor's; WB = World Bank; WRI = World Resources Institute.

Overall, our analysis shows that flood scenarios can lead to declines in capital adequacy that could moreover coincide with other shocks (figure 2.6). We present high-level outcomes for two groups: domestic (12 banks) and foreign (8 banks). For domestic banks, the average decline in the CAR for the severe flood scenarios (scenarios A to C) ranges between 0.3 and 1.0 percentage point. For foreign banks, the decline ranges between 0.3 and 1.2 percentage point. In the double shock scenario (scenario D) the average decline in the CAR is 3.1 and 3.4 percentage points for domestic and foreign banks, respectively. Across all banks, total losses in the double shock scenario can be mostly attributed to the economic recession (76 percent) with about a quarter of losses caused by severe floods. Furthermore, we find that a worst-case climate change scenario (RCP 8.5) could add an additional 0.1 to 0.6 percentage points in CAR impact—per event—compared with a scenario with limited climate change (RCP 2.6) depending on the bank. This range reflects differences in individual bank's exposures and hence their vulnerability to climate change. These results are under the assumption that banks do not change their business model and asset allocation to reflect climate change. If banks would adjust their operations, impacts could be more limited. Adjustments could, among others, include altering origination processes and requiring better insurance for households and firms at high risk of flooding.

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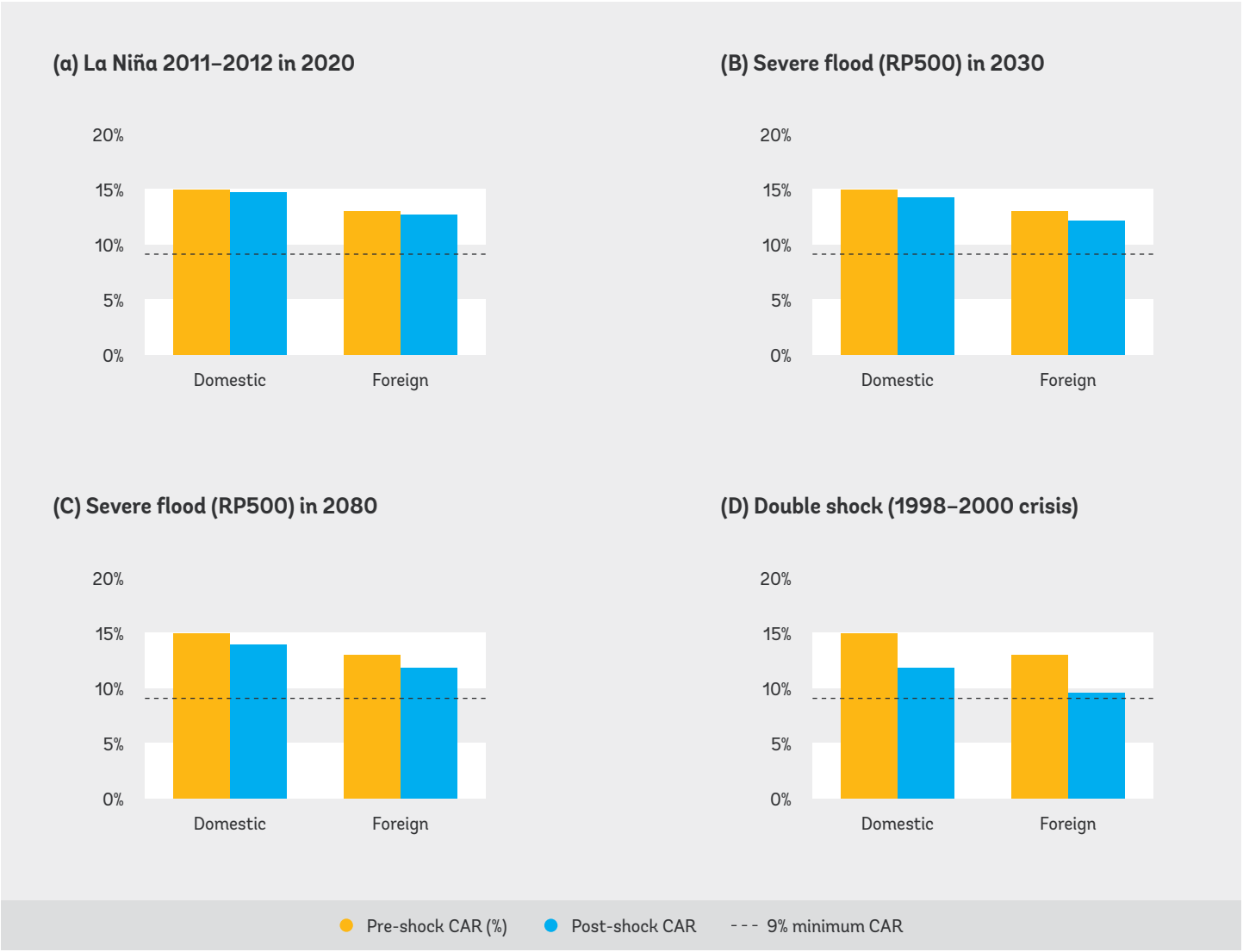
FIGURE 2.6. - Estimated impact on capital adequacy for physical risk scenarios with varying severity



Source: Staff calculations.

Note: CAR = capital adequacy ratio; RP = return period. Results are obtained using an accounting-based framework, in which banks only recognize market value losses on sovereign exposures in the trading book (and not in the banking book). For future scenarios, we assume semistatic balance sheets with socioeconomic development that grows in line with the size of banking sector balance sheets and the structure of banks' lending staying constant. The double shock scenario combines the severe flood scenario (RP 1 in 500 years) occurring in 2030 (scenario B) with a credit risk shock that is calibrated to the 1998–2000 banking crisis in Colombia, using a portfolio-wide increase in nonperforming loans of 14 percent of total loans. We calculate loan losses using a provisioning rate of 25% for nonperforming loans while accounting for a reduction in required capital related to the provisioned loans.

The vulnerability of individual banks shows high heterogeneity, reflecting exposures in more metropolitan areas versus more rural areas and exposures to sovereign debt. Looking at the severe flood scenario in 2080 (scenario C), aggregated loan losses for Colombian banks range between 0.2 percent of total assets for the least vulnerable bank to 2.2 percent for the most vulnerable ones. The difference between the banks with the lowest relative vulnerability compared with the highest is more than tenfold, pointing to focusing supervisory efforts at those banks that are most vulnerable. For the double shock scenarios (scenario D) the impact is high for all banks, with less pronounced differences between individual banks. In this case the difference between the worst and least affected banks is about 2 times (figure 2.7). We note that this analysis assumes that exposures of banks are homogeneous. In reality, some banks will have loans that are more exposed than others, for example, in specific sectors such as agriculture and mining. Such differences in sectoral exposures could lead to higher or lower estimates than the ones provided in figure 2.7 and would require more detailed analysis of each bank.

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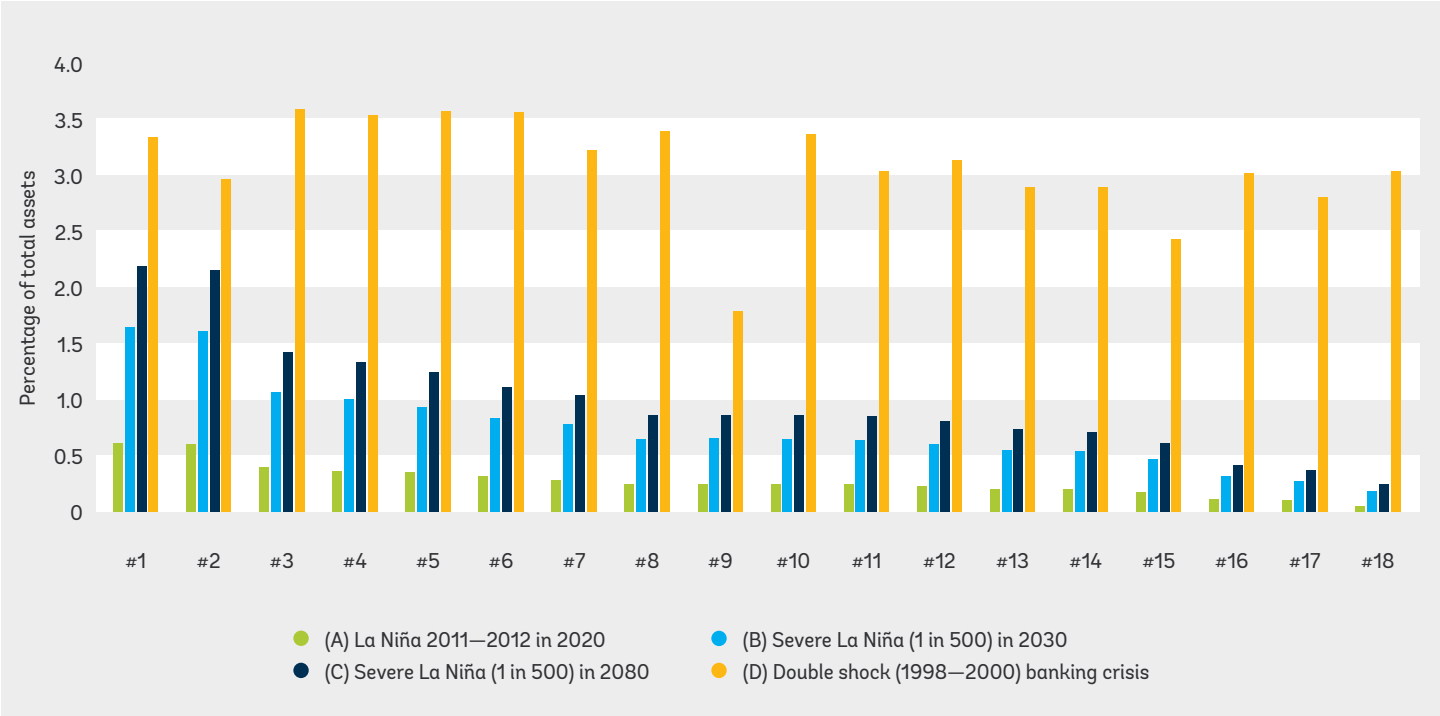
FIGURE 2.7. - Accounting-based losses for flood scenarios per bank (percentage of total assets)



Source: Staff calculations.
Note: accounting-based losses only account for market valuation changes in part of the sovereign bond portfolio that is market-to-market. Losses would be higher if a market-value based approach is used.

Losses for banks in due to floods are primarily driven by loan losses in vulnerable areas. Under an accounting based approach, credit losses account for 85 percent and 54 percent of total losses for domestic and foreign banks, respectively. However, especially for foreign banks the potential impact through the sovereign bond channel also constitutes an important driver of total losses. Figure 2.8 shows the contribution of the credit risk and sovereign bond channel to the percentage point reduction in the CAR for the different groups of banks. Moreover, results using a full market-based valuation approach show that banks may be more vulnerable than the accounting based approach would suggest, due to sovereign holdings not valued on a market basis. If we repeat the analysis by treating all sovereign debt being valued on a market-consistent basis, we find that losses increase substantially, owing to the relatively large share of sovereign exposure held as part of the banking book. For domestic banks, using a full market value-based approach increases the CAR impact with an average of 0.6 percentage point in the 2010–2011 La Niña scenario (scenario A) representing a 113 percent increase in losses through the sovereign bond channel. For foreign banks this increase is 0.5 percentage points while representing a 28 percent increase in losses on sovereign exposures. Hence, using an accounting-based approach could mask a part of the economic losses that may arise during a severe disaster.

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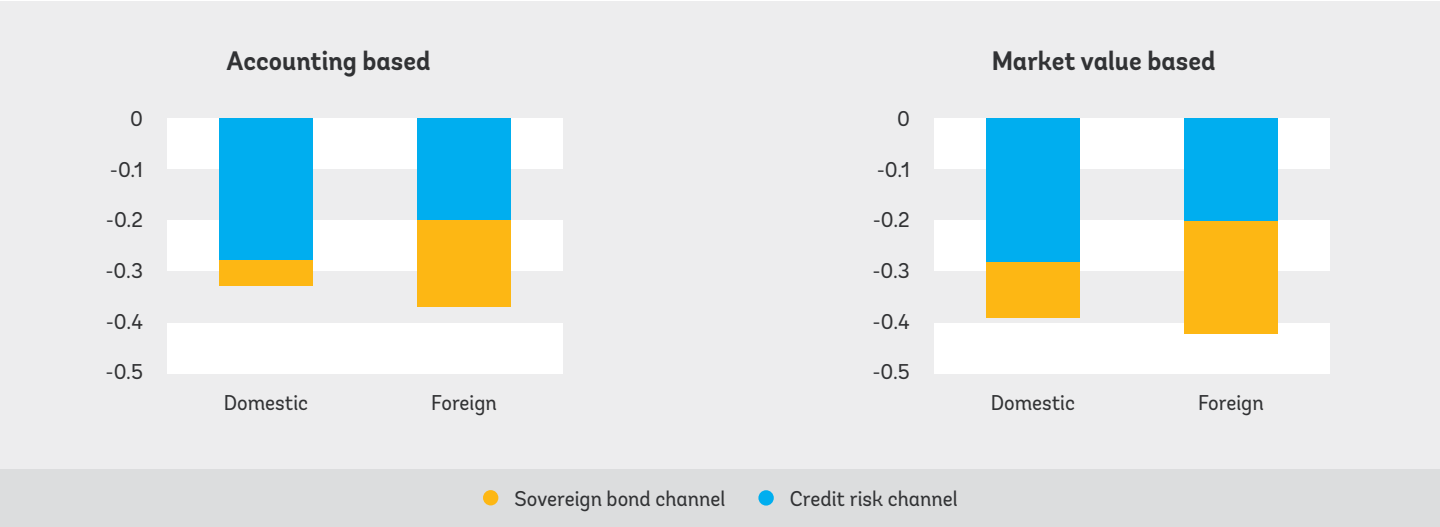
FIGURE 2.8. - Breakdown of losses through different channels (percentage point decline in the CAR)



Source: Staff calculations.
Note: CAR = capital adequacy ratio; data based on the 2010–2011 La Niña scenario (A).

Our estimates for riverine flood risks are most likely conservative, that is, providing lower bound estimates. There are three main reasons for this. First, provisioning estimates are likely on the conservative side owing to forbearance (that is, lower initial provisioning than needed with some additional provisions possibly being taken over time) and supply-chain effects (which could lead to losses outside of the affected areas and, hence, falling outside of our loss estimate). Second, our focus is on the credit risk and sovereign bond channels. Additional losses may occur through other channels, including simultaneous disaster losses incurred through investments in foreign subsidiary banks. And, third, our analysis assumes that losses from floods are growing linearly with the scale of the flood hazard. However, more severe floods could cause disproportionally higher losses in some cases (for example, if a building fully collapses). In general, our estimates provide a first indication of vulnerability, but more detailed analysis should be carried out to understand the exposures of individual banks (which may, for example, depend on the type of exposure of individual banks per region).

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Transition risk assessment

A broad spectrum of sectors are potentially at risk when the economy decarbonizes. Firms in transition-sensitive sectors may lose a substantial share of their value when the economics of their industries change because of new policies, technological innovation, and changing consumer preferences. Those industries include sectors that have high direct GHG emissions as part of their business processes, such as utilities and agriculture (scope 1). However, a much larger share of the economy could be affected. In particular, this includes firms that are part of the fossil fuel supply chain, such as fossil fuel extraction and automobile producers, or that use large amounts of heat or electricity, such as heavy manufacturing (scope 2 and 3). For individual sectors, the economic impact depends on their reliance on GHG emissions but also on the ease with which companies can reduce their internal footprint (for example, owing to abatement investments) and on the ease with which their products can be substituted for lower carbon alternatives (for example., traditional versus electric cars). Currently, for Colombia, only estimates for direct (scope 1) emissions per sector are available, as shown in figure 3.1. We address this issue by working with a macroeconomic model that also includes scope 2 and scope 3 effects in sectoral estimates.

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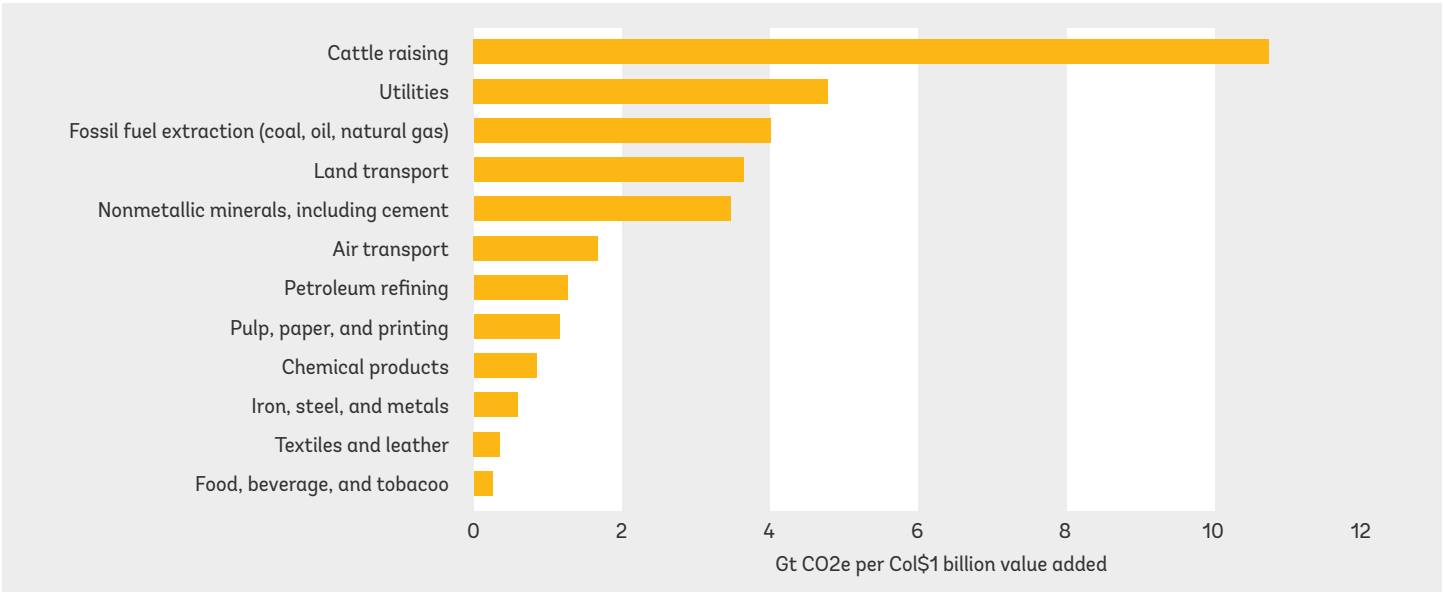
FIGURE 3.1. - Direct (scope 1) GHG emissions per sector in Colombia (Gt CO2e per Col$1 billion value added)



Sources: DANE; IDEAM 2014; staff calculations.
Note: Col$ = Colombian peso; GHG = greenhouse gas; Gt CO2e = gigatonnes of equivalent carbon dioxide.

The objective of this chapter is to investigate the potential for banking sector stress in delayed transition scenarios, following three steps. First, we define transition risk scenarios that are in line with Colombian NDC targets. We do this based on an already available emission trading system (ETS) scenario at the DNP while increasing the severity of the scenarios under investigation for our stress test exercise. Second, we model what the consequences in these scenarios can be for different sectors in the economy, looking at the value-added impact per sector. For this we include dependencies between sectors in our analyses by employing a macroeconomic modeling approach.[26] In this way, we look at scope 1, 2, and 3 emissions. As a third step, we perform a simplified stress test to size the potential impact on the Colombian banking sector. See figure 3.2.

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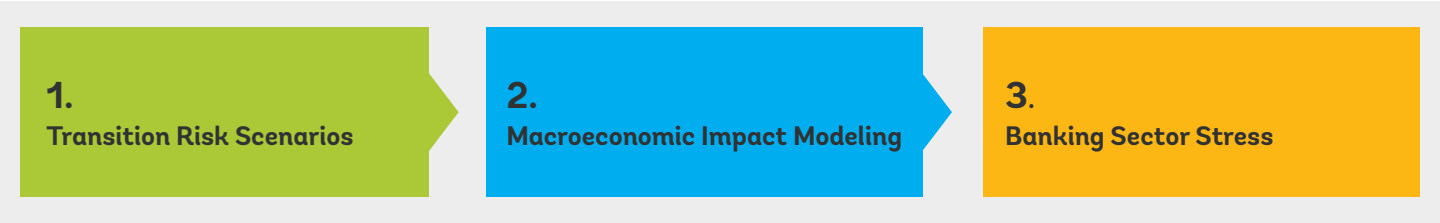
FIGURE 3.2. - Main elements of the transition vulnerability assessment



Source: Staff illustration.

Transition risk scenarios

We define four scenarios that are relevant for Colombia and that vary based on the target GHG emission reduction in 2030 and the timing of climate policies. We start with an existing scenario used by the DNP to investigate the impact of an ETS on the Colombian economy, which assumes a 10-year phase in and an achievement of a 20 percent emissions reduction until 2030 (scenario A). We then extend this scenario along two dimensions. With respect to timing, we define "smooth" scenarios in which climate policies are introduced from 2021 and "delayed" scenarios in which policies are introduced only from 2026. With respect to targets, we define scenarios with a low target (20 percent GHG emission reduction in 2030) and scenarios with a high target (51 percent GHG emission reduction in 2030). We use a combination of the higher target and delayed scenarios as adverse scenarios to size the potential impact on the banking system, including a scenario that incorporates both dimensions (scenario D). See table 3.1 for a summary of the scenarios. We note that the high target (51 percent) is in line with the current NDC in Colombia. We note that GHG emission reduction targets in the Colombian NDC are reductions with respect to a business-as-usual scenario which is part of the DNP model. Compared with 2020 emissions, the reduction in the high target scenario in 2030 equals 41 percent.

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TABLE 3.1. - Construction of delayed transition scenarios based on the existing DNP ETS policy scenario

	Smooth (from 2021)	Delayed (from 2026)
Old NDC target (20 percent in 2030)	**(A)** Smooth 20% (DNP ETS policy scenario)	**(B)** Delayed 20%
New NDC target (51 percent in 2030)	**(C)** Smooth 51%	**(D)** Delayed 51%

Source: Staff illustration.
Note: DNP = National Planning Department; ETS = emission trading system; NDC = nationally determined contribution.

26 In the computable general equilibrium model, dependencies between sectors are modeled using input-output tables. This method provides a much better, but not perfect, estimate of broad economic impacts owing to decarbonization policies.

The implicit carbon price in Colombia in these four scenarios is expected to increase between US$64–216 in 2030 depending on the reduction target. This implicit carbon price is derived from a macroeconomic model used by DNP, which is described in the next section. This model determines the carbon price based on a reduced supply of emission rights over time to achieve the 2030 GHG emission reduction target. A similar pricing dynamic would be observed if, instead of emission rights, the government would tax GHG emissions at a rate equal to the price of an emission right. Hence, whereas the DNP modeling is based on ETS scenarios, outcomes in sectoral impacts are roughly similar when other climate policy instruments are considered. In general, the implied carbon price estimates are valid as long as emissions are reduced in line with the NDC targets, with a similar scope of sectors (in this case, the whole economy) and at its lowest economic cost. We note that climate policies may exclude some sectors or differentiate between sectors because of political choices. In this case implied carbon prices between sectors could vary. Figure 3.3 shows the implicit carbon price as part of the four scenarios and represents the carbon price that would be needed to achieve the stipulated GHG emission reduction goals in the Colombian NDCs.

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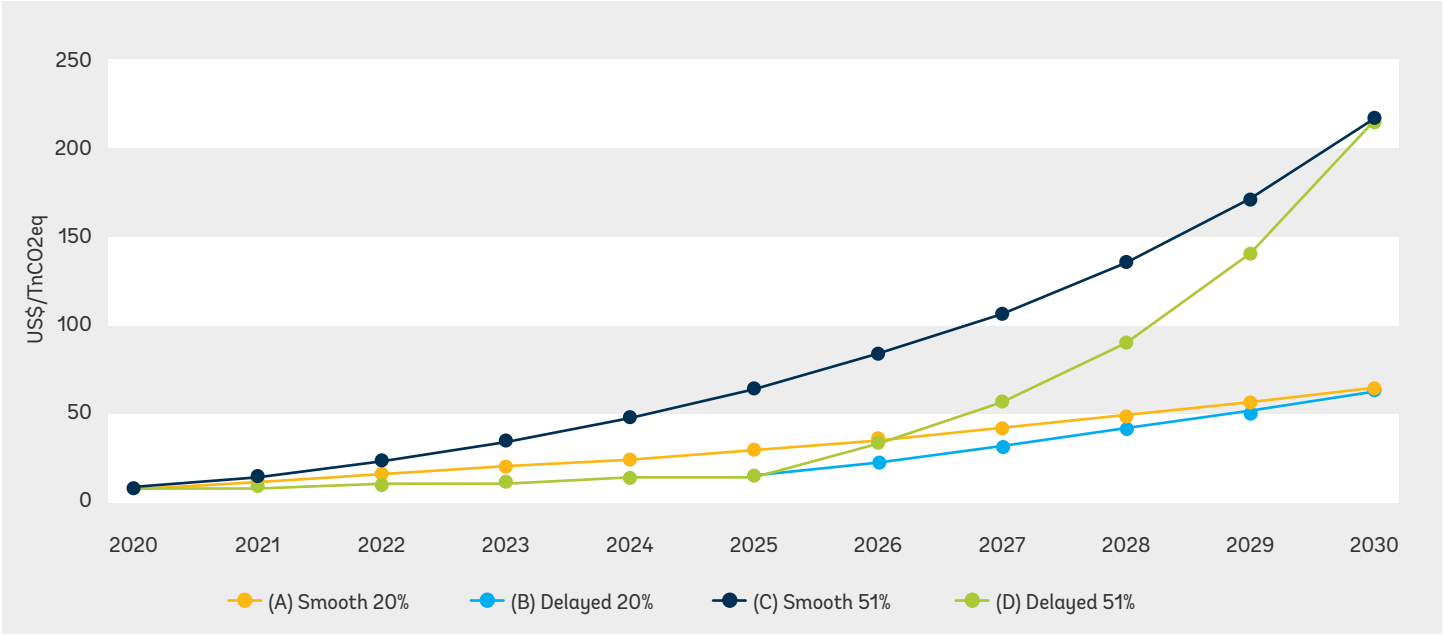
FIGURE 3.3. - Implicit carbon price development in the four scenarios



Source: Data obtained from DNP CGE model.
Note: ETS = emission trading system; TnCO2eq = ton of carbon dioxide equivalent.

Macroeconomic impact

We explore the potential effect of climate policies on the Colombian economy and banking sector using a CGE model of the DNP on the basis of four transition scenarios. This model provides estimates for GDP and employment impact per economic sector in Colombia, on the basis of scenarios in which an ETS is implemented. Such an analysis provides a good indication of vulnerable sectors, as the implicit carbon price used in this modeling specifically targets those industries that contribute the most to global warming and, hence, are the most likely target of any type of climate policies. The DNP model achieves a cut in GHG emissions through final consumption, intermediate consumption, and process emissions by increasing the implicit price of carbon using an ETS. The ETS covers all sectors of the economy and also shows broader effects on sectors that are outside the set of transition-sensitive sectors. Revenue from the ETS is assumed to be recycled with a lump sum transfer to the representative agent, and firms are perfectly competitive. Furthermore, the model takes into account an existing US$5 per ton emission tax on coke, gasoline, and other refined products. Baseline GDP growth in the model is set at 3.5 percent per year.

Results from the DNP macroeconomic modeling show that decarbonization trends may affect a broad range of sectors and can potentially be sizeable. In the scenarios with a low GHG emission reduction target (20 percent) the impact on GDP growth is not leading the economy into negative growth territory. However, the GDP impact increases strongly with higher GHG emission reduction targets. In the scenarios with a high GHG emission reduction target (51 percent), relatively high negative growth rates are obtained in the second half of the decade., driven by strong reductions in output in GHG intensive sectors and in sectors that are dependent on those sectors.[27] Whereas the impact on sectors is mainly limited to the fossil fuel sector in the low target scenarios, we find that sectors throughout the economy are affected in high target scenarios. With a 51 percent GHG emission reduction target and a delayed start of climate policies in 2026, the model finds that total value added declines up to 56 percent in the worst affected industries between 2028 and 2030 (figure 3.4). A summary table of the effect on change in value added between 2028 and 2030 for all sectors in each of the four scenarios is provided in appendix D.

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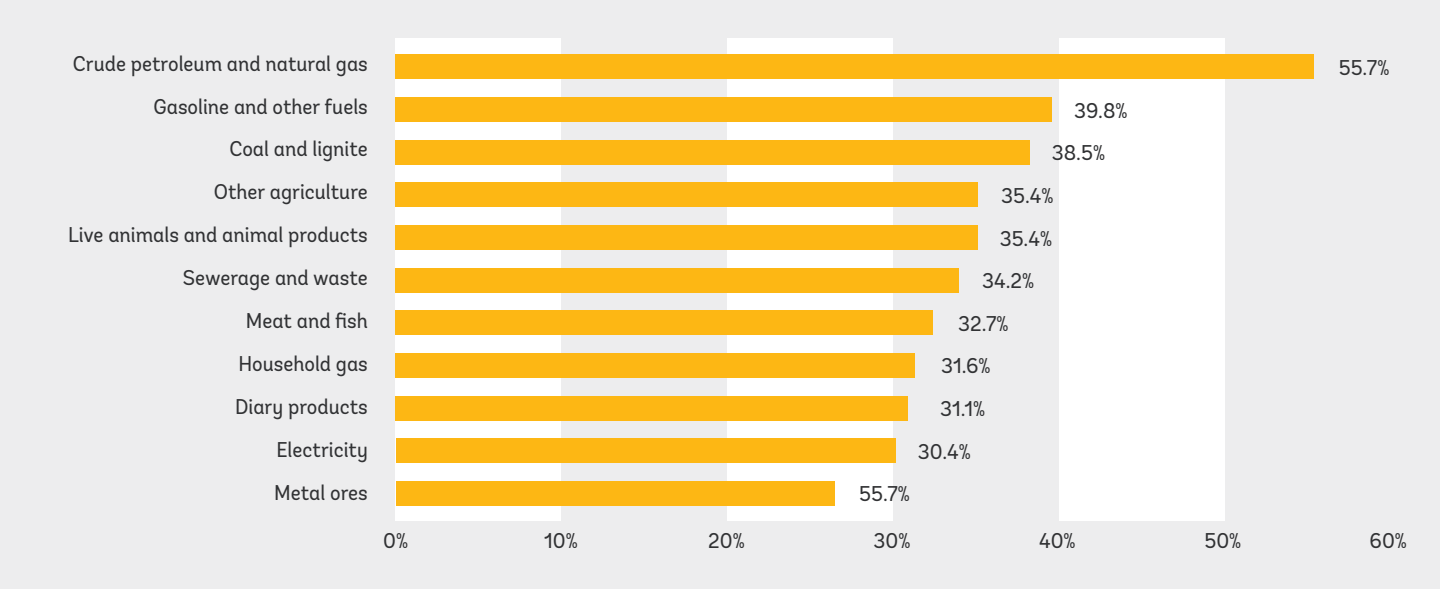
FIGURE 3.4. - Decline in value added in the worst affected sectors between 2028 and 2030 in the delayed scenario with 51 percent GHG emission reduction (scenario D)



Source: Data obtained from DNP CGE model.
Note: ETS = emission trading system; GDP = gross domestic product; GHG = greenhouse gas. Results show outcomes under adverse conditions, assuming little or no technological change in the economy.

27 We note already here that these strong reductions in output in GHG intensive sectors may be partially mitigated by adaptation in the economy, for example due to technological change. Since only little technological change is imposed in the CGE modeling, estimates on GDP impact are likely on the high end (i.e., assuming that not much technological change can or will take place). We discuss this in more detail at the end of the chapter.

One important caveat with our approach is that our CGE model does not impose any technological change in the simulations and can thereby overestimate economic impacts when the economy has time to adjust, making them most useful to analyze impacts over a short time. The CGE model by DNP is based on input-output tables for the current economy in Colombia, which means that the model does not fully capture technological change such as firm level adaptation and electrification of end uses. Hence, using this model implies that our estimates for sector level impact are most accurate when decarbonization occurs over a very short time span, such as 1 year, but it may in-creasingly overestimate any effects when looking at longer time spans. Thus, this approach especial-ly overestimates outcomes in our smooth scenarios in which the Colombian economy has 10 years to adjust. Therefore, our estimates represent an upper bound of losses under adverse economic conditions in which Colombia's economy has little time to adapt. Announcing and implementing climate policies early could substantially reduce any impacts shown in our modeling.

Banking sector stress

To investigate the impact of transition scenarios on the financial sector we obtain estimates from the Banco de la República SYSMO model (Gamba and others 2017). This model, amongst others, links changes in value added and unemployment to changes in nonperforming loans in the banking sector. We estimate the impact of our three more severe scenarios on the Colombian banking system during a 2-year shock window, covering 2028 and 2029, using a sectoral disaggregation for commercial loans.[28] Results are reported as differences with respect to the baseline smooth 20% scenario sector. The SYSMO model estimates nonperforming loans in four loan categories, comprising commercial loans, mortgage loans, consumer loans, and microcredits. For the analysis we assume constant balance sheets, implying that banks do not change their sectoral exposures significantly until the start of the shock window in 2028. If banks do anticipate transition risks and adjust their portfolio in the meantime, this may lead to lower exposures and a lower banking sector impact.

We find that especially the transition scenarios with higher targets have the potential to negatively affect banks their capital position. Losses to the banking sector are very limited in a more delayed scenario that has a low GHG emission reduction target of 20 percent, which leads to no tangible impact on nonperforming loans and capital ratios of Colombian banks (figure 3.5, scenario B). The main reason is that in this scenario, the only severely affected sectors are the fossil fuel and waste management sectors, to which the Colombian banking sector has almost no loan exposures. For the scenarios with a GHG reduction target of 51 percent, however, we find sizable impacts on bank's nonperforming loans and capital ratios (figure 3.5, scenarios C and D). Higher impacts during the final years before 2030 can be explained by the observation that many more sectors start to be affected when reductions have been achieved in the fossil fuel sector and reductions have to be obtained elsewhere, including in manufacturing and agriculture. In the most severe scenario (D) we find that nonperforming loans can increase between 0.5 percent and 1.9 percent across loan categories, with CARs for Colombian banks declining with more than one percentage point during the two year shock period due to the credit shock alone.

28 We align our analysis with the timeframe inherent in the SYSMO model, which is two years. We use 2028 and 2029 as they represent the two years with the highest GDP growth impact in all four scenarios.

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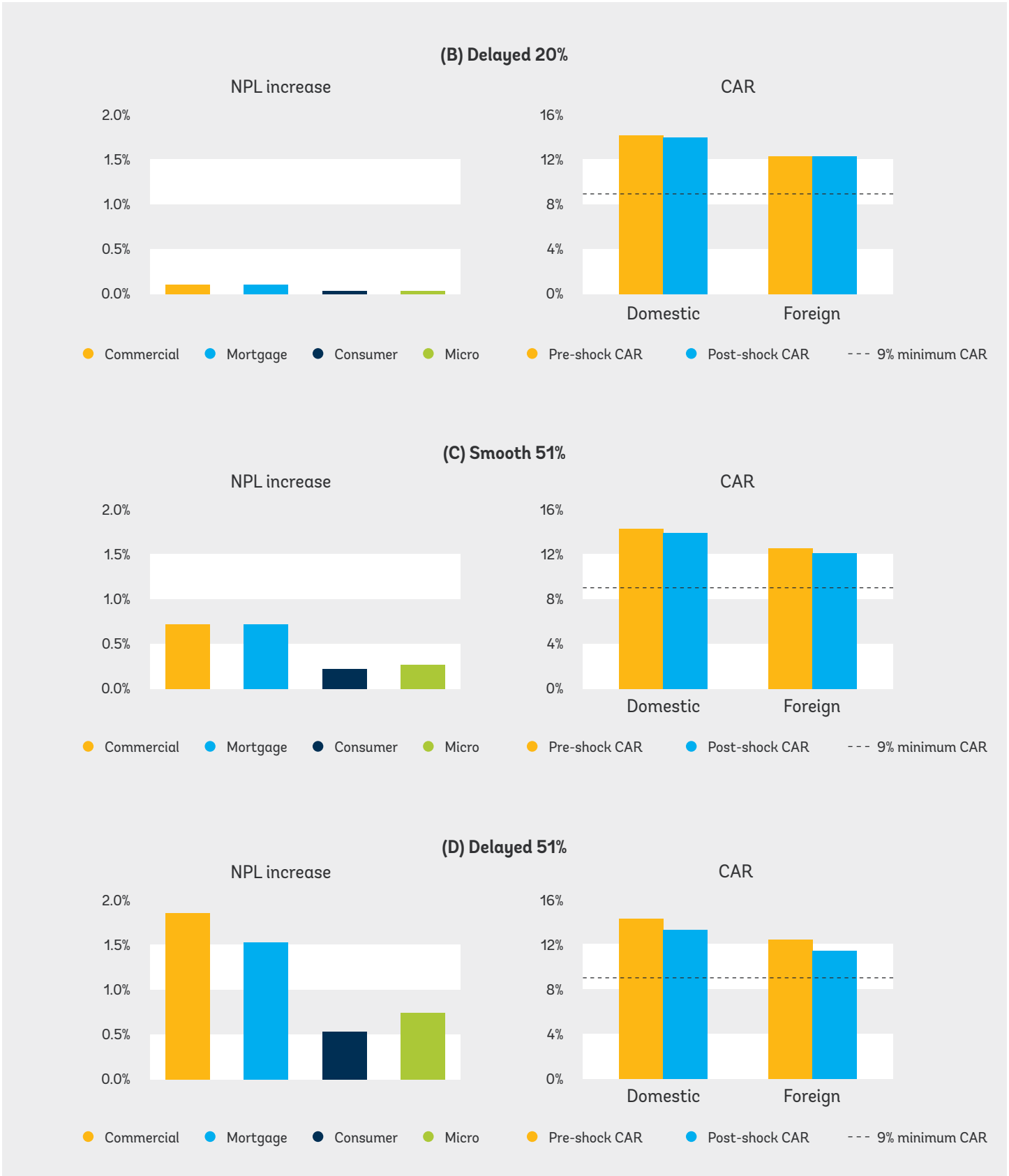
FIGURE 3.5. - Estimated impact on nonperforming loans and capital adequacy for transition risk scenarios with varying severity, compared to the smooth scenario with 20 percent GHG emission reduction (scenario A)



Source: Banco de la República SYSMO model; staff calculations.
Note: NPL = nonperforming loan; CAR = capital adequacy ratio.

Results show large differences in decarbonization vulnerabilities in credit portfolios between banks. We calculate the estimated loan losses as a fraction of total assets, based on the total loan exposures of each bank to the respective sector at a 2-digit level (83 sectors). The three most vulnerable banks have estimated loan losses ranging between 1.8 and 2.7 percent of total assets in the most severe scenario (D) while the three least vulnerable banks have estimated loan losses ranging between only 0.1 and 0.6 percent of total assets (figure 3.6). This result points to the importance of risk-based supervision regarding climate risks and specific attention to banks that are at relatively high risk. We do note that the banks with a high vulnerability may also have a high potential to contribute to greening the Colombian economy, given their focus on relevant transition industries. They could do so, for example, by engaging with their clients, by adjusting their origination practices, or by offering green products (such as products tailored to finance energy savings technologies or other clean technologies).

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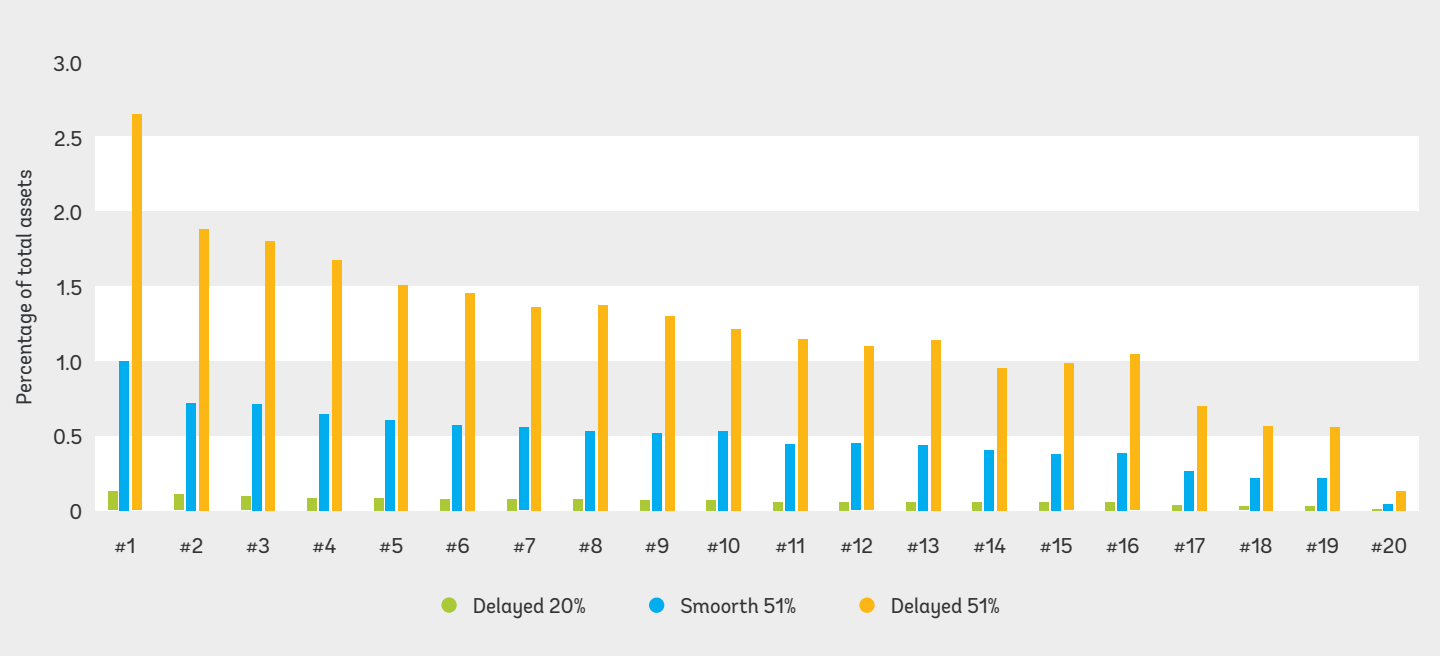
FIGURE 3.6. - Cumulative loan losses for transition scenarios per bank (percentage of total assets)



Source: Staff calculations.

Results should be interpreted with some caution. Both our economic and financial modeling rest on important assumptions. In particular, the CGE model implicitly assumes limited adaptive capacity of the Colombian economy. Because it does not impose technological change, it does for example not account fully for the emergence of new (renewable) sectors. If the adaptive capacity of the Colombian economy is higher than modeled, this could lead to a lower impact on GDP and also a lower impact on the banking sector. This mitigating effect of economic adaptation is likely the most pronounced for the smooth scenarios, in which policies are stretched over a longer time period, giving the economy and the financial sector more time to adjust. Also, our modeling assumes that deforestation emissions are cut in line with the NDC targets. If this would not be feasible, the burden of achieving those targets would be but on other activities. Furthermore, in our financial modeling we model outcomes under adverse conditions that include no profitability over the stress testing horizon. Also, due to data limitations we do not include indirect exposures to transition-sensitive sectors abroad. This could lead to an underestimation of transition risks to Colombian banks with substantial indirect exposures. Finally, there may be diversification benefits for banks that have loans toward sectors that benefit from a transition to a low carbon economy, such as renewables and real estate that is energy efficient. Decreased losses on such exposures may mitigate some of the adverse impacts in transition-sensitive exposures.

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Conclusions and policy recommendations

Main risks and vulnerabilities

The Colombian banking sector is vulnerable to gradual and more acute risks—stemming from both transition and physical risks. On the one hand, some risks (I and II) are mostly gradual in nature that are expected to play out over a relative long-time horizon. These risks are primarily relevant from a business model perspective, where banks that do not adjust to changing circumstances (for example, in pricing and loan origination practices) could become less profitable over time, eroding their capacity to replenish financial buffers when needed. In these scenarios, more abrupt shocks are possible when prices of certain assets rapidly change because of better market understanding (for example, rapid decreasing real-estate prices in coastal areas). On the other hand, more acute risks (III to V) could play out over a shorter time, including natural disasters and sudden tightening of climate policies in the coming decade (until 2030). These more acute risks are the risks that have the highest potential for banking sector stress in the next decade (table 4.1).

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TABLE 4.1. - Summary of main climate related risks for the Colombian banking sector

Risk	Likelihood	Potential for banking sector stress	Channels
I. Gradually increasing carbon price and climate policies	Medium	Low	• Increasing loan losses in transition-sensitive sectors • Value of commercial real estate
II. Gradually increasing temperature and changing weather-patterns	High	Low/medium	• Increasing loan losses in vulnerable sectors (e.g., agriculture)
III. A sudden tightening of climate policies	Low/medium	Medium/Large	• Increasing loan losses in transition-sensitive sectors • Value of commercial real estate • Macroeconomic effects
IV. Severe flood	Medium	Medium	• Real estate, corporates, house-holds in affected areas • Sovereign credit downgrades
V. Severe flood plus recession (double shock)	Low/medium	Large	• Real estate, corporates, households in affected areas • Sovereign credit downgrades • Macroeconomic effects

Source: World Bank staff.

Our quantitative analysis finds that there are climate-related risks scenarios that can lead to substantial stress for the Colombian banking sector, however, only in adverse (unlikely) scenarios. We have investigated flood risks and transition scenarios that are in line with the Colombian NDC targets for 2030.

a. For flood risk we find that that flood scenarios can lead to declines in capital adequacy that could moreover coincide with other shocks. Although our estimates suggest that the CAR of Colombian banks can decline substantially, the scenarios with the historic La Niña and the severe floods by themselves do not cause many banks to drop below the required minimum CAR of 9 percent. For those scenarios we find an average decline in the capital adequacy ratio (CAR) for Colombian banks between 0.3 and 1.1 percentage points. In the double shock scenario, the average decline in the CAR increases to 3.2 percentage points. This scenario, however, represents the combination of a flood shock with a generic economic recession and, hence, both the most severe and most unlikely scenario (but not impossible either). Results differ strongly per bank, with loan losses for individual banks ranging between 0.2 percent of total assets for the least vulnerable bank to 2.2 percent for the most vulnerable one in the most severe flood scenario.

b. For transition risks we find that decarbonization scenarios can materialize before 2030 that lead to substantial losses in the banking sector. We estimate that a delayed scenario with a high GHG reduction target could lead to aggregated loan losses for Colombian banks that range between 0.1 percent of total assets for the least vulnerable bank and 2.7 percent for the most vulnerable one. This scenario could materialize when climate policies are introduced late (from 2025), and these policies aim for a high GHG emissions reduction of 51 percent in 2030. As part of this modeling, we assume that the adaptive capacity in the Colombian economy is limited over a short (2 year) time window. Our transition impact estimates should be viewed as estimates based on adverse outcomes in the tail for the probability distribution and not as forecasts of expected outcomes. They are also conservative since they cover a two-year time frame, with more losses that could accumulate before and after the shock period. Moreover, we focus on the credit portfolio only. Losses on other assets could aggravate outcomes.

Results per bank show large differences in climate-related vulnerabilities in credit portfolios between banks, pointing to the importance of risk-based supervision. A few banks are substantially (about two to three times) more vulnerable to flood hazards than most others because of high exposures in more rural areas. Also, significant heterogeneity is found in the exposure of individual banks to transition-sensitive industries, ranging between 1 percent and 26 percent of their credit portfolio. These observations support a risk-based approach to addressing climate-related risks into SFC supervision.

Financial impact

Based on these findings, the World Bank has identified several short-term and medium-term actions to improve climate risk identification and mitigation in the banking sector. In general, the SFC could adopt a risk-based supervision approach for climate-related risks and continuously improve disclosures (both by nonfinancial corporates and by financial institutions) and data availability. The latter is also important to assess exposures through affiliated entities abroad, for which the SFC could collaborate with host supervisors to conduct a cross-country climate vulnerability assessment. For physical risks, the SFC could perform deep dives at the most vulnerable institutions, promote capacity building throughout the sector, and encourage further development of insurance markets. Regarding transition risks, the SFC can work with the banking sector and other relevant authorities to address risks in a timely and forward-looking manner. This requires dialogue between public and private stakeholders on how climate mitigation and adaptation measures will take shape, so that banks can address them early on (for example, in engagement with customers, origination practices, and pricing). It also requires capacity building in the banking sector, potentially including new tools such as scenario analysis and bottom-up stress testing. This is particularly urgent with respect to domestic transition risks, as substantial policy efforts to decarbonize the Colombian economy can already be expected this decade. See table 4.2 for an overview of recommendations.

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TABLE 4.2. - World Bank recommendations to the SFC and other stakeholders.

Recommendation	Timing	Agency
General		
Issue guidelines on governance, risk management, and climate risk disclosure to the banking sector.	ST	SFC
Promote the development of forward-looking climate risk tools in the banking sector, including scenario analysis and stress testing.	ST/MT	SFC
Incorporate climate risks as part of the risk-based supervision of banks.[a]	MT	SFC
Continue to encourage climate risk disclosure by nonfinancial firms in Colombia, and support the improvement and use of climate-risk data at the firm level.	MT	SFC
Conduct a cross-country climate vulnerability assessment with host supervisors, including improving data collection on spatial and sectoral exposures through related entities.	MT	SFC, host supervisors
Physical risks		
Identify the information and data needed to carry out physical risk assessments tailored to individual institutions' exposure.	ST/MT	SFC
Promote technical capacity building in the banking sector to understand and manage physical risks, covering both disaster risks and gradual changes in climatic conditions (for example, through a platform).	ST/MT	SFC
Promote the development and implementation of mechanisms to mitigate physical risks and their impacts, such as disaster risk insurance.[b]	MT	SFC, Government
Transition risks		
Promote capacity building in the banking sector to understand and manage transition risks, specifically focusing on ST and MT transition risks (that is, 2030 NDC targets).	ST	SFC
Promote further dialogue between climate policy makers and the financial sector including banks, other investors, and financial authorities.	ST/MT	SFC, BR, Government
Provide more detailed guidance to the financial sector on how de-carbonization policies will be implemented and on what is the time line for implementation (for example, a road map until 2030 to allow banks to better align their portfolios).	ST/MT	Government, SFC
Encourage better data collection to perform firm-level stress tests by authorities and banks. Specifically, this would require firm-level GHG emission data for nonfinancial firms in Colombia.	ST/MT	SFC

Note: BR = Central Bank of Colombia; NDC = nationally determined contribution; SFC = Financial Superintendence of Colombia; ST = short term (within one year) and MT = medium term (within one to three years).

a. This could include requiring increased supervisory reporting, addressing the risk in the banks' Internal Capital Adequacy and Assessment Process, and addressing the risk in on-site supervision (including in board-level conversations).

b. We note that sometimes the most cost-effective adaptation lies in preventing the creation of new risks by ensuring that land-use planning and infrastructure regulations take disaster risks into account. Banks could play a role here by integrating disaster and flood risks into their loan origination process (and requiring alignment with land-use plans and infrastructure regulations). Development of insurance markets could include (a) strengthening the legal framework including on the use of parametric insurance and (b) improving the availability of disaster insurance data.

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Appendixes

Appendix A. Flood regression model

We investigate the impact of large-scale floods to the Colombian banking sector by performing an event study on past large-scale flooding. To calibrate the credit risk shock, we estimate a regression model to estimate the impact of historical floods on provisioning. Specially, we focus on the 2010–2011 floods that are connected to La Niña and are among the most economically damaging disasters that occurred in Colombia over the past decades. This event falls well within the sample period for which there is credit risk data available, where we cover 15 years from 2005 to 2019. We identify the shock size by employing a difference-in-difference (DID) modeling strategy, which compares the provisions growth rate between affected regions and nonaffected regions. In this way, we control for macroeconomic effects that are common for the entire country. We estimate four variants of the model. Models (1) and (2) use a traditional DID approach also employed in previous exercises. Models (3) and (4) instead weigh impacts based on the economic losses as a fraction of GDP. All models provide significant and consistent shock estimates, indicating that exposures in more severely affected areas have experienced higher provisioning than areas that were less severely affected (or not at all). The specifications are provided in table A.1, while the regression results are provided in table A.2. Most exposure and credit risk data are obtained through the SFC, while data on economic impact are obtained from CEPAL (2012).

> > >

TABLE A.1. - Regression specifications

(1) DID, time and bank fixed effects	$\Delta PROVISIONS_{i,t,d} = SHOCK_{d,t} + D_i + D_t$
(2) DID, with bank*time fixed effects	$\Delta PROVISIONS_{i,t,d} = SHOCK_{d,t} + D_i + D_{i,t}$
(3) DID, with flood vulnerability factor (FVF)	$\Delta PROVISIONS_{i,t,d} = FVF_d * SHOCK_t + D_i + D_t$
(4) DID, with bank*time fixed effects and flood vulnerability factor (FVF)	$\Delta PROVISIONS_{i,t,d} = FVF_d * SHOCK_t + D_{i,t}$

Source: World Bank staff.

Note: in these specifications, the delta provisions are the percentage point increase in provisions as a fraction of total loans in the department compared with the previous quarter. The flood vulnerability factor (FVF) is defined as the economic damage as a fraction of GDP per department as obtained from CEPAL (2012). The shock variable is 1 when La Niña–related floods affected the specific departments over a period of six quarters following the initial floods. Furthermore, D denotes a dummy variable, while t stands for time (quarter), i for bank, and d for department.

> > >

TABLE A.2. - Regression results

	Binary shock variable		Weighted shock variable	
	(1)	**(2)**	**(3)**	**(4)**
Shock estimate	0.0020*	0.0026**	0.0011*	0.0012**
Time FE	Yes	No	Yes	No
Bank FE	Yes	No	Yes	No
Bank*time FE	No	Yes	No	Yes

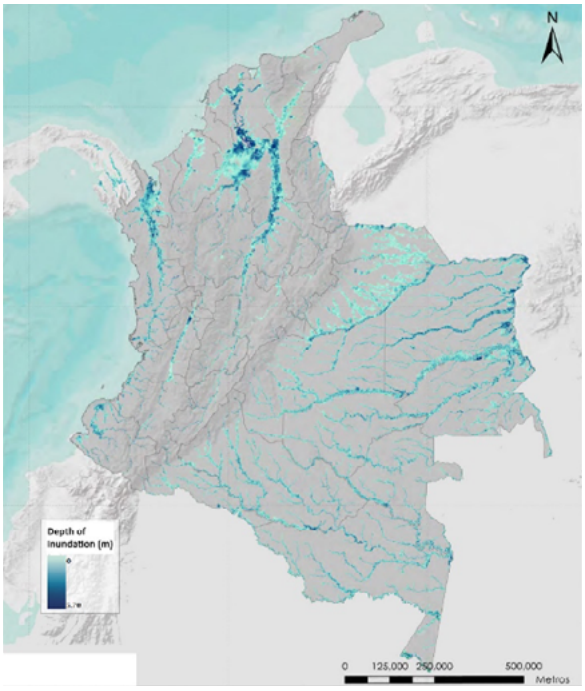
Source: World Bank staff, based on SFC data.

Note: FE = fixed effects; results obtained using robust standard errors. p < 10% (*); p < 5% (**).

Appendix B. Flood vulnerability

> > >

TABLE B.1. - Riverine flood risk in Colombia with a 50-year return



Source: Ingeniar in UNGRD 2018.

Appendix C. Stress test model

To estimate the size of climate-related risks to the Colombian banking sector, we employ a basic stress testing model and extend it to provide results using granular sectoral and regional data. The model builds on stress tester 3.0 by Martin Čihák (2014) and uses balance sheet and profit and loss data covering 21 banks for which detailed sectoral and regional breakdowns are available. Results are estimated per bank, per group of banks (state owned, domestic, foreign), and aggregated for the entire sector. Five smaller banks are excluded from the dataset owing to unavailability of a sectoral breakdown. The excluded banks represent 1.6 percent of total assets in the dataset. All data are for year-end 2019. An overview of the model's characteristics is presented in table C.1.

> > >

TABLE C.1. - Characteristics of climate stress testing model

Main characteristics	• Banking sector • Top-down solvency risk assessment • Individual bank and aggregated balance sheets • Credit exposures at granular spatial and sectoral levels • The main output is the decline in total bank capital and losses as a fraction of total assets / total loans
Risks assessed	• Credit losses from banks' loan portfolios, excluding off-balance-sheet credit commitments • Accounting and market-value losses from credit spread adjustments of banks' holding of sovereign debt securities
Data inputs for model	• Balance sheet • Risk-weighted assets • Credit risk data (nonperforming loans, provisions, collateral) • Sectoral structure of lending • Regional structure of lending • Share of sovereign exposures in banking book
Key parameters	• Average provisioning rate for nonperforming loans (25%) • Average duration of bank's sovereign bond portfolios (4.2 years) • Current sovereign credit rating (S&P BBB-)
Key calibration inputs	• Regional and sectoral shocks (% of performing loans becoming nonperforming loans or provisions taken) • Change in sovereign credit spread

Source: World Bank staff.

Appendix D. DNP CGE model results

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TABLE D.1. - Change in value added per sector between 2028 and 2030

	Smooth (NDC: 20%)	Delayed (NDC: 20%)	Smooth (NDC: 51%)	Delayed (NDC: 51%)
Productos de café	31.3%	48.9%	15.9%	41.7%
Otros productos agricolas	-0.4%	-4.2%	-22.1%	-35.4%
Animales vivos y productos animales y productos de la caza	-0.9%	-5.1%	-21.7%	-35.4%
Productos de silvicultura y extraccion de madera y actividades conexas	4.1%	2.6%	-9.1%	-16.5%
Productos de la pesca y la acuicultura y servicios relacionados	3.6%	1.8%	-8.9%	-16.8%
Carbon mineral	-5.1%	-11.9%	-22.7%	-38.5%
Petroleo crudo y gas natural y minerales de uranio y torio	-6.7%	-12.7%	-36.3%	-55.7%
Minerales metalicos	2.0%	-0.6%	-15.8%	-26.7%
Minerales no metalicos	3.6%	1.8%	-10.5%	-18.6%
Carnes y pescados	0.4%	-3.1%	-20.0%	-32.7%
Aceites y grasas animales y vegetales	3.0%	0.9%	-13.2%	-22.8%
Productos lacteos	1.2%	-1.8%	-19.2%	-31.1%
Productos de molineria y almidones y sus productos	2.2%	-0.4%	-15.3%	-25.9%
Productos de cafe y trilla	31.6%	49.7%	15.6%	40.2%
Azucar y panela	3.1%	1.1%	-13.0%	-22.4%
Cacao y chocolate y productos de confiteria	3.2%	1.3%	-14.1%	-23.6%
Productos alimenticios ncp	3.8%	2.2%	-10.7%	-19.0%
Bebidas	4.0%	2.4%	-8.4%	-16.1%
Productos de tabaco	4.5%	3.2%	-6.5%	-13.1%
Fibras textiles naturales e hilazas e hilos y tejidos de fibras textiles e incluso afelpados	5.5%	4.8%	-4.2%	-9.1%
Articulos textiles excepto prendas de vestir	6.2%	5.7%	-3.4%	-7.5%
Tejidos de punto y ganchillo y prendas de vestir	5.2%	4.2%	-4.5%	-9.9%
Curtido y preparado de cueros y productos de cuero y calzado	4.8%	3.6%	-6.6%	-12.7%
Productos de madera y corcho y paja y materiales trenzables	4.1%	2.6%	-8.9%	-16.4%
Productos de papel y carton y sus productos	4.4%	3.1%	-7.4%	-14.5%
Edicion e impresion y articulos analogos	4.4%	3.1%	-7.0%	-13.6%
Coque y semicoqu de hulla y de lignito o de turba y carbon de retorta y alquitranes	21.7%	14.4%	11.3%	7.6%
Gasolinas y otros combustibles	-2.1%	-6.9%	-24.7%	-39.8%
Diesel	-5.7%	-12.1%	-29.4%	-47.1%
Otros refinados	-0.6%	-4.5%	-27.7%	-42.4%
Sustancias y productos quimicos	4.8%	3.7%	-7.8%	-14.6%
Productos de caucho y de plastico	4.0%	2.5%	-8.4%	-15.9%
Productos minerales no metalicos	5.1%	4.2%	-6.7%	-13.1%
Productos metalurgicos basicos excepto maquinaria y equipo	2.8%	0.6%	-13.6%	-23.5%
Maquinaria y equipo	4.1%	2.6%	-10.2%	-17.9%
Otra maquinaria y suministro electrico	4.8%	3.7%	-10.0%	-15.5%
Equipo de transporte	5.1%	4.1%	-5.9%	-12.6%
Muebles	6.0%	5.6%	0.2%	-8.5%
Otros bienes manufacturados ncp	6.7%	6.7%	7.9%	-3.3%

Energia electrica	1.8%	-0.8%	-30.2%	-30.4%
Gas domiciliario	0.1%	-3.8%	-32.8%	-31.6%
Agua	5.0%	4.0%	-1.2%	-9.2%
Trabajos de construccion y construccion y reparacion de edificaciones y servicios de arrendamiento de equipo con operario	3.9%	2.3%	-12.5%	-17.1%
Trabajos de construccion y construccion de obras civiles y servicios de arrendamiento de equipo con operario	3.6%	1.7%	-13.3%	-17.8%
Comercio	3.4%	1.5%	-15.3%	-19.0%
Servicios de reparacion de automotores y de articulos personales y domesticos	4.0%	2.4%	-9.9%	-15.0%
Servicios de alojamiento y suministro de comidas y bebidas	3.9%	2.3%	-14.8%	-18.9%
Servicios de transporte terrestre	5.8%	5.3%	5.1%	-4.8%
Servicios de transporte por via acuatica	9.1%	10.2%	38.2%	16.8%
Servicios de transporte por via aerea	6.5%	6.3%	12.9%	0.5%
Servicios complementarios y auxiliares al transporte	4.4%	3.0%	-6.5%	-12.7%
Servicios de correos y telecomunicaciones	5.1%	4.1%	-0.9%	-9.0%
Servicios de intermediacion financiera y de seguros y servicios conexos	4.2%	2.8%	-6.2%	-12.5%
Servicios inmobiliarios y de alquiler de vivienda	5.2%	4.2%	0.3%	-8.1%
Servicios a las empresas excepto servicios financieros e inmobiliarios	4.4%	3.0%	-8.2%	-13.9%
Administracion publica y defensa y direccion y administracion y control del sistema de seguridad social	5.7%	5.1%	2.2%	-6.8%
Servicios de ensenanza de mercado	5.7%	5.0%	2.9%	-6.3%
Servicios de ensenanza de no mercado	5.7%	5.1%	3.1%	-6.1%
Servicios sociales y de salud de mercado	5.2%	4.3%	-1.2%	-9.1%
Servicios de alcantarillado y eliminacion de desperdicios y saneamiento y otros servicios de proteccion del medio ambiente	-2.7%	-8.2%	-37.3%	-34.2%
Servicios de asociaciones y esparcimiento y culturales y deportivos y otros servicios de mercado	5.0%	4.0%	-2.3%	-9.9%
Servicios de asociaciones y esparcimiento y culturales y deportivos y otros servicios de no mercado	5.3%	4.5%	-1.3%	-9.2%
Servicio domestico	5.9%	5.4%	5.9%	-4.2%

Source: Data obtained from DNP CGE model.
Note: NDC = nationally determined contribution.


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