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Climate-Related and Environmental Risks for the Banking Sector in Latin America and the Caribbean

A Preliminary Assessment

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Abstract

There is increasing recognition that climate-related and environmental risks are a source of financial risks. Using publicly available data, this paper attempts a preliminary estimation of the physical and transition risks for the banking sector in a sample of economies in Latin America and the Caribbean. The results show that exposure to floods, compounded by high loan concentration in and around countries' capital cities, represents the most important source of credit risk for the banking sector. After large-scale natural disasters, banks' nonperforming loans increase by up to 1.4 percentage points in affected provinces. The results also show that banks in the region are exposed to transition risks, especially in Argentina, Bolivia, Paraguay, and Uruguay, due to their high lending to the agriculture sector, which is the largest emitter of greenhouse gases in the countries. Firms operating in transition-sensitive sectors already present signs of financial stress, especially those in the fossil fuel and agriculture sectors. Overall, the results demonstrate the importance for financial authorities in the region to advance in the integration of climate-related and environmental risks in their work.

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Climate-Related and Environmental Risks for the Banking Sector in Latin America and the Caribbean: A Preliminary Assessment[1]

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1. Introduction

There is growing global recognition that climate change, natural disasters and environmental degradation can lead to risks for the financial sector (see, for example, NGFS 2020a). Climate-related and environmental risks originate from two types of sources: (i) physical risks, which emanate from natural disasters and global warming, and can lead to economic costs and financial losses; and (ii) transition risks, which are related to economic adjustment costs during the transition towards a greener, carbon-neutral economy. Both physical and transition risks can affect credit, operational, market and liquidity risks, threatening the profitability and solvency of banks and potentially the stability of the financial system.

While at the conceptual level there is broad agreement on the transmission channels through which climate-related and environmental risks can morph into financial risks, there is a need to better understand the interplay between climate-related and environmental risks and the financial sector and to quantify financial risks. Although there is growing interest in the relationship between climate change and the financial sector, the empirical literature has only recently started to pay attention to providing quantitative estimates with reasonable certainty on causality. Reliable quantitative estimates could be helpful for assessing, mitigating and monitoring climate-related and environmental risks for the financial sector. In this context, this paper attempts to provide a first and preliminary estimation of climate-related and environmental risks for the commercial banking sector in a sample of economies in Latin America and the Caribbean (LAC).

Several studies have investigated the effects of physical risks on the banking sector. Noth and Schüwer (2018) find evidence that weather-related natural disasters significantly weaken the stability of US banks with business activities in affected regions. In particular, within two years after the disaster banks' z-scores decrease, probabilities of default increase, non-performing asset ratios and foreclosure ratios increase, and returns on assets and equity ratios decrease. These effects are economically significant. Similarly, Barth et al. (2019) study the impact of natural disasters on overall bank performance in the US during 2000-2017 and find that the occurrence of natural disasters impacts banks' liquidity, especially at smaller banks. Regelink et al (2017) model the impact of severe flood scenarios on mortgages, commercial real estate, and SME loan portfolios of Dutch banks, predicting substantive financial losses. Empirical evidence also points to credit rationing in disaster-prone areas. For instance, Faiella and Natoli (2019) find that, regardless of credit demand factors and disaster insurance coverage, the amount of loans granted to firms in Italy is negatively correlated to their climate risk exposure.

For a sample of 160 countries during 1997-2010, Klomp (2014) finds that weather-related and other natural disasters increase the likelihood of a bank's default in emerging economies. In the LAC region, Brei et al. (2019) document that following a hurricane strike, banks in the Eastern Caribbean face deposit withdrawals and negative funding shock to which they respond by reducing the supply of lending and by drawing on liquid assets. However, the authors do not find signs of deterioration in loan defaults and bank capital. Berg and Schrader (2012) study volcanic eruptions in Ecuador and show that credit demand increases after a disaster strikes, while the probability of loan approval decreases, although being a repeat client provides some advantage.

Finally, Collier (2014) finds that El Niño-related flooding in Peru resulted in large loan losses that caused lenders to contract credit, hindering economic recovery.

The nascent literature on transition risks also highlights their potential impacts on the financial sector. Weyzig et al. (2014) analyze EU financial institutions' exposures to fossil fuel firms and commodities and estimate potential losses under various scenarios. Under a quick transition scenario, average losses would be of the order of 0.4 percent for large banks, 2 percent for insurance companies, and 3 percent of total assets for pension funds. Batten et al. (2016) analyze the market reaction to climate change news during 2011-2016 and find a positive and significant effect on the abnormal return for renewable energy companies. Delis, de Greiff, and Ongena (2019) find that banks have recently started to price the risk of stranded fossil fuel reserves in syndicated loan markets. Specifically, the authors find that after 2015 a fossil fuel firm with mean proved reserve paid an additional 16 basis points on its cost of credit, implying an increase in the total cost of borrowing for the mean loan by US$ 1.5 million.

Vermeulen et al. (2019) assess the impact of a disruptive energy transition on Dutch financial institutions and find that total losses could be sizeable (up to 3 percent of the stressed assets for banks, 11 percent for insurers and 10 percent for pension funds) but manageable in terms of impact on prudential supervisory metrics. By developing a network-based climate stress test methodology to account for contagion and feedback loops in the Euro area financial sector, Battiston et al. (2017) find that direct and indirect exposures to climate policy-relevant sectors represent a large portion of investors' equity portfolios, especially for investment and pension funds. For the LAC region, Ramírez, Thomä, and Cebreros (2020) examine three high-carbon intensive industries to understand the potential exposures of banks to transition risks. The authors find a significant banking sector exposure, driven by companies operating in the power and fossil fuel sector that exhibit production plans not compatible with a transition towards a greener, carbon-neutral economy.

This paper attempts a preliminary estimation of LAC commercial banks' credit risk resulting from climate-related and environmental physical risks and transition risks. This is relevant for at least three reasons. First, the LAC region is the second most disaster-prone region globally, where natural disasters have become more frequent and destructive (OCHA 2020). Across different climate-related natural disasters, floods and storms have recently increased their frequency and impact in LAC (United Nations 2015; IPCC 2012). Second, temperatures are projected to increase to a significant degree in the coming decades, negatively impacting economic activity and the financial sector. An increase in temperature is associated with lower growth, with contractionary effects felt several years after a weather-related shock (IMF 2017). Finally, although capital markets are developing in several emerging markets in LAC, the banking sector remains central to financial intermediation in the region. While there is significant heterogeneity among LAC counties, banks provide on average more than 90 percent of the credit granted by regulated financial intermediaries in the region (Trujillo and Navajas 2016), contributing to finance investment and other needs of both firms and households.

Our estimation of LAC banks' credit risk exposure to physical risks rely on a three-stage approach. First, to obtain an indication of the value-at-risk of banks' loan portfolios related to physical risks, we compare the country-province distribution of banks' nonfinancial corporate credit portfolios with country-province-specific hazards. In a second step, we narrow our physical risk assessment to the portion of assets that banks allocate to households for home loan purposes, i.e. mortgages. We therefore combine the flood hazard mapping information with the banking system's outstanding mortgages within each country-province. In a third and final step, we use geographical nonperforming loan (NPL) data at the country-province level and natural disaster information to study possible changes in banks' asset quality in the aftermath of large-scale natural disasters. Our baseline empirical methodology consists of a difference-in-difference method that exploits quasi-exogenous variations in provinces affected by natural disasters.

We estimate credit risk exposure to transition risks by relying on a sectoral exposure analysis. To obtain a rough measure of LAC banks' exposure to transition risks, we focus on exposures to highly CO_2-intensive and environmentally damaging industries and assets. We focus on industries most affected by transition risks, including fossil fuel and energy production, heavy industry, transportation, agriculture and real estate. Moreover, using firm-level data, we analyze the financial health of LAC firms operating in transition-sensitive sectors.

Our data set is composed by a cross section from 9 countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, and Dominican Republic) for the estimation of physical risks, and from 12 economies (the nine countries cited above excluding Ecuador plus Costa Rica, El Salvador, Paraguay, and Uruguay) for the estimation of transition risks. Our physical risk assessment is complemented by an empirical estimation comprising a panel of 5 countries (Argentina, Brazil, Chile, Mexico, and Peru) over a period of 35 quarters (2011q3 and 2020q1). We take all data from public sources, with data availability determining our sample composition.

Our results are the following. In terms of physical risks, we find that exposures to floods represent the most important source of credit risk for the LAC banking sector. This is compounded by high loan concentration in and around LAC capital cities, which, ceteris paribus, entails higher physical risks to province-specific natural disasters. Using a difference-in-difference method, we present empirical evidence of a significant increase in banks' NPLs in the aftermath of large-scale natural disasters, with heterogeneous effects across portfolio types. In particular, we find that large-scale natural disasters could trigger an increase in total NPLs of up to 1.4 percentage points in affected provinces. Evidence points to a higher impact on the non-financial corporate loan portfolio. Our results are in line with previous findings and are robust to different estimation strategies.

In terms of transition risks, our results show that banks located in the largest emitter LAC countries (adjusted for the size of their economy) have credit portfolios tilted to transition-sensitive sectors. This is particularly the case for Argentina, Uruguay, Paraguay, and Bolivia, where the agriculture sector takes a lion's share of greenhouse emissions and as well of banks' assets. Additionally, pre-pandemic firm-level data shows that firms operating in transition-sensitive sectors already present signs of stress, especially those in the fossil fuel and agriculture industry.

The rest of the paper is organized as follows. Section 2 briefly describes the key characteristics of the LAC banking sector, the economic damage and frequency of natural disasters, and the climate-related and environmental risk regulations for the LAC region. Section 3 presents the data and the methodology employed to estimate banking sector credit risk exposures to physical and transition risks. Section 4 discusses the key results of our analysis. Section 5 concludes with some emerging policy implications.

2. Banking sector, natural disasters, and climate risk regulations in LAC

Banking sector

The banking sector is the critical infrastructure for financial intermediation in LAC. Banks in LAC provide on average more than 90 percent of the credit granted by regulated financial intermediaries, with non-bank financial institutions (NBFIs) and credit cooperatives of secondary relevance (Trujillo and Navajas 2016). There is, however, significant country heterogeneity. NBFIs are significant players in Costa Rica, Peru, and the Dominican Republic, where they account for between 8 and 14 percent of the total credit portfolio. In Ecuador, Mexico and Costa Rica, credit cooperatives hold a market share of the credit market of about 10 percent. The deposit market shows a similar picture, with commercial banks taking the lion's share of savings.

The banking sector size varies across LAC economies and is highly concentrated. Of the countries included in our sample, Chile and Brazil exhibit the deeper banking systems, with banking assets above 90 percent of GDP at the end of 2019.[2] In contrast, the banking sectors in Argentina and the Dominican Republic are shallower, with banking assets at around 40 and 30 percent of their GDP, respectively. Banking market concentration in LAC is generally high and above that observed in other regions. As of 2018, the seven largest economies in the region exhibited an average concentration ratio, measured as the share of the three largest banks' market, of 65 percent (World Bank 2020).

Banks' assets are dominated by loans, with a non-negligible fraction of securities. As of 2019, total loans, including credit to the public sector, represented 55 percent of the median bank assets in LAC, ranging from 45 percent in Argentina to 66 percent in Chile (Figure 1). Securities, especially government securities, also account for a significant share of banks' assets, with 19 percent for the median bank in the region. Mexican and Chilean banks hold the largest proportion of their assets in securities, at a median of 34 and 21 percent, respectively.

Natural catastrophes and climate change

Natural disasters have become increasingly more frequent and destructive in LAC, leading to a sharp rise in economic damages. Moreover, empirical evidence points to increased economic damage of natural disasters, substantially driven by large-scale events (Coronese et al. 2019). The most economically damaging natural disaster events in LAC – the second most disaster-prone region in the world – have been earthquakes, floods, and storms.[3] The region suffers from geophysical, hydrological, meteorological, and climatological disasters, which have historically led to significant economic damages.[4] Overall, the economic losses directly or indirectly related

[2] IMF, Financial Soundness Indicators.

[3] See OCHA 2020.

[4] Based on EM-DAT database. The disaster events recorded fulfill at least one of the following criteria: 10 or more deaths of people, 100 or more people affected/injured/homeless, and declaration by the country of a state of emergency and/or an appeal for international assistance. For more details: https://public.emdat.be/about.

to the more than 1,000 natural disaster events that occurred in LAC between 1990 and 2020 are estimated at US$ 170 billion in today's currency.[5] Only 5 percent of those events were insured, with Mexico and Chile reporting a higher proportion of insured events but still minor, at 12 percent.

Earthquakes have been the most economically damaging disasters estimated at US$ 57 billion, with 104 events recorded. Chile, Mexico, El Salvador, and Ecuador were the most economically affected countries.[6] Storms follow as the most economically costly events in our country sample, driven primarily by Mexico (Figure 2). In terms of specific events, the top five most damaging disasters have been the 2010 earthquake (and subsequent tsunami) in Chile, the 2017 earthquake and the 2005 and 2013 storms in Mexico, and the 2014 drought in Brazil (Table 1). These events combined affected more than 30 million people with estimated damages of around US$ 55 billion.[7] Table 1 in the Annex shows the top two most damaging natural disasters for each country in the sample. In terms of frequency, floods, particularly riverine floods, are the most common. The region has recorded more than 550 flood events between 1990 and 2020, with Brazil, Colombia, and Mexico registering the higher occurrence.

Temperatures in LAC countries are expected to increase in the coming decades, with negative consequences for economic activity and, ultimately, for the financial sector. The warming is likely to be more pronounced in the central and north region of South America. In much of the Amazon the annual mean temperature is projected to increase by 1.7˚C to 5.3˚C, and the duration of heatwaves is projected to increase by 18 to 214 days by 2085.[8] Along the Atlantic coast of Brazil, Uruguay, and Argentina, the temperature increase is expected to be less marked. For the LAC region as a whole, the most pronounced temperature increases are projected to occur in September and October, where the median estimates for the whole region could increase by 4.2˚C (Figure 3). Warmer temperatures have negative consequences for economic activity. The IMF estimates that a one-degree increase in temperature in emerging market economies lowers growth in the same year by 0.9 percentage point, where the contractionary effects are statistically significant even seven years after a weather shock (IMF 2017).

LAC's dry regions will get drier and wet regions will get wetter. According to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), the Caribbean, Central America, and central Brazil are the areas where precipitation is expected to decrease the most, in the range of 20 to 40 percent (Figure 4).[9] On the flip side, extreme precipitation events' frequency and intensity are expected to increase, particularly for the tropical and subtropical Pacific coastline and southern Brazil. Water scarcity and increased mean temperatures are projected to decrease water supplies and affect most ecosystems and agroecosystems. On the other hand, an intensified rainfall could significantly increase landslide risks, particularly in sloping terrain, which is often occupied by vulnerable populations.

[5] EM-DAT estimates damage as the value of all damages and economic losses directly or indirectly related to the disaster.
[6] Economic damages estimates are sourced from EM-DAT and expressed in today's currency.
[7] Ibid footnote 6.
[8] https://climateknowledgeportal.worldbank.org/country/brazil/climate-data-projections
[9] https://climateknowledgeportal.worldbank.org/region/latin-america-caribbean/climate-data-historical

El Niño and La Niña are expected to become stronger and more frequent, further influencing rainfall pattern changes in LAC. Floods emanating from El Niño and La Niña may increase in severity due to a changing global climate (Cai et al. 2015). For instance, droughts in the northeastern region of Brazil have been highly shaped by El Niño (Magalhães 2016), and its events are expected to become stronger and more frequent in the future (USAID 2018). Nonetheless, due to Brazil's extensive and diverse territory, the effects of El Niño could be heterogeneous and potentially benefiting the southern regions, where it tends to trigger plentiful rain. As an example of past effects of this phenomenon, the UN World Food Programme estimated that in 2005, 2.3 million people in Central America needed food assistance because of widespread damage to crops and rising food prices due to a prolonged drought exacerbated by El Niño.[10]

Financial systems' response to climate change

Globally, there is novel and increasing attention being paid to the impact of climate change and environmental risks on financial sectors. Through the recently created Network for Greening the Financial System (NGFS), among other fora, financial regulators and central banks have been warning about the impact of climate-related and environmental risks on the stability and soundness of the financial sector.[11] For example, the NGFS recently published an anthology of case studies of the impact of climate-related risks on the financial systems (NGFS 2020a), a comprehensive publication of methods and tools for Environmental Risk Analysis. Special attention to the topic has been paid also by the G20 Green Finance Study Group and the Financial Stability Board Task Force on Climate-Related Financial Disclosures (TCFD).[12] At the same time, there is global recognition of the importance of the financial sector in mobilizing capital for green objectives, including those related to the Paris Agreement and the Sustainable Development Goals (SDGs).

Though explicit prudential regulations for climate-related and environmental risks in LAC are still absent, many countries' supervisory authorities (e.g., Brazil, Colombia, Mexico) have recently made plans to assess the financial risks stemming from climate change and environmental degradation, and potentially take prudential actions. Regardless, some countries have made breakthroughs by enacting Environmental, Social and Governance (ESG) risk regulations (Frisari et al., 2019). Between 2014 and 2019, financial sector regulators in Brazil, Honduras, Paraguay and Peru enacted ESG risk resolutions (Table 2). For instance, the Paraguay Central Bank (PCB) Resolution 8 – Guide on Environmental and Social Risk Management – establishes the minimum ESG requirements a financial institution needs to address.[13] Among other aspects, it aims to identify, measure, evaluate, and monitor environmental risks to which entities regulated and supervised by the PCB are exposed. By contrast, the number of countries that have implemented

[10] See https://www.wfp.org/news/over-2-million-central-america-will-need-food-assistance-due-drought-el-nino

[11] Bank of Mexico was on the of founding members of the NGFS. As of April 19, 2021, other LAC supervisory and regulatory bodies have joined: the central banks of Costa Rica, Paraguay, Uruguay, Chile, Colombia, and Brazil; *Comisión Nacional Bancaria y de Valores* (Mexico), *Comisión para el Mercado Financiero de Chile,* and *Superintendencia Financiera de Colombia*. See https://www.ngfs.net/en/about-us/membership.

[12] Of interest for this document is the framework for the identification and management of climate-related risks in the operation of financial and non-financial institutions (TCFD 2017).

[13] *Banco Central del Paraguay, Acta N° 78 de fecha 22 de noviembre de 2018. Guía para la gestión de riesgos ambientales y sociales para las entidades reguladas y supervisadas por el Banco Central de Paraguay*.

supervisory measures is more extensive, yet with limited scope (Peru, Brazil, Paraguay, Mexico, Panama, Colombia, and Chile – Table 2).[14] For example, in December 2019 financial supervisory and regulatory authorities in Chile underwrote a Joint Declaration on Climate Change, which stated their commitment and interest in promoting adequate management of risks and opportunities associated with climate change to maintain the development and stability of the financial system.[15]

Private sector-led initiatives to foster green/sustainable finance and mitigate social and environmental risks are more common. By the end of 2019, banking industry associations in 11 LAC countries had launched self-regulatory practices (Table 2). Across LAC, Brazil recorded the earlier steps in the sustainability agenda for the banking sector. In 1995, five major state-owned banks and the Environmental Ministry signed the *Protocolo Verde* (Green Protocol), which sets a charter of principles for sustainable development with proposed policies and practices.[16] The Protocol was revised in 1998 and updated in 2009, expanding its scope to commercial banks with the endorsement of the Brazilian banking industry association.

3. Data and methodology

Data

To establish the stylized facts we are primarily interested in this paper, we collect data on banking sector loans and NPLs disaggregated by sector and country-province, as well as data to identify banks' loan exposures in a country-province that was affected by a natural disaster, and the loan exposures to sectors that are transition-risk sensitive. Besides, we gather firm-level financials of firms that operate in sectors sensitive to the transition.

We collect outstanding aggregate loans and NPLs for both nonfinancial corporations and households disaggregated by economic sector and province from country authorities, i.e. financial supervisory agencies or central banks. Table 3 in the Annex presents the local authorities' data sources. All data pre-date the COVID-19 pandemic and are thus not tainted by the various support measures introduced, which may complicate the interpretation of the results. Data availability determines our sample composition. Our data set is composed of a cross section of 9 countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, and Dominican Republic) for the estimation of credit risk exposure to physical risks, and from 12 economies (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Mexico, Paraguay, Peru, and Uruguay) for the estimation of credit risk exposure to transition risks. Our physical risk assessment is complemented by an empirical estimation comprising a panel of five countries (Argentina, Brazil, Chile, Mexico, and Peru) over a period of 35 quarters (2011q3 and 2020q1).

Different standards adopted by the countries in our sample for classifying NPLs and banks' credit exposures to economic sectors present some challenges. Some countries such as Brazil and Chile record NPLs following international definitions of outstanding amounts with at least one

[14] Panama is not further discussed in this document due to data limitations.

[15] *Ministerio de Hacienda, Comisión para el Mercado Financiero, Superintendencia de Pensiones, y Banco Central de Chile. Declaración conjunta sobre el Cambio Climático.*

[16] *Banco do Brasil, Banco do Nordeste, Banco da Amazônia, BNDES, and Caixa Econômica Federal.*

payment defaulted for more than 90 days. In other countries, such as Mexico and Peru, the overdue days for recording NPLs depend on the type of credit portfolio, usually varying from 15 to 90 days. In addition, while some countries classify the sectoral exposures of their banks' credit portfolios based on the International Standard Industrial Classification of All Economic Activities (ISIC), not all of them use the same revision and most countries employ a self-defined classification of economic activities. This affects sector comparability since the high level of aggregation of the publicly available information does not allow leveraging on standard correspondence tables. Therefore, to ensure comparability of banking exposure to economic sectors across countries, we associate them manually. See Annex C for more details.

Information on hazard mapping at the level of country-province is sourced from Thinkhazard!, which is a web-based tool enabling users to consider the impacts of disasters on development projects. It was developed by the Global Facility for Disaster Reduction and Recovery in partnership with various partners, including the World Bank Group. The hazard levels are derived from modeling information that combines the spatial distribution (e.g., flood depth, ground shaking, etc.) at a given frequency or return period.[17] We gather disasters at the level of country-province from the Emergency Events Database (EM-DAT) maintained by the Center for Research on the Epidemiology of Disasters. The data set includes the worldwide natural disasters of all types and records the dates, human death toll, material damages, and geographic locations of the disasters.

Our transition risk assessment, in addition to credit outstanding data, relies on firm-level information and CO_2 emissions. Firm-level data is gathered from Orbis, a worldwide firm-level database with detailed information of balance sheets and income statements of firms compiled by Bureau Van Dijk from various national sources. After data cleaning, our sample covers 38,227 firms with total outstanding debt of US$ 2,112 billion. Data is as of the most recent available for each firm between 2018 and 2019. Table 4 reports the number of firms in each country and sector. Data on CO_2 emissions are sourced from Climate Watch.

Methodology

Physical risks

To obtain a first indication of the value-at-risk of banks' loan portfolios related to physical risks, we first compare the provincial distribution of banks' nonfinancial corporate credit portfolios with country-province-specific hazards. Our physical risk assessment is grounded in first-level administrative units, which carries unavoidable caveats. Banks' credit portfolios are commonly available at the first level administrative units in our country sample (denoted as provinces throughout the paper for simplicity), so we use them as our unit of analysis across countries. This approach entails gains in terms of getting a homogeneous identification approach across countries in our sample, yet we lose the richness of exploiting more granular data. Besides, we follow a conservative approach for the province hazards' classification by adopting the higher

[17] For instance, the hazard level of an earthquake is assessed as high if there is more than 20 percent chance of potentially-damaging earthquake shaking in the next 50 years; the hazard level of water scarcity (drought) is classified as medium if there is up to a 20 percent chance droughts will occur in the coming 10 years. For additional reference, see https://gfdrr.github.io/thinkhazardmethods/#about-thinkhazard.

hazard level of the administrative units within a province.[18] Thus our analysis may be over-estimating the country-province value-at-risk of natural hazards that do not affect all provinces equally (or affect them at differing magnitudes). Therefore, our results for physical risks should be considered as an upper-bound. Comparability caveats also arise since administrative units are not necessarily proportional to countries' surface areas when compared across countries. On the one hand, we have countries like Dominican Republic, which has 31 provinces and one national district; on the other hand, Brazil, the largest country in LAC, is 175 times as large as Dominican Republic and has a lower number of provinces: 26 states and one federal district.

In a second step, we narrow our physical risk assessment to the portion of assets that banks allocate to households for home loan purposes, i.e. mortgages. We therefore combine the flood hazard mapping information with the banking system's outstanding mortgages within each country-province. Specifically, in line with recent empirical studies (e.g., Pagliari 2021; and Bank of England 2018), we measure physical risk exposure of mortgages to floods hazard. Mortgage repayments and property values could be significantly strained by floods via repair expenses and increased insurance costs. Publicly available information allows us to dive deeper into the physical risks associated with floods by analyzing the banks' mortgage portfolios distribution at the province level for Chile, Colombia, and Mexico.

In a third and final step, we use geographical NPL data at the country-province level and natural disaster information to understand the dynamics of banks' balance sheets in the aftermath of large-scale natural disasters.[19] Data availability limits the analysis to Argentina, Brazil, Chile, Mexico, and Peru. We define large-scale natural disasters as the most economically damaging climatological, hydrological, or meteorological natural disasters occurred in our country-province sample during the past ten years. Based on EM-DAT, this identification strategy provides us with the 2018 Argentine drought that affected the north-eastern provinces during January 2018 (economic costs of US$ 3.5 billion);[20] the Brazilian drought that initiated in early 2014 in the northeast region (economic costs of US$ 5.4 billion); the March 2015 flood that hit northern Chile (economic costs of US$ 1.6 billion); the Hurricane Manuel that affected the southeastern coast of Mexico in September 2013 (economic costs of US$ 4.6 billion); and the March 2017 flood triggered by El Niño affecting coastal Peru (economic costs of US$ 3.2 billion).[21] All in all, the disasters' time span ranges between 2011q3 and 2020q1, allowing us to observe outcomes in a window of two years before and after each event.

Our baseline empirical methodology consists of a difference-in-difference (DiD) approach that allows identifying the causal effect of natural disasters on banks' asset quality. Specifically, we analyze the difference between affected and non-affected provinces in the change in NPLs. We

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[18] For additional details, see: https://gfdrr.github.io/thinkhazardmethods/#classification-process.

[19] As in Bos et al. (2018), we focus on large-scale natural disasters only. The authors argue that only relatively large events can reasonably be assumed to cause significant loan defaults, as (i) firms and banks are to some extent prepared for common disasters, and (ii) only large-scale disasters generate a significant and regionally correlated shock that affects nearly all local firms and residents at the same time.

[20] According to the Central Bank of Argentina, the GDP growth rate decline of 4 percent during the second quarter of 2018 was largely explained by agricultural production contraction due to the drought. That year, the production of soy and corn dropped 31.3 percent and 12.5 percent, respectively. For more details, see: http://www.bcra.gob.ar/Pdfs/PoliticaMonetaria/IPOM1018.pdf.

[21] Economic damages estimates are sourced from EM-DAT and expressed in today's currency.

assume that all provinces experience a similar change in NPLs as result of comparable large-scale disasters over time. Therefore, the disaster impact in the affected provinces is equal to the average difference of the change in NPLs. Based on EM-DAT and local authorities' sources we define treated provinces as those that were the most affected by the natural events and use the rest of the provinces (i.e., the not affected ones) as counterfactuals.[22] To measure the effects of a disaster on our outcome of interest, we follow Schüwer, Lambert, and Noth (2019) and estimate the following baseline specification:

$$NPL_{pt} = \delta \left(Affected_p \, x \, Post_t\right) + \mu_p + \lambda_t + \varepsilon_{pt} \tag{1}$$

where NPL_{pt} is the country-province specific NPLs to total loans ratio at quarter t; $Affected_p$ equals 1 if a province is affected, and 0 otherwise; $Post_t$ equals 1 if the observation is one quarter after the natural disaster started, and 0 otherwise. Hence, the interaction term $Affected_p$ $x \, Post_t$ equals one if both variables are equal to 1, and 0 otherwise. The coefficient δ is our primary interest and shows how NPLs in affected provinces vary after the event compared to their counterfactuals. We omit the single terms $Affected_p$ and $Post_t$ because they are absorbed by country-province and time fixed effects, respectively. Specifically, the term μ_p captures country-province fixed-effects, and λ_t time fixed-effects. The former represents unchanging macro-financial and institutional conditions that have a bearing on NPLs within country-provinces, while the latter captures any regional shock common to all countries in each quarter. An unobserved error term adjusted for potential serial-correlation within each province clustering at the country-province level is captured by ε_{st}. To test the robustness of our results, we estimate two alternative specifications. First, we remove time fixed effects and include the variable $Post_t$ in the equation, which will otherwise interfere with time fixed effects. Second, we estimate the canonical DiD model by removing both country-province and time fixed effects and incorporating the single terms $Affected_p$ and $Post_t$.

In addition, we exploit the time dynamics of NPLs by applying a panel event study design, which is a generalized extension of DiD models that, instead of a single post-treatment period, allows for dynamic lags and leads based on the timing of the treatment (Schmidheiny and Siegloch 2019). We consider the variation in affected and non-affected country-province-level NPLs around the date when natural disasters occurred compared with a baseline period, which as standard, we define as one quarter before the event started. Following Clarke and Schythe (2020), we denote as $Event_p$ a variable recording the time period *t* in which the event occurs in province *p*. Denoting the outcome of interest, the bank NPL ratio at the province level, as NPL_{pt}, our specification can be formally written as:

$$NPL_{pt} = \alpha + \sum_{j=2}^{8} \beta_j (Lag\ j)_{pt} + \sum_{k=1}^{8} \varphi_k (Lead\ k)_{pt} + \mu_p + \lambda_t + \varepsilon_{pt} \tag{2}$$

where lags and leads to the event are defined as follows:

$$(Lag\ 8)_{pt} = \mathbb{1}\left[t \leq Event_p - 8\right], \tag{3}$$

[22] Our grouping composition provides the following number of treated (counterfactual) provinces: 9 (15) in Argentina, 4 (23) in Brazil, 3 (12) in Chile, 5 (27) in Mexico, and 7 (18) in Peru.

$$(Lag\ j)_{pt} = \mathbb{1}\left[t\ = Event_p - j\right] for\ j\ \in \{1, \ldots, 7\}, \quad (4)$$

$$(Lead\ k)_{pt} = \mathbb{1}\left[t\ = Event_p + k\right] for\ k\ \in \{1, \ldots, 7\}, \quad (5)$$

$$(Lead\ 8)_{pt} = \mathbb{1}\left[t\ \geq Event_p + 8\right]. \quad (6)$$

Lag and $Lead$ are binary variables indicating that the given province was a number of quarters away from the natural disaster in the respective time period. The baseline difference between provinces where the natural disaster occurred and those that were not affected by it is captured by the first lag, where $j = 1$.

DiD and event study designs have been used in the natural disasters literature to tackle similar empirical analyses, such as banks risk-based capital ratios adjustments induced by the Hurricane Katrina shock (Schüwer, Lambert, and Noth 2019), banks' asset structure adjustments in response to changes in loan demand after natural disasters (Bos et al. 2018), the estimation of the fiscal cost of US hurricanes (Deryugina 2017), how households coped with the financial shock induced by Hurricane Katrina (Gallagher and Hartley 2017), foreign aid flows in the aftermath of large natural disasters (Becerra et al. 2014), and the natural catastrophes impact on commodity and gold bond markets (Chesney 2011), among others.

Transition risks

To obtain a preliminary indication of the value-at-risk of banking exposures to transition risks associated with the move to a low carbon economy, we analyze the sectoral distribution of bank loans to nonfinancial corporations. Data availability allows us to focus our analysis on 12 LAC countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Mexico, Paraguay, Peru, and Uruguay. Specifically, we analyze the banks' credit portfolio exposures to highly CO_2-intensive and environmentally damaging industries to obtain a rough estimation of the exposure to transition risks. These exposures are then benchmarked to countries' specific carbon emissions per sector. We focus on industries most affected by transition risks, including fossil fuels, energy generation, heavy industry, transportation, and agriculture. These high-level categories align with climate policy relevant sectors as put forward, for example, by Battiston et al. (2017).[23]

Additionally, we present stylized facts on the financial health of firms that operate in transition-sensitive sectors. As a proxy variable for firms' financial soundness, we use the interest coverage ratio (ICR), defined as the ratio of earnings before interest and taxes (EBIT) to interest expense.[24] The ICR measures whether a firm can cover its interest expenses through its operating earnings. We define financially distressed firms as those with annual interest payments exceeding operating profits (i.e., an ICR below 1). Due to the limited firm observations in the Orbis database for some of the countries in our sample, we do not implement this analysis by country but offer

[23] We acknowledge the caveat arising by considering these high-level categories. In some sectors, we may be overestimating exposures. For instance, it could be the case that in the energy sector, banks are financing renewable energy producers, which shouldn't be considered a source of transition risk.

[24] The interest expense variable in Orbis does not have information for some countries in our sample. Thus, we use financial expenses, which cover all financial expenses such as interest charges.

a regional characterization of the share of distressed firms and debt-at-risk in each economic sector (Table 4). The firm debt is defined as the sum of current liabilities and long-term debt.

4. Assessing physical and transition risks

Physical risks

Geographical exposure analysis: Nonfinancial corporations

Our results for the geographical analysis of banks' credit exposures show that banks typically lend the bulk of their credit portfolio to locations in and around capital cities. In 7 out of 9 countries for which we assess exposure to physical risks, the provinces where the countries' capital cities are located receive over 40 percent of the credit extended by banks (Figure 5). In detail, at the higher end of the distribution are capital provinces in Peru (Lima), and Chile (Región Metropolitana), which hold 73 and 79 percent of the system-wide loans, respectively. At the other end, capital provinces in Bolivia (La Paz), and Brazil (Brasilia) receive a lower share of credit volume at 27 and 2 percent, respectively. Differently from other LAC countries under analysis, La Paz is not the main recipient of bank lending, since Bolivian banks allocate 60 percent more credit in Santa Cruz than in La Paz. Likewise, Brazil's case departs from its peers since Brasilia is away from states that lead economic activity such as São Paulo.

Banks' credit portfolios are less geographically concentrated in Brazil and Colombia. Measured as the share of loans that holds the top three largest provinces in terms of the credit portfolio, Brazil and Colombia are in the lower end of the indicator distribution with 50 and 70 percent, respectively. The low level of concentration is also confirmed by the Herfindahl-Hirschman Index (HHI), a quantitative measure of concentration in a certain market.[25] In these two countries, the HHI is below 2,500, confirming a moderate banking loan geographical concentration. The above may be symptomatic, ceteris paribus, of lower physical risks, as province-specific natural disasters leading, for instance, to business interruption, damages to real estate, and damages to other capital goods would not take a significant, direct toll on banks' credit portfolios. Conversely, banks' credit portfolios in Bolivia, Chile, and Peru are less geographically diversified as the three largest provinces hold more than 83 percent of their loan portfolios across the country. The HII for the above countries is greater than 2,800.

Natural disasters do not affect all economic sectors equally. To arrive at an estimate of physical risks, it is necessary to distinguish which economic sectors banks are lending to within each province. For instance, landslides tend to affect the transport sector primarily, while agricultural activities are more directly affected by droughts. Other natural disasters such as floods or storms have a more ample effect across different sectors. Our mapping of physical risks and sectors is presented in Table C1 in the Annex. However, this identification is subject to constraints due to data availability. In some countries, public data does not allow us to know the volume of loans

[25] The HHI is calculated as a sum of the squared market shares (measured as a share of total credit portfolio of the banking sector) of each bank in a market An HHI of less than 1,500 identifies low concentration, an HHI between 1,500 to 2,500 identifies a moderately concentrated marketplace, while an HHI of above 2,500 suggest a highly concentrated marketplace.

allocated to a specific sector within each province. We face this issue in four countries, for which we make imputations based on the province-specific sectoral distribution of GDP.[26]

Historical probabilistic information allows natural disasters geographical mapping in LAC for different kinds of events. Table 5 shows the percentage of provinces in a country affected by specific hazards across four hazard levels: very low, low, medium, or high. For example, the drought hazard is assessed as high for 11 percent of the provinces of Bolivia, which corresponds to one province (Potosi) out of the nine Bolivian provinces. The selection of natural disasters for which we assess physical risks is based on the most economically damaging and frequent ones in the LAC region: wildfires, floods (riverine), landslides, earthquakes, cyclones, and droughts.[27]

Wildfires and floods have high hazard mapping for most of each country's provinces in our sample, with landslides and earthquakes representing a relevant threat. The prevalence of hazards varies across the country's provinces (Table 5). The hazard of wildfire is classified as high for all or almost all provinces in our sample of countries, except for Ecuador where less than half of their provinces present a high chance of encountering weather that could support a substantial wildfire. Floods are also a highly prevalent risk across the countries' provinces, but to a lesser extent in Chile and Peru. More than three quarters of the states in Mexico, Colombia, and Ecuador include provinces with land conditions that make localized landslides a frequent threat. Moreover, the chance of having a potentially damaging earthquake is a significant threat in a high share of provinces, especially in Chile, Peru, and Ecuador.

Cyclone and droughts are the hazards with the lower share of provinces with high hazard classification. Potentially damaging cyclone-strength winds are a relevant hazard for Mexico and Dominican Republic, and to a lesser extent for Colombia. Alternatively, water scarcity (drought) is the natural disaster with the lowest hazard level province-wide across LAC; still, some countries have a relevant share of provinces with high or medium hazard level, namely Chile, Dominican Republic, and Mexico.

Information on hazard mapping is combined with data on the sector-specific geographical distribution of banking loans to estimate the banking sector's exposure to specific physical risks. We calculate the total amount/percentage of banking loans exposed to a specific physical risk, distinguishing between the different sectors' characteristics and their vulnerability to natural disasters. For instance, assuming landslides affect primarily the transport, storage and communication sector in Brazil, the amount of banking loans that are highly exposed to landslides consist of the sum of banking loan portfolios invested in the sector in Rio de Janeiro, Minas Gerais, and Espírito Santo, which are the Brazilian states where the hazard level of a landslide is assessed as high. Our measure of bank loan exposure to physical risks is presented in Table 6.

[26] The value of goods produced and the amount of credit that banks allocate to economic sectors in specific provinces have a strong positive correlation. To measure this relationship, we leverage on countries with publicly available data for both banks' outstanding loans and GDP disaggregated by sector and province: Mexico, Chile, and Bolivia. As we do with credit information, we map the economic sectors most affected by the climate hazards under analysis using the same approach described Annex C. The correlation coefficients show evidence of the strong positive and statistically significant relationship between these two variables. Results are available upon request.

[27] As in Pagliari (2021) we focus on riverine floods. Of the type of floods cataloged by CRED EM-DAT, riverine floods accounts for more than 80 percent of the economic damage and more than 90 percent of the people affected in our sample of countries.

This is similar to Table 5, but with the addition of another important layer of information: the percentage of bank loans potentially exposed to physical risks. Following the Brazilian example, whereas Rio de Janeiro, Minas Gerais, and Espírito Santo hold 21 percent of the country-wide banks' total credit portfolio, only 1.1 percent of this portfolio is allocated to the most sensitive sectors to landslides. Due to the lack of data on loss given default for different types of disasters, we can only consider information on the frequency/probability of a disaster, but we are unable to extend our analysis to an expected loss framework.

Our estimate of the exposure of the LAC banking sector to physical risks shows that potential exposures to floods are much higher than those stemming from other physical risks. As shown in Table 6, six out of nine countries under analysis have a high potential exposure to floods in terms of hazard level, number of provinces, and share of banks' loans allocated to floods-sensitive sectors. In detail, more than 10 percent of the banking sector credit portfolio have a high hazard mapping to floods in Brazil, Mexico, Colombia, Argentina, Bolivia, and Dominican Republic. This exposure is larger for Bolivia and Brazil, at 50 and 29 percent, respectively.

While not presenting a significant high exposure to floods, 15 percent of Chilean banks' loans have a medium exposure to this event, and 12 percent are exposed at low level in Peru. In addition to the hazard mapping, these results are also driven by the relative size of bank portfolio exposures to the affected sectors across countries' provinces. The above explains why wildfires do not entail a significant portfolio risk for the banking sector despite having a high hazard mapping for most of countries' provinces. Banks' credit portfolios are also significantly exposed to earthquakes in Chile and Bolivia. Table 6 shows that Chilean provinces with a high hazard mapping to earthquakes hold an amount of loans to nonfinancial corporations corresponding to 13 percent of the banking sector total credit portfolio. In the case of Bolivia this same share goes up to 40 percent but at a medium hazard level. With almost 20 percent of the total loan portfolio, Dominican Republic and Mexico also have a high potential exposure to cyclones.[28]

Geographical exposure analysis: Residential mortgages

In this section, we analyze the exposure of banks' mortgage portfolios to floods in Chile, Colombia, and Mexico, where data are available. The results show that Chile is the country with the higher proportion of mortgages in banks' total credit portfolios with 30 percent, followed by Colombia and Mexico with around 14 percent.[29] The mortgage distribution across provinces mirrors the credit to nonfinancial corporations' distribution presented in the previous section. In detail, the mortgage portfolio is highly concentrated province-wide, with the top three provinces accounting for more than 70 percent in the three countries under analysis.

Chile has the higher mortgage portfolio but is less exposed to floods, while the Mexican mortgage market is shallower but highly exposed. Chilean provinces with high hazard mappings for floods are Los Lagos and Araucania, capturing 4.6 percent of banks' mortgage portfolio or 1.4 percent of the total credit. Valparaiso and Metropolitana provinces, where flood hazard is classified as

[28] These countries might also be exposed to rising sea-level risk, a hazard that is gradual in nature and that could play over a relatively long-time horizon.

[29] Although public information is available for Ecuador, it is rather partial thus we exclude it from the analysis. The social security state-owned bank (*Banco del Instituto Ecuatoriano de la Seguridad Social*) is a key player in the mortgage market but does not have publicly available information on the geographical distribution for this portfolio.

medium, account for two-thirds of banks' mortgages. The prevalence of flood hazards in Mexico is much higher since flood hazard is classified as high for 27 out of its 32 provinces. Those provinces account for 96.6 percent of banks' mortgage portfolios or 13.5 percent of the total credit. As stated in the previous section, since our assessment is grounded in the first-level administrative units, it conceals a certain degree of cross-sub-province heterogeneity, so these estimations should be considered an upper-bound.

Outstanding mortgages at the second administrative level (municipality) in Colombia allows a more precise estimation. The granularity of available information for Colombia allows us to map mortgages potentially exposed to floods without the need for inferring a hazard level for higher administrative units (Table 7). Floods are assessed as high for 334 municipalities out of 1,061 for which we were able to obtain a hazard measure (31 percent of the municipalities). These municipalities account for 62 percent of banks' mortgage portfolios or 8.4 percent of their total credit.

Historical impact analysis

The results of the empirical analysis show that total NPLs in provinces affected by natural disasters increased compared to those that were not affected. The coefficients are both statistically and economically significant. Our baseline model shows that, on average, NPLs in the provinces affected by the natural disaster increase by 1.1 percentage points in the post-treatment period (Table 8, column 1). The results are robust to different estimation strategies as shown in Table 8, columns 2 and 3.

We also find evidence that these main results are driven by nonfinancial corporation NPLs. By disaggregating total NPLs by nonfinancial corporation NPLs and household NPLs, we are able to disentangle the heterogeneous effect across aggregate types of borrowers. We find that the average treatment effect on the treated group is 1.79 percentage points for nonfinancial corporation NPLs, while the effect for household NPLs is 0.39 percentage points (Table 9, columns 2 and 3). This could be explained by the fact that nonfinancial corporations tend to be more directly exposed to natural disasters via business interruption and facilities destruction. On the other hand, household loan portfolios are composed by consumption loans and mortgages, with the latter usually insured.[30]

The main and heterogeneous results described before are positive and statistically significant after controlling for the intensity of the natural disasters across countries. As the different natural disasters can cause heterogeneous economic damages, we employ a DiD model that control for the event' intensity. In that regard, we calculate a natural disaster vulnerability factor (VF) defined as the economic damage as fraction of the country GDP one year before the disaster. The VF is then interacted with the DiD coefficient.[31] Thus, factoring-in the VF we find that the impact on NPLs in the aftermath of the disaster is still statistically and economically significant for total, nonfinancial corporation, and household NPLs (Table 9, columns 4 - 6). Specifically, the

[30] For instance, Chile has the statutory insurance obligation that mortgage loans require fire, earthquake, and flood Insurance (IMF 2014).

[31] As in Acemoglu et al. (2004), which faced the same analytical problem of varying treatment intensity but applied in a different context. In our analysis, the VF take the value of 1.6 percent for Peru, 0.5 for Argentina, 0.6 for Chile, 0.4 percent for Mexico, and 0.2 for Brazil.

DiD coefficient is 0.6 for the total NPLs, and 3.71 and 1.04 for nonfinancial corporation and household NPLs, respectively.

To learn more about the time dynamics of NPLs and as a further robustness test for our analysis, we implement a panel event study. The visual representation of our results is in Figure 6. Before the disaster took place, there were no statistically significant differences between the trends of the two sets of provinces. Post disaster NPLs in the affected provinces start to diverge from their counterfactuals at the fourth quarter after the event, reaching a maximum of 1.43 percentage points for the total credit portfolio and 2.52 for the nonfinancial corporate credit portfolio. In the fifth quarter, NPLs start to decline, fading the differences between the two groups. In the seventh quarter, the effect on NPLs is statistically equal to zero. This progressive reaction is expected as NPLs are a slow-moving indicator only recorded when payments are overdue by (usually) more than 90 days.

The higher proportion of borrowers not able to meet their payment obligations suggest insufficient protection against natural disasters in the LAC region. For instance, following the 2018 drought, the production of soy and corn in Argentina dropped by 31.3 percent and 12.5 percent, respectively (Central Bank of Argentina 2018). In the absence of a developed insurance market that can assist in smoothing such negative shocks, firms' profit margins are expected to be substantially hit, hindering their ability to honor the loan payments. In that regard, whereas the depth of the insurance market in LAC (insurance premiums as percentage of the GDP) is higher than in most regions, it is significantly lagging behind high income countries.[32] For example, in France, one of the high-income countries with higher insurance penetration, a recent survey on the preparedness for climate change shows that physical risks appear to be modest in the short term as these risks are covered by insurance companies (ACPR 2019).

Our empirical results are in line with the findings of similar studies. Directly comparable with our outcomes, an IMF report shows that natural disasters contribute to a deterioration in NPLs in Sub-Saharan Africa, which is up to 1 percentage point in the case of storms (IMF 2016). The Central Bank of Mexico undertook a more granular analysis than the one carried out in our paper by analyzing the effect of the exposure to unusual extreme heat events on the delinquency rate of small, micro, and medium enterprises in the Mexican agriculture sector (Central Bank of Mexico 2020). This analysis finds evidence of an increase in NPLs of 1 percentage point following a 20 days of unusual extreme heat wave during a given trimester. In a developed country-setting, Noth and Schüwer (2018) document that natural disasters significantly weaken the stability of US banks with business activities in regions affected by natural disasters, reflected, among others, in higher NPLs. Moreover, Gallagher and Hartley (2017) show evidence that four quarters after the Katrina Hurricane hit New Orleans, there is a 2.5 percentage point increase in the share of residents in flooded areas with at least one NPL account.

[32] Measured as life and non-life insurance premiums as a percentage of the GDP, the depth of the LAC insurance market is above most regions at 1.8 percent of the GDP, only slightly surpassed by the East Asia and Pacific region. Nonetheless, the LAC insurance market is shallower when compared with high-income countries, where the insurance premiums represent 4.9 percent of the GDP. In addition, there is significant heterogeneity across LAC economies, where the indicator varies from 1 percent in Paraguay to 4.5 percent of GDP in Chile.

Our results should be considered a conservative estimation as natural disasters could become more frequent and intense in the future. This is a global trend that has been widely documented in previous studies (see Masson-Delmotte and Moufouma-Okia 2019, United Nations 2015, IPCC 2012), and is particularly relevant for the LAC region (OCHA 2020). Therefore, the results of a historical impact analysis of natural disasters in the financial system should not be necessarily interpreted as predictors of future events outcomes. Along these lines, Bolton et al. (2020) describe the risk of "green swans" – a low probability-high impact scenario of "extremely financially disruptive events that could be behind the next systemic financial crisis."

Transition risks

Transition risks can materialize through bank holdings in CO_2-intensive and environmentally damaging industries and assets. The literature on transition risks is mostly focused on so-called "stranded assets", i.e. assets that lose economic and financial value due to stricter regulations to reach climate goals, rapid changes in carbon neutral technology and changes in behavior of consumers and markets (Delis, de Greiff, and Ongena 2019; Bos and Gupta 2019). In the short-run, banks may face write-offs on loans to polluting companies who face additional costs or cannot comply to regulations. In the long-run, stranded assets can materialize as a less carbon-intensive development path is chosen.

Although the transition to a low-carbon and sustainable economy implies adjustment costs, especially in the short-term, those are outpaced by long-term benefits. According to a recent study (WRI and NCE 2020), in the face of the current COVID-19-induced economic slowdown, a transition towards a greener and carbon-neutral economy could add US$ 535 billion to Brazil's GDP by 2030 compared with a business-as-usual scenario. This can be achieved by prioritizing low-carbon, integrated infrastructure, promoting industrial innovation through green investments, and implementing deforestation-free, high-productivity agriculture. Similarly, Groves et al. (2020) show that the Costa Rica National Decarbonization Plan may bring US$ 41 billion in net benefits to the Costa Rican economy between 2020 and 2050 through, among others, energy savings, reduced transportation costs, improvements in ecosystem services and agricultural yields.

All LAC countries have ratified the Paris Agreement, committing to curb greenhouse gas (GHG) emissions in the coming years. Nationally determined contributions (NDCs) are at the heart of the Paris Agreement, embodied by each country to reduce national emissions and adapt to the impacts of climate change.[33] All countries under analysis have specific GHG target emissions as part of their NDCs. Exceptions are El Salvador and Bolivia, which specify their mitigation contributions in terms of actions.[34] Comparison of NDC stringency across countries is difficult to assess (Pauw et al. 2018). Yet, Brazil's NDCs are known to be one the most ambitious by committing to reducing GHG emissions by 37 percent and 43 percent by 2025 and 2030, respectively, compared to the estimated emissions for 2005 (Kossoy 2018). Colombia also has very ambitious targets, including a 51 percent GHG emission reduction by 2030.[35] Besides, Costa Rica's NDCs submitted in 2020 to the UNFCCC positions the country as one of the few economies,

[33] Due to simultaneous efforts to achieve NDC targets, transition risks may also be correlated across countries.
[34] See World Resources Institute.
[35] *Actualización de la Contribución Determinada a Nivel Nacional de Colombia (NDC)*

globally, committing to be on a trajectory consistent with the global goal of limiting the increase in global average temperature to 1.5C.[36] This goal is also consistent with that noted in Costa Rica's long-term National Decarbonization Plan. Through global value chains, international commitments also have a bearing on countries' specific GHG emission trends (Kaltenegger et al. 2017). The implementation of an orderly transition, particularly in the case of ambitious NDCs, is key to the mitigation of transition risks for the banking sector (NGFS 2020b).

Bolivia, Paraguay, and Uruguay are the largest emitters of GHG when adjusting for the size of their economy. While Mexico and Brazil are the largest emitters of GHG in absolute terms, this is not the case when we account for the size of their economies and look at emissions per unit of GDP (Figure 7).[37] Bolivia, Paraguay, and Uruguay sit around or below the median emitters of the sample countries but are in the higher end of CO_2e per unit of GDP, which is largely explained by their agricultural sector emissions.

To obtain a preliminary indication of banks' loans value-at-risk to the transition to a low carbon economy, we analyze the sectoral distribution of bank loans to nonfinancial corporations. We find that more than one quarter of banks' credit portfolios in Argentina, Uruguay and Bolivia are tilted towards transition-sensitive industries that are also high CO_2 emitters. The relatively higher exposure to transition risks in these countries is driven by the agricultural sector, and to a greater extent in Uruguay where agriculture explains two-thirds of the total exposure (Figure 8). Although we could not retrieve credit outstanding information with the required granularity to compare Paraguay across LAC, data from Paraguay Central Bank show that banks allocate around 30 percent of their total credit portfolios to the agricultural sector. This allocation is larger than the exposure to all transition-sensitive sectors in the rest of our sample of countries. Banking systems less exposed to transition risks are in El Salvador, Costa Rica, Colombia, and Chile.

LAC firms operating in transition-sensitive sectors already present signs of stress, especially those in the fossil fuel and agricultural industries. In the event of materialization of transition risks, the effects on the banking sector may be greater if ex-ante firms are financially stressed.[38] Available firm-level data show that 26 percent of the LAC firms that operate in transition-sensitive sectors had annual interest payments exceeding profits as of 2019 (Figure 9). This share is six percentage points higher than firms operating in non-transition-sensitive sectors. In terms of individual sectors, fossil fuels have the higher share of firms with an ICR below or equal to one, at 32 percent, and heavy industry the lowest at 23 percent.[39] When we look at the share of outstanding debt that financially distressed firms hold, firms' higher vulnerability in transition-sensitive sectors is more pronounced at 38 percent, which is 12 percentage points higher than firms in

[36] Costa Rica commits to an absolute maximum of net emissions by 2030 of 9.11 million tons of carbon dioxide equivalent (CO2e) including all emissions and all sectors covered by the corresponding National Emissions Inventory.
[37] We consider emissions from carbon dioxide, methane, nitrous oxide, and F-gases measured in tonnes of carbon dioxide equivalents (CO_2e). Emissions other than carbon dioxide (CO_2) are particularly relevant for LAC. CO_2 emissions represent 75 percent of GHG at the global level, a figure 20 percentage points lower for LAC (Data obtained from Climate Watch).
[38] See Grippa and Mann (2020) for an exercise that uses firm-level information to conduct transition risk stress testing.
[39] Compounding our findings, Ramírez, Thomä, and Cebreros (2020) find a sizable exposure of banks in LAC to transition risk driven by companies increasing fossil fuel production. For instance, the authors show that Brazilian companies could increase their oil and coal production by 40 percent and 11 percent in the next 5 years.

non-transition-sensitive sectors. The sector with the highest share of debt-at-risk is agriculture, at 53 percent.

The short-term duration nature of banks' credit portfolio in LAC might mitigate the transition impacts. Although LAC's long-term credit market compares favorably to other developing regions, it is significantly lagging when compared with higher-income economies. While the outstanding loans with a maturity of more than one year are around 30 percent, those are twice as much in high-income countries (Gutierrez, Karmali, and Sourrouille 2018). In the specific case of Argentina, the weighted average term of banks' credit portfolios stood at only 10.7 months as of December 2018. According to the Central Bank of Argentina (2019), this low duration is partially explained by the low participation of mortgages in the total credit to the private sector. Consequently, the impacts of an energy transition might be negligible since banks should be able to realign their portfolios quickly.

5. Concluding remarks

This paper offers preliminary evidence on the climate-related and environmental risks for the banking sector in LAC. We first provide an overview of the key features of the banking sector, the economic damage and frequency of natural disasters, and the climate-related and environmental risk regulations for the LAC region. We then provide preliminary evidence on the extent of the banking sector credit risk exposure to physical and transition risks based on publicly available data.

Exposures to floods represent the most important source of credit risk for the LAC banking sector. This is compounded by high loan concentration in and around LAC capital cities, which, ceteris paribus, entails higher physical risks to province-specific natural disasters. Using a DiD method, we present empirical evidence of a significant increase in banks' NPLs in the aftermath of large-scale natural disasters with heterogeneous effects across portfolio types. Our results show that large-scale natural disasters trigger an increase in total NPLs of up to 1.4 percentage points in affected provinces. Evidence points to a higher impact on the nonfinancial corporate loan portfolio.

The banking sector in LAC is also exposed to sectors sensitive to the green transition. Particularly, banks operating in countries that are among the largest GHG emitters per unit of GDP have credit portfolios tilted toward transition-sensitive sectors. This is more pronounced in the cases of Argentina, Bolivia, Paraguay and Uruguay, where the agriculture sector is the largest emitter of GHG emissions as well as one of the most relevant borrowing sectors. In addition, exploratory analysis at the firm-level shows that firms operating in transition-sensitive sectors already present signs of stress, especially those in the fossil fuel and agricultural industries.

While our study is limited in scope due to data gaps in terms of coverage of countries in LAC and granularity of information, our findings have important policy implications. They point to the need for financial authorities to undertake more in-depth assessments of climate-related and environmental risks for the financial system, with a view to ultimately integrate those risks into their supervisory framework in case they are found to be material. Some countries have already made breakthroughs by enacting ESG risk regulations, but no supervisory authority has so far integrated climate-related and environmental risks into financial stability surveillance and micro or macroprudential supervision. This is expected to change, however, as more and more LAC financial authorities join the NGFS and adopt a more proactive stance towards climate-related and environmental risks.

Follow-up research could conduct more in-depth assessments that leverage granular and non-public information provided by financial authorities, potentially allowing for more precise and policy-prone analyses. Also, stress-testing exercises could be explored to understand the extent to which stress in nonfinancial corporations triggered by a transition to a greener economy could transmit to the banking system based on scenario analysis.

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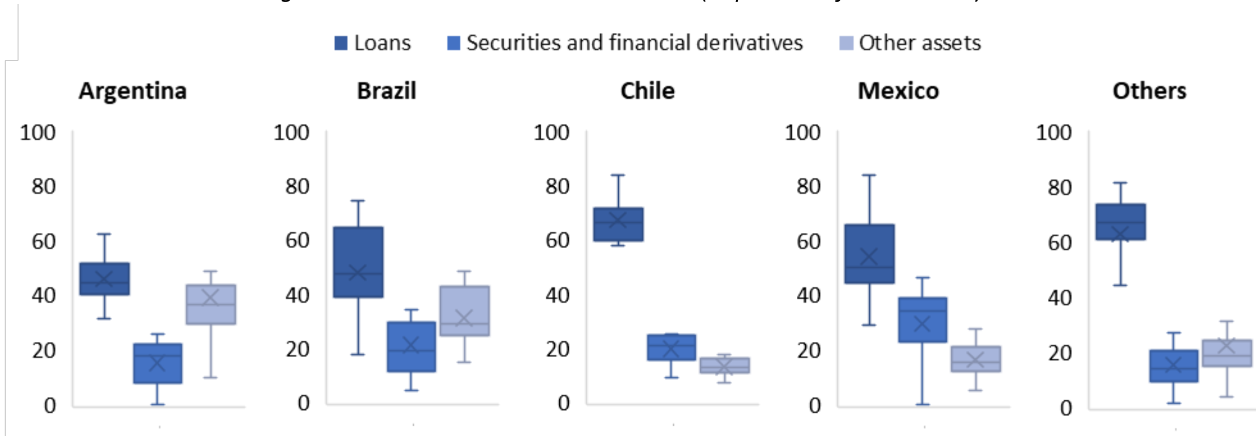
ANNEX

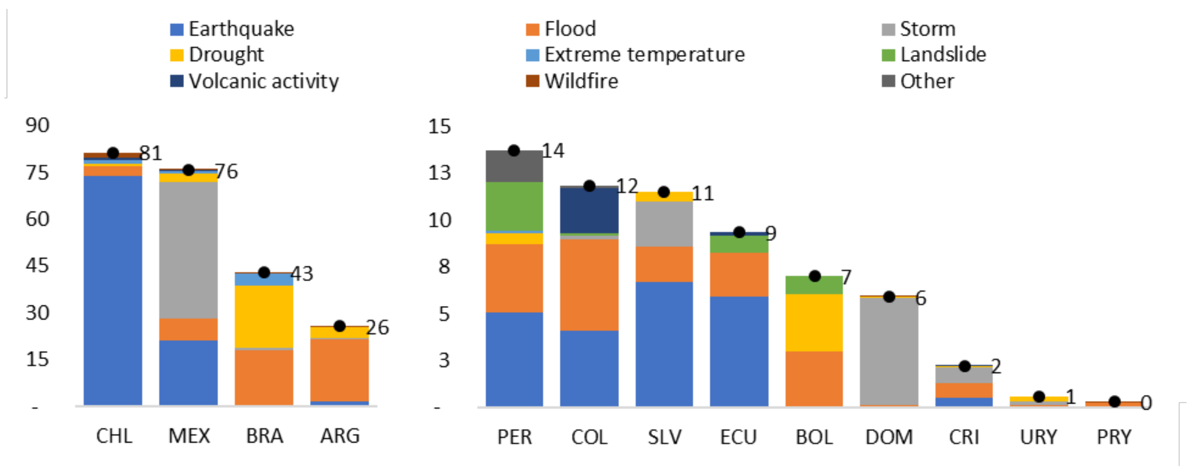
A. Figures

Figure 1 – Banks' assets structure in LAC (In percent of total assets)



Source: Orbis.
Note: As of 2019. Considers 80 LAC banks (Brazil 20, Mexico 14, Argentina 18, Chile 8, and others (20, includes banks from Uruguay, Peru, Bolivia, Costa Rica, Dominican Republic, and El Salvador).

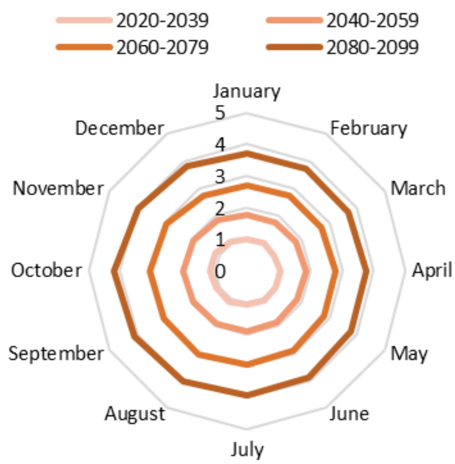
Figure 2 – Economic damage of natural disasters in LAC between 1990 – 2020 (In US$ billion)



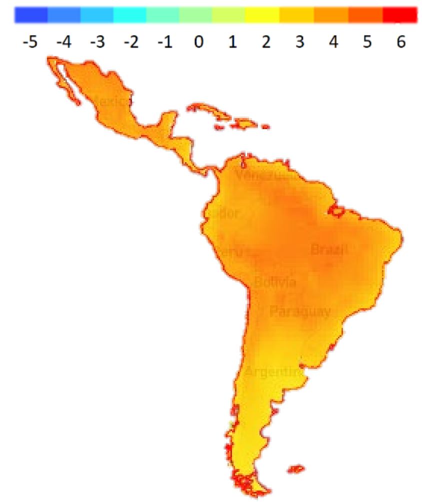
Source: EM-DAT.
Note: Not all disasters have a damage estimate. Damages have been adjusted to reflect the 2019 Consumer Price Index (CPI). Other includes volcanic activity, wildfire, mass movement (dry), epidemic, and insect infestation. LAC countries restricted to the sample under analysis.

Figure 3 - Projected change in monthly temperature compared to 1986 – 2005

Panel A – Median estimates (In temperature - °C)



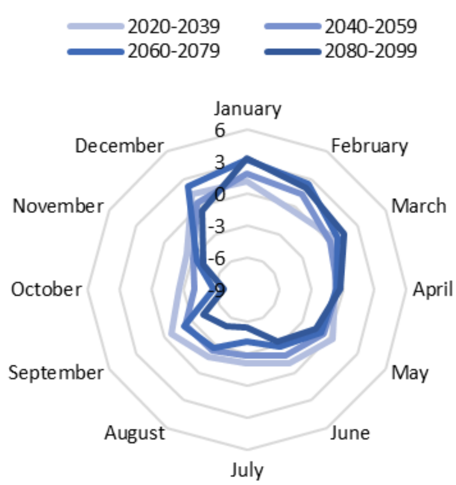
Panel B – Projections for 2080 – 2099 (In temperature - °C)



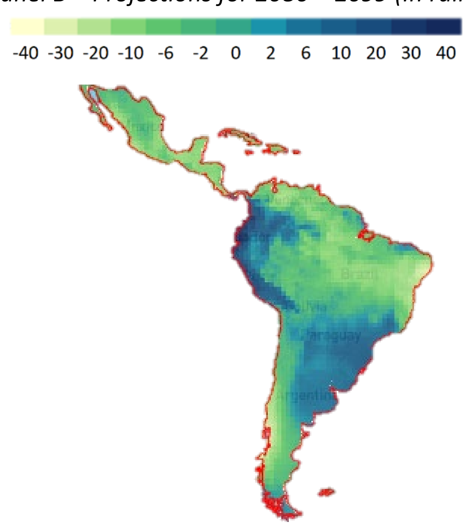
Source: World Bank Climate Change Knowledge Portal
Note: Spirals shows the projected rise of monthly LAC temperature over the period from 2020 to 2099, compared to base period 1986-2005.

Figure 4 - Projected change in monthly precipitation compared to 1986 – 2005

Panel A – Median estimates (In rainfall – mm)

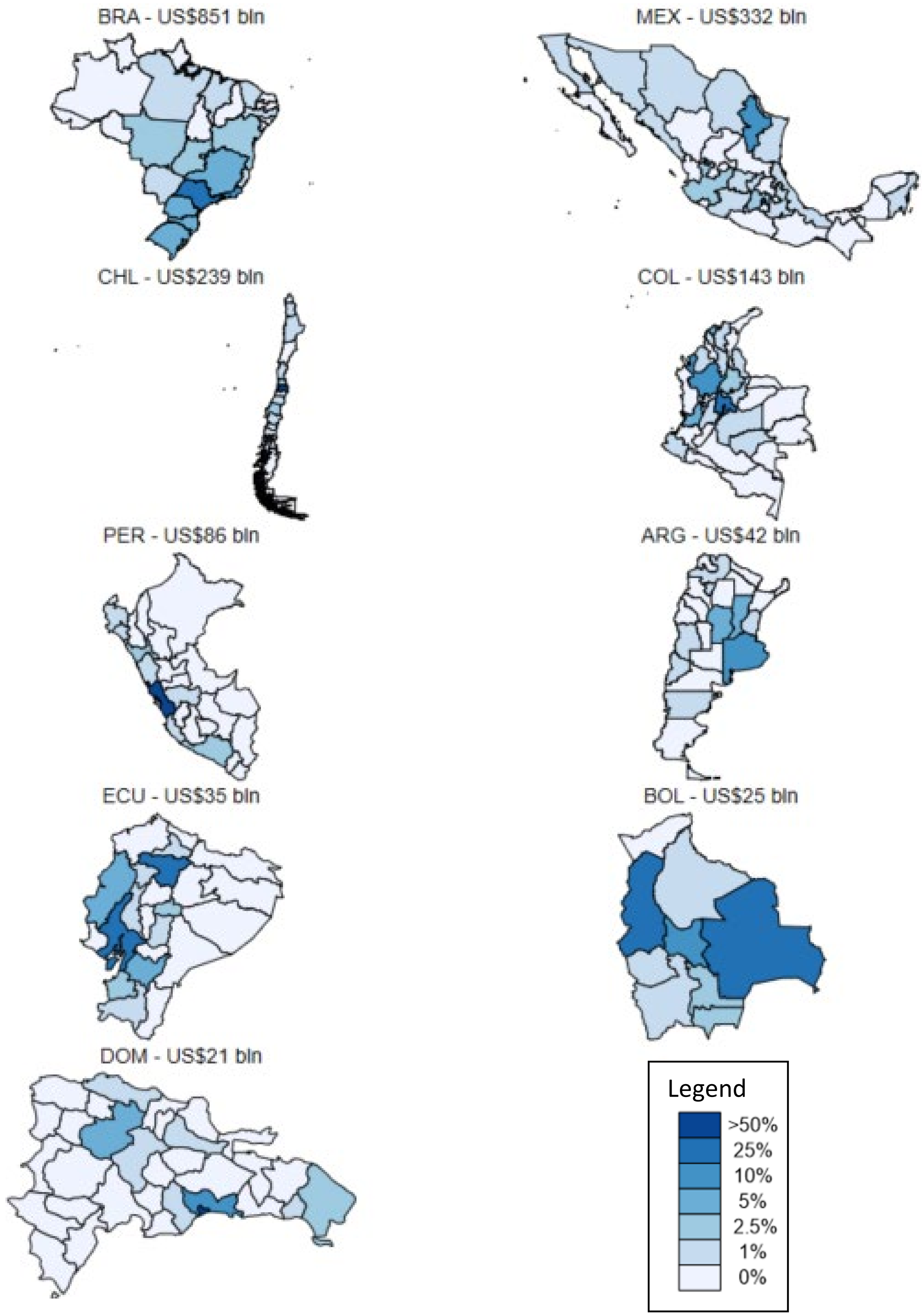


Panel B – Projections for 2080 – 2099 (In rainfall - mm)



Source: World Bank Climate Change Knowledge Portal.
Note: Spirals shows the projected rise of monthly LAC precipitations over the period from 2020 to 2099, compared to base period 1986-2005.

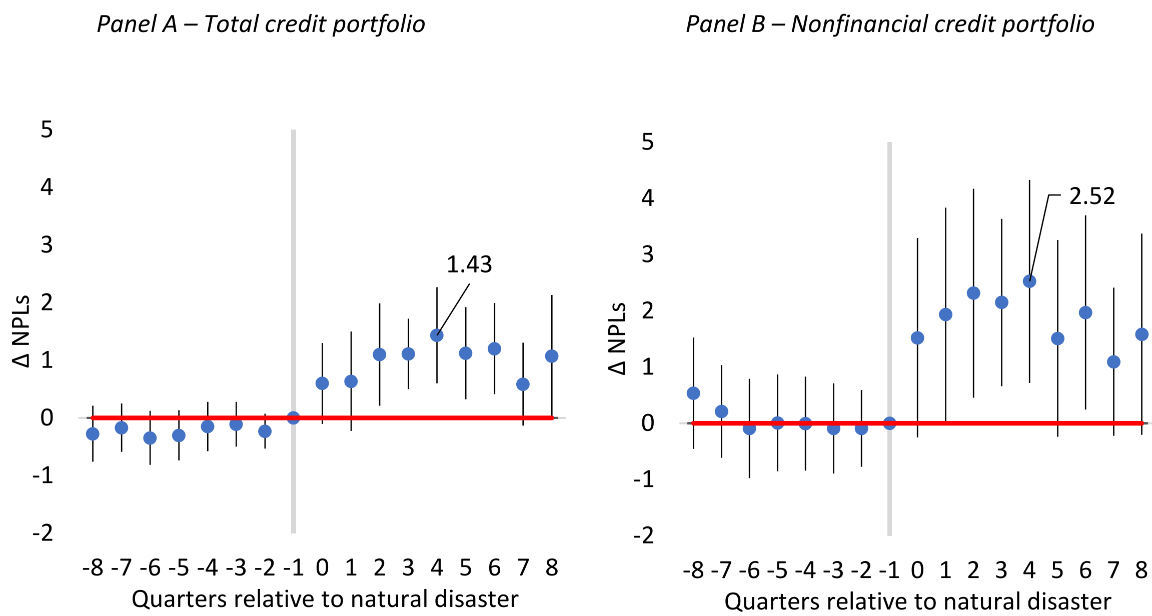
Figure 5 - Geographical mapping of banks' total credit portfolio shares across provinces, December 2019



Source: Own elaboration.

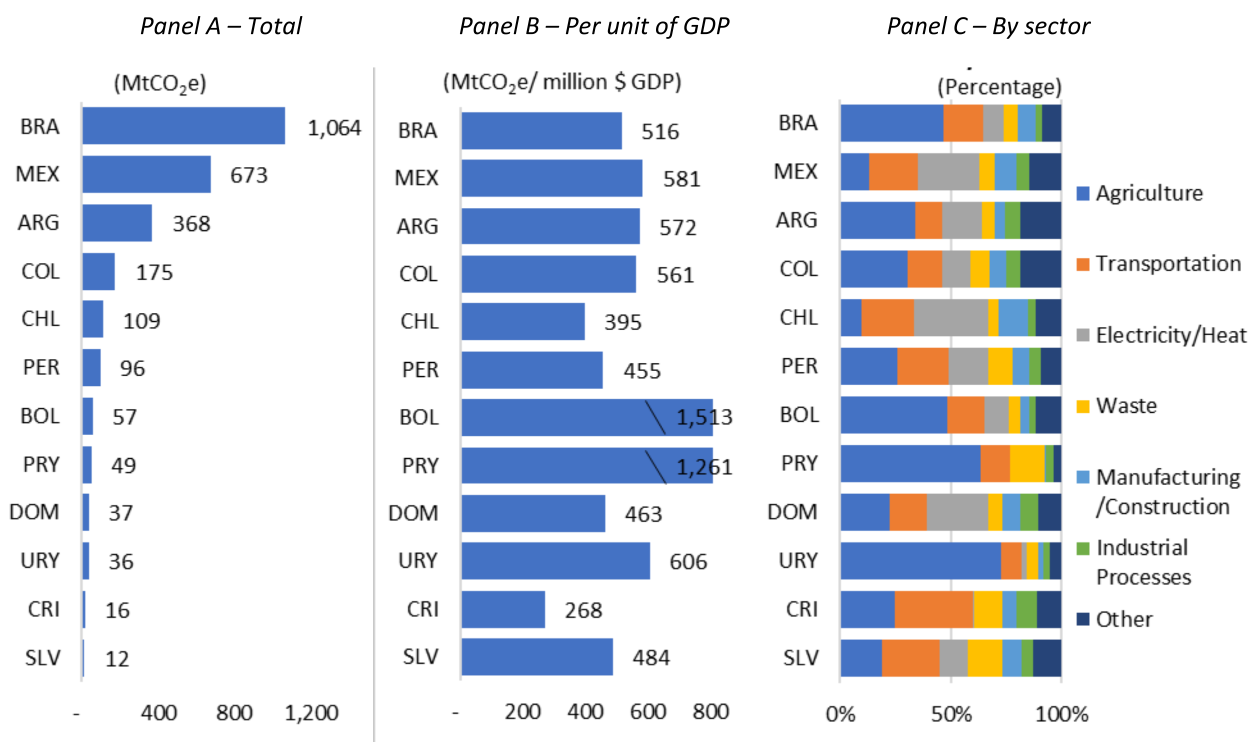
Note: Figures on the side of each country name indicate the banks' total credit portfolio. Publicly available geographical breakdowns for Costa Rica, Paraguay, and Uruguay are not available.

Figure 6 - Impact of large-scale natural disasters on non-performing loans



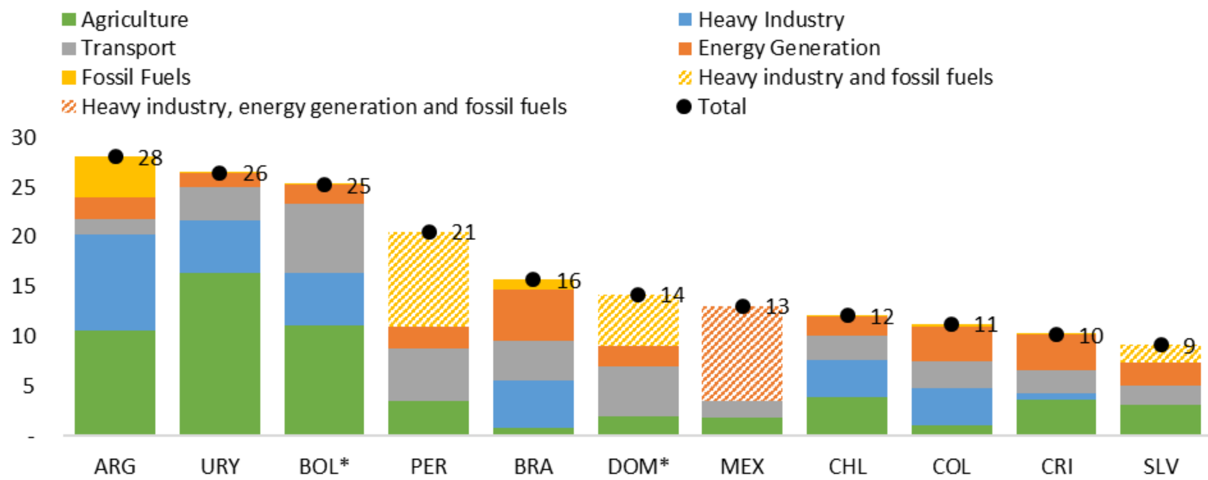
Source: Own elaboration.
Note: Point estimates are displayed along with their 95% confidence intervals as described in equations 2 - 6 . Standard errors are clustered at the country-province level. The baseline (omitted) base period is 1 quarter prior the event start, indicated by the solid vertical line in the plot.

Figure 7 – Greenhouse gas emissions (CO_2e)



Source: Climate Watch.
Note: Greenhouse gas emissions – from carbon dioxide, methane, nitrous oxide, and F-gases – are summed up and measured in tonnes of carbon-dioxide equivalents (CO_2e). Emissions from land use change are excluded.

Figure 8 - Sectoral breakdown of credit portfolios by transition-sensitive industries (share of total credit portfolios)



Source: Own elaboration.
Note: *Estimated shares for heavy industry. In the cases of Bolivia and the Dominican Republic the credit outstanding information does not allow us to identify the transition-sensitive sectors within manufacturing according to Table C1 of the Annex. We took the credit outstanding share for the whole manufacturing sector and subtracted the proportion of not transition-sensitive sectors based on the GDP sectoral distribution of each country. See Annex B for additional classification details.

Figure 9 – Interest coverage ratio (ICR), latest available data (2018 or 2019)

Panel A – Share of firms *Panel B – Share of debt*

Note: Sample covers 38,227 firms with total outstanding debt of US$ 2,112 billion. See Table 4 for sample details.
Source: Own elaboration based on Orbis data.

B. Tables

Table 1 - Top 2 most damaging natural disaster for each country between 1990 and 2020

Country	Type	Date	Damage* (in US$ million)	Insured damage (In US$ million)	People affected
Chile	Earthquake	February 2010	35,173	9,380	2,671,556
Chile	Flood	March 2015	1,618	539	193,881
Mexico	Earthquake	September 2017	6,258	2,086	256,000
Mexico	Storm	October 2005	6,546	2,356	1,000,000
Brazil	Drought	January 2014	5,400	-	27,000,000
Brazil	Drought	December 2004	2,233	-	-
Argentina	Drought	January 2018	3,462	-	-
Argentina	Flood	April 2013	1,427	179	350,000
Peru	Flood	March 2017	3,233	396	1,800,505
Peru	Earthquake	August 2007	740	247	658,331
Colombia	Earthquake	January 1999	2,851	153	1,205,933
Colombia	Flood	September 2011	1,466	-	498,924
Ecuador	Earthquake	April 2016	2,130	597	389,364
Ecuador	Flood	January 2008	1,187	-	289,122
El Salvador	Earthquake	January 2001	2,166	419	1,334,529
El Salvador	Flood	September 2011	1,137	-	300,000
Dominican Republic	Storm	September 1998	3,108	627	975,595
Dominican Republic	Storm	September 2004	401	-	14,009
Bolivia	Flood	December 2007	617	-	485,000
Bolivia	Drought	March 2016	479	-	665,000
Uruguay	Drought	January 2018	509	-	11,135
Uruguay	Drought	June 1999	384	-	-
Costa Rica	Flood	February 1996	407	-	20,000
Costa Rica	Storm	July 1996	326	-	500,000

Source: CRED ME-DAT. "-" denote missing values.
Note: *Damages have been adjusted to reflect the 2019 Consumer Price Index (CPI). Disasters with no damage estimates are not shown. Date refers to the start date of the disaster. LAC countries restricted to the sample under analysis.

Table 2 – Regulatory and supervisory efforts in LAC

(i) ESG regulations	(ii) Supervisory measures	(iii) Private sector initiatives
Peru	Peru	Peru
Brazil	Brazil	Brazil
Paraguay	Paraguay	Paraguay
Honduras	Mexico	Mexico
	Panama	Panama
	Colombia	Colombia
	Chile	El Salvador
		Costa Rica
		Ecuador
		Argentina
		Honduras

Source: Frisari et al. (2019) and local authorities.

Table 3 – Financial and GDP data sources

Country	Financial Information	Sectoral and/or geographical distribution of GDP
Argentina	*Banco Central de la República de Argentina*	*Instituto Nacional de Estadísticas y Censos*
Bolivia	*Autoridad de Supervisión del Sistema Financiero*	*Instituto Nacional de Estadística*
Brazil	*Banco Central do Brasil*	*Instituto Brasileiro de Geografía e Estadística*
Chile	*Comisión para el Mercado Financiero*	*Banco Central de Chile*
Colombia	*Superintendencia Financiera de Colombia*	*Departamento Administrativo Nacional de Estadística*
Costa Rica	*Superintendencia General de Entidades Financieras (SUGEF)*	*Banco Central de Costa Rica*
Dominican Republic	*Superintendencia de Bancos*	*Oficina Nacional de Estadística*
Honduras	*Comisión Nacional de Bancos y Seguros*	*Banco Central de Honduras*
Ecuador	*Superintendencia de Bancos de Ecuador*	*Banco Central del Ecuador*
El Salvador	*Superintendencia del Sistema Financiero*	*Banco Central de la Reserva de El Salvador*
Mexico	*Comisión Nacional Bancaria y de Valores* *Banco de México*	*Instituto Nacional de Estadística y Geografía*
Paraguay	*Banco Central de Paraguay*	*Banco Central de Paraguay*
Peru	*Superintendencia de Banca, Seguros y AFP*	*Instituto Nacional de Estadística e Informática*
Uruguay	*Banco Central de Uruguay*	*Banco Central de Uruguay*

Source: Own elaboration

Table 4 – Interest coverage ratio by transition-sensitive sectors: sample details

Panel A – By sector

Sector	Number of firms
Non transition-sensitive sectors	26,280
Transition-sensitive sectors	11,947
Heavy industry	*6,239*
Agriculture	*1,945*
Energy generation	*1,873*
Transport	*1,650*
Fossil fuels	*240*
Total	**38,227**

Panel B – By country

Country	Number of firms
Colombia	19,400
Brazil	9,454
Mexico	5,625
Uruguay	2,602
Chile	621
Argentina	364
Peru	126
Bolivia	25
Costa Rica	5
Dominican Republic	4
El Salvador	1
Total	**38,227**

Source: Own elaboration based on Orbis data.
Note: The sample includes all non-financial firms (listed and non-listed) that have observations for financial expenses or earnings before interest and taxes (EBIT) in 2019 or 2018. For firms that have 2018 and 2019 observations, the 2019 values are taken.

Table 5 – Percentage of first level geographical units (provinces) with very low, low, medium, or high hazard mapping by hazard and country. Conservative approach

0-25 | 25-50 | 50-75 | 75-100

Hazard	Hazard level	BRA	MEX	CHL	COL	PER	ARG	ECU	BOL	DOM
Wildfires	Very low				0-25			0-25		
	Low				0-25			0-25		
	Medium	0-25			0-25			25-50		
	High	75-100	75-100	75-100	50-75	75-100	75-100	25-50	75-100	75-100
Floods	Very low	0-25		0-25	0-25	25-50		0-25		0-25
	Low		0-25	25-50		0-25	0-25	25-50	0-25	0-25
	Medium		0-25	25-50		0-25	0-25	0-25	0-25	0-25
	High	75-100	75-100	0-25	75-100	25-50	75-100	50-75	75-100	75-100
Landslides	Very low		0-25				25-50		0-25	
	Low	25-50	0-25	0-25	0-25	0-25	0-25		0-25	0-25
	Medium	25-50	0-25	25-50	0-25	0-25	0-25	0-25		25-50
	High	0-25	75-100	50-75	75-100	50-75	25-50	75-100	50-75	25-50
Earthquake	Very low	25-50	0-25		0-25		0-25		0-25	
	Low	25-50	0-25		0-25		0-25		0-25	
	Medium	0-25	25-50	0-25	50-75	25-50	50-75	50-75	75-100	75-100
	High		0-25	75-100	0-25	50-75	0-25	25-50		
Cyclone	Very low	0-25			50-75	0-25		75-100		
	Low				0-25					
	Medium				0-25					
	High		75-100		0-25					75-100
Drought	Very low	25-50		25-50	50-75	25-50	25-50	75-100	50-75	
	Low	0-25	0-25		25-50	25-50	0-25			
	Medium	25-50	50-75	0-25			25-50		0-25	75-100
	High		0-25	25-50		0-25	0-25		0-25	

Source: thinkhazard.org.
Note: *Riverine. Colors show the percentage of first level administrative unit with very low, low, medium, or high hazard mapping, by hazard and country. First level administrative unit refers to state, province, department, region depending on each country. Blank cells indicate that the hazard is not assessed.

Table 6 - Percentage of first level geographical units with very low, low, medium, or high hazard mapping by hazard and country (colors) and share of bank assets potentially exposed to physical risks (figures)

0-25 | 25-50 | 50-75 | 75-100

Hazard	Hazard level	BRA	MEX	CHL	COL	PER	ARG	ECU	BOL	DOM
Wildfires	Very low				0.0			-		
	Low				0.1			0.0		
	Medium	0.0			0.9			0.4		
	High	0.4	1.9	0.3	2.2	3.8	0.0	0.5	0.2	2.0
Floods	Very low	0.5		0.4	0.0	1.4		0.6		0.0
	Low		0.4	0.5		12.5	0.0	2.5	2.5	0.2
	Medium		0.2	15.1		1.4	0.0	15.5	1.1	0.1
	High	28.6	10.7	0.6	26.9	1.0	15.2	17.4	50.3	19.5
Landslides	Very low		0.1				1.7		0.0	
	Low	0.3	0.0	0.0	0.1	0.0	0.1		0.2	1.2
	Medium	3.1	2.5	0.2	1.0	0.2	0.0	2.3		0.7
	High	1.1	1.0	2.7	9.5	6.2	0.1	5.4	4.5	0.7
Earthquake	Very low	17.2	1.3		0.0		0.1		0.3	
	Low	2.7	0.1		0.1		0.4		1.0	
	Medium	1.9	5.5	0.1	8.7	0.6	1.6	3.5	39.8	12.5
	High		0.3	13.4	4.4	5.5	0.1	24.2		
Cyclone	Very low	1.4			18.0	0.1		35.7		
	Low				7.3					
	Medium				2.5					
	High		18.1		0.3					19.8
Drought	Very low	2.0		1.1	1.6	0.8	0.6	6.7	9.1	
	Low	1.7	0.3		1.6	2.8	1.9			
	Medium	1.7	1.3	0.1			7.7		1.9	2.0
	High		0.3	2.1		0.2	0.3		0.1	

Source: Own elaboration and thinkhazard.org.
Note: Ibid Table 1. Numbers represent the percentage of bank credit portfolio (measured as the sector specific credit portfolio divided by total credit) potentially exposed to physical risks. See Annex B for additional classification details.

Table 7 - Banks mortgage portfolio potentially exposed to floods in Colombia (percentage of total credit), by province

Province	Very low	Low	Medium	High
Amazonas	-	-	-	0.0
Antioquia	0.3	1.7	0.2	0.0
Arauca	-	-	0.0	0.0
Atlántico	0.0	0.0	-	0.7
Bolívar	0.0	0.0	0.3	0.0
Boyacá	0.1	0.0	0.0	0.0
Caldas	0.0	0.2	0.0	0.0
Caquetá	0.0	0.0	-	0.0
Casanare	-	0.0	0.0	0.0
Cauca	0.0	0.1	0.0	0.0
Cesar	-	0.0	0.0	0.2
Choco	-	-	-	0.0
Córdoba	0.0	0.0	0.0	0.1
Cundinamarca	0.1	0.1	0.0	6.0
Guainía	-	-	-	0.0
Guajira	-	0.0	0.0	0.0
Guaviare	-	-	-	0.0
Huila	0.0	0.0	0.0	0.0
Magdalena	-	0.0	0.0	0.0
Meta	0.0	0.0	-	0.2
Nariño	-	-	-	-
Norte De Santander	-	-	-	-
Putumayo	0.0	0.0	0.0	0.0
Quindío	0.0	0.0	-	0.0
Risaralda	0.0	-	0.0	0.3
San Andres Y Providencia	-	-	-	-
Santander	0.1	0.0	0.0	0.6
Sucre	0.1	0.0	0.0	0.0
Tolima	0.3	0.0	0.0	0.0
Valle Del Cauca	1.1	0.0	0.0	0.2
Vaupés	-	-	-	-
Vichada	-	-	-	0.0
Total	**2.1**	**2.2**	**0.8**	**8.4**

Source: Own elaboration

Table 8 - Difference-in-difference results

Variables	Total NPLs - Binary shock variable		
	(1)	(2)	(3)
Affected X Post	1.095**	1.673**	1.312***
	(0.505)	(0.640)	(0.478)
Post		0.140	0.140
		(0.142)	(0.138)
Affected			-0.166
			(0.326)
Constant			3.410***
			(0.201)
Country - Province FE	Yes	Yes	No
Time FE	Yes	No	No
Countries	ARG, BRA, CHL, MEX, PER	ARG, BRA, CHL, MEX, PER	ARG, BRA, CHL, MEX, PER
Provinces	123	123	123
Affected provinces	28	28	28
R-squared	0.931	0.911	0.031
Observations	2,091	2,091	2,091

Source: Own elaboration

Note. This table present the results of our baseline DiD model of the impact large-scale natural disasters on NPLs (nonperforming loans to total loans ratio) at the province level, using two-year event window. The natural disasters considered are: 2018 and 2014 droughts in Argentina and Brazil, 2015 and 2017 floods in Chile and Peru, and 2013 Hurricane Manuel in Mexico. Cluster-robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 9 -Difference-in-difference ancillary regressions

Variables	Binary shock variable			Vulnerability factor weighted shock variable		
	Total	NFCs	HHs	Total	NFCs	HHs
	(1)	(2)	(3)	(4)	(5)	(6)
Affected x Post	1.095**	1.791*	0.394*			
	(0.505)	(0.994)	(0.231)			
Affected x Post x VF				0.600*	3.771*	1.040*
				(0.320)	(1.998)	(0.572)
Country - Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Countries	ARG, BRA, CHL, MEX, PER	ARG, BRA, CHL, MEX	ARG, BRA, CHL	ARG, BRA, CHL, MEX, PER	ARG, BRA, CHL, MEX	ARG, BRA, CHL
Provinces	123	98	66	123	98	66
Affected provinces	28	21	16	28	21	16
R-squared	0.931	0.865	0.937	0.929	0.864	0.937
Observations	2,091	1,666	1,122	2,091	1,666	1,122

Source: Own elaboration
Note: This table present the results of our ancillary DiD model of the impact large-scale natural disasters on NPLs (nonperforming loans to total loans ratio) at the province level, using two-year event window. The natural disasters considered are: 2018 and 2014 droughts in Argentina and Brazil, 2015 and 2017 floods in Chile and Peru, and 2013 Hurricane Manuel in Mexico. Cluster-robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

C. Economic sector mapping across countries

Countries' varied standards for classifying banks' credit portfolios exposures into economic sectors entails comparability challenges. While some countries classify the sectoral exposures of their banks' credit portfolios grounded on the International Standard Industrial Classification of All Economic Activities (ISIC), not all of them use the same revision. This challenges sector comparability since the high level of aggregation of the publicly available information does not allow us to leverage on correspondence tables. In addition, most economies employ a self-defined classification of economic activities. Therefore, to ensure comparability of banking exposures to economic sectors across countries, we associate them manually. As a consistently general approach, we classify the ISIC Rev. 3.1 sectors indicated in Table C1 as transition or physical risk sensitive.

Table C1 – Physical and transition risks sectoral mapping: most affected sector(s), ISIC Rev 3.1

Panel A – Physical risks

Natural disaster	Most affected sector(s)
Wildfire	A 02- Forestry, logging and related service activities
Flood	A 01- Agriculture, hunting and related service activities
	F - Construction
	K - Real estate, renting and business activities
	H - Hotels and restaurants
Landslide	I - Transport, storage and communications
Earthquake	F - Construction
	K - Real estate, renting and business activities
Storm	A 01- Agriculture, hunting and related service activities
	B - Fishing
	F - Construction
	K - Real estate, renting and business activities
	H - Hotels and restaurants
	C 11 - Extraction of crude petroleum and natural gas
Droughts	A - Agriculture, hunting and forestry

Source: Own elaboration.
Note: This mapping considers only the most affected sector(s) and is based on authors judgment, which in turn rely on scenario analysis from a wide variety of sources, including previous World Bank FSAP assessments, McKinsey Global Institute (2020), The Intergovernmental Panel on Climate Change (2014), Central Bank of Mexico (2020).

Panel B – Transition risks

Transition sensitive industry	Mapped sectors
Fossil fuels	C 11 - Extraction of crude petroleum and natural gas
Energy generation	E - Electricity, gas and water supply
Heavy industry	C - Mining and quarrying (excl. C 11 - Extraction of crude petroleum and natural gas)
	D 20 - Manufacture of wood and of products of wood and cork
	D 21 - Manufacture of paper and paper products
	D 23 - Manufacture of coke, refined petroleum products and nuclear fuel
	D 24 - Manufacture of chemicals and chemical products
	D 25 - Manufacture of rubber and plastics products
	D 26 - Manufacture of other non-metallic mineral products
	D 27 - Manufacture of basic metals
	D 28 - Manufacture of fabricated metal products, except machinery and equipment
	D 29 - Manufacture of machinery and equipment
	D 31 - Manufacture of electrical machinery and apparatus
	D 34 - Manufacture of motor vehicles, trailers and semi-trailers
	D 35 - Manufacture of other transport equipment
	D 36 -Manufacture of furniture; manufacturing
Transport	I - Transport, storage and communications
Agriculture	A - Agriculture, hunting and forestry

Source: Own elaboration.

We detail below some comparability caveats for the sectoral mapping by type of risk:

- **Physical risk-sensitive sectors.** Mapping performed for 8 countries due to data constraints: Argentina, Bolivia, Brazil, Chile, Colombia, Mexico, Peru, and Ecuador. Data for Brazil, Colombia, Peru, and Ecuador are imputed based on the sectoral distribution of GDP.

    - Wildfire: The sectoral classification in Bolivia, Brazil, additionally include “hunting” and “fishing” activities. For Mexico, Colombia, and Peru, the whole ISIC section “agriculture, hunting and forestry” is considered.

    - Flood: Chile excludes “hotels and restaurants”. Mexico and Peru exclude “real estate, renting and business activities”. For Mexico, Colombia, and Peru, the whole ISIC section “agriculture, hunting and forestry” is considered.

    - Landslide: Colombia additionally includes “wholesale and retail trade”.

    - Earthquake: For Mexico and Peru, we only consider the “construction” sector, as we cannot retrieve the “real state, renting and business activities” sector breakdown.

    - Storm: Same caveats as in floods. Additionally, Brazil and Colombia factors in all mining and quarrying activities.

- **Transition risk-sensitive sectors.** Mapping performed for 12 countries due to data constraints: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Mexico, Paraguay, Peru, and Uruguay. Heavy industry mapping for Bolivia and Dominican Republic is estimated, as the available information does not allow us to identify the transition-sensitive sectors within manufacturing accordingly. For Paraguay, we only identify exposure to the agriculture sector. We took the credit outstanding share for the whole manufacturing sector and subtracted the proportion of not transition-sensitive sectors based on each country's GDP sectoral distribution.

  - Energy generation: This sector is proxied by the category “electricity, gas and water supply”, mostly available across countries. In the case of Mexico, we bundle together energy generation, fossil fuels and heavy industry.

  - Heavy industry: In some countries, heavy industry is bundled together with other transition-sensitive subsectors due to the impossibility to isolate specific subsectors. This is the case for Mexico, where we bundled together heavy industry with energy generation and fossil fuels. Similarly, in Peru, Dominican Republic, and El Salvador heavy industry and fossil fuels are joint.

  - Transport: Transport industries are proxied by “transport, storage and communications”, as this was the most common category for transport industries. Nonetheless, for Brazil and Mexico, we could not aggregate the storage and communication sub-sectors, while Colombia and Costa Rica do not consider communication.