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Understanding the Macroeconomic Effects of Natural Disasters

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ABSTRACT: Climate change is causing more frequent and devastating natural disasters.The goal of this paper is two-fold. First, it examines the dynamic effects of natural disasters on the growth of output and its components. Government expenditure in advanced economies (AEs) rises immediately in the same year of the natural disaster, offsetting the decline in private investment growth and thereby mitigating the negative effect on output growth. As a result, output growth in AEs is not significantly affected by natural disasters. In contrast, the increase in government expenditure in emerging markets and developing countries (EMDEs) after a natural disaster is smaller and thus, unable to mitigate the contemporaneous negative effect on output growth (which mainly reflects the fall in investment in non-small-island EMDEs and in net exports in small-island EMDEs). In addition, the output recovery in the subsequent year does not fully offset the decline during the year of the disaster. Second, this paper assesses the role of pre-exisiting country characteristics in mitigating the adverse impact of natural disasters. The paper finds that small islands and countries with limited pre-disaster fiscal space tend to experience more significant declines in output growth following a natural disaster.

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WORKING PAPERS

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Contents

I. Introduction

Climate change poses an existential threat to the global economy. The global average temperature is 1.1 degrees Celsius higher than the pre-industrial level and is projected to rise further in the next decades should countries not take sufficient mitigation actions (IPCC 2023). One important channel through which climate change can affect economic activities is by increasing the frequency and intensity of natural disasters in many parts of the world (IPCC 2014). These natural disasters can incur significant human costs and economic damages. This paper focuses on the impact of natural disasters on macroeconomic outcomes, one of the most important manifestations of climate change that concerns economic policymakers.

Understanding the impact of natural disasters is critical for designing countries' adaptation efforts. This paper quantitatively evaluates the extent to which natural disasters affect growth of output and its components. This is relevant for several reasons. First, understanding the impact on output growth and its components can provide useful insights into how various output components (e.g., investment, consumption, imports or exports) evolve after disasters hit as well as information about the corresponding economic transmission channels and areas of vulnerabilities. Second, analyzing the impacts of natural disasters on growth and other macroeconomic outcomes can inform governments' macroeconomic decisions, including saving and allocating resources effectively for natural disaster preparedness, recovery and reconstruction. Third, understanding the impact of natural disasters on macroeconomic outcomes helps provide a global view on how risks and damage from natural disasters are distributed across countries. This can serve as a basis for the discussion of coordinated policy responses in the international community. Our results can stimulate further discussions around adaptation measures that help limit and help cope with disaster damages (such as pooling risk to insure against disasters or assisting in adaptation measures) and policies that support the economic recovery after disasters (such as assisting for reconstruction).

The paper contributes to the literature in a few ways. First, going beyond the literature that focuses on the impacts on the aggregate output, this paper examines the impacts of natural disasters on the components of output, namely consumption, investment, exports, imports, and government expenditure. Examining these potential different impacts can help shed light on the economic channels through which natural disasters affect growth. We also examine the impact of natural disasters in three main country groups according to their income level: advanced economies (AEs), non-small-island emerging markets and developing economies (NSI EMDEs), and small-island emerging markets and developing economies (SI EMDEs). These three groups of countries differ, for instance, in their overall readiness to tackle natural disasters and in their vulnerabilities to these disasters (such as related to the high reliance on the tourist sector in many SI EMDEs). These varying degrees of readiness and vulnerabilities across country groups may result in important differentiating effects on output growth that may warrant different policy responses.

The second contribution of this paper is shedding light on how a country's structural and cyclical characteristics matter for the post-disaster outcomes. For example, when a country has ample fiscal space and a strong institutional framework, we may expect that government expenditure quickly responds to disasters, and consequently, the negative impact on growth can be significantly mitigated. Following this reasoning, we examine the role of a rich set of country characteristics: pre-disasters fiscal space, adaptive capacity, income group, and being a small island or not. We also control for disaster-related characteristics including the magnitude of the disaster's physical damage and the type of the disaster (floods, storms, droughts, or other disasters).

Using data on historical and large natural disasters and economic variables between 1980 and 2019, we find several empirical findings.[2] In terms of the magnitude, we find that output growth on average drops by around 1.3 percent in the year of the disaster relative to the countries that did not experience a large disaster in that year (the control group). Output growth recovers in the year immediately following the disaster by about 0.8 percent higher than in the control group. In later subsequent years, there is no statistical difference between disaster countries and the control group in output growth. These findings imply that there are temporary impacts on output growth. However, the loss in output level is permanent because the GDP growth recovery in the subsequent years following a disaster does not fully offset the decline in GDP growth in the year of the disaster.

[2] In our empirical analysis, we focus on large natural disasters, defined as single-year disasters with total damages exceeding 1 percent of GDP. See more details in Section II on Data.

Second, the impact differs across countries. Government expenditure in AEs rises immediately in the year of the disaster. This rapid rise in government expenditure in AEs largely offsets the decline in private investment and mitigates the negative effect on output growth. As a result, output growth in AEs does not appear to be significantly affected by natural disasters. In EMDEs, government expenditure response after natural disasters is limited, and thus, it is unable to fully compensate for the negative effects on output growth. In NSI EMDEs, investment is mostly adversely affected by natural disasters, whereas in SI EMDEs, exports bear the bulk of the impact. This can reflect the fact that export infrastructure (such as ports) in SI EMDEs is generally more likely to incur damages or suffer disruptions following natural disasters and this can cause exports to fall, as found in recent studies (Feng and others, 2023). In addition, small islands' exports are usually more dependent on the tourism sector, which is also generally more sensitive to natural disasters.

We also find that, within a country group, countries with larger fiscal space (proxied by pre-disaster fiscal balance) tend to increase government expenditure more after natural disaster hits. Furthermore, we find that the magnitude of the damage matters. On average, holding other factors the same, a larger disaster measured by the damage of physical assets on average prompts a larger response in the government expenditure a year later.

The literature has examined the impact of natural disasters on output growth, often reaching mixed conclusions. Fomby and others (2013) find differentiating effects on growth in agricultural compared to non-agricultural sectors. Lian and others (2022) find large and persistent effects of natural disasters on GDP per capita. However, Cavallo and others (2013) find that once they control for political events after natural disasters, even very large disasters do not have significant effects on growth. Cevik and Jalles (2023a) find that droughts and storms do not have significantly negative effect on growth in neither AEs nor EMDEs. Our analysis shows that natural disasters lower output growth.

Examining country characteristics, Noy (2009) finds that developing countries and smaller economies face much larger output declines following a disaster than developed countries or bigger economies. Countries with a higher literacy rate, better institutions, higher per capita income, higher degree of openness to trade, and higher levels of government spending are better able to withstand the initial disaster shock. Bayoumi and others (2021) find that countries with disaster preparedness mechanisms and lower public debt face a lower probability of growth decline after a natural disaster. Similarly, Jaramillo et al. (2023) find that output losses are more severe and persistent in fragile, conflict-affected states (FCS) than in other countries, possibly due to weak social safety nets, slow post-disaster reconstruction, and lack of diversification (e.g., reliance on agricultural exports). Jaramillo et al. (2023) also find that larger fiscal buffers and stronger institutional capacity can help mitigate the adverse impacts. Cevik and Jalles (2023b) discover that corruption increases the number of disaster-related deaths, after controlling for economic, demographic, healthcare and institutional factors. Similarly, Barone and Mocetti (2014) find pre-disaster institutions help with long-term recoveries.

The paper is also related to a growing literature that examines the impacts of natural disasters on macroeconomic outcomes, such as inflation (Kabundi and others, 2022), fiscal outcomes (Noy and others, 2011), and exchange rates (Hale, 2022).

The rest of the paper is organized as follows. Section II describes data. Section III discusses the econometric approach. Section IV presents the empirical results by country group. Section V examines robustness checks. Section VI examines potential ex-ante country and disaster characteristics associated with macroeconomic outcomes. Section VII concludes.

II. Data

Natural disaster data

Data of natural disasters are from The International Disaster Database (EM-DAT) hosted by Université Catholique de Louvain.[3] This database contains information on both natural[4] and technological (man-made)

[3] https://www.EM-DAT.be/

[4] Natural disasters in EM-DAT include earthquake, mass movement (dry), volcanic activity, extreme temperature, fog, storm, flood, landslide, wave action, drought, glacial lake outburst, wildfire, epidemic, insect infestation, and animal accident.

disasters,[5] recording over 15,500 natural disasters between 1960 until 2022. Despite its limitations, discussed more below, this database is the most comprehensive and the most commonly used in the literature. For each disaster, the dataset contains detailed information (where available) such as country, disaster type, start year and end year, number of deaths, and number of people affected such as injured or missing. It also contains information about estimated damages, which is the amount of damages to property, crops, and livestock. The estimated damages refer to the damage to stock of assets in US dollars rather than flows of production although they can be related.[6] Note that asset damages do not easily translate to the effects on GDP, which is the focus of our paper. The effects of natural disasters to GDP reflect the disruptions to economic activities (which hurt GDP growth) and the reconstruction efforts (which help).

Table 1 below lists the natural disasters and their distribution since 1960 from EM-DAT. The majority of natural disasters recorded are climate-related disasters, including floods (5,615 disasters) and storms (4,300 disasters). While the dataset is very comprehensive, it is possible that it did not capture all disasters, especially smaller ones in earlier periods. In our empirical analysis, we restrict the sample to years after 1980 to reduce any potential biases that can result from data availability issues. Figure 1 shows the number of recorded natural disasters between 1980 and 2022.

We focus on non-overlapping, single-year, large natural disasters in our main empirical specification. "Large" disasters are defined as those that had dollar value of damages exceeding one percent of national GDP.[7] A disaster is defined as a "single-year" disaster when it starts and ends in the same calendar year. Multi-year droughts, for example, are excluded from our baseline sample. "Non-overlapping" means that no other large disasters happened in the preceeding or subsequent two years. We make these restrictions to our sample in the main empirical specification to more accurately examine the growth dynamics up to two years (i.e., t+1 and t+2) after a disaster takes place (in time t). Allowing for overlapping large disasters could bias our estimates as it would not be clear which overlapping disaster is causing the macroeconomic effects. Therefore, overlapping episodes are excluded in the baseline estimation sample in both the treatment and control groups. We conduct an additional robustness check by including overlapping disasters and multi-year disasters.

Table 1. Natural Disasters from EM-DAT, 1960-2022

Disaster Type	Frequency	Percent
Animal accident	1	0.01
Drought	759	4.87
Earthquake	1,258	8.07
Epidemic	1,492	9.57
Extreme temperature	597	3.83
Flood	5,615	36.01
Glacial lake outburst	3	0.02
Insect infestation	92	0.59
Landslide	752	4.82
Mass movement (dry)	43	0.28
Storm	4,300	27.57
Volcanic activity	238	1.53
Wildfire	443	2.84
Total	15,594	100

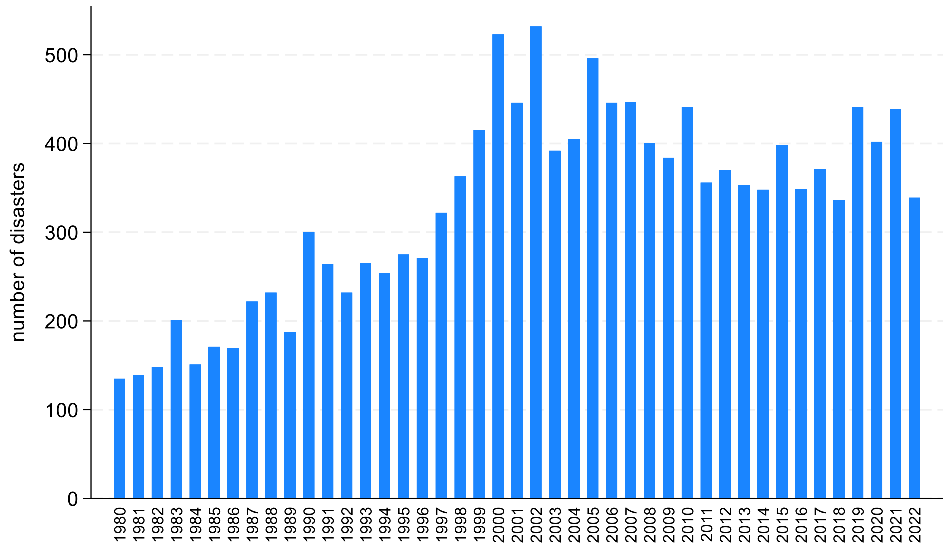
Source: EM-DAT and IMF staff calculations.

[5] Technological disasters include chemical spill, gas leak, poisoning, radiation, and oil spill, among others.

[6] The dollar value of economic damages to assets can sometimes be linked to the present value of the lost future production from these assets following a disaster. For example, damages to crops may be assessed to represent the potential lost output from these crops. Similarly, the values assessed for property or livestock losses from a disaster can be linked to the present value of the lost output from these property and livestock.

[7] Alternative measures of a disaster's severity include the number of people affected or the number of casualties. Though we argue that damage to assets (infrastructure, properties, livestock) have a more direct link to GDP disruptions than say the number of casualties, we provide a robustness check for an alternative selection of large disasters based on the percentage of population that were affected.

Figure 1. Total Annual Recorded Natural Disasters



Source: EM-DAT and IMF staff calculations.

Another step to clean the data is to process the few cases in the dataset where multiple large single-year disasters (with economic damage exceeding 1 percent of GDP) took place in a country in a given year. For example, a large drought and a large storm took place in El Salvador in 1998 and we treat them as one disaster by adding up the damages. Combining these cases yields a list of 197 disasters between 1980 and 2022 among all IMF member countries.

The final step is to winsorize the data, especially in cases with large GDP growth swings. While some of these swings might be driven by climate-related natural disasters, many are related to non-climate extreme events (such as major financial crises, domestic economic recessions, global political events or wars).[8] We also drop data in 2020 and the years after the COVID-19 global pandemic.[9] Further data cleaning includes dropping observations at the top and bottom 1 percent of the entire output growth distribution, i.e., country and year with real annual output growth above 18 percent or below -13.1 percent. These steps further drop four disasters between 2020 and 2022 and three other disasters with extreme GDP growth, leaving 190 large, single-year, non-overlapping disasters in our sample (Table 2).

Table 3 shows the distribution of physical damages as percent of national GDP, by the three country groups AE, NSI EMDES and SI EMDEs. There are 18 large, single-year, non-overlapping disasters in AEs, 116 in NSI EMDEs and 56 in SI EMDEs. EMDEs have registered larger disasters (in terms of physical damage as percentage of GDP) than AEs. The median damage is NSI EMDEs is 2.7 percent of GDP, in SI EMDEs is 5.5 percent of GDP, while the figure is 2.2 percent of GDP for AEs.

[8] Panama (1988); Moldova (1994); and Zimbabwe (2003) experienced recessions not related to natural disasters.

[9] The COVID-19 pandemic caused significant economic disruptions in many economies and tourism-dependent small islands economies were hit particularly hard. Including the large swings in GDP growth during 2020-2022 would likely distort our estimation, especially for smaller economies that are prone to natural disasters and were hit hard by the pandemic at the same time.

Table 2. Sample of Large, Single-year Natural Disasters, 1980-2019

Disaster Type	Frequency	Percent
Drought	10	5.43
Drought & Storm	1	0.54
Earthquake	34	17.93
Extreme temperature	2	1.09
Flood	43	23.37
Flood & Landslide	1	0.54
Flood & Storm	2	1.09
Landslide	2	1.09
Landslide & Storm	1	0.54
Storm	87	44.57
Storm & Wildfire	1	0.54
Volcanic activity	2	1.09
Wildfire	4	2.17
Total	190	100

Source: EM-DAT and IMF staff calculations.

Table 3. Summary Statistics: Physical Damage of Disasters in Sample (percent of GDP)

	Number of disasters	Mean	Min	p25	Median	p75	Max
AEs	18	5.84	1.03	1.46	2.18	2.98	65.73[10]
Non-Small-Island EMDEs	116	6.79	1.01	1.59	2.74	7.27	127.025
Small-Island EMDEs	56	17.02	1.097	2.81	5.54	18.28	148.38
All countries	190	9.511	1.011	1.769	2.984	8.148	148.385

Source: EM-DAT and IMF staff calculations.

Other data

For the income groups, we use the IMF classification for advanced economies (AEs) and emerging markets and developing economies (EMDEs) comprising emerging market and middle-income economies (EMMIEs), and low and developing countries (LIDCs). We apply the latest classification to all the years.

Data on growth in real output, real investment, real private consumption, real export of goods and services, and real imports of goods and services are from the World Economic Outlook (WEO).[11] In addition, we also draw from this data source the GDP, and government revenue and expenditure in local currency to calculate the overall fiscal balance. We choose pre-disaster overall fiscal balance as a measure of pre-disaster fiscal space because of its comprehensive country coverage and good explanatory power for output growth after disasters. Other potential proxies for fiscal space, such as central government debt and interest payments have much less data coverage, while general government debt has reasonable data coverage but weaker explanatory power for growth. Data on country-specific commodity export price shocks are obtained from the IMF's Commodity Terms of Trade database (see Gruss and Kebhaj, 2019). They construct country-specific export commodity price shocks that depend on the price fluctuations of a country's export commodities and the shares

[10] Puerto Rico is listed by WEO as a separate high-income economy (having a storm of 65.7 percent GDP destruction) which skews the distribution.

[11] WEO codes for these five variables are NGDP_RPCH; NI_RPCH; NCP_RPCH; NX_RPCH; and NM_RPCH. For investment, as data on real private investment are scarce, we have used growth of real total investment (NI_RPCH) instead, which includes both public and private investment.

of these commodities. Forty commodities are included. The index is constructed as follows (see equation 1 in Gruss and Kebhaj, 2019):

$$\Delta \log(index)_{i,t} = \sum_{j=1}^{J=40} \Delta P_{j,t} \Omega_{\mathrm{i,j}}$$

where $P_{j,t}$ is the logarithm of the real price of export commodity *j* in year t. $\Omega_{\mathrm{i,j}}$ denotes commodity and country-specific average weights in terms of GDP.

For adaptative capacity, we use two main adaptive capacity indexes, ND-GAIN and INFORM-RISK.

The ND-GAIN index, from Notre Dame University (https://gain.nd.edu/our-work/country-index/methodology/), captures "*availability of social resources for sector-specific adaptation. In some cases, these capacities reflect sustainable adaptation solutions. In other cases, they reflect capacities to put newer, more sustainable adaptations into place. Adaptive capacity also varies over time.*" The index aggregates infrastructure capacity, medical staff capacity, access to sanitation and drinking water, quality of logistics and access to electricity (https://gain.nd.edu/our-work/country-index/methodology/indicators/). The availability of ND-GAIN's sub-indices makes it our preferred choice compared to INFORM-RISK. It also has a stronger explanatory power to growth outcomes after natural disasters. The data are available from 1995 to 2020 for 176 countries. To circumvent the lack of data before 1995, for each country, we assign the value in 1995 to the years between 1980 and 1994.[12]

The second index is the climate-driven INFORM RISK index with raw data from Disaster Risk Management Knowledge Centre (2022). It captures "*lack of coping capacity relates to the ability of a country to cope with disasters in terms of formal, organized activities and the effort of the country's government as well as the existing infrastructure which contribute to the reduction of disaster risk*". We obtain the data from the IMF's Climate Change Dashboard. The data are available from 2013 to 2022 and do not have sub-indices. For these two reasons, we use this index only as a robustness check.

III. Empirical specification

The empirical specification follows the local-projection approach à la Jordà (2005)

$$y_{i,t+h} = \alpha + \beta_h ND_t + CommodityPriceShock_{i,t+h-1} + y_{i,t-1} + fe_i + fe_t + \epsilon_{\mathrm{i,t}} \quad (1)$$

where

- $y_{i,t+h}$ is the variable of interest, which can be the growth in real output or in the individual components (such as govenrment expenditure, investment, consumption, imports and exports) at year $t + h$;
- ND_t dummy variable with value of 1 if there is a large, single-year, non-overlapping natural disaster at year t;
- fe_i country fixed effects, to control for country's characteristics (such as trend growth);
- fe_t year fixed effects, to control for global shocks for that year;
- $CommodityPriceShock_{i,t+h-1}$ export commodity price shocks;[13]
- $y_{i,t-1}$ lagged dependent variable (at year *t-1*).

[12] Note that ND-GAIN capacity index ranges from 0 (highest capacity) to 1 (lowest capacity). Except some developing countries, the ND-GAIN index changes little over time. To check the extent of countries' changes in ND-GAIN index over time, we take the index in 2020 minus the index in 1995 for each country. The average change across 176 countries is -0.055 and the standard deviation of the change is 0.039. These statistics suggest relatively little change on average in the capacity over time within a country.

[13] The literature has documented strong effects of commodity shocks on GDP growth (see Arezki and Bruckner, 2012 for a seminal paper).

We will collect β_h to plot the responses of output from year t to year $t+h$. h takes the values 0, 1, and 2—that is, we consider a 3-year horizon. There are tradeoffs between the 3-year horizon and a longer horizon. Due to the need to keep non-overlapping disasters, adopting a longer horizon would mean reducing the number of disasters in the sample. In addition, as will be clarify later, output growth already returns to the baseline at t+2, which further support the decision to keep the 3-year horizon. This specification considers a disaster happening at time t and compares real output growth at times t, t+1, and t+2 of countries with disasters, with real output growth at times t, t+1, and t+2 of countries without disasters.

Conceptually, the impact of natural disasters can take three forms: destruction (damage to assets), disruption to economic activity (which can reduce GDP growth), and reconstruction after disasters (which can increase GDP growth). We select the large disasters based on the first channel as our dataset contains disasters with destruction exceeding 1 percent of GDP. We then examine the impact on output growth, which captures both the disruptions to economic activity and the recontruction efforts after the disasters.

In section V, we examine the role of country and disaster characteristics on macroeconomic impacts. The empirical specification follows (1) closely and adds the interactions between country and disaster characteristics with the natural disaster dummy variable:

$$y_{i,t+h} = \alpha + \beta_h ND_t + Characteristics_{i,t-1} + \gamma_h ND_t * Characteristics_{i,t-1} + CommodityPriceShock_{i,t+h-1} + y_{i,t-1} + fe_i + fe_t + \epsilon_{i,t} \quad (2)$$

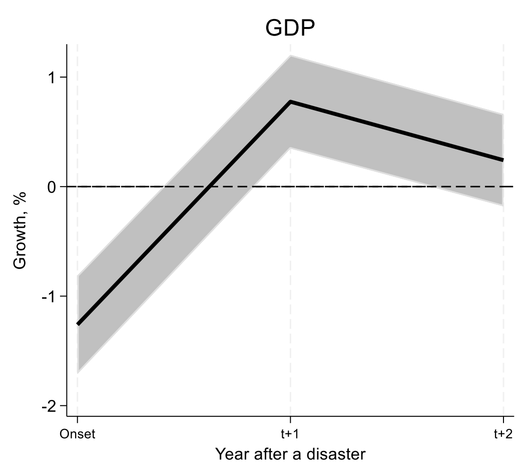
The focus of (2) is on the coefficient γ_h of the interaction term between the natural disaster dummy and the country and disaster characteristics. Note that time-invariant characteristics (such as income group) are absorbed by the country fixed effects.

IV. Impacts by country group

Aggregate impact of natural disasters on output growth: All countries

First, to provide an overview of natural disasters' impact on output growth, we examine the impact of natural disasters on output growth for all countries. Since a few countries do not have data on commodity price shocks, the empirical analysis covers 179 countries over the span of about 31 years. Figure 2 shows that on average, output growth drops significantly in the year of disaster, then recovers in the following year. The recovery does not complely offset the decline. The effects of commodity price shocks are highly significant and will be discussed in more detailed in section VI.

Figure 2. Impact of natural disasters on output growth, all countries



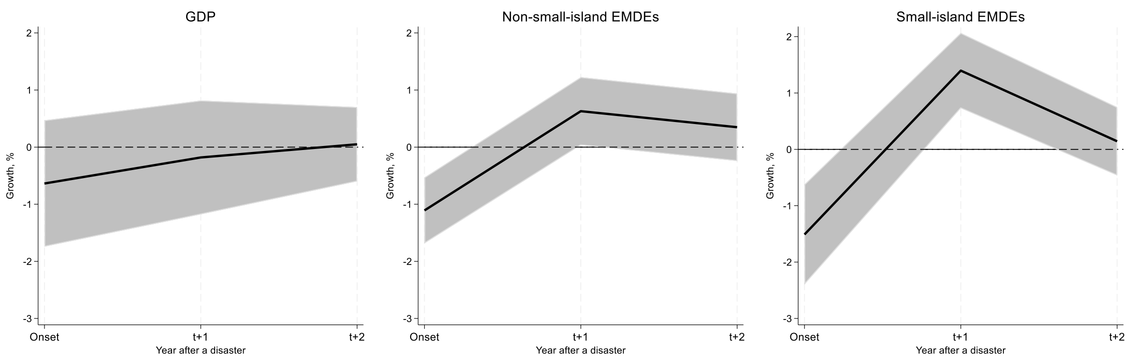
Note: This figure follows the local-projection approach à la Jordà (2005) and described in equation (1). Year and country fixed effects are included. Commodity price shocks are included. Bands show 90 percent confidence intervals.

On average across countries, large natural disasters hurt output growth. Considering only large, single-year, non-overlapping natural disasters with damages of at least 1 percent of GDP, results suggest that output growth drops by about 1.3 percent in the year of the disaster and recovers by about 0.8 percent in the following year. The impact on output growth is not statistically significant two years after the disaster. These findings imply temporary impacts on output growth as output growth returns to the baseline at t+2. They also imply a permanent loss in the level of output, as the GDP growth recovery in the subsequent years does not fully compensate for the decline in GDP growth in the disaster year.

Impact of natural disasters on output growth: By income group

The impacts of disasters differ across income groups (Figure 3). Disasters seem to have insignificant impact on output growth in AEs while having significant negative effects in EMDEs, especially for small-island EMDEs. These findings suggest that, on average, EMDEs incur greater (transitory) growth impact from natural disasters than AEs. This potentially makes EMDEs more vulnerable to the increasingly frequent and intense natural disasters amidst climate change. But what factors are driving the differential impact?

Figure 3. Impact of Natural Disasters on Output Growth: A Summary Across Income Groups



Notes: This figure follows the local-projection approach à la Jordà (2005) and described in equation (1). Bands show 90% confidence intervals.

Impacts on output components by income group

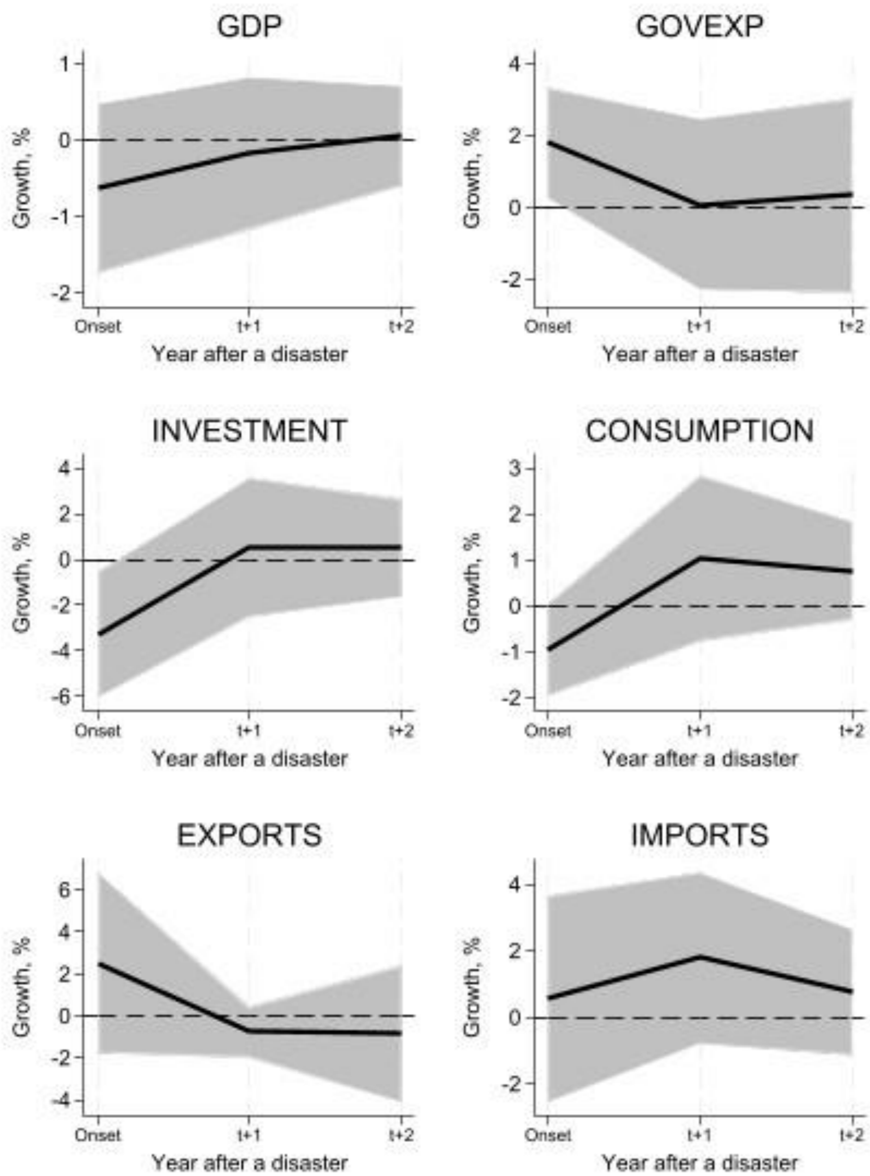
To shed light on why EMDEs tend to experience more negative growth impact from natural disasters compared to AEs, we delve into the growth impacts on the output components: government expenditure, investment, consumption, and imports and exports.

Advanced Economics (AEs)

We re-run the baseline regression but limit the sample to AEs only. Our data in the regression includes 35 high-income countries covering an average span of 37 years. There are 18 large, non-overlapping disasters in AEs between 1980 and 2019.

Figure 4 displays the findings and Table 4 the local projection results for AEs. Real GDP growth is not significantly affected by large natural disasters. The main reason is that government expenditure rises significantly in the same year (by about 1.8 percent). This helps offset the decline in investment. Growth in net exports does not seem to significantly change, indicating the resilience of export and import activities in advanced countries.

Figure 4. Impact of Natural Disasters on Growth of Output and Components: Advanced Economies



Notes: This figure follows the local-projection approach à la Jordà (2005) and described in equation (1). Bands show 90% confidence intervals.

Table 4. Impact of Natural Disasters on Growth of Output and Components: Advanced Economies

		T	T+1	T+2
REAL GDP GROWTH	Natural Disaster (T)	**-0.637**	**-0.180**	**0.051**
		[0.675]	[0.608]	[0.397]
	Observations	1,197	1,164	1,131
	R-squared	0.450	0.364	0.367
	Number of countries	35	35	35
REAL GOVEXP GROWTH	Natural Disaster(T)	**1.798***	**0.088**	**0.338**
		[0.938]	[1.441]	[1.656]
	Observations	1,026	993	960
	R-squared	0.113	0.105	0.108
	Number of countries	35	35	35
REAL INVESTMENT GROWTH	Natural Disaster(T)	**-3.295***	**0.519**	**0.522**
		[1.677]	[1.859]	[1.309]
	Observations	1,222	1,189	1,156
	R-squared	0.223	0.222	0.224
	Number of countries	35	35	35
REAL CONSUMPTION GROWTH	Natural Disaster(T)	**-0.954**	**1.032**	**0.757**
		[0.614]	[1.106]	[0.654]
	Observations	1,225	1,192	1,159
	R-squared	0.308	0.233	0.237
	Number of countries	35	35	35
REAL EXPORT GROWTH	Natural disaster(T)	**2.519**	**-0.780**	**-0.841**
		[2.627]	[0.756]	[1.993]
	Observations	1,227	1,194	1,161
	R-squared	0.394	0.374	0.373
	Number of countries	35	35	35
REAL IMPORT GROWTH	Natural disaster(T)	**0.560**	**1.778**	**0.744**
		[1.895]	[1.568]	[1.155]
	Observations	1,227	1,194	1,161
	R-squared	0.402	0.389	0.383
	Number of countries	35	35	35

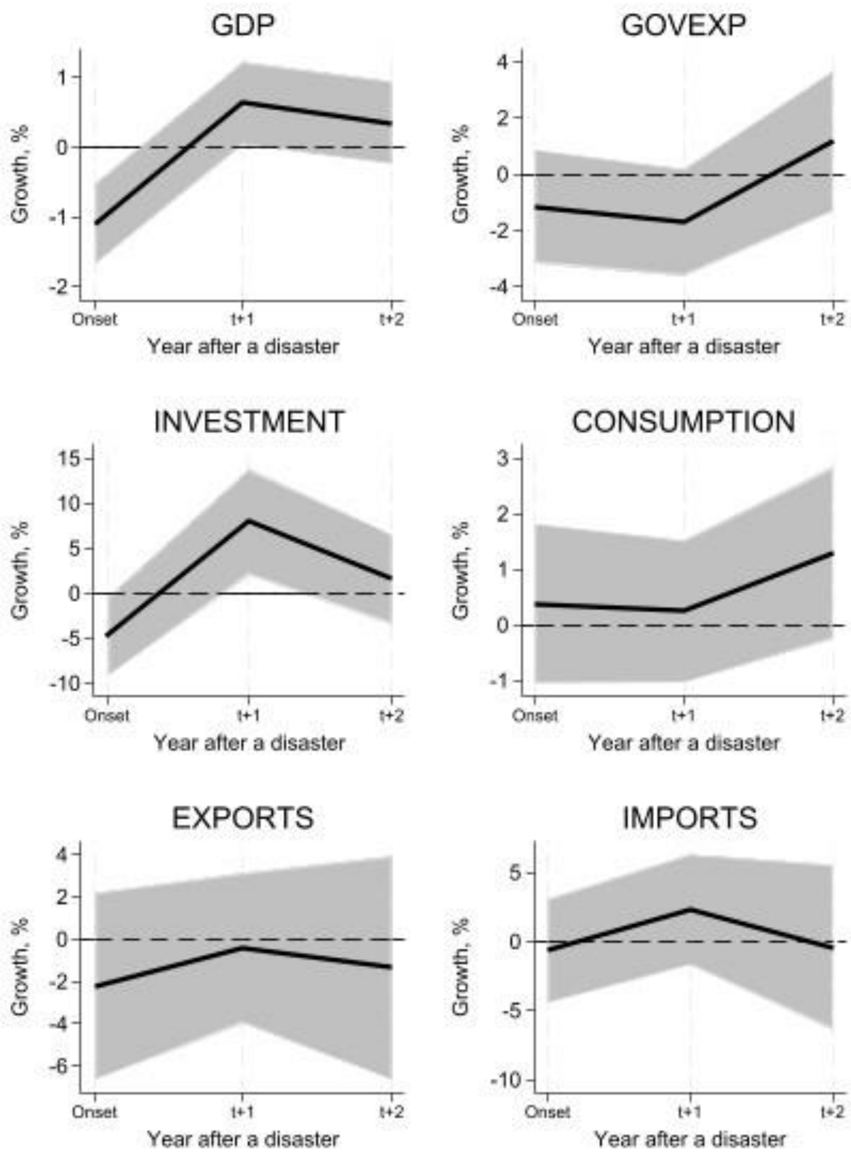
Notes: This table corresponds to Figure 4. It presents macroeconomic impacts of natural disasters in advanced economies using the local projection method à la Jordà (2005) and described in equation (1). Only the estimated coefficients of natural disasters are shown. Year and country fixed effects are included. Commodity price shocks are included. *,**,** indicate statistical significance at 10%, 5% and 1% levels.

Non-Small-Island (NSI) EMDEs

Figure 5 and Table 5 present the macroeconomic impact of natural disasters in NSI EMDEs. Growth in government expenditure drops not only in the year of the disaster but also in the subsequent year, although the drop is not statistically significant.[14] Investment growth drops significantly more in the disaster year by about 5 percent but recovers in the year after. In short, real investment growth drops, but real government expenditure also drops after a disaster. Therefore, GDP growth of NSI EMDEs falls in the disaster year. In the following year, investment recovers, pulling up output growth. However, output growth in year t+1 does not completely offset the decline in year t. These findings suggest that natural disasters tend to have more negative impact on output growth for NSI EMDEs than for AEs given the drop in real investment growth and the weaker offset from government expenditures in NSI EMDEs.

[14] Using data for 19 developing Asian countries, Gerling (2017) similarly finds that key fiscal aggregates remain stable after natural disasters. Case studies in her paper suggest that this reflects a deliberate policy choice or binding constraints in these countries.

Figure 5. Impact of Natural Disasters on Growth of Output and Components: Non-Small-Island EMDEs



Notes: This figure follows the local-projection approach à la Jordà (2005) and described in equation (1). Bands show 90% confidence intervals.

Table 5. Impact of Natural Disasters on Growth of Output and Components: Non-Small-Island EMDEs

		T	T+1	T+2
REAL GDP GROWTH	Natural Disaster (T)	**-1.109*** **	**0.630***	**0.349**
		[0.352]	[0.363]	[0.360]
	Observations	3,776	3,649	3,529
	R-squared	0.164	0.115	0.093
	Number of countries	118	118	118
REAL GOVEXP GROWTH	Natural Disaster (T)	**-1.154**	**-1.721**	**1.164**
		[1.226]	[1.160]	[1.518]
	Observations	2,651	2,535	2,420
	R-squared	0.060	0.060	0.064
	Number of countries	117	116	116
REAL INVESTMENT GROWTH	Natural Disaster (T)	**-4.913***	**7.905****	**1.500**
		[2.637]	[3.609]	[3.029]
	Observations	3,405	3,296	3,185
	R-squared	0.014	0.016	0.014
	Number of countries	108	108	108
REAL CONSUMPTION GROWTH	Natural Disaster (T)	**0.381**	**0.246**	**1.294**
		[0.872]	[0.780]	[0.946]
	Observations	3,409	3,301	3,190
	R-squared	0.062	0.027	0.027
	Number of countries	108	108	108
REAL EXPORT GROWTH	Natural Disaster (T)	**-2.230**	**-0.418**	**-1.353**
		[2.691]	[2.175]	[3.225]
	Observations	3,429	3,320	3,209
	R-squared	0.101	0.117	0.023
	Number of countries	109	109	109
REAL IMPORT GROWTH	Natural Disaster (T)	**-0.683**	**2.295**	**-0.413**
		[2.293]	[2.436]	[3.651]
	Observations	3,439	3,330	3,219
	R-squared	0.162	0.204	0.038
	Number of countries	109	109	109

Notes: This table corresponds to Figure 5. It presents macroeconomic impacts of natural disasters in advanced economies using the local projection method à la Jordà (2005) and described in equation (1). Only the estimated coefficients of natural disasters are shown. Year and country fixed effects are included. Commodity price shocks are included. *,**,** indicate statistical significance at 10%, 5% and 1% levels.

Small-Island (SI) EMDEs

Our regression sample contains 26 SI EMDEs.[15] Five SI EMDEs are not included because they do not have data on export commodity price shocks.[16] There are 56 large, single-year, non-overlapping natural disasters that happened in SI EMDEs. Figure 6 and Table 6 show that, in SI EMDEs, government expenditure rises with a lag in the year after the disaster. For the disaster year, growth in government expenditure in the treatment group drops but it is not statistically significant. In t+1, growth in government expenditure rises by about 3 percent. Exports of goods and services (largely tourism in many countries[17]) drops, though the coefficient is not statistically significant despite the expected relative sensitivity of small islands' exports to natural disasters. Meanwhile, investment growth and also to some extent imports of goods and services seem to rise immediately.

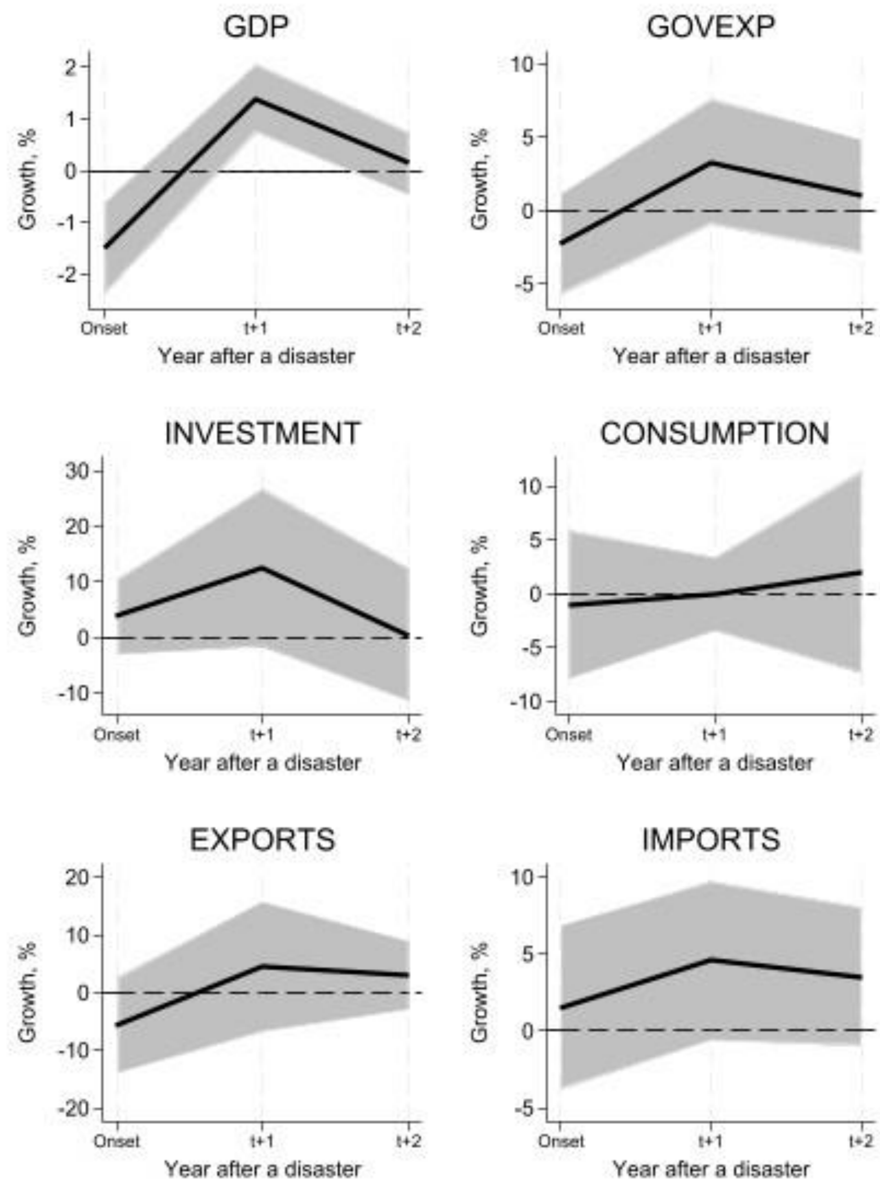
[15] Antigua and Barbuda, Barbados, Belize, Brunei Darussalam, Cabo Verde, Comoros, Dominica, Fiji, Grenada, Jamaica, Kiribati, Maldives, Mauritius, Samoa, Seychelles, Solomon Islands, St. Kitts and Nevi, St. Lucia, St Vincent and the Grenadines, Suriname, São Tomé and Príncipe, The Bahamas, Timor-Leste, Tonga, Trinidad and Tobago, Vanuatu.

[16] Marshall Islands, Micronesia, Nauru, Palau, Tuvalu.

[17] For example, for 2019, data for from UN Tourism (UNWTO) show tourism constituted 11.2 percent of GDP for Fiji, 9.2 percent of GDP for Mauritius and 9.8 percent for Jamaica.

To summarize, the decline in net exports (likely due to tourism in many small island EMDEs) is the main drag of GDP growth for these countries during disaster times, whereas government expenditure does not appear to sufficiently offset the decline. One caveat, however, is that data for growth in investment, consumption, imports, and exports are only available for 15 to 19 small-island EMDEs in our sample (see Table 6). Therefore, the findings for these variables may or may not apply to other small island EMDEs.

Figure 6. Impact of Natural Disasters on Growth of Output and Components: Small-Island EMDEs



Notes: This figure follows the local-projection approach à la Jordà (2005) and described in equation (1). Bands show 90% confidence intervals.

Table 6: **Impact of Natural Disasters on Growth of Output and Components: Small Island EMDEs**

		T	T+1	T+2
REAL GDP GROWTH	Natural Disaster (T)	**-1.510*** **	**1.398*** **	**0.144**
		[0.541]	[0.407]	[0.370]
	Observations	917	893	870
	R-squared	0.173	0.147	0.129
	Number of countries	26	26	26
REAL GOVEXP GROWTH	Natural Disaster (T)	**-2.283**	**3.342**	**0.965**
		[2.099]	[2.631]	[2.363]
	Observations	667	643	619
	R-squared	0.094	0.080	0.076
	Number of countries	26	26	26
REAL INVESTMENT GROWTH	Natural Disaster (T)	**3.689**	**12.517**	**0.455**
		[4.125]	[8.700]	[7.293]
	Observations	406	391	376
	R-squared	0.063	0.096	0.057
	Number of countries	15	15	15
REAL CONSUMPTION GROWTH	Natural Disaster (T)	**-1.003**	**-0.043**	**2.022**
		[4.220]	[2.097]	[5.742]
	Observations	408	393	378
	R-squared	0.199	0.147	0.167
	Number of countries	15	15	15
REAL EXPORT GROWTH	Natural Disaster (T)	**-5.647**	**4.471**	**2.980**
		[5.079]	[6.866]	[3.600]
	Observations	480	462	444
	R-squared	0.066	0.080	0.068
	Number of countries	19	19	19
REAL IMPORT GROWTH	Natural Disaster (T)	**1.523**	**4.567**	**3.541**
		[3.248]	[3.156]	[2.765]
	Observations	476	458	440
	R-squared	0.093	0.112	0.094
	Number of countries	19	19	19

Notes: This table corresponds to Figure 6. It presents macroeconomic impacts of natural disasters in advanced economies using the local projection method à la Jordà (2005) and described in equation (1). Only the estimated coefficients of natural disasters are shown. Year and country fixed effects are included. Commodity price shocks are included. *,**,** indicate statistical significance at 10%, 5% and 1% levels.

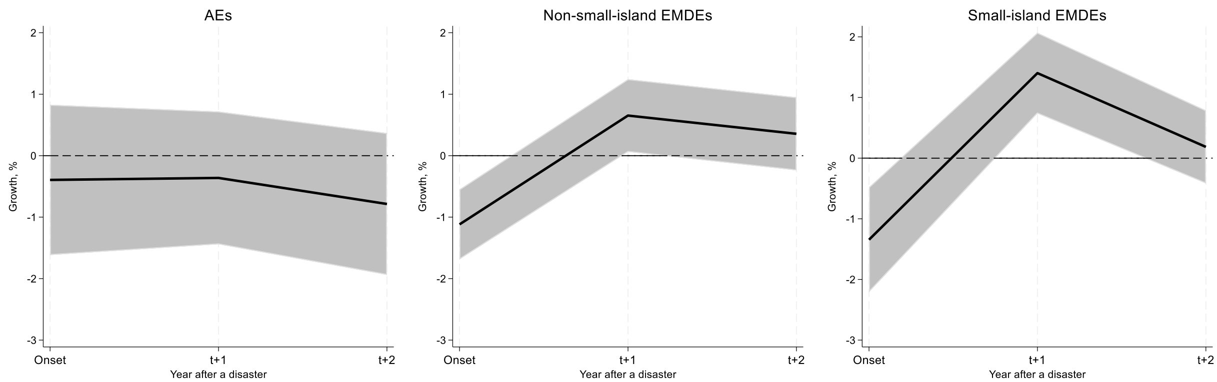
V. Robustness Checks and Alternative Specifications

This section provides alternative specifications and robustness checks to our main findings.

Robustness Check 1: Excluding export commodity price shocks

In the first robustness check, we do not control for export commodity price shocks. The findings are very similar to the baseline results (see Figure 7). In AEs, natural disasters have statistically insignificant effects, while in EMDEs, natural disasters bring down growth in the disaster year, although growth recovers partly in the year after.

Figure 7. GDP Growth Impact of Natural Disasters, Without Controlling for Export Commodity Price Shocks



Notes: This figure follows the local-projection approach à la Jordà (2005) and described in equation (1). Bands show 90% confidence intervals.

Robustness Check 2: Including overlapping and multi-year natural disasters

In the robustness check, we include overlapping natural disasters and multi-year disasters. Overlapping disasters refer to large disasters that are preceded or followed by another large natural disaster within two years. Recall that in the baseline regressions, we have removed the country-year observations of overlapping disasters from our estimation sample so that the impact estimations were as identified as possible. In addition to overlapping disasters, this robustness check also includes large multi-year disasters (that are excluded in the baseline regressions). Table 7 shows the number of large natural disasters (defined as having physical damage exceeding 1 percent of GDP) by disaster duration. Most happened within one year (i.e., disaster duration is zero), but some disasters last for multiple years (many of which are droughts).

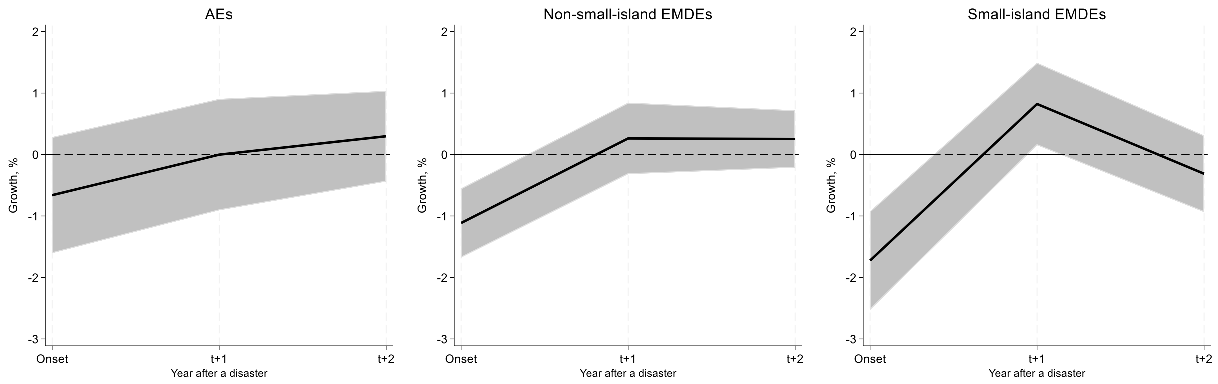
Figure 8 shows that if large, overlapping natural disasters are included, the macroeconomic impacts of natural disasters remain similar to the baseline findings. In the disaster year, output growth drops in NSI EMDEs and SI EMDEs, but not in AEs. However, for NSI EMDEs, growth recovery at t+1 is no longer statistically significant.

Table 7. Large Disasters in EM-DAT by Length

Disaster duration (End Year minus Start Year)	Number	Percent
0	392	93.78
1	15	3.59
2	6	1.44
3	1	0.24
4	1	0.24
6	2	0.48
9	1	0.24
Total	418	100

Source: EM-DAT

Figure 8. GDP Growth Impact of Natural Disasters, Including Overlapping and Multi-year Natural Disasters

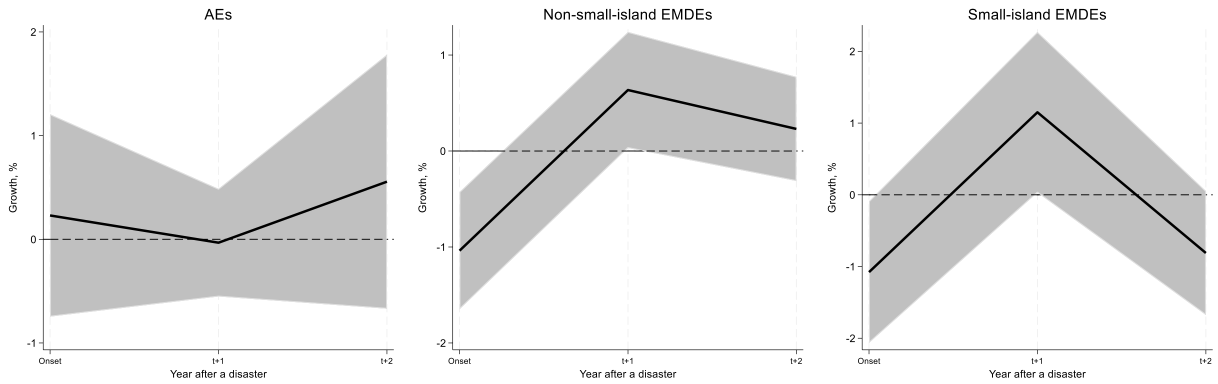


Notes: This figure follows the local-projection approach à la Jordà (2005) and described in equation (1). Bands show 90% confidence intervals.

Robustness Check 3: An alternative selection of disasters

In this robustness check, we use an alternative selection of disasters: share of population affected. Recall that in the baseline regression, selected natural disasters have at least 1 percent of GDP in damage in assets (infrastructure, properties, livestock). We argue earlier that damage to assets (infrastructure, properties, livestock) might have a more direct link to GDP disruptions than say the number of affected populations, hence this criterion is chosen for the baseline regressions. Here, we select large natural disasters that affected at least 5 percent of the population. We have 155 large, single-year and non-overlapping natural disasters with this criterion (including 50 droughts, 38 floods and 47 storms). Figure 9 presents the impacts on GDP growth of large, single-year and non-overlapping disasters. The results are similar to the baseline. In AEs, natural disasters have statistically insignificant effects, while in EMDEs, natural disasters bring down growth in the disaster year, although growth recovers partly in the year after.

Figure 9. GDP Growth Impact of Natural Disasters (An Alternative Selection of Disasters)



Notes: This figure follows the local-projection approach à la Jordà (2005) and described in equation (1). Bands show 90% confidence intervals. Large disasters are defined as affecting at least 5 percent of the population.

Alternative Specification: Panel quantile regressions

In our analysis above, we have used the local projection method to examine the paths of the mean forecasts of key macroeconomic variables such as output growth after a natural disaster. In addition to the “mean” forecasts, policymakers are also generally interested in what would happen in the “worst” scenario. To answer this, we employ the method of quantile regressions using the same sample and examine how the conditional quantiles of the GDP growth distribution in a country are shifted by a natural disaster shock.

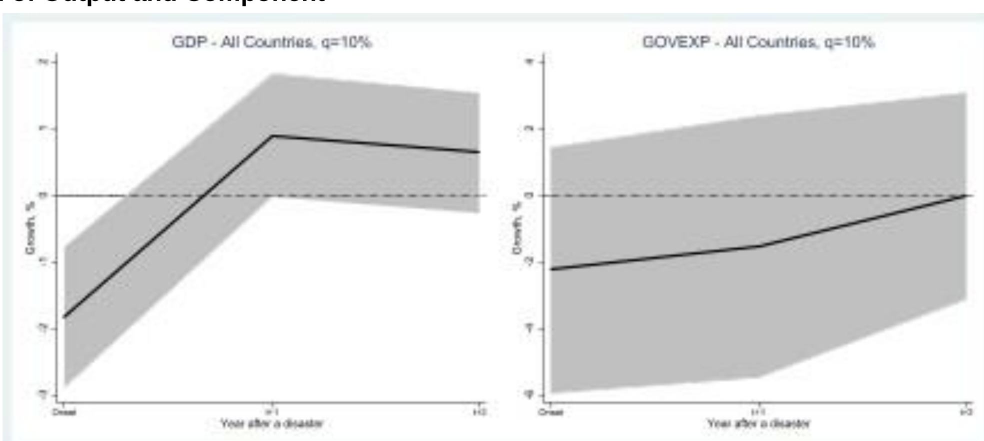
Specifically, we examine the following quantile relationship for conditional quantile at *q* (e.g., *q=10 percent*):

$$\Delta y_{i,t+h}^{q} = \alpha^{q} + \beta_h^{q} ND_t + CommodityPriceShock_{i,t+h-1}^{q} + fe_i^{q} + fe_t^{q} \quad (3)$$

As we are mostly concerned about the downside scenario, or the left tail of the GDP growth distribution, we are particularly interested in the results at, for example, *q=10 percent*. If the natural disaster shock *ND* shifts the 10^{th}-percent conditional quantile of the GDP growth rate distribution to the left *more* than it shifts the mean of that distribution (in other words, β_h^q at *q*=10 percent is more negative than β_h), it would suggest that a natural disaster not only lowers the expected average GDP growth rate for the country but also increases the downside risk more strongly relative to that average scenario.

Results are shown in Figure 10. One can see that in the year of the disaster onset, the estimated coefficient for the 10^{th}-percent conditional quantile is negative and statistically significant. In terms of its magnitude, it is lower, slightly more negative than the results obtained from the local projection method. This means that, the natural disaster not simply shifts the GDP growth distribution to the left (i.e., by lowering the mean) but also makes the left tail fatter. This implies (slightly) greater downside risk to GDP growth in the disaster-hit country. Such a pattern is also present in the result for government expenditure. However, we also observe that the coefficients for the 10^{th} percent conditional quantile in subsequent years are not always lower than the local projection estimates and, in some cases, they are even higher. This indicates that, during economic recovery after a disaster, the distribution of GDP growth rate becomes tighter in the left tail. These findings suggest that the downside risk to GDP growth is amplified and increased only in the disaster year.[18]

Figure 10. A Natural Disaster’s Impact on the Lower Tail (*q=10 percent)* of the Conditional Distribution for Growth of Output and Component



Note: These figures are generated using panel quantile regressions, controlling for country and year fixed effects and commodity price shocks. Bands show 90% confidence intervals.

[18] Bayoumi and others (2021) further finds that disaster preparedness mechanisms and lower public debt can help countries lower probability of growth decline after a natural disaster.

VI. What Factors Are Driving the Heterogenous Effects of Natural Disasters?

What factors can explain the differential impacts of natural disasters on economic growth across countries? In this section, we analyze the role of the following disaster and country characteristics.[19] The empirical specification follows equation (2). The focus is on the coefficient of the interaction between the natural disaster dummy and the country and disaster characteristics.

Disaster characteristics include:

- **Economic damage** (in percent of GDP): Economic damage includes the amount of damage to property, crops, and livestock. Data are from the EM-DAT database. We expect that the greater the economic damage, the larger the disruptions to output growth but also the larger the reconstruction needs. Therefore, the impacts on output growth of economic damage are ambiguous and should be assessed empirically.
- **Disaster types**: We consider three main climate disaster types separately ("droughts", "storms", and "floods") and the rest is grouped into "others" (which includes earthquakes, volcanos, wildfires).

Country characteristics include:

- **Income group**: Advanced economies (AEs), emerging market and middle-income economies (EMMIEs), and low and developing countries (LIDCs). As shown in the previous sections, the impact of natural disasters on economic growth in AEs is more muted than in EMDEs, thanks to the swift responses of government expenditure.
- **Small islands**: It is possible that natural disasters have a more severe impact on small islands' output growth than in non-island economies. Small islands tend to have infrastructure (such as seaports) that are more vulnerable to damages from natural disasters, affecting imports and exports heavily after a natural disaster hits. Small island's economic structure tends to gear to tourism. For instance, damage after natural disasters can deter tourists after natural disasters.
- **Adaptive Capacity**: We use the ND-GAIN adaptive capacity (https://gain.nd.edu/our-work/country-index/methodology/). We expect that countries with better adaptive capacity would cope better with natural disasters and hence can mitigate the impact of natural disasters on economic growth.
- **Pre-disaster fiscal space**: Countries with larger pre-disaster fiscal space are likely more able to spend more resources for reconstruction. Therefore, we expect countries with larger pre-disaster fiscal space being able to mitigate to a larger extent the negative output impact from natural disasters. As indicated in the data section, we choose pre-disaster overall fiscal balance (in percent of GDP) because it has comprehensive country coverage, it is sensible, and it has good explanatory power to output growth after disasters.

[19] The characteristics studied here are by no means exhaustive. For example, von Peter et al. (2024) highlight the role of insurance in mitigating the effects.

Table 8. Heterogeneous Growth Impacts of Natural Disasters

VARIABLES	(1) GDP GROWTH (t)	(2) GDP GROWTH (t+1)	(3) GDP GROWTH (t+2)
Commodity price shocks (t-1)	6.160***		
	[1.886]		
Commodity price shocks (t)		8.101***	
		[2.201]	
Commodity price shocks (t+1)			8.998***
			[2.080]
GDP growth (t-1)	0.299***	0.106***	0.070***
	[0.027]	[0.023]	[0.022]
Natural Disaster (ND)	0.160	1.480	1.972
	[2.493]	[2.846]	[2.604]
ND(t)*physical damage	-0.031***	0.018	-0.032
	[0.007]	[0.018]	[0.021]
ND(t)*storm	0.040	1.602*	0.203
	[0.705]	[0.844]	[0.815]
ND(t)*flood	-0.903	0.802	0.159
	[0.804]	[0.882]	[0.691]
ND(t)*drought	-0.489	2.259**	-0.163
	[0.995]	[1.038]	[1.369]
ND(t)*AE	0.364	-0.569	-0.570
	[1.465]	[1.496]	[1.386]
ND(t)*LIDC	1.503*	-0.571	-0.432
	[0.797]	[1.071]	[1.018]
ND(t)*small island	-1.324**	0.309	0.232
	[0.670]	[0.738]	[0.843]
ND(t)*Adaptive capacity(t-1)	-0.879	-2.202	-0.788
	[3.994]	[5.270]	[4.649]
Adaptive capacity (t-1)	4.634	10.487**	9.040*
	[3.922]	[4.820]	[5.082]
ND(t)*Fiscal Balance(t-1)	0.070	0.131*	0.155**
	[0.111]	[0.079]	[0.066]
Fiscal Balance(t-1)	0.029**	0.032**	0.013
	[0.012]	[0.015]	[0.013]
Constant	-1.206	-5.445*	-3.244
	[2.312]	[2.968]	[2.980]
Country fixed effects and year fixed effects	yes	yes	yes
Observations	4,321	4,151	3,984
R-squared	0.199	0.132	0.123
Number of countries	172	172	172

Notes: Local projection method à la Jordà (2005) following equation (2). Robust standard errors in brackets, *,**,** indicate statistical significance at 10%, 5% and 1% levels. “Other disasters” and EMMIEs country group are the omitted categories.

Table 9. Heterogeneous Impacts of Natural Disasters on Government Expenditure Growth

VARIABLES	(1) GOVEXP GROWTH (t)	(2) GOVEXP GROWTH (t+1)	(3) GOVEXP GROWTH (t+2)
Commodity price shocks (t-1)	14.346**		
	[7.066]		
Commodity price shocks (t)		28.866***	
		[7.243]	
Commodity price shocks (t+1)			28.437***
			[8.003]
GovExp growth (t-1)	0.010	-0.019	-0.040*
	[0.023]	[0.021]	[0.022]
Natural Disaster (ND)	-10.047	-6.449	2.786
	[7.624]	[8.100]	[7.910]
ND(t)*physical damage	-0.024	0.084**	0.032
	[0.044]	[0.037]	[0.030]
ND(t)*storm	-1.521	-2.078	-4.307*
	[2.536]	[2.802]	[2.446]
ND(t)*flood	0.768	-2.596	-4.448*
	[2.711]	[2.597]	[2.306]
ND(t)*drought	2.619	-5.622**	1.516
	[3.155]	[2.666]	[5.818]
ND(t)*AE	8.116**	5.792	0.639
	[3.766]	[4.049]	[4.219]
ND(t)*LIDC	1.692	0.067	-4.045
	[3.217]	[3.365]	[2.838]
ND(t)*small island	-1.792	1.987	1.985
	[3.002]	[3.703]	[3.018]
ND(t)*adaptive capacity(t-1)	14.248	10.289	7.631
	[12.973]	[15.595]	[13.181]
Adaptive capacity (t-1)	1.683	18.911*	14.327
	[11.769]	[11.263]	[10.750]
ND(t)*Fiscal Balance(t-1)	0.117	0.120	0.796***
	[0.270]	[0.293]	[0.304]
Fiscal Balance(t-1)	0.416***	0.264***	0.133***
	[0.109]	[0.069]	[0.042]
Constant	3.638	-3.299	-1.144
	[7.175]	[6.720]	[6.733]
Country fixed effects and year fixed effects	yes	yes	yes
Observations	4,131	3,963	3,797
R-squared	0.094	0.062	0.057
Number of countries	171	170	170

Notes: Local projection method à la Jordà (2005) following equation (2). Robust standard errors in brackets, *,**,** indicate statistical significance at 10%, 5% and 1% levels. “Other disasters” and EMMIEs country group are the omitted categories.

Tables 8 and 9 show the correlates of the disasters' impact, summarized as follows.

On output growth	On government expenditure growth
Physical damage: disasters with larger physical damage cause significantly lower output growth at the year of disaster (t=0). **Single-year storms** and **droughts** are associated with higher output growth than floods and other disasters such as earthquakes (at t+1), indicating a stronger recovery after storms and droughts (consistent with Fomby et al., 2013).	Larger physical damage is associated with significantly higher government expenditure growth at t+1. The relationship between the types of natural disasters and government expenditure growth is not clear
LIDCs have higher growth than the EMMIEs (the omitted country group in the regression) and AEs, holding all other explanatory factors the same. It is possible that grants and other donor funding might help LIDC's growth after disasters.	**AEs** have higher government expenditure growth than EMMIEs and LIDCs (about 8.1 percent), holding other factors constant.
Small Islands have lower output growth than non-small islands (the omitted group) about 1.3 percent at the year of disasters	**Small islands** have lower government expenditure growth than non-small islands, but the difference is not statistically significant.
Better **adaptive capacity** (a smaller value of ND GAIN index) is associated with higher growth after the disasters. However, the association is not statistically significant. Similar results are obtained with INFORM risk's lack of coping capacity index.	Better **adaptive capacity** (a smaller value) is associated with lower government expenditure growth, probably because of lower reconstruction needs. However, the association is not statistically significant.
A higher **pre-disaster fiscal balance** is associated with higher output growth. The association is statistically significant at t+1 and t+2. The interaction coefficient reveals that when a natural disaster hits, having a larger fiscal balance helps boost output growth.	A higher **pre-disaster fiscal balance** is associated with higher government expenditure growth when a disaster happens. The interaction is statistically significant at t+2.

In addition, the impacts of commodity shocks on GDP growth and growth in government expenditure are highly significant, indicating the importance of commodity price shocks in country's fiscal response and GDP growth outcomes.

VII. Conclusion

This paper studies the impact of natural disasters on a range of macroeconomic outcomes, including the aggregate GDP growth and its components. Understanding the impacts of natural disasters is critical to assessing the impacts of climate change and to developing appropriate policy responses, both before and after disasters hit.

We find that natural disasters temporarily reduce GDP growth of EMDEs but not in AEs in the year of the disaster, partly because government expenditure in AEs typically responds quickly. Government expenditure in EMDEs is slower to rise after natural disasters hit and does not fully compensate for the negative effects on output growth. In non-small-island EMDEs, investment is more adversely affected whereas in small-island EMDEs, exports are more affected. We find that the output growth effects are temporary, however, the output level effects are permanent because the growth recovery does not fully offset the negative growth impact at the year of the disaster.

This paper sheds light on what country characteristics matter for the post-disaster response of government expenditure. Countries with larger pre-disaster fiscal space seem to be able to implement greater responses in government expenditure and hence on average have higher output growth after disasters hit.

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