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Banking Sector Risk in the Aftermath of Climate Change and Environmental-Related Natural Disasters

Owen Nie
Martijn Regelink
Dieter Wang

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Abstract

Climate change and environmental risks are increasingly recognized as a concern for financial authorities, yet empirical evidence of the damage for bank balance sheets is relatively scant. This paper provides preliminary estimates of the aggregate impact of physical risks from climate and environmental-related natural disasters on bank balance sheets across 184 countries over nearly 40 years. Using the local projection method, the analysis finds that severe disaster episodes lead to an increase in the level of systemwide non-performing loans, which is persistent over time. The paper complements the cross-country results with a country-specific example, which finds that typhoon damages lead to a significant increase in non-performing loans in the Philippines between 2011 and 2018. The results suggest a role for financial policy and supervision to monitor, assess, and mitigate climate and environmental related physical risks to the banking sector.

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Banking Sector Risk in the Aftermath of Climate Change and Environmental-Related Natural Disasters

Owen Nie*, Martijn Regelink†, Dieter Wang‡ §

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*Corresponding author. The World Bank. Email: onie@worldbank.org

†The World Bank. Email: mregelink@worldbank.org

‡The World Bank. Email: dwang5@worldbank.org

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1 Introduction

There is increasing global recognition that climate change, natural disasters and environmental issues can lead to risks for the financial sector. Financial sector authorities are devoting greater attention to understand and quantify such impact in the banking sector (Bank for International Settlements 2020; Network for Greening the Financial System 2020), and global standard-setting bodies have recently issued guidelines for the assessment, management and supervision of such risks for the financial sector, including the Financial Stability Board's (FSB)'s Roadmap for addressing climate-related financial risks (FSB 2021) and the Basel Committee on Banking Supervision's (BCBS's) Principles for the effective management and supervision of climate-related financial risks (BCBS 2022).

There is a need for better understanding the effects of climate change and environmental related natural disasters on financial sector soundness through reliable quantitative estimates. Although there is growing interest in the relationship between climate change and the macroeconomy and financial sector, the economics and finance literature has so far paid limited attention to providing generic quantitative estimates with reasonable certainty on causality. Rigorous empirical evidence on the impact of climate risks on banking sector stability is growing but still relatively scant (Basel Committee on Banking Supervision, 2021). Such quantitative estimates could provide a helpful reference in monitoring, assessing and mitigating these types of risks, such as in climate-related risk assessments and stress testing. This paper seeks to provide such quantitative evidence to fill this gap, focusing on physical risks.

In this paper, we examine the association between such natural disasters and banks' asset quality. Credit risk may arise because of the direct effect of hazard events on the likelihood of borrowers' to repay and service debt (income effect). The loss of collateral or, in general, destruction of physical assets diminishes borrowers' wealth, affecting banks' ability to fully recover the value of a loan in case of bankruptcy (wealth effect). On the other hand, government intervention, the availability of insurance, financial support by banks or alternative funding sources can keep borrowers afloat, financing the recovery in the aftermath of a natural disaster (Baltas et al., 2021). Therefore, whether natural disasters have a negative impact on banks' asset quality is an empirical question that we address using aggregate data on bank non-performing loans. We also explore whether the relationship varies depending on economic development, as less developed economies may have fewer resources and shallower financial markets to manage the losses from extreme weather events (Loayza et al., 2012). Finally, we summarize emerging policy recommendations for financial authorities to monitor, assess and manage climate and environmental related physical risks to the banking sector.

Climate and environmentally related financial risks originate mainly from two types of sources. **Physical risks** derive from natural disasters and gradual permanent shifts of the climate that can lead to economic costs and financial losses. These risks directly affect banks, potentially increasing credit, operational, market, liquidity, operational, and reputational risks, threatening the profitability and solvency of banks and the overall stability of the financial system. They can either be gradual in nature, such as rising temperatures and sea levels; or abrupt, as in the case of extreme weather events such as wild fires and storms. **Transition risks** are related to adjustment

costs during the transition towards a greener, carbon-neutral economy. These risks could be related to climate policies, technological change or shifts in investor and consumer sentiment with respect to climate change and the preservation of the environment. As for physical risks, transition risks could be mild if the economy transforms smoothly over time. Yet, if intervention and adaptation are delayed, changes in policy and taxation might be abrupt, leading to significant adjustment costs for companies and households. Financial assets may become stranded, increasing the chance that borrowers are unlikely to repay their debt obligations with negative repercussions for lenders.

Using a large, unbalanced panel dataset consisting of 184 countries over 1980-2019, we contribute to a growing literature by presenting the first systematic cross-country evaluation of the effect of a wide range of climate and environmental related natural disasters on the stability of the banking sector, with a focus on bank asset quality. We find that severe natural disaster episodes can lead to an increase in the level of system-wide non-performing loans(NPLs) to total gross loans (henceforth NPL ratios), and the effects can be persistent. For our global sample, NPL ratios are estimated to increase by 0.37 percentage points one year after disaster episodes associated with an official declaration of emergency. Two and three years after an episode involving multiple types of disasters, the cumulative increases in NPL ratios stand at 0.56 and 0.6 percentage point on average respectively. The relationship between severe climate and environmental related disasters and the level of system-wide NPL ratios is observed across multiple World Bank regions,[1] including in East Asia and Pacific (EAP), Latin America and the Caribbean (LAC), South Asia (SA) and Sub-Saharan Africa (SSA). Moreover, this relationship is also observed across almost all income groups except for lower-middle-income countries. These results should be interpreted with caution due to a limited sample at the country-year level and a lack of a generally consistent cross-country source of major natural disasters.

To address important caveats of the cross-country results regarding data granularity and quality, we also present results from a country-specific example. Using banking sector data at the regional level, we study the impact of typhoons on NPL ratios between 2011 and 2018 for the Philippines, a country highly exposed to climate related natural disasters. We find that a 1 percentage point increase in the typhoon damage ratio, defined as the amount of damage divided by regional GDP, could lead to an increase in the NPL ratio as large as 2.3 percent, an estimate larger in magnitude than these found for the cross-country sample. On balance, although the magnitude of our empirical results should be taken with caution due to concerns on data quality and granularity, the qualitative relationship between disaster episodes and NPLs seems reasonably robust.

Beyond the effects on bank asset quality, we also find tentative evidence that severe climate and environmental related natural disaster episodes may be associated with several other key banking sector variables, such as net interest margin, capital adequacy, credit to the private sector and liquidity-to-deposit ratio. For certain definitions and time horizons, these disaster episodes are found to be associated with: 1) increases in net interest margins, and hence higher cost of financial intermediation; 2) an increase in regulatory capital adequacy; 3) an increase of bank credit to the private sector; and 4) a decrease in liquid assets relative to deposits. While we do not identify a specific causal chain, our results point to multiple channels from physical risks to financial

[1]The World Bank country regional classification is available at the following link: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

stability at work, including through credit risks, operational risks and liquidity risks.

Policies undertaken by financial authorities could play an important role in monitoring, assessing and mitigating climate and environmental related physical risks to the banking sector. An important first step would be to collect information to track such risks, including filling any data gaps that may hinder a full understanding of such risks. Once information is in place, policy makers could consider a more detailed assessment of these risks, and specifically the various risk channels that may be at work behind the empirical results highlighted in this paper. For the banking sector, a stress testing exercise would be an important option for such in-depth assessments. This paper directly links the impacts of natural disasters to banking sector variables, and could provide inputs to parameters used in a stress test. However, due to methodological constraints, these estimates probably do not account for more granular and indirect channels of impact and non-linearities associated with forward-looking risks.

The rest of the paper is organized as follows. Section 2 briefly reviews the relevant literature and presents stylized facts on climate-related disaster events and key financial sector soundness indicators at a global level. Section 3 discusses the data and section 4 discusses the empirical methodology, the local projection method (LPM). Section 5 presents the empirical results at the global level and across different country groupings. Section 6 presents country-specific results from typhoon episodes in the Philippines. Section 7 discusses the policy options available to recognize and mitigate the effects of climate and environmental related disaster events on financial stability. Section 8 concludes, discusses caveats and provides thoughts on directions of future work.

2 Literature review

There is a small but rapidly growing literature on the relationship between climate and environmental related natural disasters and the financial sector, in the context of a larger literature on the general economic impact of such disasters. For instance, among a group of central banks piloting similar efforts, the U.S. Federal Reserve conducted a preliminary review of climate related financial stability risks for the United States (Federal Reserve 2022), including discussions of mechanisms, methodologies and applications. Bank financial stability may be impacted through both direct and indirect channels. The former causal chain involves deterioration in banks' balance sheets because of damages to physical assets, infrastructure and reduction in operational capacity. A drop in the value of collateral of existing loans means that banks may need to provision more, with a direct impact on bank earnings and capitalization. In addition, banks may also suffer from a reduction in capital and deposits, which reduces the funds available for lending. In this regard, the heterogeneous responses of banks to natural disasters depend on the pre-disaster capitalization levels as low-capitalized banks cut lending the most (Schuwer et. al. 2019 and Rehbein and Ongena 2020).

The indirect impact works through the worsening of the economic prospects of borrowers in disaster areas. For example, Klomp (2014) finds evidence that natural disasters may adversely affect bank solvency and increase the likelihood of bank default, depending on the size and scope of the disaster, financial regulation and supervision as well as the level of financial development.

Our paper contributes to this literature by focusing on the impact on non-performing loans of climate-related natural disasters.

As mentioned above, extreme weather events may decrease a borrower's likelihood to repay, increasing credit risk. By the same token of argument, natural disasters trigger a decrease in the value of real assets through physical destruction and loss of functionality (e.g., negative spillovers from destruction of infrastructure), decreasing the value of collateral in secured borrowing. Nonetheless, the overall increase in non-performing loans might be diluted by increases in lending.

An extreme weather event is usually followed by a sharp rise in new loan requests and a contemporary surge of deposit withdrawals, as affected individuals and firms need to make up for the economic damage and an increase in current expenses (Brei et al., 2019). This rise in the demand for credit may not be matched by an increase in supply, keeping low credit growth and raising the incidence of eventual non-performing loans related to the disaster. On the contrary, banks could mitigate the impact of shocks by cutting lending most where their comparative advantage is least (i.e., where competing banks have similar access to information). For instance, banks increase lending in affected areas while decreasing financing in those unaffected areas where they do not have branches (Cortés & Strahan, 2017) and in non-affected regions (Ivanov et al., 2020). In contrast, various papers suggest that banks decrease the supply of credit post-disaster. For example, BSP (2020) uses regional and bank-level data from the Philippines to show a deterioration of loan growth and loan quality in the country's banking sector after extreme rainfall events between 2014 and 2018.

This paper contributes to this strand of the literature by providing the first systematic cross-country study on the effect of climate and environmental related physical risks on banking sector stability. It provides generic estimates of the effect of such natural disasters on an entire set of financial sector soundness indicators based on the most comprehensive cross-country historical sample. We also discuss the relevance of our results for policy work in this area.

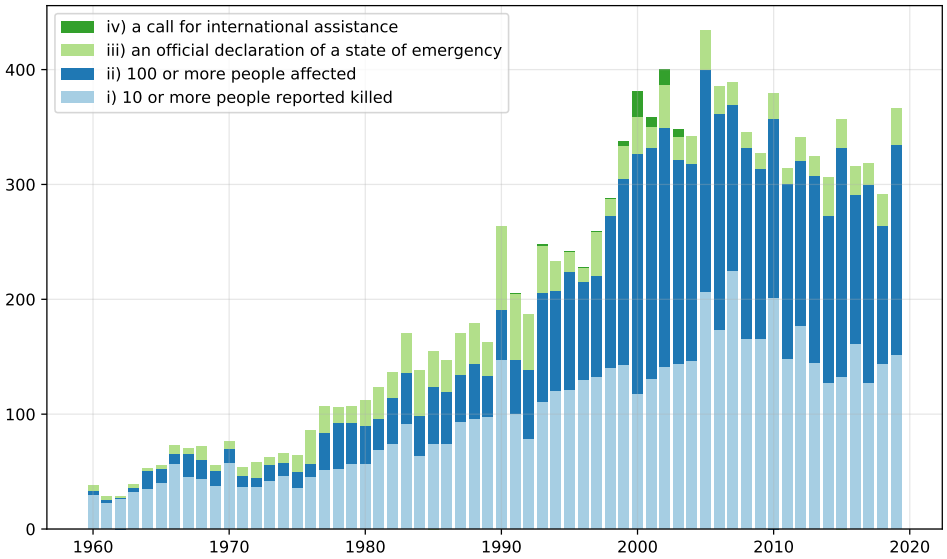
3 Data

This study uses a large panel dataset at annual frequency which combines data on natural disasters, financial sector soundness and other variables from a variety of sources for the period 1980-2019 and for 184 economies. Our sample covers a large number of countries in all income groups and from all World Bank regions and for the longest time period for which major financial sector indicators of interest are available. Data on the instances of climate change, natural disasters and environmental events are from EM-DAT[2] and data on financial sector soundness (with a focus on the banking sector) are obtained by combining information from the World Bank's Finstat database and the IMF's Financial Soundness Indicators. Since EM-DAT has a number of data quality issues, such as incomplete information for disasters happening before 2000 and bias towards disasters reported by countries themselves or by UN agencies, we have also looked at other sources of disaster data, such as DISINVENTAR, but find that it would significantly reduce the number of

[2]EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.

Figure 1: Total Number of Climate and Environmental related Natural Disasters Over Time

This figure shows the total number of disaster episodes around the world. For a disaggregated presentation across disaster groups, see Appendix, Figure 7



countries covered, and hence decided against it. We focus on the instance of disaster instead of the precise damage figures for two reasons: 1) EM-DAT damage figures are missing for most developing countries and hence using damage figures will introduce a rich-country bias[3] hard to correct for, in addition to significantly trimming the sample, and 2) anecdotal evidence and on-the-ground experiences tend to suggest that these damage figures are not very precise and accurate.

This section focuses on key stylized facts related to climate and environmental related natural disasters. We consider eight types of natural disasters related to climate change or environmental risks: wild fire, volcanic activity, earthquake, storm, landslide, drought, flood and extreme temperature. While a specific type of event can occur many times in a country each year, an episode is defined if the event occurs at least once in a country in a year. Therefore, there are typically more occurrences than episodes. The remainder of this paper focuses on the impacts of episodes.

Climate and environmental related natural disasters have increased in frequency between 1960 and 2020. Figure 1 presents the number of disaster episodes categorized by severity during the last 60 years. Between the periods 1960-79 and 2000-2020, the number of disaster episodes has almost tripled. Disaster episodes associated with an official declaration of a state of emergency (level iii) or a call for international assistance (level iv) account for a small proportion of the total number of disasters in a given year, with the former still occurring every year and the latter rarely seen in most years. These observations are generally true for all eight types of disasters, with the share of severe disasters (levels iii and iv) relatively higher in some years for wildfire and droughts. See Appendix, Figure 6 for the relative share of episodes across regions and figure 7 for a visual breakdown of disaster episodes by disaster group.

[3]For instance, damage amount data is available for 46 percent of high income countries but only 18 percent of low income countries.

Table 1: Climate and Environmental related Natural Disasters across Income Groups and Disaster types

Disaster group	Disaster type	High income	Lower middle income	Upper middle income	Low income	World
Climatological	Drought	45	129	123	106	403
	Wildfire	269	32	99	14	414
	Total	**314**	**161**	**222**	**120**	**817**
Geophysical	Earthquake	216	208	630	67	1,121
	Volcanic activity	31	63	107	6	207
	Total	**247**	**271**	**737**	**73**	**1,328**
Hydrological	Flood	949	1,563	1,663	733	4,908
	Landslide	99	202	310	80	691
	Total	**1,048**	**1,765**	**1,973**	**813**	**5,599**
Meteorological	Extreme temperature	254	144	139	13	550
	Storm	1,684	1,063	854	200	3,801
	Total	**1,938**	**1,207**	**993**	**213**	**4,351**

Table 2: Non-performing loan ratios across regions and periods

This table disaggregates the average NPL ratios (non-performing loans net of provisions to capital) over 5-year intervals and regions. The numbers are computed using the IMF's Financial Soundness Indicators data base.

Region	1995-2000	2000-2005	2005-2010	2010-2015	2015-2020	Full period
East Asia & Pacific (EAP)	45.56	26.94	13.36	5.79	4.39	13.33
Europe & Central Asia (ECA)	32.47	26.73	26.64	34.21	26.03	27.69
Latin America & Caribbean (LAC)	-	-1.72	-1.78	2.97	9.59	1.82
Middle East & North Africa (MENA)	-	32.67	21.05	9.33	6.48	13.14
North America (NA)	-	3.63	8.43	10.12	5.44	7.80
South Asia (SA)	-	17.40	12.23	14.96	15.77	14.13
Sub-Saharan Africa (SSA)	-	11.12	15.04	9.86	11.28	12.23
World	39.02	16.68	13.57	12.46	11.28	12.88

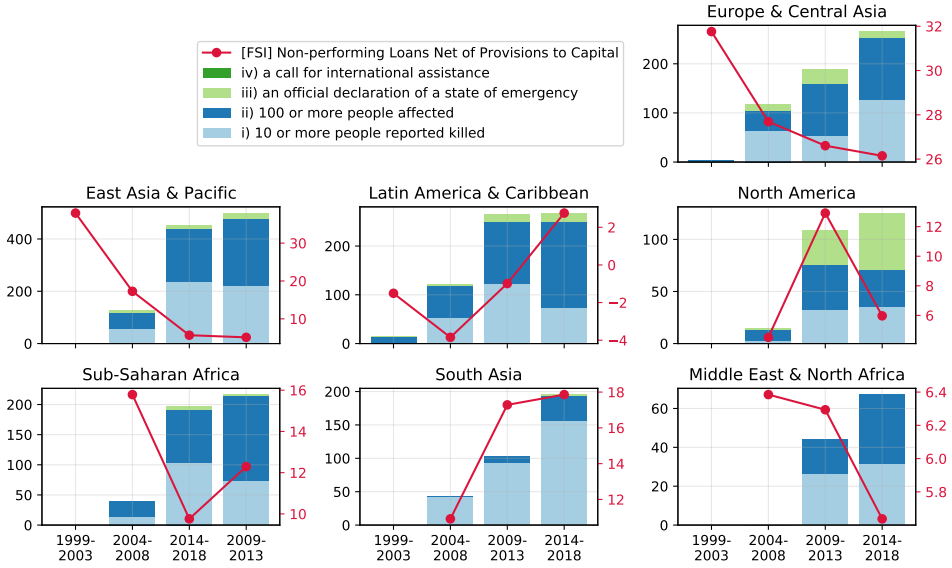
Tables 1 and 2 present statistics of key variables in this study. In Table 1 we see the disaster figures broken down by income and disaster groups/subtypes. The most frequent disaster episodes are hydrological, which mostly affect upper and lower middle income countries, and meteorological, which predominantly affect higher and lower middle income countries. Table 2 displays how average NPL ratios[4] vary over time and regions. Overall, the NPL ratio has been declining since 1995. This decline is most notable in EAP and MENA. In LAC and SA, the trend has been growing since 2005.

Figure 2 exhibits the relationship between NPL ratios (right axes) with the number of disaster events during five-year intervals (left axes). Generally, we observe a downwards trend in NPL ratios, except for LAC and SA. In these two regions, the NPL ratios have been steadily increasing. Against the backdrop of rising disaster episodes, the increases in LAC and SA suggest a possible relationship between financial stability and natural disasters. The following empirical section examines this hypothesis in more detail.

[4]NPL ratios are calculated as nonperforming loans net of provisions to capital. This indicator is often used as a capital adequacy ratio and is an important indicator of the capacity of bank capital to withstand losses from loan defaults.

Figure 2: Climate and Environmental related Natural Disasters and Non-performing Loans

This figure exhibits the relationship between NPL ratios (right axes) with the number of disaster events during five year intervals (left axes). Except for Latin America & Caribbean (LAC) and South Asia (SA), we generally observe an downwards trend in NPL ratios versus an overall increase in disaster numbers across all regions.



4 Empirical methodology

To provide econometric estimates of the average impact of climate change, natural disasters or environmental related events on key financial soundness variables, such as the non-performing loans (NPL) ratio, we use the local projection method (LPM) as in Jorda (2005). This methodology identifies the effects of an event on dependent variables over various horizons by direct computation of impulse response functions without specification and estimation of the underlying multivariate dynamic system. It offers numerous advantages over the Vector Auto-Regression(VAR) methodology, including easy implementation with simple regression techniques, robustness to misspecification, easier joint or point-wise inference and easier accommodation of highly non-linear and flexible specifications. Identification is further helped by the relative exogeneity of the occurrence of the climate-related natural disaster events with respect to developments in the financial sector, at least in the short run, where our focus is primarily on physical risks.

The dependent variable is the cumulative change in NPL and other financial sector variables between time $t-1$ and $t+j$, measured as difference in levels. The explanatory variables include the event dummies as well as the lags of both the dependent variables and the event dummies. For a specific type of event, the explanatory variable of interest is an episode which equals 1 if the event occurred at least once in a particular country in a year and 0 otherwise. For each horizon (year in our case) $h = 0, 1, 2, 3$, the empirical model is given by:

$$y_{t+h,j} - y_{t-1,j} = \alpha(h)_j + \tau(h)_t + \beta(h)E_{t,j} + \Sigma_{s=1}^{p}\gamma(h)_s E_{t-s,j} + \Sigma_{s=1}^{p}\delta(h)_s y_{t-s,j} + \epsilon(h)_{t,j} \qquad (1)$$

where $\alpha(h)_j$ and $\tau(h)_t$ are country and year fixed effects, respectively, and $\epsilon(h)_{t,j}$ is an error term. The coefficient of interest $\beta(h)$ is the impulse response function of the dependent variable with

respect to $E_{t,j}$, the event dummy. The number of lags for the dependent variable and the event dummy is denoted by p and set to 2 for estimation. This specification controls for country specific trends, lagged event dummies and past values of the dependent variable.

For our purpose, the potential endogeneity bias caused by contemporaneous interaction between financial sector variables and climate and environmental related natural disasters could reasonably be dismissed. It is unlikely that changes in banking sector asset quality, profitability and capital adequacy, for instance, can trigger natural disaster events, at least in the same year and several years after. In the longer run, when one's focus is on transition risks, this direction of causality becomes more likely. Nonetheless, to guard against possible reverse causation between financial sector variables and disasters, lagged financial sector variables are used as controls.

5 Empirical results

5.1 Non-performing loans

We find that severe climate and environmental related natural disaster episodes lead to an increase in the level of system-wide NPLs to total gross loans, and the effects can be persistent (figure 3 and table 3). We consider two types of severe disaster episodes: a country-year identified by the EM-DAT database as associated with an official declaration of a state of emergency(as calls for international assistance are relatively rare) and a country-year consisting of multiple types of disaster episodes. As shown in figure 1, for the entire sample, the system-wide NPLs are estimated to have increased by 0.37 percentage point on impact after a disaster episodes associated with an official declaration of emergency. Two to three years after an episode with multiple types of disasters, the cumulative increase in system-wide NPLs stands at 0.56-0.6 percentage point on average. The magnitudes may seem to be modest, but at the country level, our estimates are probably biased against finding results of larger magnitude as most disaster episodes tend to affect selected regions within a country. This effect is likely due to the impact of disasters on repayment capacity of borrowers and damages to underlying collateral and hence on credit risks.

Figure 3: Estimated effects of disaster episodes on NPLs

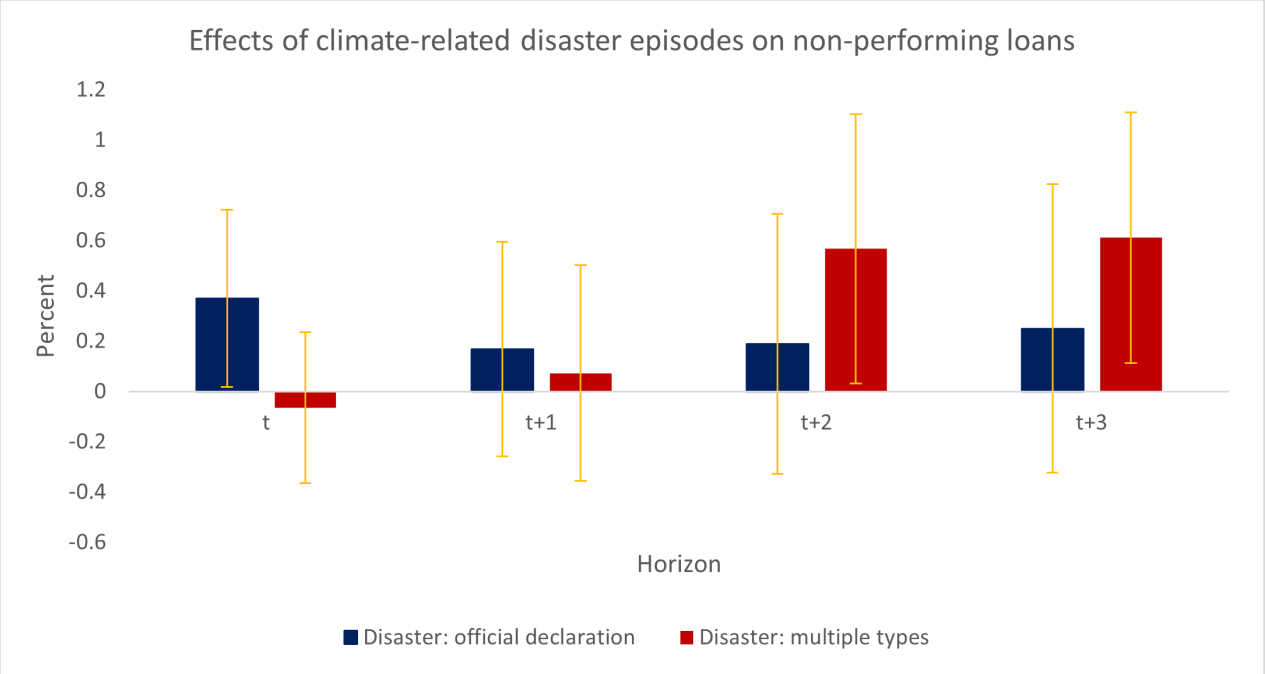


Table 3: Main results: estimated effects of disaster episodes on NPLs

Disaster type	Multiple Types	Official Declaration
0 year	-0.06	0.37*
	(0.18)	(0.21)
1 years	0.07	0.17
	(0.26)	(0.25)
2 years	0.56*	0.18
	(0.32)	(0.31)
3 years	0.61**	0.25
	(0.30)	(0.34)
Country FE	Yes	Yes
Time FE	Yes	Yes

The table displays point estimates for the effect of climate-related natural disasters on NPLs using both episodes associated with an official declaration of state of emergency and episodes associated with multiple types of disasters. Standard errors(in round brackets) are two-way clustered by country and time. Significance levels: *0.10, **0.05, ***0.01.

The relationship between severe climate and environmental related disasters and the level of system-wide NPLs is robust across multiple World Bank regions (table 4), including East Asia and Pacific (EAP), Latin America and the Caribbean (LAC), South Asia (SA) and Sub-Saharan Africa (SSA). In EAP, 2-3 years after an episode with multiple types of disasters, the estimates of cumulative increase in NPLs reach 1.1 percentage point; in LAC, these estimates reach 0.8 percentage point after one years. The effects of disaster episodes on NPLs seem to be quantitatively larger in SA and in SSA: in the former, 2-3 years after a disaster episodes associated with an official declaration of emergency, system-wide NPLs increase by between 2-3 percentage points; in the later, the cumulative increase in NPLs is well over 3 percentage points 3 years later. Our results for Europe and Central Asia (ECA) and for the Middle East and North Africa (MENA) are not

conclusive. In general, these results confirm that our baseline findings are not driven by one or two particular regions.

This relationship is also observed across almost all income groups except for lower-middle income countries(table 5). In high income countries, 3 years after a disaster episodes associated with an official declaration of emergency, NPLs see a cumulative increase by 0.72 percentage points. In upper-middle income countries, the estimate is around 0.77 percentage point one year after an episodes with multiple types of disasters. The effects of climate and environmental related disasters on system-wide NPLs seem to be much larger in low income countries than in other income groups: one year after an episode with official declaration, there is a 5.8 percentage point increase in NPLs. Result for lower-middle income countries is not conclusive as it depends on the horizon and the definition of severe disaster.

This paper also finds that several different types of disasters are estimated to have a significant effect on the level of system-wide NPLs, including volcanic activity, wildfires, landslides and droughts(table 6). To study the effect of individual types of severe disaster episodes on NPLs, we look at episodes of each of the eight types of disasters in our sample associated with an official declaration of emergency. Two years after a volcanic activity episode associated with an official declaration of emergency, system-wide NPLs are estimated to have increased by 0.65 percentage points. One to two years after a wildfire associated with an official declaration, the cumulative increase of NPLs is estimated to be between 0.5-0.85 percentage point. The magnitude of the effects are estimated to be similar for landslides and droughts as well: for the former, the estimates is 0.83 percentage points two years after impact; for the later, the estimate stands at 0.54 percentage point after three years. In this specification, results are inconclusive regarding the other disaster types in our sample, i.e. storms, extreme temperature, earthquakes and floods. However, we think this is mainly due to data limitations at the country level. Studies using more granular data and anecdotal evidences show that these types of disasters may also have a significant impact on system-wide NPLs and other important financial sector variables.

Lastly, we try to validate our results for NPLs using a couple of additional placebo test/robustness checks. First, we use the whole sample of disaster episodes, including type i and type ii under the EM-DAT classification and finds that our estimates on the impact on NPLs become statistically and economically insignificant. This is consistent with our finding that severe natural disasters are linked to a rise in NPLs. Second, we run the same regression but lag the dependent variable by one period, and find that disasters happening at time t do not affect the outcome at t-1.

Table 4: Estimated effects of disaster episodes on NPLs by World Bank region

Disaster: Official Declaration						
horizon	EAP	ECA	LAC	MENA	SA	SSA
0 year	-0.48	-0.03	0.32	-0.01	-1.89	-0.63
	(0.76)	(0.23)	(0.29)	(1.89)	(0.58)	(0.98)
1 years	-0.05	-0.22	0.30	-1.07	-0.57	-0.38
	(1.02)	(0.30)	(0.23)	(1.59)	(1.66)	(1.73)
2 years	0.58	0.56	0.12	2.21	3.12***	-0.19
	(0.42)	(0.54)	(0.23)	(3.09)	(0.75)	(1.90)
3 years	0.73	0.48	0.01	1.34	2.06***	3.39**
	(0.71)	(0.37)	(0.38)	(3.12)	(0.40)	(1.72)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Disaster: Multiple Types						
horizon	EAP	ECA	LAC	MENA	SA	SSA
0 year	0.15	0.31	0.87***	3.79	0.55	-0.08
	(0.31)	(0.32)	(0.26)	(2.45)	(0.78)	(0.96)
1 years	0.63	-0.47	0.78**	-0.09	0.60	-1.00
	(0.48)	(-0.60)	(0.30)	2.18	(0.87)	(0.82)
2 years	1.13*	-0.35	0.46	3.80	1.01	-0.28
	(0.61)	(0.53)	(0.49)	(3.49)	(1.03)	(1.75)
3 years	1.10**	-0.21	0.54	-3.99	-3.68***	1.34
	(0.50)	(0.81)	(0.56)	(1.13)	(0.25)	(1.79)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

The table displays point estimates for the effect of climate-related natural disasters on NPLs by region. Standard errors(in round brackets) are two-way clustered by country and time. Significance levels: *0.10, **0.05, ***0.01.

Table 5: Estimates of disaster episodes on NPLs by income group

Disaster: Official Declaration				
horizon	HI	UMI	LMI	LI
0 year	0.32	-0.32	-1.77	5.81*
	(0.15)	(0.40)	(1.19)	(3.48)
1 years	0.26	0.00	-0.56	0.66
	(0.22)	(0.44)	(1.23)	(3.89)
2 years	0.81	0.12	1.50	2.61
	(0.52)	(0.36)	(1.13)	(2.58)
3 years	0.72*	0.34	0.81	1.87
	(0.37)	(0.44)	(0.98)	(4.28)
Country FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Disaster: Multiple Types				
horizon	HI	UMI	LMI	LI
0 year	0.00	0.77***	0.59	0.28
	(0.21)	(0.29)	(0.87)	(1.65)
1 years	0.00	0.40	0.30	0.37
	(0.25)	(0.32)	(0.68)	(1.92)
2 years	-0.35	0.42	1.74	-0.55
	(0.34)	(0.40)	(1.08)	(2.97)
3 years	-0.44	0.42	0.53	1.23
	(0.30)	(0.44)	(1.52)	(3.25)
Country FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes

The table displays point estimates for the effect of climate-related natural disasters on NPLs by income groups. Standard errors(in round brackets) are two-way clustered by country and time. Significance levels: *0.10, **0.05, ***0.01.

Table 6: Estimates of disaster episodes on NPLs by disaster type

Disaster type	Volcanic	Wildfire	Storm	Extreme Temp	Earthquake	Landslide	Drought	Flood
0 year	-0.93	0.12	0.07	0.18	-0.40	-0.47	0.10	-0.03
	(1.11)	(0.47)	(0.19)	(0.30)	(0.62)	(0.71)	(0.33)	(0.23)
1 years	-0.01	0.84*	0.17	0.72	-0.07	-0.11	0.26	0.03
	(0.43)	(0.49)	(0.27)	(0.44)	(0.68)	(0.76)	(0.42)	(0.30)
2 years	0.65**	0.50**	-0.03	0.29	0.24	0.83*	0.22	0.02
	(0.21)	(0.23)	(0.23)	(0.25)	(0.35)	(0.46)	(0.29)	(0.19)
3 years	-0.28	0.29	0.06	0.29	-0.08	0.87	0.53*	-0.10
	(0.66)	(0.37)	(0.33)	(0.35)	(0.40)	0.54	(0.30)	(0.26)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The table displays point estimates for the effect of climate-related natural disasters on NPLs by disaster type, using episodes associated with an official declaration of state of emergency. Standard errors(in round brackets) are two-way clustered by country and time. Significance levels: *0.10, **0.05, ***0.01.

5.2 Other banking sector variables

Beyond the effects on bank asset quality, we also find that severe climate and environmental related natural disaster episodes may have an impact on several other key banking sector variables, such as net interest margin, capital adequacy, credit to the private sector and liquidity-to-deposit ratio(table 7). First, such disaster episodes are associated with increases in net interest margins, a widely accepted measure of financial intermediation efficiency: on impact after an episode with multiple types of disasters, the net interest margin increases by 0.18 percentage point on average, decreasing financial efficiency. This effect may be due to the change to market structure and concentration caused by disasters, or else to disruptions in operations, which reduce bank efficiency. Further, disaster episodes seem to be associated with an increase in capital adequacy for one definition of severe disaster. One year after an episode with multiple types of disasters, the ratio of regulatory capital to risk-weighted assets increases by 0.38 percentage point on average, with increases over time. This result is consistent with the findings in Schuwer et al.(2019) that banks increase their risk-based capital ratios after a disaster relative to unaffected banks to strengthen their buffer against future income shocks and mitigate bankruptcy risks.[5]

Climate and environmental related disaster episodes do not appear to cause an overall contraction of bank credit to the private sector. In fact, we find the opposite to be true: 1-3 years after an episode associated with an official declaration of emergency, the cumulative increases in private credit-to-GDP is estimated to be between 1 and 1.5 percentage points on average. There are a few potential explanations for this results: Schuwer et al.(2019) find that banks actually increases new lending to non-financial firms after a severe disaster, i.e. they do not decrease their exposures to non-financial firms through reduced lending, but through other strategies to reduce existing exposures to non-financial firms, such as loan sales or securitization. Moreover, government ownership of banks has been a large and pervasive phenomenon around the world, especially in EMDEs. State-owned banks are perceived to play crucial roles such as mitigating important market failures and achieving specific social and policy objectives. Hence, they may be directed by the government to channel credit to affected areas and sectors for specific policy objectives

[5]Our results on capital adequacy vary with the definition of severe disaster, so they should be taken with caution.

such as disaster relief or reconstruction, driving the observed increase in bank credit to the private sector.

Last but not least, disaster episodes are associated with a decrease in liquid assets relative to deposits. One year after an episode with multiple types of disasters, the liquid assets-to-deposits ratio decreases by 0.82 percentage point on average. This may be due to depositors and other investors withdrawing funds from their banks after a severe disaster, both to cover post-disaster expenses and for fear of solvency problems with banks, especially if they believe banks have substantial exposures to a vulnerable area.

Our preliminary results on the effects of climate and environmental related natural disasters on banking sector variables other than the NPLs should be interpreted with caution. First, our results on banking sector profitability and liquidity are tentative: aside from our results on net interest margins, we do not find a significant relationship between disaster episodes and other important measures of profitability, such as interest margin to gross income and non-interest expenses to gross income; we also fail to find a meaningful relationship between disaster episodes and liquid assets to total assets. Second, our results depend on the type of severe disaster we consider (official declaration or multiple types) and on the horizon.

Table 7: Estimated effects of disaster episodes on other banking sector variables

Disaster: Official Declaration				
Dependent variable	NIM	Capital Adequacy	Private Credit to GDP	LADR
0 year	-0.02	-0.18	0.43	-0.68
	(0.08)	(0.12)	(0.31)	(0.53)
1 years	0.12	-0.27**	1.28***	-0.07
	(0.09)	(0.13)	(0.45)	(0.68)
2 years	-0.06	-0.18	1.01**	0.14
	(0.10)	(0.16)	(0.50)	(0.77)
3 years	-0.14	-0.09	1.46***	1.14
	(0.10)	(0.20)	(0.50)	(0.79)
Country FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Disaster: Multiple Types				
Depedent variable	NIM	Capital Adequacy	Private Credit to GDP	LADR
0 year	0.18*	0.05	-0.02	0.77
	(0.10)	(0.14)	(0.28)	(0.57)
1 years	-0.06	0.38**	0.21	-0.82*
	(0.10)	(0.17)	(0.31)	(0.48)
2 years	0.16	0.21	0.07	-0.26
	(0.16)	(0.23)	(0.33)	(0.57)
3 years	0.04	0.76***	-0.14	0.32
	(0.13)	(0.25)	(0.48)	(0.69)
Country FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes

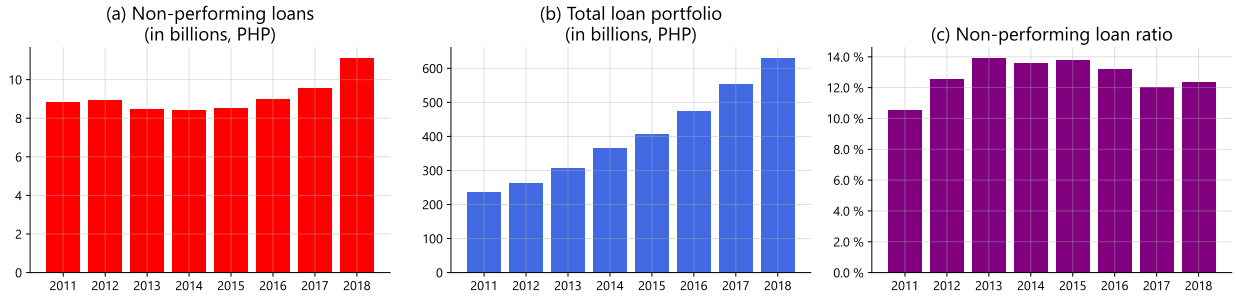
The table displays point estimates for the effect of climate-related natural disasters on selected banking sector variables: NIM (net interest margins), Capital Adequacy(Regulatory Capital to Risk-weighted Asset Ratio), Private Credit to GDP and LADR (Liquid Assets to Deposits). Standard errors(in round brackets) are two-way clustered by country and time. Significance levels: *0.10, **0.05, ***0.01.

6 The impact of typhoons on the stability of the Philippine banking system

There are important caveats to our main empirical results from a large cross-country sample, and hence we complement the main results with a country-specific example using the same methodology and more granular data. Using cross-country data on banking sector indicators ensures comparability, consistency and maximal sample coverage, but it limits our data at the country level. Identifying a disaster in the particular geographical area where it occurred would permit more precise identification. Further, we use official declaration and multiple types as proxies for identifying the severity of the disasters, as the available cross-country damage figures are limited and unreliable, which is open to criticism that these disasters may not be that severe. Therefore, we present empirical results from a country-specific example from the Philippines where we focus on a severe disaster, typhoon, alone and use geographical NPL data. This exercise was conducted between 2020 and 2021 as part of the joint World Bank-IMF Financial Sector Assessment Program (FSAP) for the Philippines (see the World Bank FSAP technical note (Regelink, 2021) and joint WB-IMF research paper (Hallgatte et al., 2022)).

The Philippines is among the most disaster-prone countries in the world. At least 60 percent of its total land area and close to 74 percent of its population are exposed to multiple natural hazards, many exacerbated by climate change, including typhoons, floods, storm surges, tsunamis, and landslides.[6] In the past thirty years, 33,000 people have died and 120 million people have been adversely affected by disasters.[7] For instance, the 2013 Super Typhoon Yolanda (Haiyan)—the strongest typhoon to ever make landfall in the world— was a tragic reminder of the devastating impact natural disasters can have in the Philippines. Over 6,000 people lost their lives and more than 16 million were affected, with 2.3 million people falling below the poverty line. Over 1.1 million houses were damaged or destroyed. The typhoon also had a devastating impact on public infrastructure, including roads, bridges, water and power utilities, hospitals and schools, government buildings, and agricultural and irrigation facilities. Damages were estimated at Php571.1 billion (USD12.9 billion), or 4.6 percent of GDP.[8]

Figure 4: NPL components (2011–2018)



Source: Bangko Sentral ng Pilipinas.

[6] GFDRR (Global Facility for Disaster Reduction and Recovery) and World Bank. 2011. "Climate Risk and Adaptation Country Profile: Philippines," World Bank, Washington DC.

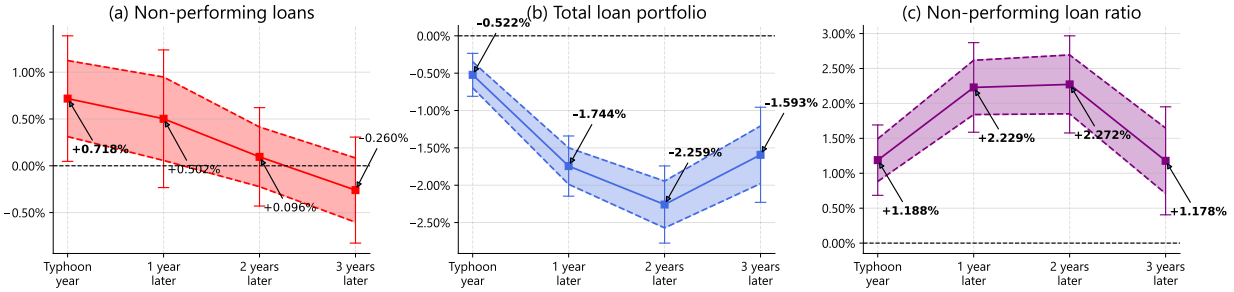
[7] World Bank. 2019. "Country Partnership Framework for the Republic of the Philippines 2019-2023."

[8] National Economic and Development Authority (NEDA). 2013. "Reconstruction Assistance on Yolanda (RAY): Build-Back-Better."

In this section, we use geographically disaggregated data on NPLs and bank pending portfolio from the Philippines' central bank and other government authorities to estimate the effect of typhoon damage on the non-performing loans (NPL), the total loan portfolio, and the NPL ratio in the Philippine banking system (Figure 4). Our sample consists of a 7-year period between 2011-2018 period for 16 administrative regions in the country. We use the panel local projection model with correction for future biases and controlling for past regional economic growth. We find that for a 1 percentage point increase in the damage ratio, which is calculated as the typhoon damage over the regional GDP, leads to an increase of NPL by 0.72 percent in the year of the disaster and abates over subsequent years (see Figure 5a). The effect is only statistically significant in the typhoon year.

As NPLs only constitute the numerator of the NPL ratio, we repeat the exercise for the total loan portfolio size, we find that a 1 percentage point damage ratio increase leads to a significant drop in the overall loan portfolio size, up to three years into the future (see Figure 5b). Following a typhoon, the combined effect of bank lending contraction and an increase in defaulting loans leads to an overall increase of the NPL ratio. This evidence suggests that typhoons have a destabilizing effect on the Philippine banking system. Further, the peak estimate for the increase in the NPL ratio reaches around 2.3 percent, much larger than the estimates for our cross-country sample, suggesting that severe disasters may indeed have an outsized impact on banking sector resilience.

Figure 5: Dis-aggregated impulse response functions



Source: Bangko Sentral ng Pilipinas, NDRRMC reports, Philippine Statistics Authority.
The dashed lines represent the standard errors and the whiskers delineate the 95% confidence intervals.

7 Policy implications

Our results show the importance of climate and environmental related natural disasters for the banking sector, and hence a role for financial sector policy makers to actively monitor, assess and mitigate climate-related risks. An important first step would be to collect information to track such risks, including filling any data gaps that may hinder a full understanding of such risks. Once information is in place, policy makers could consider a more detailed assessment of these risks, and specifically the various risk channels that may be at work behind the empirical results highlighted in this paper. For the banking sector, a stress testing exercise would be an important option for such in-depth assessments. This paper directly links the impacts of natural disasters to banking sector variables, and could provide inputs to parameters used in a stress test: for instance, the magnitude of the impact estimated could guide the selection of model parameters in a climate risk stress testing for a country's banking sector.

8 Conclusions

Severe climate and environmental related natural disasters can have long-lasting negative effects on bank asset quality. Using a large panel dataset and the local projection method, this paper presents a comprehensive analysis on the effects of disaster events on NPLs and other important banking sector variables, and also discusses policies to monitor and mitigate these adverse effects. Severe disaster episodes are estimated to increase system-wide NPLs by between 0.5 and 0.6 percentage points after two to three years. The estimated effects are found for multiple regions across the developing world and for most income groups and four different types of disasters, although cross-country results are less significant for climate related disasters than for environmental ones. To partially address important caveats of the cross-country results, including data quality and granularity, we also look at a country-specific example of the effect of typhoons on NPLs in the Philippines and find the same relationship holds, but the estimated effects are much larger. In addition, we also present tentative evidence that climate change and environmental related disasters could reduce bank intermediation efficiency, lower system-wide liquidity relative to deposits and increase the regulatory capital ratio, although they may not necessarily reduce the overall volume of lending to the private sector. While we do not identify any specific transmission channel, our results point to multiple channels from physical risks to financial stability at work, including through credit risks, operational risks and liquidity risks.

Future extensions using more granular data would be promising. To arrive at a generic estimate using the largest possible sample, we have chosen to work with data at the country-year level. This has very likely biased us against finding stronger results, as disasters tend to affect a specific geographical area within a country disproportionately, and financial institutions serving specific areas. In general, stronger results are likely found at the more granular geographical level. While we try to mitigate this concern with the case study of the Philippines, a global sample using balance-sheet-level loan data and geographical NPL data would potentially improve the results while allowing us to explore in more detail the particular transmission channel at work. Promising work in this direction has already been undertaken for the LAC region in Calice and Miguel Liriano (2021).

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A Additional Figures

Figure 6: Shares of Climate-related Natural Disasters by Region

This figure displays the relative share of disaster occurrences between all regions as a 10-year centered moving average. The share has been declining for LAC, SA and MENA, while steadily increasing for SSA. ECA's portion had been growing steadily until early 2000, before declining again. This pattern is mirrored by EAP, which is home to the majority of the disasters reported throughout the observation period.

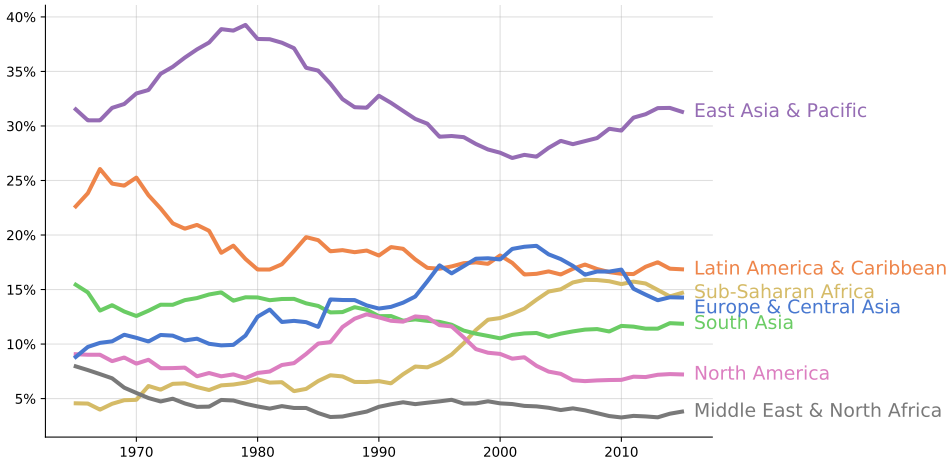

Figure 7: Climate-related Natural Disasters Over Time: by Disaster Type

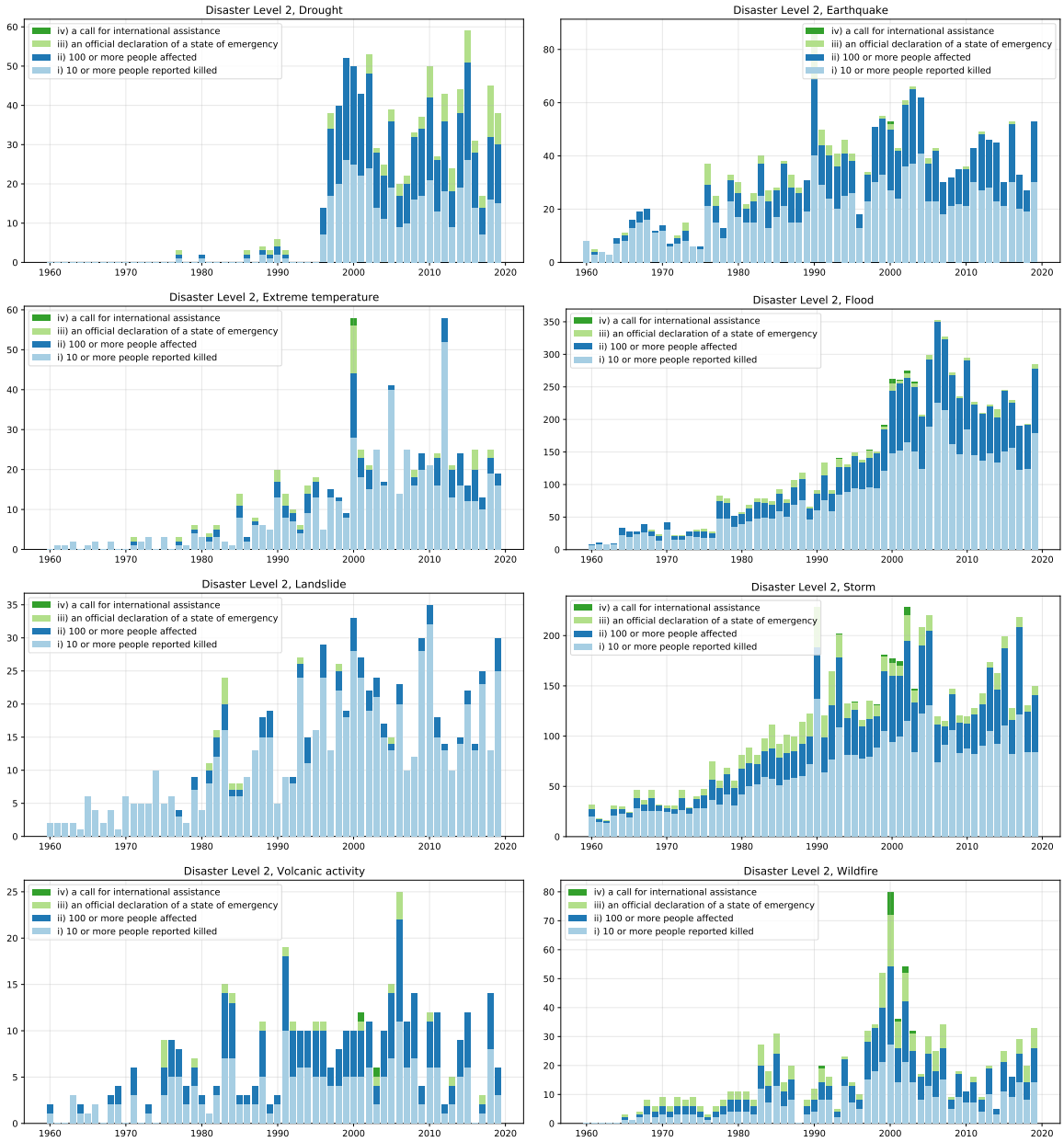

Figure 8: Climate-related Natural Disasters in 20-year interval: by region and by income group