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The Macro-Fiscal Aftermath of Weather-Related Disasters:
Do Loss Dimensions Matter?

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The Macro-Fiscal Aftermath of Weather-Related Disasters: Do Loss Dimensions Matter?

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Abstract

Weather-related natural disasters and climate change pose interrelated macro-fiscal challenges. Using panel-VARX studies for a sample of 19 countries in Developing Asia during 1970 to 2015, this paper contributes new empirical evidence on the dynamic adjustment path of growth and key fiscal variables after severe weather-related disasters. It does not only show that output loss can be permanent, but even twice as large for cases of severe casualties or material damages than people affected. Meanwhile, key fiscal aggregates remain surprisingly stable. Event and case studies suggest that this can reflect both a deliberate policy choice or binding constraints. The latter can make governments respond through mitigating fiscal policy efforts such as ad hoc fiscal rebalancing and reprioritization. The findings help better customize disaster preparedness and mitigation efforts to countries' risk exposure along a particular loss dimension.

JEL Classification Numbers: Q54; E62; O11; O44; H84

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I. INTRODUCTION

While severe weather-related disasters are a growing macro-critical risk, their macro-fiscal impact remains poorly understood. Concerns are widespread that the frequency and strength of such events will likely increase with the intensification of extreme weather conditions related to global climate change and rising concentration of people and material assets in high-risk areas (IPCC, 2014a; or Freeman et al., 2003). The economic significance of such disasters arises not only from the direct damages to material assets and people, but also from the ensuing pressures in the post-disaster period: output contraction and fiscal strain, as lower revenues (because of lower economic activity and disrupted tax collection infrastructure) meet higher expenditure needs (especially for emergency relief and reconstruction where households and companies need public support). However, while providing evidence for an adverse short-term growth impact, the literature remains inconclusive on both the sign of the longer-term growth impact and significance of the fiscal impact.

This paper helps to fill this gap. It goes beyond the literature in two ways. First, it is the first to emphasize that the severity of disaster events has different dimensions. It contrasts the dynamic adjustment path of economic growth and key fiscal variables in the disaster aftermath across three different loss dimensions (i.e. material damages, people affected, and casualties). Thereby, it builds on the literature: it focuses on a group of countries with similar development status and considerable risk of natural disasters (i.e. 19 countries in Developing Asia (DAS) from 1970-2015),[2] clusters disaster hazards (i.e. those related to weather), centers on severe disaster episodes (i.e. those in the top 10 percentile of the respective distribution of scaled losses),[3] and derives impulse reaction functions (IRFs) from a panel vector autoregressive model with exogenous shocks (i.e. a panel-VARX including growth, primary fiscal balance, tax revenues, and expenditures). Second, this paper sheds light on the drivers of the fiscal results.

A key finding is that disasters' loss dimensions are hardly correlated and trigger different macro-fiscal response. To lay the ground, DAS countries feature a particularly high disaster proneness and low resilience of exposed people and infrastructure. This explains why, on average over the past 4½ decades, they suffered less frequent, but in many ways costlier events than their peers in the rest of the Developing World (RoDW)

Table 1. Average Weather-Related Losses, 1970-2015
(Annual occurrence per tsd. sq. km, material damages in pct. of GDP, human damages in pct. of population, conditional on an event)

	DAS	RoDW	Asian AMs
Occurrence	0.0160	0.0165	0.0670
Material damage	1.2615	0.4484	0.0774
People affected	4.0497	2.6237	0.1385
People dead	0.0024	0.0032	0.0002

Source: Own calculations using CRED EM-DAT, WB WDI, IMF WEO.

[2] DAS includes 19 countries: Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, India, Indonesia, Lao PDR, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Timor-Leste, and Vietnam.

[3] The empirical results are broadly robust to the threshold selection, e.g. to alternatively choosing the 95 percentile or ad-hoc thresholds elsewhere used in the literature (such as a 1 percent of GDP material damage).

and Asian advanced markets (AMs):[4] three and 16 times higher material damages, 1½ and 30 times more people affected, and a slightly smaller and 12 times larger death toll, respectively (Table 1). Contrary to the previous literature, though, this paper explicitly exposes those three loss dimensions of material damage, people affected and dead as largely uncorrelated.[5] With this in mind, it is not surprising to see the loss dimensions trigger different mean economic growth and fiscal disaster responses in terms of scale, timing, and persistency. While severe episodes across all loss measures cause an instantaneous growth decline of more than 1 percentage point, only those affecting people come with a swift rebound. Those involving material damages or fatalities even trigger a permanent output loss of more than 2 percentage points.[6] Meanwhile, the effect on fiscal aggregates remains surprisingly small and insignificant.

In addition, the paper sheds light on the underlying dynamics at play. It shows that the impact on fiscal aggregates largely reflects a policy choice, which often appears subdued on account of four key factors: (i) direct disaster costs typically fall more on the private than the public sector; (ii) the private sector response—also facilitated by the availability of fast and fresh financing, above all from higher remittances—typically substitutes at least partially for a public sector response; (iii) public intervention is only warranted for aggregate demand management in support of ailing growth or for distributional measures in assistance of the distressed part of the population or economy; and (iv) the ability of the public sector to react can be constrained by insufficient fiscal space, weak capacity, or rigid budget and political procedures. Evidence suggests that in the face of such constraints, governments react through compensating budget measures, including mobilizing revenues and grants, rebalancing expenditures, and curtailing non-essential spending.

These insights can help improve fiscal policy aimed at enhancing countries' preparedness for and response to the impact of weather-related disasters, which are predicted to further acerbate with climate change. They include advancing fiscal risk management and public financing assistance, regularizing budget process flexibility, generating fiscal space to finance climate change mitigation and disaster response programs, overhauling energy subsidies and taxation, and strengthening government effectiveness.

The remainder of the paper is structured as follows. Section II reviews the literature. Then, Section III presents the data and some stylized facts on disaster patterns. Section IV discusses the empirical approaches and results. Finally, Section V concludes and briefly outlines fiscal policy implications.

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[4] RoDW comprises all 189 IMF members except for 35 advanced markets (AMs) as defined by the IMF WEO, 34 small developing states (SDSs) as defined in IMF (2013), and 19 DAS countries as defined above. Based on IMF WEO classifications, Asian AMs include Japan, the Republic of Korea, and Singapore.

[5] The nature and severity of a disaster's impact is determined by a combination of impact intensity and vulnerability of exposed assets and people. It often includes an element of coincidence, as highlighted by two large cyclones in Myanmar: Komen (2015) and Nargis (2008). While Komen hit the rural countryside (severely affecting people), Nargis hit the commercial center Yangon (causing severe material losses and fatalities).

[6] This might be due to persisting difficulties of replacing lost material or human capital, or a lack of investor confidence fueled by a perceived higher business risk.

II. LITERATURE REVIEW

Cross-country studies are inconclusive on the macro-fiscal impact of natural disasters. The bulk of the literature draws on the only publicly available cross-country database on disaster losses: the Centre for Research on the Epidemiology of Disasters (CRED) Emergency Events Database (EM-DAT).[7] Nevertheless, the comparability of results remains limited, mainly due to differences in the selected disaster events (regarding the employed loss measure, scaling of losses, or loss intensity thresholds), disaster hazards, samples and empirical approaches. Most studies focus on the economic impact, only a few examine the fiscal performance.

The net effect of natural disasters on economic growth remains ambiguous. In the short-term, the economy takes a hit because of direct costs through the loss of lives, damage to physical assets, and immediate output contraction (e.g. Cashin et al., 2017 and 2016; Loayza et al. 2012; Noy, 2009; Hochrainer, 2009; Strobl, 2012; or Raddatz, 2007). Over time though, the effect seems to become uncertain. Some studies point to an overwhelmingly contractionary effect (e.g. Cavallo et al., 2013; Noy and Nualsri, 2011; or Raddatz, 2009), mainly confirming a crowding-out of productive capital expenditures by reconstruction efforts. Others find an expansionary effect (Skidmore and Toya, 2002), attributable to an accelerated Schumpeterian creative destruction process that boosts productivity by triggering investment in upgraded capital and new technologies (Cuaresma et al., 2008; Benson and Clay, 2004).

To reconcile these results, other papers stress the importance of factors such as institutional quality (driving the speed and usefulness of response measures) or the effectiveness of demand smoothing mechanisms through counter-cyclical fiscal policies (World Bank, 2003), economic size and diversification (Auffret, 2003), or insurance payouts (von Peter et al., 2012).[8] More recent studies focus on the dynamic economic growth path, typically employing panel-VARX and differentiating along disaster perils and levels of development. For instance, using EM-DAT data to construct a composite indicator of the share of population affected and dead for 84 countries over 1960-2007, Fomby et al. (2013) find that droughts and storms negatively impact economic growth, but not earthquakes. Using data from the Global Archive of Large Flood Events for 135 countries over 1985-2008, Cuñado and Ferreira (2014) detect a positive GDP impact of moderate floods in developing, but not developed countries. Drawing on insurance industry data for 203 countries over 1960-2011, von Peter et al. (2012) obtain that a major catastrophe (i.e. one costing at least 100 lives or direct losses of 250 million in constant 2011 USD) causes a significant, permanent wealth decline through a sizable reduction in GDP. Finally, two studies focus on small

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[7] A fundamental caveat is that damage data appears distorted, mainly due to reporting thresholds, weak capacity, and accounting difficulties (Kousky, 2012). Biases can arise even across loss measures, as selection in the database (especially above a threshold) could be correlated with factors such as GDP—with larger reported damages along the material dimension for advanced countries (due to their higher value of exposed assets and broader insurance coverage providing incentives for comprehensive damage assessment and recordation (Felbermayr and Gröschl, 2014)) and along the human dimension for developing countries (due to their higher share of exposed vulnerable population, exacerbated by weaker disaster forecasting and coping strategies (Raddatz, 2009) and incentives for overreporting to secure more international assistance (Albala-Bertrand, 1993)).

[8] Aid and remittances get hardly placed within the context of post-disaster recovery. Scarce evidence suggests that they may lessen the growth impact (Hochrainer, 2009) or be neutral (Raddatz, 2009). Case studies hint at donors reallocating aid budgets, rather than providing additional aid after a disaster (Benson and Clay, 2004).

island states. They find a growth-dampening effect of large disasters in the short term, using EM-DAT data to derive intensity measures for material and human damages à la Fomby et al. (2013): Cabezon et al. (2015) for natural disasters (pooling all hazards) in 5 Pacific countries over 1980-2014 and Acevedo (2014) for storms and floods in 12 Caribbean countries over 1970-2009.

The significance of the fiscal effect remains unclear. For 81 high- and middle-income countries over 1975-2008, Melecky and Raddatz (2011) detect an expansion of the budget deficit after weather-related disasters only. Yet, when singling out lower-middle-income countries, they find some deficit increase across all hazard types. In a similar vein, Lis and Nickel (2010) find a higher budgetary impact in developing countries than in advance economies. In contrast, though, controlling for the business cycle in 42 countries using quarterly data over 1990-2005, Noy and Nualsri (2011) find a counter-cyclical response in developed countries, with lower revenues, and higher government consumption and debt. In developing countries, however, they discover pro-cyclical fiscal dynamics in the form of decreased spending, increased revenues and lower debt. Acevedo (2014) discovers that public debt somewhat increases after floods, but only in a subset after storms. Cabezon et al. (2015) obtain a significant widening of the overall balance (amounting to ½ percentage point of GDP) only in the first year after a disaster with large material damages, but never after one with large human damages.

III. DATA DESCRIPTION

A. Definition of Variables and Sources

The analysis centers on the extent of annualized and scaled losses caused by weather-related disasters. It studies the impact of experiencing a disastrous year (rather than event) to capture both the effect of rare large-scale events and frequent smaller-scale events. Data on disaster losses come from CRED's EM-DAT. Along six disaster hazards (Appendix Table 1), it reports disaster frequency (i.e. number of event occurrences) and three loss measures—one material and two human ones:[9] (i) material damages (in USD); (ii) total affected (i.e. number of people injured, homeless, and affected); and (iii) total deaths (i.e. number of people dead or missing). Thus, preparing the disaster data takes two steps. First, loss measures are aggregated across the four weather-related hazards: (i) meteorological hazards (e.g., cyclone or snow storm); (ii) hydrological hazards (e.g., flood or storm surge); (iii) climatological hazards (e.g., heat/cold wave or drought); and (iv) biological hazards (e.g., epidemic or locust infestation). Second, the data is standardized to allow comparability across time and countries. Material losses are scaled by GDP and human losses by population, using data from the IMF's WEO.

[9] EM-DAT claims to include all disasters from 1900 until the present, conforming to at least one of the following four criteria: (i) 10 or more people dead; (ii) 100 or more people affected; (iii) declaration of a state of emergency; and (iv) call for international assistance. For more detail, see Guha-Sapir et al. (2015).

A "severe disaster year" dummy is constructed for each of the three loss measures, i.e. material damage, people affected and casualties. In doing so, this paper follows the literature in studying the impact of a severe disaster year, regardless of its actual intensity above a chosen threshold level to help identify a disaster shock in its effect. Yet, unlike the literature, it differentiates across loss dimensions and employs a sample distribution-dependent threshold. More specifically, a dummy takes a value of 1 if an annualized and scaled loss observation ranks in the top 10 percentile of its loss distribution (pooled across all DAS countries and disaster years in the sample). Out of the 874 DAS country-year observations, 580 are disaster years, meaning that they saw at least one weather-related occurrence.[10] Thereof, 58 are severe along each loss dimensions, i.e. they cause losses exceeding the respective threshold (Table 2).

Table 2. Severe Disaster Year Thresholds, 1970-2015
(Annual material damages in pct. of GDP, human damages in pct. of population, conditional on an event)

Loss measure	90th percentile
Material damage	1.12
People affected	11.78
People dead	0.0019

Source: Own calculations.

Finally, the disaster dummies are matched with a set of macro-fiscal data. The macro-fiscal time series come from the IMF's WEO vintage in autumn 2016. Where data availability is an issue, series are complemented through splicing from different sources—including older IMF WEO vintages, World Bank WDI series, and IMF staff reports.[11] Remaining data constraints keep the panel unbalanced. Appendix Table 2 provides a full set of variables and data sources.

B. Stylized Facts

DAS countries face considerable risk of natural disasters, putting them ahead of peers worldwide. This owes to the interaction of their considerable exposure and high vulnerability to natural hazards (Appendix Figure 1).[12] Consequently, many DAS countries feature prominently in global rankings.[13] Relative to the RoDW and Asian AMs, their risk profile over the past 4½ decades exhibits:

- *predominance of weather-related disaster hazards* (Appendix Figure 2). Due to their geographical location and topography, all disaster hazards (except extraterrestrial) played a role in DAS countries. Yet unlike in peer countries, weather-related hazards were generally the predominant hazard type along all impact dimensions: EM-DAT reports 3250

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[10] Disaster years allow isolating the zero-damage observations related to lacking events and missing data, and so making damages conditional on occurrence.

[11] When splicing, several decision rules and robustness checks help minimize time series inconsistencies.

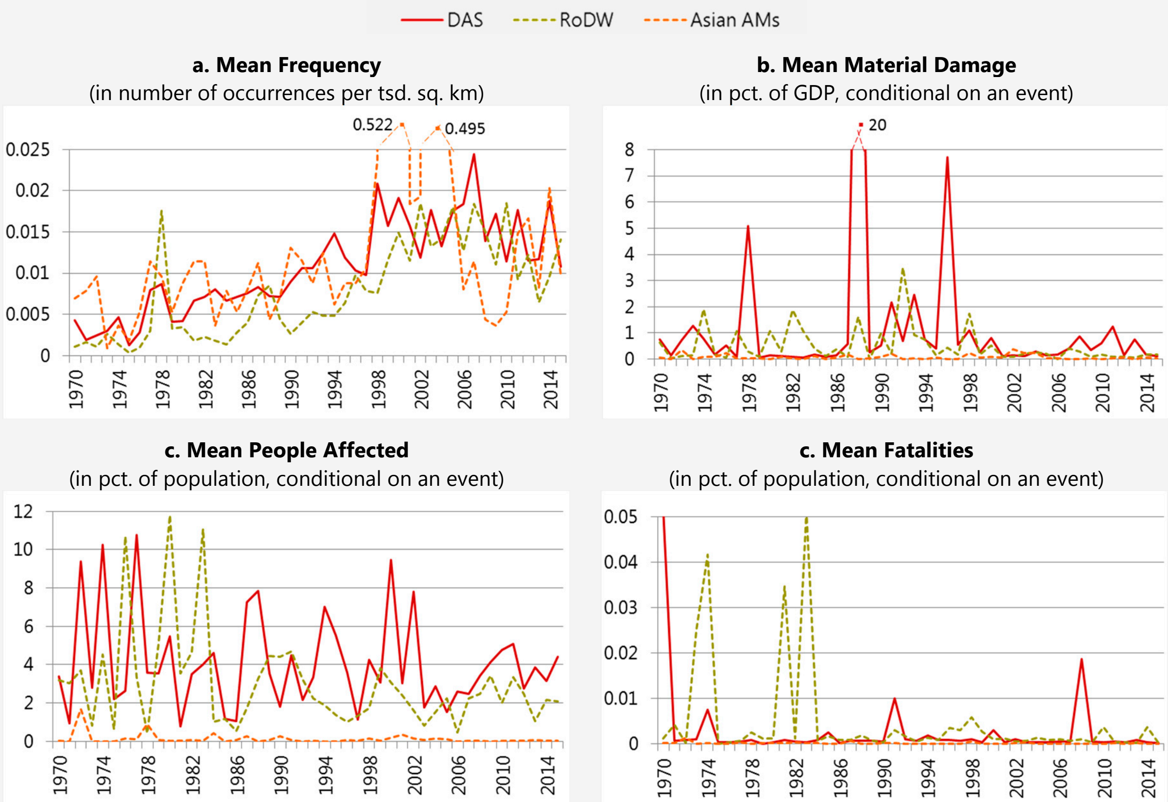
[12] As laid out in UNU-EHS (2016), vulnerability captures the combination of three factors: susceptibility (i.e. the likelihood of suffering harm, which depends on, e.g., public infrastructure, nutrition, income, and the general economic framework); coping capacity (i.e. the capacity to reduce negative disaster consequences, which hinges on e.g. governance, medical care, and material security); and absorptive capacity (i.e. the capacity to develop long-term strategies for societal and spatial change related to future natural events and climate change).

[13] In the top ten of the most affected countries worldwide, the World Risk Index 2016 (UNU-EHS, 2016) lists four DAS countries (i.e. the Philippines, Bangladesh, Brunei Darussalam, and Cambodia) and the Global Climate Risk Index (Kreft et al., 2016) five (i.e. Myanmar, the Philippines, Bangladesh, Vietnam, Pakistan, and Thailand).

occurrences, causing USD 590 billion in material damages, affecting 6 billion people and killing more than 1 million.[14] Average impact severity varies across hazard types: while hydrological hazards were the most frequent and meteorological the deadliest, climatological caused the highest toll of material damage and affected people.

- *heavily drawn-out right tail of the loss distribution*. Along all loss dimensions alike, average disaster intensity varies considerably across countries and years (Table 1 and Figure 1), mostly driven by extreme events. These events make damages follow a heavily right-skewed distribution, especially in DAS and RoDW countries (Appendix Table 3).

Figure 1. Patterns of Weather-Related Disasters, 1970-2015



Source: Own calculations using CRED EM-DAT, WB WDI and IMF WEO.

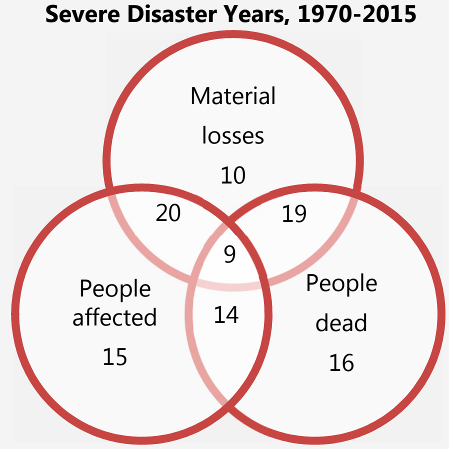
- *higher frequency of severe disaster years*. Applying the DAS-specific loss thresholds (Table 2) to all countries shows that DAS countries experienced a much larger number of extreme disaster years per country than their peers, particularly in terms of material damage and people affected (Appendix Figure 3). Their occurrence also fluctuated notably over time.

[14] Despite including earthquake-prone countries located on the intersection of the Indian and Eurasian plate (e.g., Nepal, India, or Myanmar), weather-related disasters occurred 18 times more often, caused 3 times more material damages, affected 13 times more and killed almost as many people over 1970-2015 compared to geophysical disasters. In the RoDW and Asian AMs, geophysical events were both less frequent and affected fewer people, but they caused higher material damage and casualties than weather-related events.

- *almost no co-movement of disaster indicators*. Over time, average frequency and severity measures have not been moving in tandem (Figure 1). Unlike average frequency, average material and human damages have generally been trending downward.[15] More recently though, this seems on the reverse in DAS countries: frequency has eased, but more significantly, the number of people affected and material damages have ticked up. More formally, Pearson correlation coefficients (PCCs) close to zero point to largely uncorrelated disaster indicators in DAS and the RoDW alike, particularly across the loss measures of material damages, people affected and dead (Appendix Table 4). Correlation somewhat strengthens in a subset of disaster years with positive losses along all three loss measures, especially in Asian AMs.

- *limited overlap between affected loss dimensions in severe disaster years*. Hardly correlated loss measures also translate into limited overlap between severe disaster year dummies for DAS countries (Figure 2): nine across all three loss dimensions and some more across two loss dimensions (i.e., 14 across people affected and dead, 19 across people dead and material losses, and 20 across material losses and people affected). Each dummy also captures a unique set of severe episodes across various hazard types (Appendix Table 5), determined by the combination of the hazard strength and the vulnerability of the exposed people and physical assets. More extremely, the top 10 most severe disaster years in DAS features no case of overlap across three loss dimensions and only two cases across two (Appendix Table 6): one between material damages and people affected (Myanmar 2008, reflecting mainly the impact of cyclone Nargis) and one between people affected and dead (Bangladesh 1974, reflecting mainly the impact of two cyclones).

Figure 2. DAS—Overlap between Severe Disaster Years, 1970-2015



Source: Own calculations.

IV. Economic Outcomes and Policies After Weather-Related Disasters

Drawing on an unbalance panel of DAS countries from 1970-2015, this section starts by using regression analysis to derive how weather-related natural disasters affect growth and key fiscal aggregates. To shed light on the drivers of the results, the section then takes a more granular approach by discussing evidence from event and case studies on the behavior of decomposed macro-fiscal variables.[16]

[15] OCHA (2016a) partly attributes decreasing fatalities to advances in early warning and disaster preparedness.

[16] While not attempting to establish causality, these event studies better capture relationships (including non-linear dynamics) and are less demanding on the length of the time series than the panel-VARX approach.

A. Impact on Growth and Key Fiscal Aggregates

This sub-section estimates a fixed effects unbalanced panel vector autoregressive model with exogenous shocks (panel-VARX) to simulate the impulse response functions (IRFs) of growth and key fiscal aggregates to a severe weather-related natural disaster.

Empirical Approach

The panel-VARX specification assumes that weather-related disasters are exogenous shocks in t_0 with a contemporaneous macro-fiscal impact.[17] The model includes four endogenous variables (i.e. real GDP per capita growth, primary balance, tax revenues, and expenditures)[18] and a severe disaster year dummy. To contrast the impact across loss dimensions, the model is run separately for each dummy. Fiscal variables are expressed as a share of GDP and first-differenced to ensure stationarity.[19] Data constraints require dropping two countries (Afghanistan and Timor-Leste) and minimizing the number of parameters (only allowing for one lag structure, although including longer lags corroborates the robustness of the results).

$$Y_{i,t} = \alpha_{j,i} + \beta_{j,1} Y_{i,t-1} + \gamma_{j,0} X_{j,i,t} + \gamma_{j,1} X_{j,i,t-1} + \varepsilon_{j,i,t}$$

with

$$Y_{i,t} = \begin{bmatrix} real\ GDP\ p.c.growth_{i,t} \\ \Delta\ overall\ fiscal\ balance - to - GDP\ ratio_{i,t} \\ \Delta\ tax\ revenue - to - GDP\ ratio_{i,t} \\ \Delta\ total\ government\ revenue - to - GDP\ ratio_{i,t} \end{bmatrix},$$

where $i = \{1, 2, \ldots, \mathrm{N}\}$ is the country index; $t = \{1, 2, \ldots, T_i\}$ the time index for each country i; $j = \{\text{material damage, people affected, people dead}\}$ the index for the disaster loss dimension; $\alpha_{j,i}$ a fixed effect coefficient (capturing the unobserved (time-invariant) heterogeneity); $\varepsilon_{j,i,t}$ a vector of errors; $Y_{i,t}$ a vector including the four endogenous variables; and $X_{j,i,t}$ the severe disaster year dummy along the loss dimension j (as defined in Section III.A).

Results

Two key findings stand out, from the IRFs on the period-by-period macro-fiscal (Figure 3) and cumulative growth impact (Figure 4). First, there is evidence of a significant negative impact on growth (even permanent), but not on fiscal aggregates.[20] Second, the scale, timing, and permanency of the growth and fiscal effects vary with the loss dimension. The latter is not implausible, considering the very weak correlation across loss measures (Section III.B), which in turn limits the overlap between the three severe disaster year dummies (Figure 2). Besides, the

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[17] Following IMF (2008), natural disasters are treated as conditionally exogenous variables, since they are not determined by economic choices, at least not in the short run.

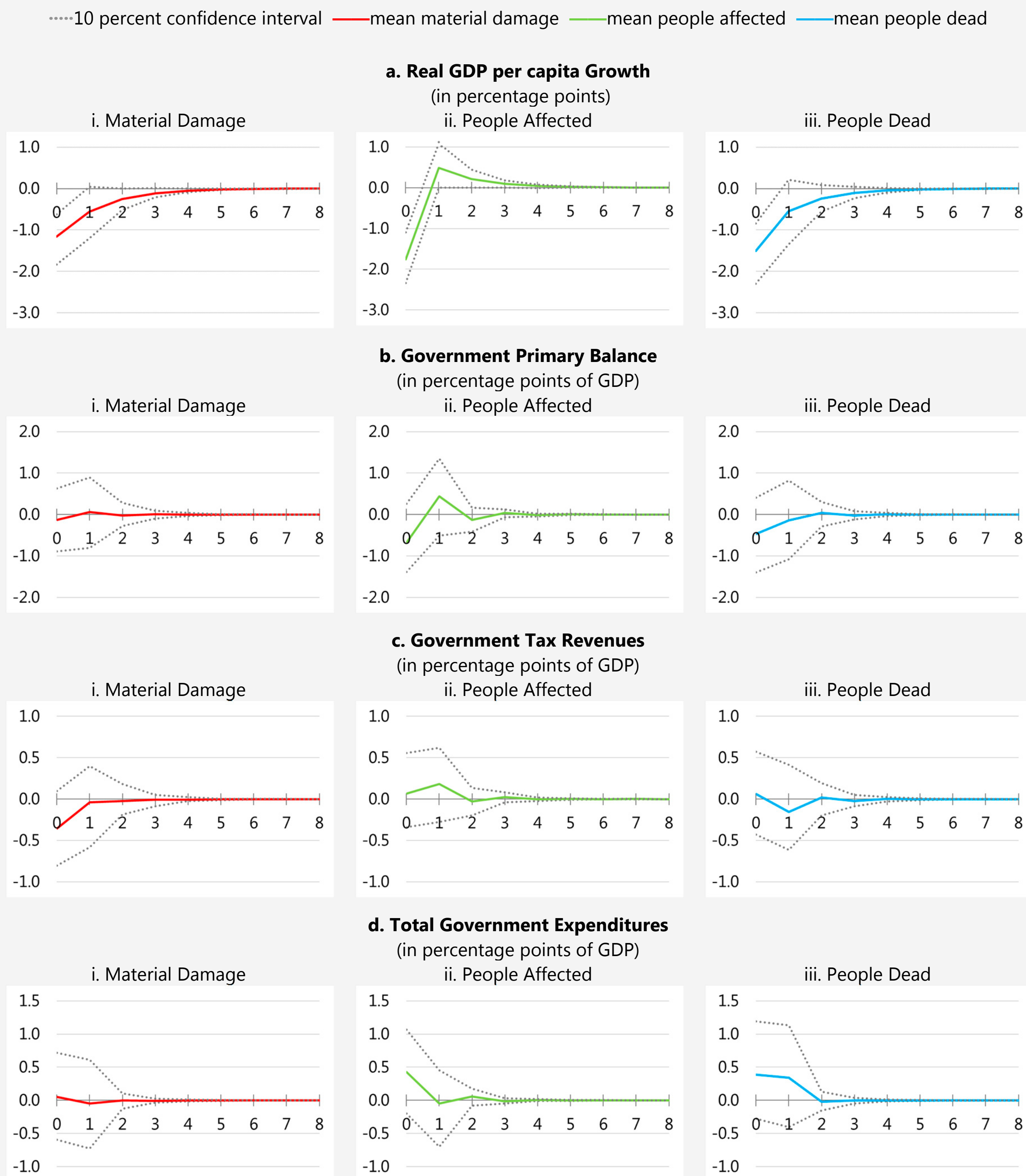
[18] The empirical results are broadly robust to the inclusion of other variables, such as total revenues, overall balance, primary expenditures, or public debt.

[19] While both the Fisher-type and Im-Pesaran-Shin panel data unit root tests allow rejecting the null hypothesis of the growth and overall balance-to-GDP series containing a unit root, they do not allow doing so for the tax revenue- and expenditure-to-GDP ratio. This is only possible after first-differencing the latter two.

[20] Where the focus of analysis overlaps, this paper's results are broadly consistent with Acevedo (2014), Cabezon et al. (2015), and von Peter et al. (2012).

IRFs along each loss measure capture quite heterogenous post-disaster outcomes and policies, as evidenced by the width of the confidence bands.

Figure 3. DAS—Period-By-Period Response to Severe Weather-Related Disasters, 1970-2015
(17 DAS countries, 300 bootstraps)



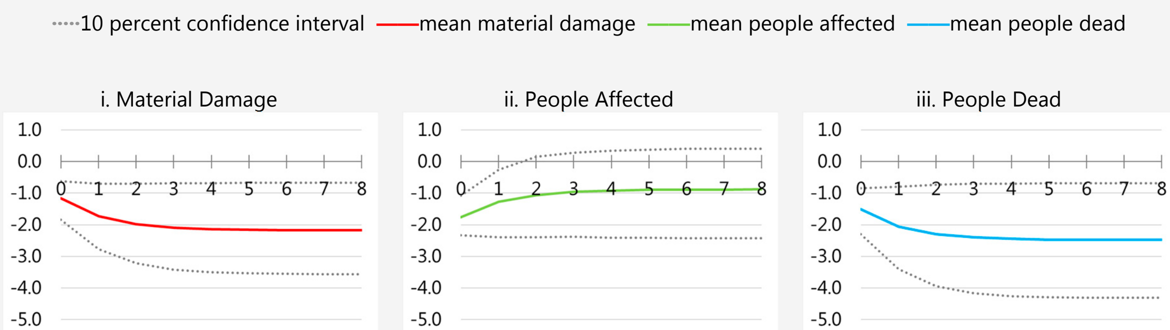
Source: Own calculations using EM-DAT; WB WDI; IMF WEO; and IMF staff reports.

More specifically, while short-term GDP growth declines the most when people are affected, permanent output losses occur when material assets are damaged or people die.

Irrespective of the loss dimension, severe disaster episodes entail an immediate significant growth collapse of more than 1 percentage point. Yet, while those that affect people hit economic growth the hardest in t_0 (on average by 1.8 percentage points, Figure 3.a.ii), they also cause a boom in *t+1*. This attenuates the significance and scale of the permanent output loss (Figure 4.ii). In contrast, the severe episodes that entail material damages or casualties, suffer a sluggish growth rebound spanning several periods (Figure 3.a.i and iii). This results in significant permanent output losses of 2.2 and 2.5 percentage points, respectively (Figure 4.i and iii).

Meanwhile, fiscal aggregates remain insignificant and subdued across all loss measures, albeit differently shaped (Figure 3.b-d). Along both human loss dimensions, the mean primary deficit temporarily widens by about ½ percentage point of GDP in t_0, reflecting spending increases by almost ½ percentage point of GDP in the presence of roughly stable tax revenues. However, unlike in *t+1* after severe episodes involving fatalities, those involving people affected see tax revenues increase and spending stabilize with the economic rebound. In contrast, the episodes involving severe material damages leave the primary balance and expenditures largely unaffected. It is tax revenues that take a temporary hit in t_0.

Figure 4. DAS—Cumulative Growth Response to Severe Weather-Related Disasters, 1970-2015
(i.e. real GDP per capita output, in percentage points, 17 DAS countries, 300 bootstraps)



Source: Own calculations using EM-DAT; WB WDI; IMF WEO; and IMF staff reports.

B. Drivers of the Macro-Fiscal Impact

What could drive the result of severe weather-related disaster episodes causing a substantial economic growth decline in DAS over 1970-2015, but not fiscal deterioration? In fact, two thirds of these severe episodes came with an immediate reduction of the real GDP per capita growth rate—with almost a quarter and half of them exceeding five and two percentage points, respectively. In contrast, fewer than half of these severe episodes saw a worsening of the fiscal balance—with roughly half of them exceeding one percentage point of GDP. Unfortunately, however, fiscal policy responses are not documented in detail. That is why this sub-section resorts to event and case studies to shed light on the underlying dynamics at play.

Empirical Approach

Simple event studies allow describing in greater detail the evolution of a range of decomposed macro-fiscal variables.[21] They capture variables' mean behavior within a 5-year event window, i.e. two years before until two years after a severe disaster year t_0 (separately along each of the three loss dimensions). An overlap of event windows is prevented by dropping any subsequent severe disaster episode.[22] The influence of a small number of extreme outliers is removed by excluding periods of hyperinflation.[23] Besides, to derive meaningful and comparable mean paths, all variables (except for growth) are scaled by GDP and (except for the primary balance) first-differenced. Furthermore, for an episode to be included, data must be available not only for each year within the event window, but also for the primary balance.

Table 3. DAS—Overview of Case Studies

Severe Disaster Case	Loss Dimension			Outcome: Annual Change		Public Debt	
	material damage	**people affected**	**people dead**	**real GDP p.c. growth rate** (in pct. points)	**primary balance** (in pct. points of GDP)	**level** (in pct. of GDP)	**sustainability** (risk rating and year of analysis in paranthesis)
Afghanistan (2008, drought)			x	-9.0	-1.4	n.a.	high (2007)
Bangladesh (2007, twin floods/cyclone)	x	x	x	-0.2	0.4	39.1	low (2006)
Cambodia (2000, floods)	x	x	x	-2.9	-1.0	35.2	n.a. 1/
Lao PDR (2009, typhoon Ketsana)	x			-0.3	-2.9	62.8	high (2008, 09)
Mongolia (2008, severe winter dzuds)			x	-1.2	-5.3	20.4	low (2008)
Mongolia (2009, severe winter dzuds)		x		-9.9	-0.7	46.6	low (2009)
Myanmar (2008, cyclone Nargis)	x		x	-8.4	0.8	53.0	distress (2007)
Myanmar (2015, cyclone Komen)		x		-1.6	-2.0	33.3	low (2014)
Pakistan (2010, floods)	x	x		1.6	-1.5	61.5	n.a. 1/
Philippines (2011, twin typhoons)		x	x	-4.6	1.5	41.4	n.a. 1/
Philippines (2013, typhoon Yolanda)	x	x	x	0.4	0.3	39.2	n.a. 1/
Thailand (2011, heavy rain combined with multiple tropical storms)	x	x		-6.5	1.5	39.4	n.a. 1/

Note: 1/ No ratings are available for emerging market countries. However, for Pakistan (2010), IMF CR No. 10/6 attests that a "relatively benign debt outlook under the baseline scenario is subject to serious downside risks." For the Philippines (2011 and 2013), IMF CR No. 12/49 and 11/59 conclude that "the outlook for public debt dynamics is favorable." For Thailand (2011), IMF CR 10/344 summarizes that "in all scenarios, Thailand's public debt path would remain sustainable."

Sources: Own calculations using CRED EM-DAT, WB WDI, IMF WEO, Debt Sustainability Analyses (DSAs). Moreover, IMF Country Reports No. 09/135 for Afghanistan; 08/334 for Bangladesh; 01/35 for Cambodia; 10/294 and 11/76 for Mongolia; 17/30 and 17/31 for Myanmar; 10/295 for Pakistan; 14/245 and 12/49 for the Philippines; 12/124 and 13/323 for Thailand; Fernandez-Gimenez et al. (2012) for Mongolia; Lao (2009); World Bank (2015) and TCG (2008) for Myanmar; World Bank (2011a) for the Philippines; World Bank (2011b) for Thailand.

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[21] Data constraints, exacerbated by the prevalence of event window years in a substantial number of countries, preclude a meaningful application of an event study approach à la Gourinchas and Obstfeld (2012) or scaling of outcomes during (pre- and post-disaster) event windows against that during out-of-window normal periods.

[22] Results are generally robust if instead the less severe disaster episodes get dropped. What remains is a subset of severe disaster episodes (i.e. 37 for material damage, 33 for people affected, and 30 for people dead).

[23] Following Fischer et al. (2002), the inflation threshold amounts to 100 percent yearly. Note that the results are also broadly robust to a lower threshold, such as the 20 percent used in Reinhart and Rogoff (2011).

In addition, case studies provide valuable anecdotal evidence. They cover 12 especially damaging severe disaster year episodes since 2000, gathering insights from various sources (primarily IMF Staff Reports). See Table 3 for details.

Results

Overall evidence suggests that in contrast to growth, the fiscal impact is largely under the direct control of a government. Several key factors shape the size and structure of the fiscal policy response: (i) extent of the public sector's losses; (ii) efficacity of the private sector's response; (iii) motivation for public intervention (i.e. aggregate demand management to support ailing growth or distributional measures to assist the distressed part of the population or economy); and (iv) ability of the public sector to react (reflecting the extent of constraints, including those related to fiscal space, capacity, or budget and political rigidities). The following discussion touches upon every aspect separately.

First, the extent of the public sector's direct disaster cost—which typically only amounts to a fraction of the total (if at all). Direct strain on public balance sheets is generally limited: direct human losses and damages fall entirely on the private sector, and so do in general the bulk of the direct material ones. In some cases, the private sector's share was as high as 90 percent (e.g., the Philippines 2011 and 2013, Thailand 2011, and Myanmar 2015), in others nearly two-thirds (e.g., Lao PDR 2009). An exception seems to be Myanmar (2008), where two-thirds of the total cost fell on the public sector because of the involvement of large state-owned enterprises. In any case, the public sector usually prioritizes the repair and reconstruction of crucial infrastructure, putting upward pressures on current and capital expenditures, respectively.[24] Yet, given lags related to impact assessment, project planning, and procurement processes, this spending often only materializes in subsequent budget cycles in a quite seamless way through a reprioritization of maintenance and project plans.

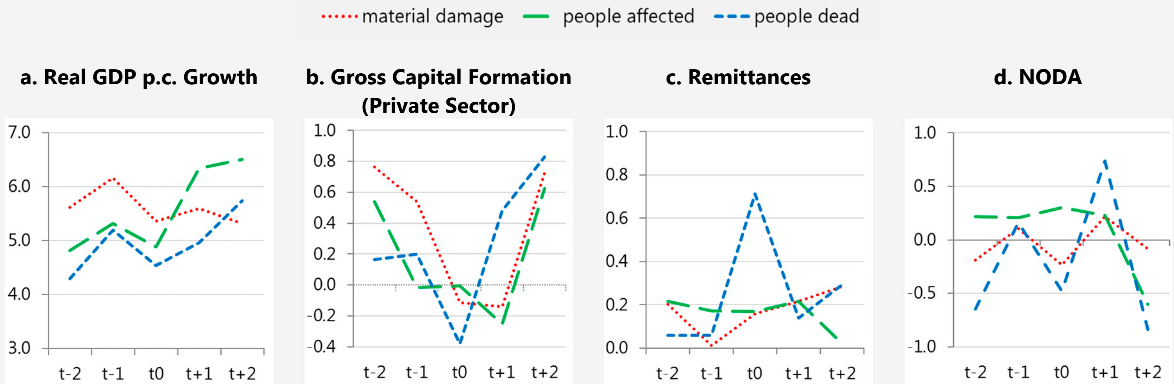
Second, the efficacity of the private sector's disaster response—which (at least partially) substitutes for a public response. The private sector's disaster response seems faster and stronger than the public sector's, pressured by relatively higher direct costs and aided by external support.[25] Comparing the evolution of the gross capital formation of the private sector (Figure 5.b) to that of the government's capital expenditure (Figure 6.c) suggests that the private sector plays an important role in the disaster response. It even precedes and hence can at least in part substitute for a public response. It is also facilitated by the availability of fast and new financing. While financial and insurance markets are still in a development stage in DAS, remittances are a

[24] Revenues may take a hit as well, especially where payment systems or tax administrations (physical and human capacity alike) are destroyed (e.g., Haiti earthquake in 2010).

[25] For instance, after the 2004 Indian Ocean earthquake and tsunami, the UN raised half of its support from private donors and many global companies sent in-kind goods, provided communications or IT support, and lent logistics staff (Thomas and Fritz, 2006). Many multinational corporations also got deeply involved in the relief effort through their local subsidiaries and in partnership with the Red Cross and other aid agencies (such as Coca-Cola converting its soft-drink production lines to bottle drinking water and using its own distribution network to deliver it to relief sites; or British Airways, UPS, FedEx, and DHL working with their existing aid agency partners to furnish free or subsidized transportation for relief cargo). Also, see Chandra et al. (2016) for a general discussion of the role of the private sector in supporting disaster preparedness and recovery.

more important source (Figure 5.c). They increase immediately after the disaster (especially after those with severe casualties) and continue to grow, first financing emergency relief and then reconstruction.

Figure 5. DAS—Event Study on Growth, Capital Formation, and External Inflows, 1970-2015
(19 DAS countries, in first differences (i.e. percentage points of GDP) for all variables but growth (in percent))



Source: Own calculations using EM-DAT, WB WDI, IMF WEO and staff reports.

Third, the motivation for public intervention—which can be managing aggregate demand and/or distributional impacts. After a severe disaster, governments assess damages and losses, evaluate the private sector response, and revisit their fiscal frameworks to decide on the appropriate fiscal policy response. Where fiscal space and available financing allow (including where helped by donor support), fiscal stimulus would help economies respond to weakening demand. This seems particularly warranted after severe cases of material damage and people dead. Some governments indeed answered with countercyclical fiscal policy (e.g. Pakistan 2010 or Afghanistan 2008), at times even supported by large off-budget investment packages (e.g. Thailand 2011). Others seem to have felt they had more room to let the primary balance deteriorate when they started from a surplus in the pre-disaster period (e.g., Mongolia 2008). But even where growth remains resilient or fiscal space and available financing are a bottleneck, at least distributional measures might be needed to assist the distressed part of the population or economy. More often, however, demand management and distributional objectives coincide (e.g., Pakistan 2010).

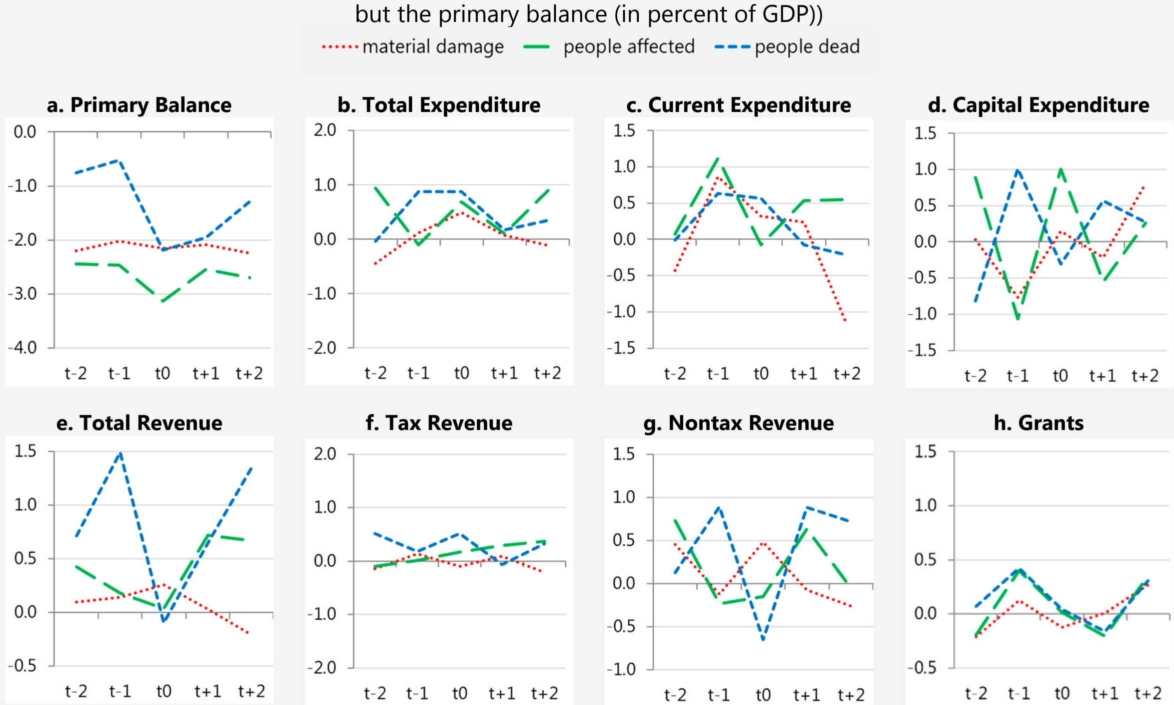
Fourth, the ability of the public sector to react—which can be limited to compensating budget measures, especially where fiscal space, capacity, budget, and political rigidities are an issue (Figure 6). Even in the face of a growth decline, some governments largely preserve their original fiscal stance. Some capitalize on budgetary overperformance (e.g. Bangladesh 2007, Cambodia 2000, or Mongolia 2008 and 2009); others exert strict budget discipline, even if debt levels provided some fiscal buffer for countercyclical policy (e.g. Myanmar 2015) or end up contracting their fiscal stance (e.g., the Philippines 2011). All in all, they rather spend in line with available resources. This is particularly evident along the material dimension. The fiscal stance is broadly preserved (Figure 6.a) thanks to total spending (Figure 6.b) moving in tandem with total revenue (Figure 6.e), especially during the expansion in t_0 and subsequent contraction. However, both human loss dimensions experience some fiscal deterioration in t_0 as spending expands whilst total revenue plateaus. These dynamics reverse subsequently. At the same time, however, fiscal aggregates mask a range of compensating measures on both sides of the budget:

- *The revenue side sees*:
  - *tax mobilization efforts*. After severe disaster episodes along both human dimensions, tax revenues (Figure 6.f) grow before the macro environment normalizes (Figure 4.a). Anecdotal evidence attributes this to more ambitious revenue mobilization efforts on the authorities' side. For instance, in 2010, Pakistan introduced a temporary 10 percent income tax surcharge (aiming at generating 0.4 percent of GDP) and started to further broaden the tax base and improve tax compliance. Besides, tax revenues remain quite resilient in the first place, when the disaster hits parts of the economic activity or people that do not pay taxes anyways (e.g. informal sector or subsistence farmers) or when tax payments are based on pre-disaster economic activity (e.g., corporate income taxes).
  - *windfall of non-tax revenues and natural resource income*. Higher nontax revenues (Figure 6.g) compensate for ailing tax revenues (Figure 6.f) and grants (Figure 6.h) in the severe disaster year along the material dimension and the year after along both human dimensions. For instance, in 2010, the Mongolian government happened to benefit from a surge in fiscal revenues due to a large one-off cash payment from an investment agreement and strong copper prices.
  - *recourse to external official support*. Efforts to support weak tax revenues with external grants materialize in a pickup in average grants in the second year after the disaster (Figure 6.h), likely to support the reconstruction phase (characterized by increased capital expenditures). Furthermore, the magnitude and timing of net official development assistance (NODA, Figure 5.d) and debt relief (Figure 7.d) suggest that donors rather seem to respond through project grants starting in the early reconstruction phase and immediate debt relief (to reduce pressures from debt service mainly coming from the increased scarcity of cash and foreign exchange) rather than budget grants for immediate emergency relief. All in all, though, successful donor mobilization seems to depend on the availability of concrete public response plans, transparent public finances, and established donor relations. The experience of Pakistan in 2010 highlights that donors can respond quickly to fund emergency response efforts to provide food, shelter, water and sanitation, and health services. However, pledges for reconstruction financing only come in later, when damage assessments and recovery plans have been drawn up. This, however, can take time, mainly depending on the complexity of the disaster impact and government capacity. To attract more aid, countries also responded to disasters by speeding up reforms aimed at increasing the transparency of aid flows and accountability for their use (e.g. Pakistan 2010). Other governments have established Multi-Donor Trust Funds to coordinate the deployment of foreign support in the reconstruction phase (e.g. the Philippines 2013). In addition, the maturity of donor relations and political context matter. This shows in the case of Myanmar, where—despite of having made a call for assistance to the international community in 2015 (unlike in 2008)—external support largely remained absent. This could reflect the government's inexperience in dealing with donors and donors' pre-election sensitivities. Only some donors and UN agencies slightly ramped up or redirected funding from other ongoing operations for their own disaster response (OCHA, 2016c).

- *The expenditure side sees:*
    - *rebalancing of capital and current expenditure* (Figure 6.b-d). In the disaster aftermath, spending pressures seem to differ along loss dimensions. Along the loss dimensions of material damage and casualties, lower capital expenditure makes room for current expenditure from emergency relief measures. This later reverses to meet reconstruction needs. The opposite dynamics present in severe disaster years involving people affected, where capital expenditures crowd out current expenditure. In contrast, along the dimension of people affected, capital expenditure crowds out current expenditure in the severe disaster year, which reverses the year after. When several dimensions are affected, government might also opt for a mix (e.g., Pakistan in 2010, shifting resources from nonpriority current and development spending to relief and reconstruction spending).
    - *other expenditure measures.* Anecdotal evidence also points to authorities reprioritizing expenditure (especially of the capital expenditure project plan), rationalizing current expenditure, accommodating disaster needs in subsequent fiscal years through the regular budget process (e.g., Myanmar 2015), or asking provinces to scale back non-essential spending (e.g., Pakistan 2010).

Figure 6. DAS—Event Study on Fiscal Dynamics, 1970-2015

(19 DAS countries, in first differences (percentage points of GDP) for all variables but the primary balance (in percent of GDP))



Source: Own calculations using EM-DAT, WB WDI, IMF WEO and staff reports.

There are several reasons why governments might engage in these compensating budget measures to contain fiscal deterioration. They may face:

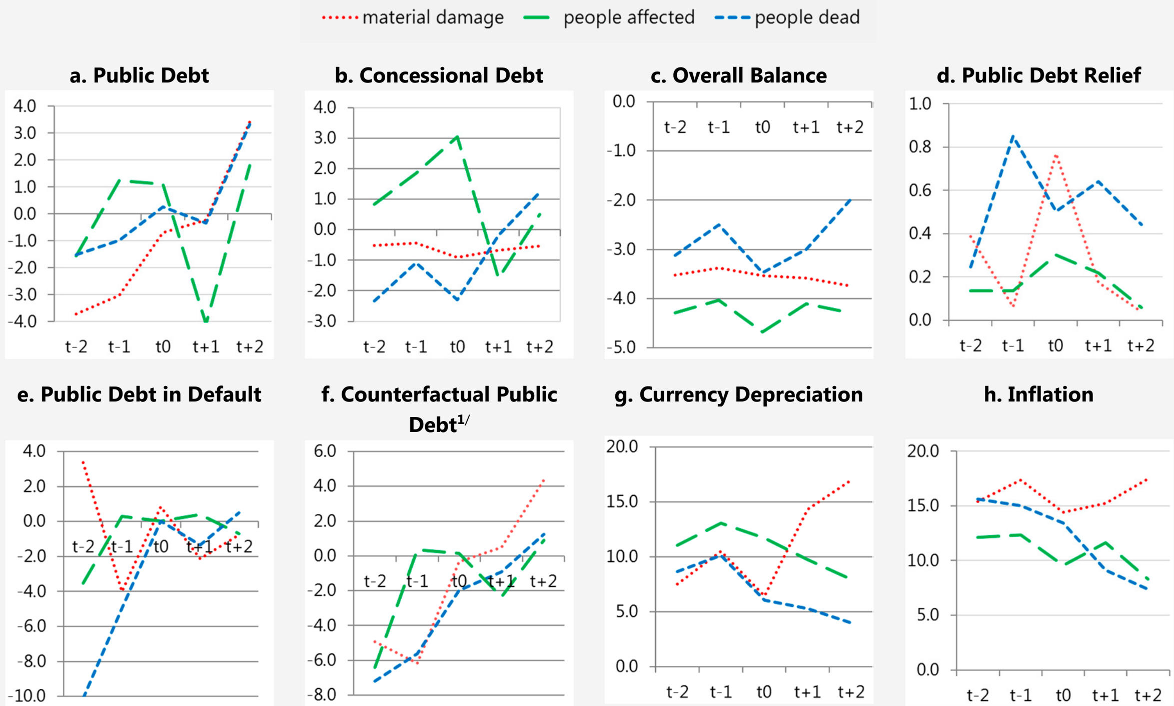
- *insufficient fiscal buffers.* Although most governments make budgetary provisions for unforeseeable events—some even specifically earmarked for natural disasters—their size commonly remains insufficient relative to the country's disaster risk (e.g., in Myanmar currently amounting to 0.1 percent of GDP). In case of a severe disaster, it then only covers a small part of the recovery and reconstruction needs. More governments have recently started off-budget natural disaster funds (e.g., the Philippines and Myanmar in 2013), with the aim of coordinating and financing measures that strengthen their response and resilience to future natural disasters at the supra-ministerial level. Yet, their firepower often remains quite small, hampered by slow resourcing (typically reflecting competing spending needs) and timid donor support (often reflecting transparency and governance issues). Also, a fiscal disaster response can fall short in the presence of limited debt buffers (e.g., Afghanistan in 2008 and Lao PDR in 2009) or limited room for additional domestic financing when access to external financing is difficult (e.g., Myanmar in 2015). Especially when paired with insufficient external grants, this can even result in procyclical fiscal policy (e.g., Myanmar in 2008).

- *weak capacity.* A subdued and slow public response can also reflect weak institutional capacity and quality, which are crucial to e.g., adequately assess damages and losses (including in areas that might be difficult to reach), aggregate information, design response policies, coordinate and communicate measures (not only within the public sector, but also with the civil society, donors, and multilateral organizations), and implement policies.
- *rigid budget processes and political impasse*. Financial rules and regulations often only allow for re-appropriations within the same budget line (at times even only at the level of line ministries, projects or sub-federal bodies). This confines governments to responding to the most immediate spending pressures by reprioritizing within spending categories. With escape clauses being widely unusual, more substantial spending reallocations or an expansion of the spending envelope require passing a revised budget. However, complex and lengthy budget preparation procedures and a tight parliamentary majority can deter governments from doing so. Like in Myanmar in 2015, they may then rather opt for addressing sizable spending pressures in upcoming budget cycles. Regulatory delays around the public investment plan can lead to a similar outcome (see above).

Nevertheless, public debt dynamics ultimately see some worsening in the severe disaster aftermath (Figure 7). This happens despite increased debt relief (which also helps contain the amount of government debt in default) and contained fiscal deterioration, most foremost because of adverse growth dynamics (Figure 5.a). Beyond this, debt dynamics also exhibit some stock-flow-adjustment, owing to a depreciation of the exchange rate and materialization of contingent liabilities. Concessional borrowing resumes with reconstruction, with little effect on debt dynamics thanks to typically long grace periods.

Figure 7. DAS—Event Study on Debt Dynamics, 1970-2015

(19 DAS countries, in first differences (percentage points of GDP) for all variables but the overall balance (in percent of GDP) and annual rates of currency depreciation and inflation (in percent))



Source: Own calculations using EM-DAT, WB WDI, IMF WEO and staff reports.

Note: 1/ The counterfactual debt ratio adds the cumulative debt relief to the public debt ratio.

V. CONCLUSION

This paper shows that weather-related disasters trigger different macro-fiscal outcomes, depending on whether they involve severe losses along the dimension of material damage, people affected, or fatalities. Given their very weak correlation and different pattern of macro-fiscal responses, disaster intensities along the three available material and human loss measures are not interchangeable and hence need to be considered separately.[26]

In addition, this paper finds that while the impact of a severe weather-related disaster on growth is large along all loss dimensions, the impact on fiscal aggregates appears muted. Yet, stressing that the latter is largely under the control of a government, event and case studies help understand why a—commonly expected—fiscal deterioration fails to appear: it may indeed be the appropriate reaction or reflect binding constraints. Four key drivers of a fiscal policy reaction to a severe disaster emerge: (i) the extent of direct public sector damages losses, which is most often only a fraction of the private's; (ii) the adequacy of the private sector response, which often substantially substitutes for the public's (as it is faster, also aided by fresh financing, above all from remittances); (iii) the normative case for public intervention, either originating in the need for countercyclical fiscal policy or distributional objectives; and (iv) the room to

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[26] This also implies that deriving intensity measures as the (weighted) average of different loss measures—such as in Fomby et al. (2013) or Adedeji et al. (2016)—can significantly bias the results.

maneuver of the public sector, which may be inhibited by insufficient fiscal space, weak capacity, or rigid budget and political procedures. This can result in a recourse to a range of mitigating fiscal policy measures aimed at containing a fiscal deterioration (e.g., expenditure rebalancing, reprioritization, or revenue and grant mobilization).

Acknowledging the particularities of the macro-fiscal impact along various loss dimensions can help adopt a more customized risk-based approach to disaster-risk management and adaption. This would help inform resilience strategies, prioritize climate change actions, and improve the cost-efficiency of adaptation measures. This is especially important for DAS countries, which are severely affected along all loss dimensions at varying degrees and which will likely be among the hardest hit by climate change worldwide (IPCC, 2014b and GFDRR, 2015).[27] While natural disasters can neither be prevented, nor their impact be fully predictable, DAS countries should reduce their macroeconomic vulnerability by enhancing ex-ante resilience and ex-post adaptive capacity to more effectively mitigate the impact of weather-related disasters. To address weaknesses in the areas of fiscal policy, institutions and capacity, they should:[28]

- *improve fiscal risk management and public financing assistance*,[29] mainly by explicitly identifying and adequately integrating weather-related natural disaster risks into the medium-term fiscal framework, setting of the fiscal stance and debt sustainability analysis. This would help determine how much to spend on mitigating impact and how much to self-insure by creating an adequate fiscal contingency buffer within the budget. To sustain those buffers, a fiscal rule—targeting an underlying fiscal balance during normal times that builds buffers and borrowing space—could provide the needed discipline.
- *regularize fiscal policy and budget process flexibility*, e.g. by incorporating some escape clauses for natural disasters in budget laws and fiscal rules, or streamlining the process for preparing and passing a revised budget;
- *generate fiscal space to finance climate change mitigation and disaster response programs,* by enhancing domestic revenue mobilization and tapping into newly available international

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[27] Some countries have already started to feel the pinch of changing weather patterns relative to the natural variability, such as Myanmar during the unusually severe El Niño phenomenon in 2015–16: extreme temperatures, unusual rainfall patterns, dry soil, high risk of fires, and acute water shortages (OCHA 2016b). Going forward, though, the overall economic impact is hard to quantify, as it depends not only on how effectively global climate policy measures can limit global mean temperature increases, but also how effectively countries can adapt to the changing climate environment. Even for the global economy as such, there are only a few, but very varying cost estimates. For instance, Tol (2014) estimates that a global warming of 3ºC might cost about 2 percent of GDP, while the World Bank (2013) estimates that a 1.5° to 2°C warming could lead to a 6 to 12 percent reduction in rice yields in the Mekong River Delta, whilst other crops may experience decreases ranging from 3 to 26 percent by 2050.

[28] For a discussion of the range of fiscal institutions and policies that are relevant for managing the macroeconomic vulnerabilities posed by weather-related disasters, see e.g. Laframboise and Loko (2012), Mechler et al. (2106), Clarke and Dercon (2016), or Farid et al. (2016), as well as ADB (2013) more specifically for Asian countries and IMF (2016) for small states.

[29] See Guerson (2016) for an assessment of government self-insurance needs in the Eastern Caribbean Currency Union, OECD (2015) for a cross-country comparison of government disaster compensation and financial assistance arrangements, including examples from the region (such as India, Malaysia, or the Philippines), and World Bank (2014) for an operational framework for disaster risk financing and insurance.

support[30] to finance programs that address macroeconomic vulnerabilities, including improving social safety nets, facilitating access to finance and insurance (including disaster insurance), and promoting disaster-resilient infrastructure (especially of physical transport and energy generation, public health capacity, risk-informed spatial planning, building standards, and payment systems);

- *overhaul energy subsidies and taxation (as a means to deliver on both creation of fiscal space and concretization of a climate change adaption policy),* by gradually eliminating poorly targeted energy subsidies, adjusting artificially low electricity prices, and introducing carbon taxation. Besides raising revenue, the latter can help countries follow a cleaner, more sustainable economic development path, and deliver on their emission commitments (e.g. as part of the 2015 Paris Agreement on climate change).[31] Carbon taxes are easy to implement and administer, e.g. through a straightforward extension of fuel taxes. The redistributive implications of such measures would require mitigating measures, such as the introduction of well-targeted subsidies for the most vulnerable.
- *strengthen government effectiveness,* by improving institutional capacity and quality, especially coordination and communication (not only within the public sector, but also with the civil society, donors, and multilateral organizations), planning, information aggregation and management, policy design and implementation.

[30] To secure more resources for integrating the adaption to and mitigation of climate change in development planning and countries' Sustainable Development Goals (SDGs), advanced countries promised developing countries during the Paris Conference on climate change at end-2015 to mobilize US$100 billion annually by 2020 to support developing countries.

[31] Excluding China, DAS countries' share of 2012 global greenhouse emissions was on average 0.8 percent per country, compared to 0.4 percent in the RoDW and 1.4 percent in Asian AMs, but often more due to ongoing deforestation than old and dirty industries (Admiraal et al., 2015).

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APPENDIX

Appendix Table 1. Natural Disaster Epidemiology

Peril type	Definition: A hazard ….	Examples
Weather-Related		
Meteorological	… caused by short-lived, micro- to meso-scale extreme weather and atmospheric conditions that last from minutes to days.	tropical cyclone; extra-tropical cyclone or winter storm; snowstorm; convective storm, including severe storm, hailstorm, tornado and lightning; local windstorm; sand or dust storm
Hydrological	… caused by the occurrence, movement, and distribution of surface and subsurface freshwater and saltwater.	general flood; flash flood; storm surge; glacial-lake-outburst flood; avalanche; landslide caused by rainfall
Climatological	… caused by long-lived, meso- to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability.	heat wave; drought; wildfire; cold wave; frost; extreme winter conditions
Biological 1/	…. caused by the exposure to living organisms and their toxic substances (e.g. venom, mold) or vector-borne diseases that they may carry. Examples are venomous wildlife and insects, poisonous plants, and mosquitoes carrying disease-causing agents such as parasites, bacteria, or viruses (e.g. malaria).	locust infestation; plague of vermin; epidemic plant diseases
Non-Weather-Related		
Geophysical	… originating from solid earth.	earthquake; volcanic eruption; tsunami; subsidence due to geological causes; "dry" landslide caused by earthquake, volcanic eruption, or geological processes; rock fall
Extraterrestrial	… caused by asteroids, meteoroids, and comets as they pass near-earth, enter the Earth's atmosphere, and/or strike the Earth, and by changes in interplanetary conditions that affect the Earth's magnetosphere, ionosphere, and thermosphere.	asteroid impact; solar storm

Source: EM-DAT (2016), Below (2009), and Kron et al. (2012).

Note: 1/ In practice, what first seems a biological event (such as insect infestation) was often actually triggered by a weather-related peril (e.g. climatological peril). Different databases might thus classify an event in different peril classes. Hence, biological disasters in general are often classified as weather-related perils.

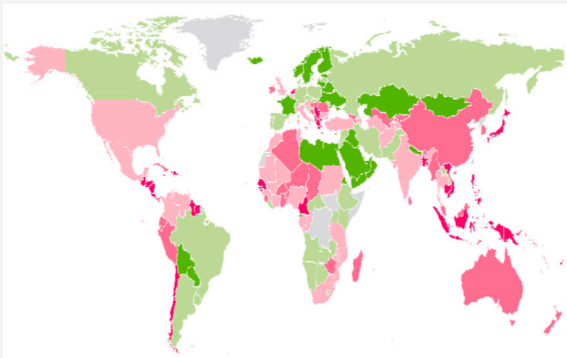
Appendix Table 2. Variables and Data Sources

Data	Definition	Source
Natural disaster data		
Occurrence	Number of disaster events.	CRED's EM-DAT
Material damage	Amount of damage to property, crops, and livestock (in USD). For each disaster, the registered figure corresponds to the damage value at the moment of the event, i.e. the figures are shown true to the year of the event.	CRED's EM-DAT
Total affected	Sum of injured, homeless, and affected. ▪ Injured are people suffering from physical injuries, trauma or an illness requiring immediate medical assistance as a direct result of a disaster. ▪ Homeless are people whose houses are destroyed or heavily damaged and therefore need shelter after an event. ▪ Affected are people requiring immediate assistance during a period of emergency, i.e. requiring basic survival needs such as food, water, shelter, sanitation and immediate medical assistance.	CRED's EM-DAT
Total death	Sum of people dead and missing. ▪ Deaths are people who lost their lives because the event happened. ▪ Missing are people whose whereabouts since the disaster are unknown, and who are presumed dead (official figure when available).	CRED's EM-DAT
Macro data		
Nominal GDP (in USD)		IMF WEO vintages, World Bank's WDI
Nominal GDP (in domestic currency)		IMF WEO vintages, World Bank's WDI
Real per capita GDP		IMF WEO vintages
Population		IMF WEO vintages, World Bank's WDI
Inflation		IMF WEO vintages, World Bank's WDI
Exchange rate	Units of national currency per US Dollar	IMF WEO vintages
Fiscal data		
General government primary fiscal balance	Overall fiscal balance excluding interest payments and receipts.	IMF WEO vintages, IMF staff reports
General government tax revenue		IMF WEO vintages, IMF staff reports, and IMF FAD-TP database
General government revenue		IMF WEO vintages, IMF staff reports
General government budget grants		IMF WEO vintages, IMF staff reports
General government current expenditure		IMF WEO vintages, IMF staff reports
General government capital expenditure		IMF WEO vintages, World Bank's WDI
General government gross debt		IMF WEO vintages, IMF staff reports
General government concessional debt		World Bank's IDS
Debt relief and forgiveness		World Bank's IDS
Public debt in default		Bank of Canada
Other data		
Land size		World Bank's WDI
Net official development assistance		World Bank's WDI
Remittances		World Bank, Remittances database
Gross capital formation, private sector		World Bank's WDI

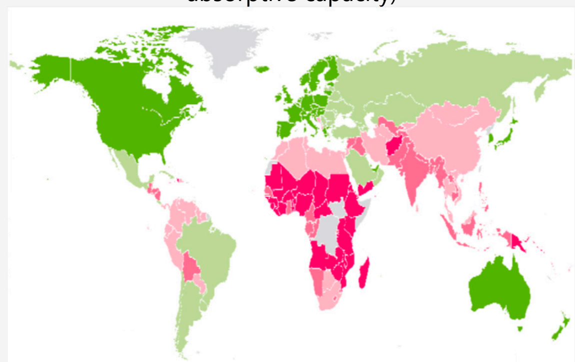
Appendix Figure 1. Disaster Vulnerability

very low quintile · low quintile · medium quintile · high quintile · very high quintile · no data

a. Exposure
(to natural hazards)



b. Vulnerability
(as the sum of susceptibility, lack of coping, and absorptive capacity)

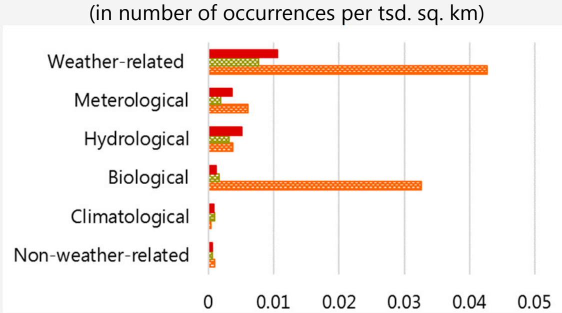


Source: World Risk Index 2016 from UNU-EHS (2016).

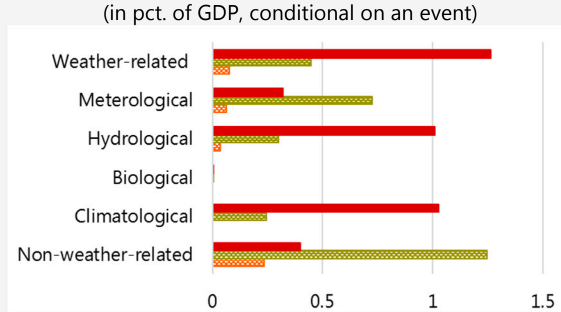
Appendix Figure 2. Disaster Impact Across Hazard Types, 1970-2015

DAS · RoDW · Asian AMs

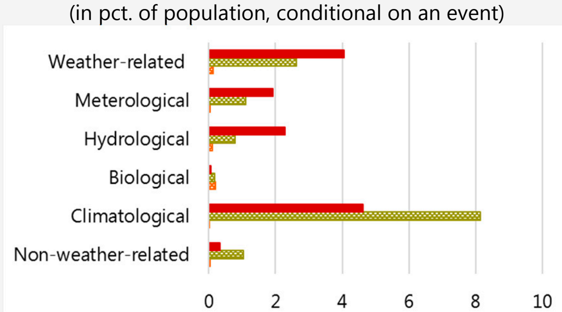
a. Mean Frequency
(in number of occurrences per tsd. sq. km)



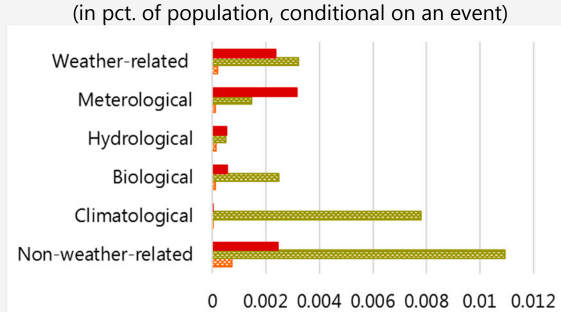
b. Mean Material Damage
(in pct. of GDP, conditional on an event)



c. Mean People Affected
(in pct. of population, conditional on an event)



c. Mean Fatalities
(in pct. of population, conditional on an event)



Source: Own calculations using CRED EM-DAT, WB WDI and IMF WEO.
Note: The non-weather-related disaster impact reflects that of geophysical events, as there were no extraterrestrial events.

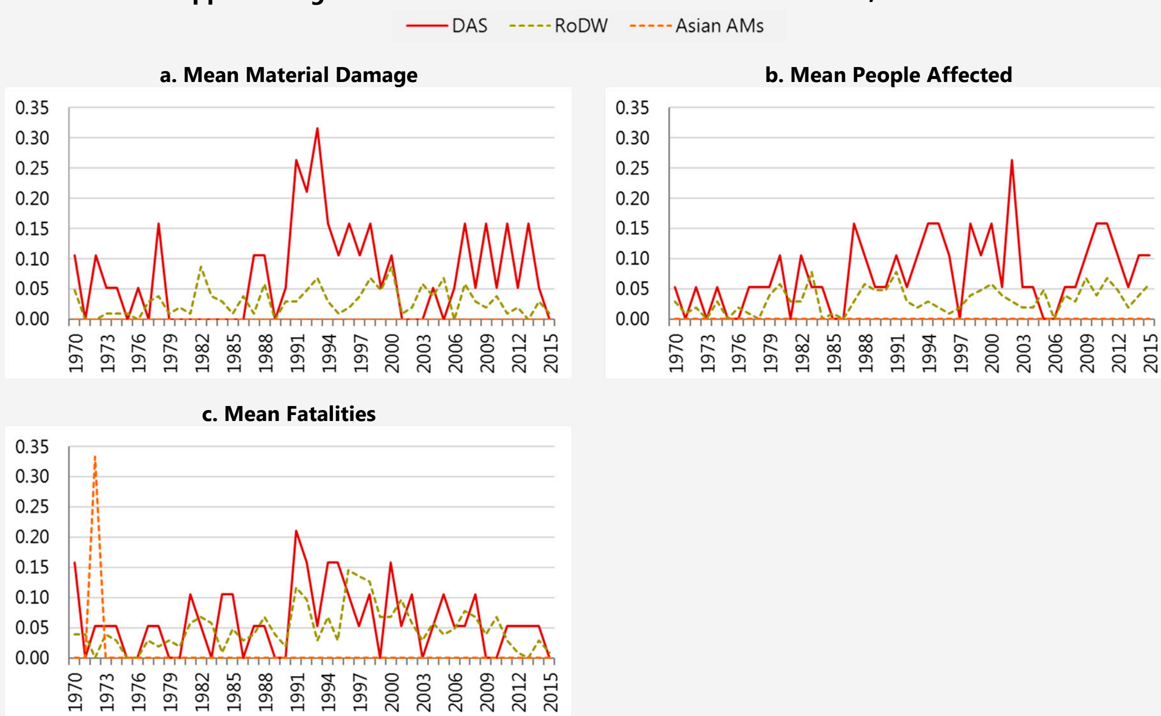
Appendix Table 3. Summary Statistics for Disaster Years, 1970-2015

(Occurrence per tsd. sq. km., material damages in pct. of GDP, human damages in pct. of population)

	No. of Obs.	No. of Disaster Years	Mean	Median	90 Percentile	95 Percentile	Max	St. Dev.	Skewness	Kurtosis
DAS										
Occurrence	874	580	0.02	0.01	0.05	0.06	0.20	0.02	3.28	19.90
Material damage	874	580	1.26	0.01	1.12	3.15	260.00	12.08	18.49	376.61
People affected	874	580	4.05	0.81	11.78	17.85	111.82	8.73	5.58	51.57
People dead	874	580	0.0024	0.0003	0.0019	0.0034	0.4530	0.0226	16.82	307.29
RoDW										
Occurrence	4692	2188	0.02	0.00	0.04	0.08	1.45	0.04	17.22	517.03
Material damage	4737	2188	0.45	0.00	0.40	1.35	111.76	3.43	20.36	565.53
People affected	4734	2188	2.62	0.12	5.46	15.18	105.04	8.94	6.36	54.29
People dead	4737	2188	0.0032	0.0001	0.0021	0.0047	0.9375	0.0356	20.60	469.09
Asian AMs										
Occurrence	138	88	0.07	0.01	0.04	0.06	1.49	0.27	5.12	27.26
Material damage	138	88	0.08	0.02	0.21	0.37	0.75	0.15	2.93	11.85
People affected	138	88	0.14	0.03	0.28	0.50	3.37	0.42	6.10	44.33
People dead	138	88	0.0002	0.0001	0.0005	0.0008	0.0022	0.0003	3.93	21.24

Source: Own calculations using CRED EM-DAT, WB WDI and IMF WEO.

Appendix Figure 3. Mean Occurrence of Severe Disaster Years, 1970-2015



Source: Own calculations using CRED EM-DAT, WB WDI and IMF WEO.

Note: For comparability, the threshold for all country groups is the 90th percentile of the DAS sample of the respective loss measure.

Appendix Table 4. Correlation of Disaster Indicators, 1970-2015

(Pearson correlation coefficient)

	All disaster years					Disaster years with positive damages along all 3 loss measures				
	No. of Obs.	Occurr.	Material damage	People affected	People dead	No. of Obs.	Occurr.	Material damage	People affected	People dead
DAS										
Occurrence	580	1				335	1			
Material damage	580	-0.038	1			335	-0.048	1		
People affected	580	0.088	0.015	1		335	0.152	0.052	1	
People dead	580	0.045	0.028	0.108	1	335	0.060	0.063	0.136	1
RoDW										
Occurrence	2188	1				561	1			
Material damage	2188	0.044	1			561	0.103	1		
People affected	2188	0.040	0.151	1		561	0.108	0.259	1	
People dead	2188	0.002	0.103	0.175	1	561	0.008	0.364	0.201	1
Asian AMs										
Occurrence	88	1				61	1			
Material damage	88	-0.084	1			61	0.228	1		
People affected	88	-0.050	0.471	1		61	0.074	0.542	1	
People dead	88	0.064	0.567	0.652	1	61	0.206	0.603	0.779	1

Source: Own calculations using CRED EM-DAT, WB WDI and IMF WEO.

Appendix Table 5. Share of Severe Disaster Years along Hazard Types, 1970-2015

(in percent of all severe disaster years along a particular loss dimension)

	DAS			RoDW		
	Material damage	People affected	People dead	Material damage	People affected	People dead
Meterological	25	19	40	37	14	13
Hydrological	58	40	28	48	15	19
Biological	0	0	19	0	0	62
Climatological	12	24	0	17	69	4

Source: Own calculations using CRED EM-DAT, WB WDI and IMF WEO.

Note: An insufficient number of observations prevents a meaningful inclusion of Asian AMs in the table.

Appendix Table 6. Top 10 Most Severe Disaster Years, 1970-2015

(occurrence per tsd. sq. km., material damages in pct. of GDP, human damages in pct. of population)1/,2/

	Frequency	Material Damage	Human Damage	
			People Affected	Fatalities
DAS				
1	Timor-Leste (2007, 0.2)	Afghanistan (1988, 260)	Laos (1977, 111.8)	Bangladesh (1970, 0.45)
2	Brunei Darussalam (1998, 0.19)	Mongolia (1996, 109.1)	Mongolia (2000, 63.4)	Myanmar (2008, 0.27)*
3	Timor-Leste (2003, 0.13)	Afghanistan (1978, 65)	Bangladesh (1988, 54.5)	Bangladesh (1991, 0.13)
4	Sri Lanka (2014, 0.11)	Laos (1993, 21.7)	Bangladesh (1974, 53.6)*	Bangladesh (1974, 0.04)*
5	Philippines (2011, 0.11)	Afghanistan (1991, 15)	Cambodia (1994, 48.4)	Bhutan (2000, 0.04)
6	Bangladesh (2000, 0.11)	Myanmar (2008, 11.6)*	India (1987, 39)	Bangladesh (1985, 0.02)
7	Bangladesh (1993, 0.09)	Thailand (2011, 10.9)	India (1972, 35.2)	Afghanistan (2002, 0.01)
8	Bangladesh (2005, 0.09)	Bangladesh (1998, 8.3)	Laos (1995, 32.7)	Philippines (1970, 0.01)
9	Bangladesh (1995, 0.08)	Pakistan (1973, 7.6)	Bangladesh (1984, 32.7)	Laos (1994, 0.01)
10	Bangladesh (1999, 0.08)	Cambodia (1991, 7.5)	Mongolia (2015, 32.5)	Afghanistan (1991, 0.01)
RoDW				
1	Bahrain (1978, 1.45)	Tajikistan (1992, 111.8)	Ghana (1983, 105)	Sudan (1983, 0.94)
2	Lebanon (2015, 0.29)	Honduras (1998, 59.6)*	Mauritania (1980, 104.6)	Mozambique (1981, 0.81)
3	Haiti (2005, 0.29)	Honduras (1974, 33.8)*	Mauritania (1976, 103.7)	Ethiopia (1983, 0.78)
4	Jamaica (2002, 0.28)	Jamaica (1988, 31.5)	Albania (1989, 99.1)	Somalia (1974, 0.52)
5	Jamaica (2005, 0.28)	Liberia (1990, 29.4)	Botswana (1982, 96.9)	Ethiopia (1973, 0.32)
6	Burundi (2006, 0.27)	Bolivia (1983, 26.8)	The Gambia (1980, 83.3)	Honduras (1974, 0.26)*
7	Haiti (2007, 0.25)	Nicaragua (1988, 26.7)	Kenya (1999, 76.5)	Honduras (1998, 0.24)*
8	Haiti (2012, 0.25)	Moldova (1994, 25.9)	Senegal (1977, 72)	Somalia (2010, 0.21)
9	Haiti (2003, 0.22)	Haiti (1980, 25.8)	Malawi (1992, 71.7)	Venezuela (1999, 0.13)
10	Haiti (2010, 0.22)	Tajikistan (1993, 21.9)	Moldova (2000, 71.4)	Liberia (2014, 0.11)
Asian AM				
1	Singapore (2000, 1.49)	Korea (2002, 0.8)**	Korea (1972, 3.4)**	Korea (1972, 0.0022)**
2	Singapore (1999, 1.49)	Korea (1972, 0.7)**	Japan (1978, 1.8)	Korea (1987, 0.0016)**
3	Singapore (2003, 1.46)*	Korea (2003, 0.7)	Korea (1984, 0.9)**	Korea (1998, 0.0011)***
4	Korea (2004, 0.07)	Korea (1998, 0.4)***	Korea (2001, 0.7)*	Korea (1977, 0.0009)
5	Korea (2000, 0.06)	Korea (1987, 0.4)**	Korea (1987, 0.5)**	Singapore (2003, 0.0008)*
6	Korea (1998, 0.05)***	Japan (2004, 0.4)*	Korea (1990, 0.4)**	Japan (1972, 0.0005)
7	Korea (2005, 0.05)	Korea (1976, 0.3)	Japan (2000, 0.4)*	Korea (1984, 0.0005)**
8	Korea (2001, 0.04)*	Japan (1991, 0.3)	Japan (1976, 0.3)	Japan (1982, 0.0005)
9	Korea (2002, 0.04)**	Korea (1984, 0.2)**	Japan (2004, 0.3)*	Korea (2002, 0.0005)**
10	Korea (1990, 0.03)**	Japan (2000, 0.2)*	Korea (1998, 0.3)***	Korea (1990, 0.0005)**

Source: Own calculations using CRED EM-DAT, WB WDI and IMF WEO.

Note: 1/ The brackets report the disaster year, and the scaled frequency and losses. 2/ * (respectively ** or ***) denotes a disaster year that simultaneously features in the top 10 along 2 (respectively 3 or 4) disaster dimensions.