

Article

Natural Disasters and Human Development in Asia-Pacific: The Role of External Debt

Markus Brueckner^{1,*}, Sudyumna Dahal² and Haiyan Lin¹

¹ Research School of Economics, Australian National University, 25 Kingsley Drive, Acton, ACT 0200, Australia; haiyan.lin@anu.edu.au

² United Nations Development Programme, 1 United Nations Plaza, New York, NY 10017, USA; sudyumna.dahal@undp.org

* Correspondence: markus.brueckner@anu.edu.au

Abstract: The average country in Asia–Pacific experiences more natural disasters than average countries of other developing regions. This paper presents stylized facts on natural disasters, human development, and external debt in Asia–Pacific. The paper also contains estimates of the effects that natural disasters have on human development. Controlling for country- and time-fixed effects, the dynamic panel model estimates show that external debt has a mitigating effect on the adverse impacts that natural disasters have on human development; in countries with low external debt-to-GDP ratios, natural disasters significantly decrease the human development index, but not so in countries with high external debt-to-GDP ratios. External debt (i.e., borrowing from abroad) is a financial contract for obtaining resources from abroad (i.e., imports of goods and services). When a country experiencing a natural disaster borrows from abroad to increase imports of goods and services, the population suffers less when a natural disaster strikes. Natural disasters destroy goods and capital (e.g., food, machinery, buildings, and roads) in the countries in which they occur. If imports of goods and services do not increase, then the population has less goods and services to consume following a natural disaster. By increasing imports, which are mirrored on the financial side by an increase in external debt, the population of a country that was struck by a natural disaster can experience consumption smoothing. As the incidence of natural disasters increases globally, a policy recommendation for disaster-prone countries, supported by the empirical results of this paper, is the need for deeper and innovative mechanisms of access to international financing, including reforms in both domestic and international financial systems. The paper’s most significant contribution is the unique lens through which it analyzes the often-studied subject of natural disasters. Rather than looking at disasters as merely adverse events and debt as an unwelcome obligation in isolation, it connects the two and uncovers the paradoxically positive and beneficial role a healthy level of external debt can play in mitigating the adverse effects of these disasters. It provides a fresh perspective, a shift in thinking that may immensely benefit external debt and disaster management policies.

Keywords: natural disasters; shocks; debt; human development

JEL Classification: O4; F3; Q54; H6



Citation: Brueckner, Markus, Sudyumna Dahal, and Haiyan Lin. 2024. Natural Disasters and Human Development in Asia-Pacific: The Role of External Debt. *Journal of Risk and Financial Management* 17: 246. <https://doi.org/10.3390/jrfm17060246>

Academic Editor: Svetlozar (Zari) Rachev

Received: 22 April 2024

Revised: 30 May 2024

Accepted: 7 June 2024

Published: 12 June 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

A prominent characteristic of many countries within the Asia–Pacific region is their vulnerability to natural disasters. As climate change accelerates, the frequency and severity of disasters, like floods, cyclones, and earthquakes, inevitably increase. This situation poses a significant threat to the social and economic development of the nations in question; however, the implications are more profound, given the region’s overall role in the global economy. As a hub of global manufacturing and supply chains, the potential disruption has a far-reaching impact.

The primary research question that we aim to answer is how external debt acts as a moderator in the relationship between natural disasters and human development, keeping in focus the Asia–Pacific region, with case studies selected for their disaster-prone nature and varying debt characteristics. Our objective is to develop an understanding grounded in data and contribute valuable insights to policymakers in those nations who grapple with the complex task of managing disasters, development, and debt.

The paper’s most significant contribution is the unique lens through which it analyzes the often-studied subject of natural disasters. Rather than looking at disasters as merely adverse events, and debt as an unwelcome obligation in isolation, it connects the two and uncovers the paradoxically positive and beneficial role a healthy level of external debt can play in mitigating the adverse effects of these disasters. It provides a fresh perspective, a shift in thinking that may immensely benefit external debt and disaster management policies. To the best of our knowledge, this is the first paper to empirically investigate how the impact of natural disasters on human development depends on external debt.

The Asia–Pacific region is home to many of the world’s rapidly growing economies and provides a significant contribution to global economic growth; however, this region is also highly exposed to a wide array of recurrent natural disasters, including typhoons, floods, and earthquakes, that pose substantial threats to its continued development and prosperity. These disasters cause considerable physical damage, economic losses, and, tragically, loss of life, presenting consequential challenges for the region’s human development.

Human development extends beyond simple measures of economic prosperity, such as GDP, and includes a wider array of criteria that reflect the socioeconomic health of a population, including factors such as quality of health, education levels, and overall living standards. The recurring natural disasters can significantly disrupt progress in these human development indices by causing direct harm to people, damaging infrastructure and productive assets, and diverting essential resources from development to emergency response and recovery. This disruption is particularly concerning for the still-developing Asia–Pacific region, home to several low- and middle-income countries that may lack the necessary resources for effective disaster response and recovery.

External debt has emerged as an intriguing factor in the discussion of natural disaster response and human development. Modern economies often rely on external debt, typically borrowing from foreign entities, to finance gaps in their budget or balance of payments, invest in key development projects, or address emergency situations like natural disasters. Contrarily, the increasing reliance on foreign borrowing has prompted critical debates about debt sustainability and the potential negative impacts on economic and social outcomes, particularly in the context of developing economies. The relationship between external debt and human development becomes more enigmatic in the context of natural disasters.

Given the growing incidence and intensity of natural disasters in the Asia–Pacific region, it is vital to understand the relationship between external debt, natural disasters, and human development. This may provide insights into guiding national and international policy towards improving disaster resilience while promoting sustainable human development in the Asia–Pacific region, a context marked by rapid economic growth but also high disaster exposure. Understanding the way that these intertwined factors interact will inform better policy making, particularly in the context of an evolving global economy and changing climate. The task is to unravel the subtle dynamics at play, providing a clearer perspective.

Remarkably, the relationship observed between external debt and human development in post-disaster scenarios within the Asia–Pacific region appears to deviate from the conventionally accepted view. The conventional view is that high levels of external debt have negative socioeconomic consequences; however, emerging empirical evidence in the context of disaster management indicates a buffering effect caused by maintained or increased external debt-to-GDP ratios on the deleterious impacts of natural disasters on human development.

The natural-disaster-induced destruction of goods and infrastructure results in a significant drop in available consumables for the affected populace. If this decrease in production is not counteracted through increased imports, the population experiences a reduction in available goods for consumption. Borrowing from foreign entities enables the affected country to increase imports, thereby allowing consumption smoothing in the face of disaster-induced output losses. This suggests that external debt has the potential to cushion the detrimental impacts of natural disasters on human development.

The documented correlations in this paper necessitate a deeper understanding and investigation. The relationships between natural disasters, human development, and external debt are complex and influenced by a multitude of other relevant factors, such as mitigation measures, local economic factors, and governmental policies. It is also crucial to consider the potential downsides and limits to relying on external debt in offsetting the impacts of natural disasters on development, such as the potential for causing financial instability in the future, creating a reliance on external entities, and triggering other socioeconomic crises. A careful balance, therefore, needs to be struck, and optimal conditions identified in order to harness the potential of the positive impact of external debt in such scenarios for informed policy making.

It is important to clarify that the study will primarily provide a broader, regional perspective and not delve into exhaustive country-specific analyses. In the section on case studies, we limit the discussion to two country-specific analyses. The output can lay the groundwork for more granular and exhaustive country-focused investigations in the future. Our research can bolster the evidence base and guide policy making in the realm of disaster management and human development, within and even beyond the geographical bounds of Asia–Pacific. The implications stemming from our research are expected to resonate with a global audience and contribute to the global dialogue on sustainable development, disaster resilience, and external debt management.

Given the multifaceted nature of the study, this research will aim to answer several interconnected questions, which are crucial to understanding the nuanced relationship between natural disasters, human development, and external debt:

- (1) How does the incidence of natural disasters influence human development indices over time? This question focuses on evaluating the direct impact of natural disaster occurrence on health, education, and living standards, which are key elements of human development.
- (2) Are high levels of external debt always detrimental, or can they have potential benefits, such as bolstering economic resilience to natural disaster shocks? This query strives to unpack the dual role of external debt, serving as a financial resource and as a potential source of economic vulnerability.
- (3) How do the short- and long-term effects of natural disasters on human development indices change with varying levels of external debt?

Given the above research questions, our study develops and tests several hypotheses: (1) The presence of natural disasters in the Asia–Pacific region negatively impacts human development. (2) Higher levels of external debt can reduce the adverse impact of natural disasters on human development by supplementing the financial resources available for disaster response and recovery; however, if not managed properly, excessive levels of external debt could potentially exacerbate societies' vulnerability to natural disasters by creating economic instability and diverting resources away from human development endeavors to debt servicing. (3) The temporal dimension may also play a role, with the effects of natural disasters on human development varying across short- and long-term timelines, potentially moderated by the level of external debt. The testing of these hypotheses will involve econometric modeling, allowing us to control for a range of other influential variables.

Our paper involves the use of publicly available data and statistical analyses to scrutinize the interrelation between external debt, human development, and natural disasters. It adopts a longitudinal research design, investigating the changes and trends over the period

of 1990–2020. The key dependent variable in this study is the human development index, serving as a comprehensive measure of human development. The independent variables include the external debt-to-GDP ratio and the incidence of natural disasters. Panel data econometrics will be the main tool used for analysis. The econometric model will include fixed effects to account for the intrinsic characteristics of each country. Our paper includes several robustness checks, such as employing different model specifications to ensure that our findings are not an artefact of any particular methodological choice. In summation, the methodology is comprehensively designed to tease out layered dynamics between natural disasters, human development, and external debt, allowing us to formulate relevant policy recommendations.

Following this introduction, this paper is divided into several sections: After discussing related literature in the next section, we move on to present our econometric model and discuss the results of the econometric model estimates in Section 3. Section 4 presents case studies. Section 5 concludes the paper. A discussion of stylized facts can be found in the Supplementary Materials.

2. Related Literature

2.1. Impact of Natural Disasters on Human Development

The existing literature on the impact of natural disasters on the HDI is still scarce, but a number of studies have examined the impact of natural disasters on the three main components of the HDI separately, namely health, education, and living standards. Overall, the consensus that has emerged is that the costs of natural disasters on human development are larger in developing countries (Khan et al. 2023).

Exposure to natural disasters is associated with increased levels of physical, psychological, and economic stress, which have been shown to be detrimental to the health of both infants and adults. Torche (2011) studied the impact of the 2005 Tarapaca earthquake on birth outcomes in Chile. Using a difference-in-difference methodology, he found that exposure to the high-intensity earthquake during the first trimester of pregnancy resulted in a significant decline in birth weight and an increase in the proportion of low-birth-weight babies. Currie and Rossin-Slater (2013) examined the effects of exposure to severe storms and hurricanes during pregnancy in Texas. With comprehensive birth records over the period 1996 to 2008, they found that, compared with mothers who lived further away, those who lived in the path of a hurricane were more likely to have newborns with abnormal conditions. A potential pathway suggested by the authors is the stress generated by the fear of hurricanes during pregnancy. Kim et al. (2017) found that the 1994 Northridge earthquake in Los Angeles, California, led to a higher probability of newborns with a low birth weight. Additionally, de Oliveira et al. (2023) documented a similar adverse impact on infant health from the March 2004 Catarina hurricanes in Brazil.

Due to the damage of property and loss of family, survivors of natural disasters may be more susceptible to morbidity and mortality in the years to come. Armenian et al. (1998) studied the impact of the 1988 Armenian earthquake by following the survivors for four years. The study found that the more people lost in terms of material possessions and family members in the earthquake, the more likely they were to develop hypertension, heart disease, diabetes, or arthritis in the first six months after the earthquake. Nakagawa et al. (2009) examined the impact of the 2004 Niigata–Chuetsu earthquake in Japan on the deaths from acute myocardial infarction (AMI) three years later. In more exposed areas, AMI mortality increased significantly compared to the pre-earthquake levels. Ho et al. (2017) considered the selection effect of tsunamis, and found that males in more exposed areas had a lower mortality risk five years after the 2004 Indian Ocean tsunami; however, the scarring effect was large enough to elevate the mortality for older adults ten years after the tsunami (Frankenberg et al. 2020).

The disruption of education by natural disasters also attracts much attention. Pane et al. (2006) found that roughly one-quarter of Louisiana's total enrollment was displaced by Hurricane Katrina, and the affected students missed five weeks of school on average. In

the first year following the hurricanes, [Sacerdote \(2012\)](#) found large declines in test scores for students who were forced to switch schools but remained in Louisiana public schools. The likelihood of displaced students attending college declined as well. The negative effects on human capital were not restricted to very large disasters, as shown by [Husted et al. \(2022\)](#). Less severe disasters also had a negative impact on students' educational attainment, as measured by high school graduation rates and college enrollment. In comparison, the mechanism for the human capital destruction of large disasters was mainly increasing out-migration, but smaller disasters did not lead to a meaningful migration response. The influx of internal migrants incurred by Hurricane Maria had an adverse effect on the test scores of the incumbent students in Florida public schools, as found by [Özek \(2023\)](#). In addition to the short-term impact, researchers also examined the impact of infant exposure to natural disasters on long-term education outcomes. [Caruso and Miller \(2015\)](#) found that earthquake exposure in utero led to less schooling, and [Paudel and Ryu \(2018\)](#) revealed that infants born in areas more affected by earthquakes were less likely to complete middle as well as high school.

Many studies have investigated the impact of natural disasters on macroeconomic outcomes, but there is no consensus on the conclusions. Natural disasters can benefit future GDP growth through increasing reinvestment and upgrading capital stock. [Albala-Bertrand \(1993\)](#) found an increase in GDP and capital formation after natural disasters, using a sample of 28 disasters in 26 countries during 1960–1979. Expanding the sample size to 89 countries between 1960 and 1990, [Skidmore and Toya \(2002\)](#) found a positive effect of climatic disasters and a negative effect of geological disasters on output growth. [Noy \(2009\)](#) illustrated heterogeneous responses to natural disasters across countries, with developing countries facing larger output declines after a disaster than developed countries. The impact of natural disasters on output growth might also differ at different aggregate levels within a country, as found by [Strobl \(2011\)](#). After the hurricanes, annual economic growth at the county level fell on average in the US, but the aggregate effects at the state and national levels were not obvious. Some of the decline in economic output at the county level can be explained by richer individuals' out-migration. The intensity of natural disasters also makes a significant difference in the output responses. [Cavallo et al. \(2013\)](#) identified a negative impact on economic growth only for extremely severe disasters, which was explained away by the radical political revolutions following the disasters.

2.2. Impact of External Debt on Human Development

Empirical studies on the impact of external debt on health and education are still scant, while there is a large body of work on its impact on economic growth. Below, we review these studies in two strands.

[Loko et al. \(2003\)](#) assessed the impact of external debt on health and education. Using annual data for 67 low-income countries from 1985 to 1999, they found that high external indebtedness was associated with low life expectancy at birth and a high infant mortality rate, but had no significant impact on primary gross enrollment rates. The study suggested that debt service payments crowded out social spending on health. [Fosu \(2007\)](#) argued that actual debt service payments can be endogenous, as governments may adjust their debt service payments to accommodate pressing needs, and, therefore, they may not reflect the degree of liquidity constraints. Instead, he constructed a predicted debt service ratio to capture the binding nature of the debt servicing constraint. Using five-year panel data over the period 1975–1994 for 35 countries in Sub-Saharan Africa, [Fosu \(2007\)](#) showed that the actual debt service had little or no effect on education spending, but predicted debt service that reflects the debt burden having a substantial adverse impact. Similarly, [Fosu \(2008\)](#) found that the binding debt servicing constraint had a substantial adverse impact on health spending. In the same vein, [Dessy and Vencatachellum \(2007\)](#) found that the debt relief provided by the G8 to African countries over the period 1989–2003 had a positive impact on social spending on education and health if countries improved their institutions.

While most papers document a negative impact of external debt on health and education expenditure, the literature on the impact of external debt on economic growth generally finds a nonlinear relationship. External borrowing can be used to relieve internal deficits and to finance critical capital investments, but high debt service payments could be harmful if they divert budgetary resources from necessary spending to improve economic growth. Using a large panel dataset of 93 developing countries over the period 1969–1998, [Pattillo et al. \(2002\)](#) noted a nonlinear effect of external debt on growth. The average impact of debt became negative at debt ratios above 160–170 percent of exports or 35–40 percent of GDP. Similar results for low-income countries were found by [Clements et al. \(2003\)](#). According to [Checherita-Westphal and Rother \(2012\)](#), based on a sample of 12 euro area countries over 40 years from 1970, there was a turning point for government debt, above which the debt was detrimental to long-term growth. For Turkey, [Doğan and Bilgili \(2014\)](#) also documented a nonlinear relationship between growth and borrowing, with the impact of public external borrowing being larger than that of private external borrowing.

In addition to studies on the components of the HDI, [Zaghoudi \(2018\)](#) examined the impact of external debt on the composite HDI. Using panel data for 95 developing countries between 2002 and 2015, [Zaghoudi \(2018\)](#) identified a nonlinear relationship between external debt and human development, as measured by the HDI. Below the optimal external debt threshold, i.e., 41.76%, external debt has a positive impact on human development, but the impact becomes negative when external debt exceeds the debt threshold. One key difference between [Zaghoudi \(2018\)](#) and our paper is that we control for country- and time-fixed effects as well as the lagged dependent variable, while [Zaghoudi](#) controls only for country-fixed effects (but not time-fixed effects and a lagged HDI, which in the context of external debt are both very important control variables). In contrast to [Zaghoudi](#), we do not find any evidence of an inverse U-shaped effect of external debt on the HDI.

2.3. The Role of External Debt on the Impact of Natural Disasters on Human Development

A number of papers have found that, due to natural disasters, developing (poor) countries suffer more deaths ([Kahn 2005](#); [Toya and Skidmore 2007](#)) or economic losses ([Toya and Skidmore 2007](#); [Noy 2009](#); [Felbermayr and Gröschl 2014](#)) than developed (rich) countries. Several hypotheses concerning natural disaster mitigation have been tested, such as educational attainment, economic development, trade openness, institutional quality, and financial conditions. What we are particularly interested in is the financial channel.

[Toya and Skidmore \(2007\)](#) used a sample of 151 countries over the 1960–2003 period and found that countries with a stronger financial sector experienced fewer deaths from disasters. Using panel data from 1970 to 2003 for 109 countries, [Noy \(2009\)](#) documented that domestic credit and foreign exchange reserves reduced the cost of disasters in terms of foregone output growth.

[Felbermayr and Gröschl \(2014\)](#) found strong evidence that higher financial openness protected economies from the adverse impact of disasters. [Howard et al. \(2020\)](#) noted that a large increase in official development assistance (ODA) after disasters had a positive effect on economic growth, and the effect increased with disaster severity, suggesting that ODA is an effective post-disaster recovery instrument.

A closely related paper by [Melecky and Raddatz \(2015\)](#) found that countries with higher debt market development suffer smaller real consequences from disasters. [Melecky and Raddatz's \(2015\)](#) empirical analysis is for a panel of high- and middle-income countries spanning the period 1975–2008. Our empirical analysis also covers low-income countries and expands the time period up to 2020. Our finding that external debt-to-GDP ratios significantly mediate the relationship between natural disasters and the HDI is broadly in line with the results of [Melecky and Raddatz \(2015\)](#).

3. Effects of Natural Disasters on Human Development: The Role of External Debt

3.1. Econometric Model

The econometric model is described by Equation (1):

$$HD_{it} = a_i + b_t + \alpha Disaster_{it} + \beta Debt_{it-1} + \gamma Disaster_{it} \times Debt_{it-1} + \theta HD_{it-1} + \varepsilon_{it} \quad (1)$$

where HD is a measure of human development, Disaster is the incidence of natural disasters, Debt is the external debt-to-GDP ratio, and ε denotes an error term.

Country- and time-fixed effects are denoted by a_i and b_t , respectively. Including these fixed effects as controls means that the model delivers a within-country effect of (unexpected) increases (i.e., above country average) in the incidence of natural disasters on human development.

The contemporaneous, i.e., year t , effect of natural disaster incidence (in year t) on human development (in year t) is $\alpha + \gamma \times Debt_{it-1}$. Coefficient γ measures how much the effect of natural disaster incidence on human development changes for a one unit increase in debt. The long-run effect of natural disaster incidence on human development is $(\alpha + \gamma \times Debt_{it-1}) / (1 - \theta)$.

We estimate the above model by least squares. Given that natural disaster incidence is exogenous to the human development of a country, least squares provides consistent estimates of the parameters of interest. We have also checked robustness to using sys-GMM. Sys-GMM estimations yielded similar results to the least squares estimates that are reported and discussed in this paper.

3.2. Baseline Results: Human Development Index

Column (1) of Table 1 shows the least squares estimates of Equation (1), where the dependent variable is the human development index. One can see in column (1) of Table 1 that the estimated coefficient (α) of natural disaster incidence is negative and significantly different from zero at a five percent significance level. The estimated coefficient (γ) of the interaction between natural disaster incidence and the external debt-to-GDP ratio is positive and significantly different from zero at a ten percent significance level. The estimated coefficient (β) of the external debt-to-GDP ratio is negative but not significantly different from zero at a ten percent significance level or higher. The estimated coefficient (θ) of the lagged dependent variable is positive and significantly different from zero at a one percent significance level.

Table 1. Effects of natural disasters on human development: the role of external debt.

| Dependent Variable | Human Development Index (In %) | Δ Human Capital Index (In %) | Life Expectancy (In Years) | GDP Growth Rate (In %) |
|---|--------------------------------|-------------------------------------|----------------------------|------------------------|
| Natural disasters, t | -0.014 ** (0.006) | -0.005 ** (0.002) | -0.011 ** (0.005) | -0.106 ** (0.041) |
| Natural disasters, $t \times$ external debt-to-GDP ratio, $t - 1$ | 0.020 * (0.011) | 0.011 *** (0.003) | 0.021 ** (0.010) | 0.237 *** (0.092) |
| External debt-to-GDP ratio, $t - 1$ | -0.014 (0.029) | -0.022 (0.017) | -0.065 (0.059) | -1.309 * (0.714) |
| Country-fixed effects | Yes | Yes | Yes | Yes |
| Time-fixed effects | Yes | Yes | Yes | Yes |
| Lagged dependent variable | Yes | Yes | Yes | Yes |
| Observations | 2560 | 1362 | 2531 | 1327 |

Note: Huber robust standard errors (shown in parentheses) are clustered at the country level. *, **, and *** denote that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

The estimates in column (1) of Table 1 should be interpreted as follows: Natural disasters have a significant negative effect on human development when external debt-to-GDP ratios are low. External debt mediates the effects that natural disasters have on human development. The higher the external debt-to-GDP ratio, the smaller the adverse effects that natural disasters have on human development. External debt-to-GDP has no

significant effect on the human development index when the incidence of natural disasters is zero.

The estimates in column (1) of Table 1 also imply that the higher the incidence of natural disasters the (less negative) more positive the effects of external debt-to-GDP ratios on the human development index. One can see this by differentiating Equation (1) with respect to $Debt_{it-1}$, which yields $\beta + \gamma \times Disaster_{it}$. The estimated β coefficient is negative and the estimated γ coefficient is positive. These estimates are consistent with the view that international risk sharing is particularly conducive for human development when countries are hit by exogenous, country-specific shocks—e.g., natural disasters. It is noteworthy that, for countries with a large number of natural disasters, i.e., $Disaster_{it} > 4$, that $\beta + \gamma \times Disaster_{it}$ is positive and significantly different from zero at a ten percent significance level or higher.

3.2.1. Quantitative Result I: Effects of Natural Disasters on the HDI

Quantitatively, the estimates in column (1) of Table 1 can be interpreted as follows: If external debt-to-GDP ratios are zero, then one additional natural disaster in year t decreases the human development index in year t by 0.014 percentage points. (0.014 is the estimated coefficient α ; note that in this calculation $Debt = 0$.) A one-standard-deviation increase in the incidence of natural disasters in year t (which is about six for Asia–Pacific) decreases the HDI in year t by around 0.08 percentage points.

Consider now a country in Asia–Pacific with a relatively low external debt-to-GDP ratio, say 10 percent (0.1). For a country with an external debt-to-GDP ratio equal to 10 percent, one additional natural disaster in year t decreases the human development index in year t by 0.012 percentage points. (The effect is calculated as: $-0.014 + 0.02 \times 0.1$; i.e., for a value of $Debt = 0.1$, where 0.02 is the estimated coefficient γ .) For a country with an external debt-to-GDP ratio of 20 (30) percent, one additional natural disaster in year t decreases the human development index in year t by 0.010 (0.008) percentage points.

For the median external debt-to-GDP ratio in the year 2020 in Asia–Pacific, which is 40 percent, the estimates in column (1) imply that one additional natural disaster in year t decreases the human development index in year t by 0.006 percentage points. A one-standard-deviation increase in the incidence of natural disasters in year t decreases the HDI in year t by 0.036 percentage points.

The long-run effects on human development of natural disasters are larger than the short-run effects; that is, the costs of natural disasters in terms of foregone human development cumulate over time. Statistically speaking, this is because the HDI follows an autoregressive process. The estimated coefficient on the lagged (year $t - 1$) HDI is about 0.95 and has a standard error of 0.01. Thus, any shock which affects the HDI in year t has effects in year $t + 1, t + 2, t + 3, \dots, t + n, \dots, t + \infty$ (equal to the effect of the shock on the HDI in year t times $0.95, 0.95^2, 0.95^3, \dots, 0.95^n, \dots, 0.95^\infty$ for periods $t + 1, t + 2, t + 3, \dots, t + n, \dots, t + \infty$, respectively; note that the last term, 0.95^∞ , is equal to zero).

According to the estimates in column (1) of Table 1 for a country with an external debt-to-GDP ratio of 10 percent, a one-unit increase in the incidence of natural disasters decreases the human development index by 0.22 percentage points in the long run. For a country with an external debt-to-GDP ratio of 20 (30) percent, a one-unit increase in the incidence of natural disasters decreases the human development index by 0.19 (0.15) percentage points in the long run.

For the median external debt-to-GDP ratio in the year 2020 in Asia–Pacific, which is 40 percent, the estimates in column (1) imply that one additional natural disaster decreases the human development index by 0.11 percentage points in the long run. A one-standard-deviation increase in the incidence of natural disasters decreases the HDI by 0.66 percentage points in the long run.

These numbers mean that, for countries in Asia–Pacific with median or below-median external debt-to-GDP ratios, natural disasters have substantial adverse effects on human development. Ten additional natural disasters (equal to about 1.6 standard deviations)

would reduce the human development index by around 1 to 2 percentage points in countries with below-median external debt-to-GDP ratios.

To further illustrate the quantitative implications of econometric model estimates, consider a country like Indonesia, which in 2020 had an external debt-to-GDP ratio of about 40 percent. Indonesia's external debt-to-GDP ratio is close to the median in Asia-Pacific. Let us consider the effects that, according to the estimated econometric model, 100 additional natural disasters would have on the human development index for Indonesia. (To put this number of natural disasters into perspective: Indonesia recorded 28 natural disasters in the year 2021, 29 natural disasters in 2020, 19 natural disasters in 2019, and 15 natural disasters in 2018.) According to the estimates in column (1) of Table 1, 100 natural disasters decrease Indonesia's human development index by 0.6 percentage points in the year that the natural disasters strike. Cumulated over ten years, the 100 natural disasters decrease Indonesia's human development index by about 4.7 percentage points ($0.6 \times (1 - 0.946^{10}) / (1 - 0.946)$). Additionally, in the long-run Indonesia's human development index decreases by about 11 percentage points. Given that in the year 2020 Indonesia's human development index was about 71 percent, the cost on human development of 100 natural disasters is large: in the long-run, 100 natural disasters set Indonesia's human development index back to a value of about 60 percent. Indonesia's human development index was about 60 percent in 2000. Thus, for a country like Indonesia that in the year 2020 had an external debt-to-GDP ratio of about 40 percent, 100 natural disasters would set the country back by about 20 years in terms of human development.¹

Another country example that is useful for illustrating the quantitative implications of these estimates is Afghanistan. In 2020, Afghanistan's external debt-to-GDP ratio was about 15 percent. Afghanistan has a very low external debt-to-GDP ratio by international standards. Afghanistan is at about the 10th percentile in Asia-Pacific with regard to the external debt-to-GDP ratio in 2020. Let us consider the effects that 100 natural disasters have on the human development index for a country like Afghanistan. (To put this number of natural disasters into perspective: Afghanistan experienced a total of about 100 natural disasters over the period 2005–2021.) According to the estimates in column (1), 100 natural disasters decrease Afghanistan's human development index by 1.1 percentage points in the year that the natural disasters strike. Cumulated over ten years, Afghanistan's human development index is reduced by about 8.7 percentage points ($1.1 \times (1 - 0.946^{10}) / (1 - 0.946)$). Additionally, in the long-run Afghanistan's human development index is reduced by about 20 percentage points. Given that in the year 2020 Afghanistan's human development index was about 48 percent, these are large effects. One hundred natural disasters cut Afghanistan's human development index in half—to about 28 percent.

Figure 1 plots the effects of natural disasters on the human development index for different values of the external debt-to-GDP ratio. One can see that for just about all countries in Asia-Pacific, this long-run effect is negative: natural disasters lead to a decline in human development. This is increasingly the case the lower a country's external debt-to-GDP ratio.

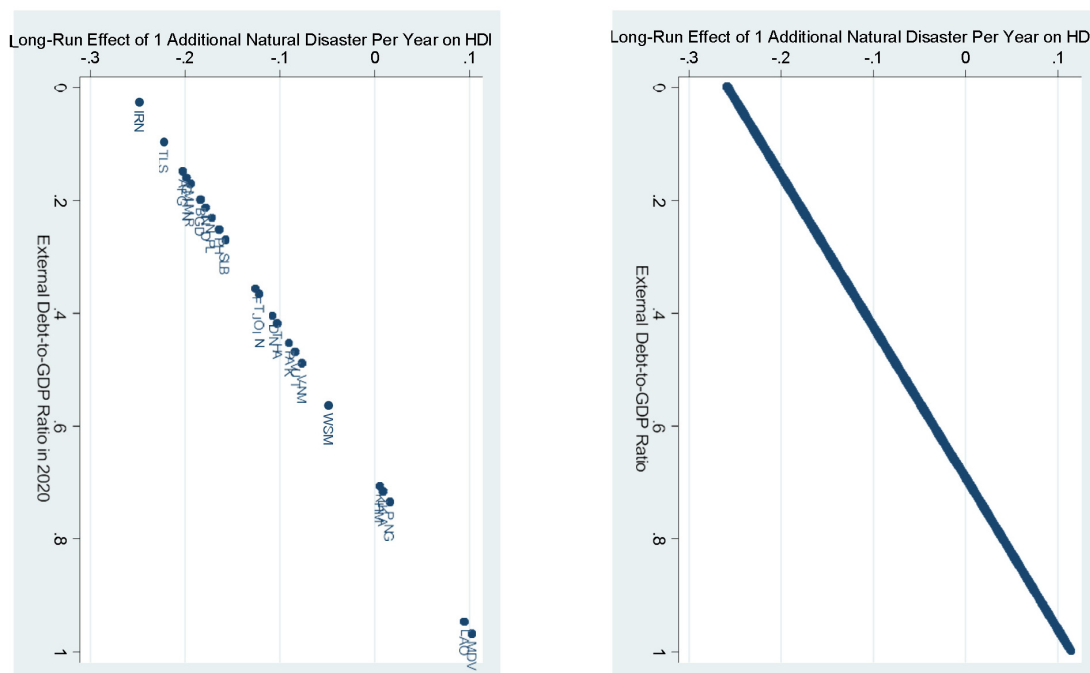


Figure 1. Effects of natural disasters on the human development index: the role of external debt.

3.2.2. Quantitative Result I: Effects of External Debt-to-GDP Ratios on the HDI

With regard to the effects of external debt-to-GDP ratios on the HDI, the estimates in column (1) of Table 1 can be interpreted as follows: For a country where the incidence of natural disasters in year t is 0, the HDI in year t is lower by 0.00014 percentage points for each percentage point (0.01) increase in the year $t - 1$ external debt-to-GDP ratio; i.e., if there are no natural disasters in year t , and a country were to increase in year $t - 1$ the external debt-to-GDP ratio by one standard deviation (0.4), then according to the estimates in column (1) of Table 1 the HDI in year t would decrease by around 0.0056 percentage points. The long-run effect is larger: if there are 0 natural disasters and a country were to increase the external debt-to-GDP ratio by one standard deviation (0.4), then the HDI would decrease by around 0.12 percentage points in the long run.

Consider now a country in Asia–Pacific with a median incidence of natural disasters during 1990–2020. For a country with four natural disasters in year t , the HDI in year t increases by 0.00066 percentage points for each percentage point (0.01) increase in the year $t - 1$ external debt-to-GDP ratio; i.e., if there are four natural disasters in year t , and a country were to increase in year $t - 1$ the external debt-to-GDP ratio by one standard deviation (0.4), then according to the estimates in column (1) of Table 1 the HDI in year t would increase by around 0.026 percentage points. The long-run effect is larger: if there are four natural disasters and a country were to increase the external debt-to-GDP ratio by one standard deviation (0.4), then the HDI would increase by around 0.57 percentage points in the long-run.

3.3. Results for Other Development Outcomes: Human Capital, Life Expectancy, and GDP Growth

This section presents results for the human capital index, life expectancy, and GDP growth. The aim of this section is to shed light on how the components of the HDI are affected by the incidence of natural disasters, external debt-to-GDP ratios, and their interactions.

3.3.1. Human Capital Index

Column (2) of Table 1 reports estimates of Equation (1) where the dependent variable is the human capital index. The HCI is a summary measure of the amount of human capital that a child born today can expect to acquire by age 18, given the risks of poor health and poor education that prevail in the country where they live.

One can see in column (2) of Table 1 that the estimated coefficient of natural disaster incidence is negative and significantly different from zero at a five percent significance level. The estimated coefficient of the interaction between natural disaster incidence and the external debt-to-GDP ratio is positive and significantly different from zero at a one percent significance level. The estimated coefficient of the external debt-to-GDP ratio is negative and significantly different from zero at a five percent significance level.

The estimates in column (2) of Table 1 should be interpreted as follows: Natural disasters have a significant negative effect on the human capital index when external debt-to-GDP ratios are low. At intermediate and high external debt-to-GDP ratios, natural disasters have a positive effect on the human capital index. External debt mediates the effects that natural disasters have on the human capital index. External debt-to-GDP ratios have no significant effects on the human capital index when the incidence of natural disasters is zero.

The quantitative interpretation of the estimates in column (2) is as follows: If external debt-to-GDP ratios were zero, then one additional natural disaster in year t decreases the human capital index in year t by 0.005 percentage points. Consider now a developing country with a relatively low external debt-to-GDP ratio, say 10 percent (0.1). For a country with an external debt-to-GDP ratio equal to 10 percent, one additional natural disaster in year t decreases the human capital index in year t by 0.004 percentage points. For a country with an external debt-to-GDP ratio of 20 (30) percent, one additional natural disaster in year t decreases the human capital index in year t by 0.003 (0.002) percentage points.

For the median external debt-to-GDP ratio in the year 2020 in Asia–Pacific, which is 40 percent, the estimates in column (2) imply that one additional natural disaster in year t decreases the human capital index in year t by 0.001 percentage points. The long-run effect of one additional natural disaster on the HCI is larger, amounting to around 0.005 percentage points.

With regard to the effects of external debt-to-GDP ratios on the human capital index, the estimates in column (2) of Table 1 can be interpreted as follows: The higher the incidence of natural disasters the (less negative) more positive the effects of external debt-to-GDP ratios on the human capital index. For a country where the incidence of natural disasters is zero, the estimated effects of the external debt-to-GDP ratio on the HCI are negative but not significantly different from zero at a ten percent level or higher. For a country in Asia–Pacific that has an incidence of natural disasters equal to five per year, the effects of external debt-to-GDP ratios on the HCI are positive and significantly different from zero at a ten percent level.

For a country with zero natural disasters in year t , the HCI in year t is lower by 0.00022 percentage points for each percentage point (0.01) increase in the year $t - 1$ external debt-to-GDP ratio; i.e., if there are no natural disasters in year t , and a country were to increase in year $t - 1$ the external debt-to-GDP ratio by one standard deviation (0.4), then according to the estimates in column (2) of Table 1 the HCI in year t would decrease by around 0.008 percentage points. The long-run effects are larger than the short-run effects. If there are zero natural disasters and a country were to increase the external debt-to-GDP ratio by one standard deviation (0.4), then the HCI would decrease by around 0.047 percentage points in the long run.

For a country with five natural disasters in year t , the HCI in year t increases by 0.00034 percentage points for each percentage point (0.01) increase in the year $t - 1$ external debt-to-GDP ratio; i.e., if there are five natural disasters in year t , and a country were to increase in year $t - 1$ the external debt-to-GDP ratio by one standard deviation (0.4), then according to the estimates in column (2) of Table 1 the HCI in year t would increase by around 0.013 percentage points. The long-run effects are larger than the short-run effects. If there are five natural disasters and a country were to increase the external debt-to-GDP ratio by one standard deviation (0.4), then the HCI would increase by around 0.08 percentage points in the long run.

3.3.2. Life Expectancy

Column (3) of Table 1 reports estimates of Equation (1), where the dependent variable is life expectancy. Life expectancy is defined as how long, on average, a newborn can expect to live, if current death rates do not change.

One can see in column (3) of Table 1 that the estimated coefficient of natural disaster incidence is negative and significantly different from zero at a five percent significance level. The estimated coefficient of the interaction between natural disaster incidence and the external debt-to-GDP ratio is positive and significantly different from zero at a five percent significance level. The estimated coefficient of the external debt-to-GDP ratio is negative but not significantly different from zero at a ten percent significance level or higher.

The estimates in column (3) of Table 1 should be interpreted as follows: Natural disasters have a significant negative effect on life expectancy when external debt-to-GDP ratios are low. External debt mediates the effects that natural disasters have on life expectancy. At intermediate debt-to-GDP ratios, natural disasters do not affect life expectancy. External debt-to-GDP ratios have no significant effect on life expectancy when natural disaster incidence is zero.

The quantitative interpretation of the estimates in column (3) of Table 1 is as follows: If external debt-to-GDP ratios were zero, then one additional natural disaster decreases life expectancy by about 0.24 years in the long run. Consider now a developing country with a relatively low external debt-to-GDP ratio, say 10 percent (0.1). For a country with an external debt-to-GDP ratio equal to 10 percent, one additional natural disaster decreases life expectancy by about 0.19 years in the long run. For a country with an external debt-to-GDP ratio of 20 (30) percent, one additional natural disaster decreases life expectancy in the long run by 0.15 (0.10) years. For the median external debt-to-GDP ratio in the year 2020 in Asia–Pacific, which is 40 percent, the estimates in column (3) imply that one additional natural disaster decreases life expectancy by about 0.06 years in the long run.

With regard to the effects of external debt-to-GDP ratios on life expectancy, the estimates in column (4) of Table 1 can be interpreted as follows: The higher the incidence of natural disasters the (less negative) more positive the effects of external debt-to-GDP ratios on life expectancy. For a country where the incidence of natural disasters is zero, the estimated effects of the external debt-to-GDP ratio on life expectancy are negative but not significantly different from zero at a ten percent level or higher. For a median country in Asia–Pacific that has an incidence of natural disasters equal to four per year, the effects of external debt-to-GDP ratios on life expectancy are positive but not significantly different from zero at a ten percent level. For a country with ten natural disasters per year or more, the effects of increasing external debt-to-GDP ratios are positive and significantly different from zero at a ten percent level.

Quantitatively, the effects of external debt-to-GDP ratios on life expectancy are sizable: For a country with zero natural disasters, increasing the external debt-to-GDP ratio by ten percentage points decreases life expectancy by about 0.1 years in the long run. For a country at the median (four natural disasters per year), increasing the external debt-to-GDP ratio by ten percentage points increases life expectancy by about 0.04 years in the long run. For countries with an extremely high number of natural disasters—e.g., 10 natural disasters per year—increasing the external debt-to-GDP ratio by 10 percentage points (40 percentage points, i.e., one standard deviation) would increase life expectancy by about 0.3 (1.2) years in the long run.

3.3.3. GDP Growth

Column (4) of Table 1 reports estimates of Equation (1), where the dependent variable is real GDP per capita growth. One can see in column (4) of Table 1 that the estimated coefficient of natural disaster incidence is negative and significantly different from zero at a five percent significance level. The estimated coefficient of the interaction between natural disaster incidence and the external debt-to-GDP ratio is positive and significantly different from zero at a one percent significance level. The estimated coefficient of the

external debt-to-GDP ratio is negative and significantly different from zero at a ten percent level. The latter result is in line with the finding in the literature (e.g., [Reinhart and Rogoff 2010](#)) that higher external debt-to-GDP ratios are a drag on GDP growth.²

The estimates in column (4) of Table 1 should be interpreted as follows: Natural disasters have a significant negative effect on GDP growth when external debt-to-GDP ratios are low. At intermediate external debt-to-GDP ratios, natural disasters have no significant effect on GDP growth. External debt mediates the effects that natural disasters have on GDP growth. The higher the external debt-to-GDP ratios the less negative the effects of natural disasters on GDP growth.

The quantitative interpretation of the estimates in column (4) is as follows: If external debt-to-GDP ratios were zero, then one additional natural disaster in year t decreases per annum GDP per capita growth in year t by about 0.11 percentage points. Consider now a developing country with a relatively low external debt-to-GDP ratio, say 10 percent (0.1). For a country with an external debt-to-GDP ratio equal to 10 percent, one additional natural disaster in year t decreases per annum GDP per capita growth in year t by around 0.08 percentage points. For a country with an external debt-to-GDP ratio of 20 (30) percent, one additional natural disaster in year t decreases per annum GDP per capita growth in year t by 0.06 (0.04) percentage points. For the median external debt-to-GDP ratio, the estimates in column (1) imply that one additional natural disaster in year t decreases per annum GDP per capita growth in year t by around 0.01 percentage points per annum.

With regard to the effects of external debt-to-GDP ratios on GDP growth, the estimates in column (5) of Table 1 can be interpreted as follows: For a country where the incidence of natural disasters in year t is 0, GDP growth in year t is lower by 0.013 percentage points for each percentage point (0.01) increase in the year $t - 1$ external debt-to-GDP ratio; i.e., if there are no natural disasters in year t , and a country were to increase in year $t - 1$ the external debt-to-GDP ratio by one standard deviation (0.4), then according to the estimates in column (5) of Table 1 GDP growth in year t would decrease by around 0.52 percentage points.

For a country where the incidence of natural disasters in year t is 5, GDP growth in year t is lower by 0.001 percentage points for each percentage point (0.01) increase in the year $t - 1$ external debt-to-GDP ratio; i.e., if there are five natural disasters in year t , and a country were to increase in year $t - 1$ the external debt-to-GDP ratio by one standard deviation (0.4), then according to the estimates in column (5) of Table 1 GDP growth in year t would decrease by around 0.05 percentage points.

3.4. Interpretation of the Econometric Results

External debt-to-GDP ratios are a measure of international risk sharing. When financial markets are incomplete, countries with higher external debt-to-GDP ratios tend to also be those countries with access to (less costly) international financial intermediation (See [Maggiori 2022](#)). In contrast, countries with low external debt-to-GDP ratios tend to also be those countries with limited access to international financial intermediation. Countries with ample access to international financial intermediation can use external debt as a buffer when natural disasters strike.³ This is not so for countries that have limited access to international financial intermediation.

According to the above view, one should see that, in countries with low external debt-to-GDP ratios, natural disasters lead to (i) a significant decrease in imports; (ii) a significant decrease in exports; and thus (iii) a significant decrease in international trade. Exports decrease because natural disasters destroy goods—or capital needed to produce goods and services. Imports decrease as well: a (debt-constrained) country cannot obtain the finance in international markets to pay for necessary imports (to smooth consumption).

In countries with high external debt-to-GDP ratios, natural disasters should lead to an increase in imports. These countries use international markets to buffer the shock: they issue external debt to finance the increase in imports so that consumption is smoothed. The effects of natural disasters on exports are ambiguous. Natural disasters directly destroy

goods—or capital, which is necessary to produce goods or services for export purposes. When these countries increase imports, they can repair quickly (build up again) the capital stock necessary to produce goods and services for export purposes. These countries may also reap the benefits from a so-called creative destruction effect: the bad is destroyed (unproductive firms exit the market and/or existing unproductive firms lose business) and the good survives and expands (productive firms enter the market and/or existing productive firms increase market size).

Panel A of Table 2 shows that external debt-to-GDP ratios significantly affect the impact that natural disasters have on imports and exports. In columns (1) and (2) of Panel A in Table 2, one can see that the estimated coefficients of natural disasters are negative and significantly different from zero at the conventional significance levels. The estimated coefficients of the interaction between natural disasters and external debt-to-GDP ratios are positive and also significantly different from zero at the conventional significance levels. These estimates imply that when external debt-to-GDP ratios are low, imports and exports significantly decrease when a natural disaster strikes. In contrast, in countries with high external debt-to-GDP ratios imports and exports increase.

It could also be the case that those countries with high debt-to-GDP ratios receive debt relief. This would be consistent, for example, with the IMF’s Catastrophe Containment Relief Trust (CCRT).⁴

Table 2. Effects of natural disasters on international trade, external debt and net current transfers.

| Panel A: Effects on international trade | | |
|--|--|--|
| Dependent Variable | Imports of Goods and Services (Growth Rate, in %) | Exports of Goods and Services (Growth Rate, in %) |
| Natural disasters, <i>t</i> | −0.277 ** (0.133) | −0.287 * (0.157) |
| Natural disasters, <i>t</i> × external debt-to-GDP ratio, <i>t</i> − 1 | 0.815 ** (0.307) | 0.797 ** (0.321) |
| External debt-to-GDP ratio, <i>t</i> − 1 | −0.972 (0.690) | −0.453 (0.871) |
| Country-fixed effects | Yes | Yes |
| Time-fixed effects | Yes | Yes |
| Lagged dependent variable | Yes | Yes |
| Observations | 2367 | 2367 |
| Panel B: Effects on external debt and net current transfers | | |
| Dependent Variable | External Debt (Growth Rate, in %) | Net Current Transfers (Growth Rate, in %) |
| Natural disasters, <i>t</i> | 0.353 ** (0.151) | −1.681 *** (0.587) |
| Natural disasters, <i>t</i> × external debt-to-GDP ratio, <i>t</i> − 1 | −1.085 *** (0.279) | 2.572 * (1.467) |
| External debt-to-GDP ratio, <i>t</i> − 1 | −0.345 (0.151) | −0.223 *** (0.072) |
| Country-fixed effects | Yes | Yes |
| Time-fixed effects | Yes | Yes |
| Lagged dependent variable | Yes | Yes |
| Observations | 1893 | 2367 |

Note: Huber robust standard errors (shown in parentheses) are clustered at the country level. *, **, and *** denote that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

According to the factsheet, the “Full cancellation of a country’s debt to the IMF is possible in cases where the natural disaster has created substantial and long-lasting balance of payments needs and where the resources freed up by debt relief are critical for meeting these needs. Typically, this would be limited to countries with a very high debt burden.

Debt stock relief would be conditional on concerted debt relief efforts by the country’s official creditors and availability of resources in the CCRT”.

We find evidence consistent with such debt relief in highly indebted countries: a natural disaster leads to an increase in the growth rate of external debt in countries with initially low external debt-to-GDP ratios; in countries with very high external debt-to-GDP ratios, a natural disaster decreases the growth rate of external debt. Furthermore, we find that highly indebted countries receive international relief that comes without a quid pro quo; i.e., net current transfers significantly increase in countries with high external debt-to-GDP ratios.

Panel B of Table 2 shows that natural disasters have a significant effect on the growth rates of external debt and net current transfers. From column (1) of Panel B in Table 2, one can see that the coefficient of natural disaster incidence is positive and significantly different from zero at a five percent level. The interaction between natural disaster incidence and the external debt-to-GDP ratio is positive and significantly different from zero at a one percent level. These estimates imply that when a natural disaster strikes countries with low external debt-to-GDP ratios, they significantly increase international borrowing, but this is not so in countries with intermediate to high external debt-to-GDP ratios. In column (2) of Panel B in Table 2, we can see that, in countries with intermediate to high external debt-to-GDP ratios, net current transfers significantly increase.

Aguiar (2023), in his Mundell–Fleming Lecture, “The Costs and Consequences of Sovereign Borrowing”, presents an overview of the literature on sovereign borrowing. There are two broad views with regard to the role of external debt: (1) the neoclassical view, which postulates that external debt speeds up investment and facilitates consumption smoothing; (2) the political economy view, according to which public external debt is used suboptimally (due to present bias) by governments for government consumption purposes. Our findings with regard to the impact of natural disasters on human development lend support to the first view.

3.5. Further Econometric Results on Risk Sharing

3.5.1. Public External Debt vs. Private External Debt

Table 3 reports estimates for public external debt (column (2)) and private external debt (column (3)). For comparison, column (1) reports the baseline estimates for total external debt.

Table 3. Effects of natural disasters on human development: public vs. private external debt.

| Dependent Variable | Human Development Index (in %) | | |
|---|--------------------------------|--|--------------------------------------|
| | Total External Debt | Public and Publicly Guaranteed External Debt | Private Non-Guaranteed External Debt |
| Natural disasters, t | −0.014 ** (0.006) | −0.010 * (0.006) | −0.006 (0.004) |
| Natural disasters, $t \times$ external debt-to-GDP ratio, $t - 1$ | 0.020 * (0.011) | 0.018 (0.012) | 0.076 * (0.042) |
| External debt-to-GDP ratio, $t - 1$ | −0.014 (0.029) | −0.013 (0.038) | −0.239 (0.166) |
| Human development index, $t - 1$ | 0.946 *** (0.011) | 0.939 *** (0.012) | 0.949 *** (0.013) |
| Country-fixed effects | Yes | Yes | Yes |
| Time-fixed effects | Yes | Yes | Yes |
| Observations | 2560 | 2560 | 1719 |

Note: Huber robust standard errors (shown in parentheses) are clustered at the country level. *, **, and *** denote that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

One can see from columns (2) and (3) of Table 3 that, qualitatively, results are similar for public external debt and private external debt. In both columns (2) and (3), the estimated coefficient of natural disasters is negative; the coefficient of the interaction between external

debt and natural disasters is positive. Qualitatively, the message of column (2) is that in countries with higher public external debt-to-GDP ratios, natural disasters have a less negative effect on the human development index. Similarly for column (3), in countries with higher private external debt-to-GDP ratios, natural disasters have a less negative effect on the human development index.

Statistically, results for private and public external debt are less significant than in the baseline model, where total external debt is used as the right-hand-side variable. In column (2) of Table 3, the estimated coefficient of natural disaster incidence is significantly different from zero at a ten percent level (p -value: 0.08); the estimated coefficient of the interaction between the public external debt-to-GDP ratio and the incidence of natural disasters is not significantly different from zero at conventional significance levels (p -value: 0.17). In column (3) of Table 3, the estimated coefficient of natural disaster incidence is not significantly different from zero at conventional significance levels (p -value: 0.19); the estimated coefficient of the interaction between the private external debt-to-GDP ratio and the incidence of natural disasters is significantly different from zero at a ten percent level (p -value 0.08). For comparison, in the baseline estimates that use total external debt, the coefficient of the external debt-to-GDP ratio is significantly different from zero at a five percent level (p -value: 0.02) and the interaction between the external debt-to-GDP ratio and natural disasters is significantly different from zero at a ten percent level (p -value 0.06).

The quantitative interpretation of the estimates for public external debt, see column (2) of Table 3, is as follows: If public external debt-to-GDP ratios were zero, then ten additional natural disasters (equal to about 1.6 standard deviations in the sample of developing countries of Asia–Pacific) in year t decreases the HDI in year t by 0.10 percentage points; in the long run, the HDI decreases by 1.9 percentage points. Consider now a developing country in Asia–Pacific with a relatively low public external debt-to-GDP, e.g., at the 10th percentile, where the public external debt-to-GDP ratio is 6 percent. According to the estimates in column (2) of Table 3, for a country with a public external debt-to-GDP equal to 6 percent, ten additional natural disasters in year t decrease the HDI in year t by 0.09 percentage points; in the long run, the HDI decreases by 1.7 percentage points. For a public external debt-to-GDP ratio at the 25th percentile, which is 13 percent, ten additional natural disasters in year t decrease the HDI by 0.08 percentage points in year t ; in the long run, the HDI decreases by 1.4 percentage points. For the median public external debt-to-GDP ratio, which is 26 percent, the estimates in column (2) imply that ten additional natural disasters in year t decrease the HDI in year t by 0.05 percentage points; in the long run, the HDI decreases by 1.0 percentage points.

The quantitative interpretation of the estimates for private external debt, see column (3) of Table 3, is as follows: If private external debt-to-GDP ratios were zero, then ten additional natural disasters in year t decrease the HDI in year t by 0.06 percentage points; in the long run, the HDI decreases by 1.2 percentage points. Consider now a developing country in Asia–Pacific with a relatively low private external debt-to-GDP ratio, e.g., at the 10th percentile, where the private external debt-to-GDP ratio is 0.1 percent. According to the estimates in column (3) of Table 3, for a country with a private external debt-to-GDP equal to 0.1 percent, ten additional natural disasters in year t decrease the HDI in year t by 0.06 percentage points; in the long run, the HDI decreases by 1.2 percentage points. For a private external debt-to-GDP ratio at the 25th percentile, which corresponds to a value of 1.5 percent, ten additional natural disasters in year t decrease the HDI in year t by about 0.05 percentage points; in the long run, the HDI decreases by 1.0 percentage point. For a private external debt-to-GDP ratio at the median, which is 5 percent, the estimates in column (3) imply that ten additional natural disasters in year t decrease the HDI in year t by 0.02 percentage points; in the long run, the HDI decreases by 0.4 percentage points.

3.5.2. Central Government Debt vs. Private Sector Debt

Table 4 reports estimates of Equation (1) using, instead of external debt, central government debt (column (1)) and private-sector debt (column (2)). The latter two variables

include domestic and foreign liabilities. External debt is, per its definition, a foreign liability. The external debt-to-GDP ratio is a measure of international risk sharing; central government debt and private-sector debt are measures of both national and international risk sharing.

One can see from columns (1) and (2) of Table 4 that, qualitatively, results are similar for central government debt and private-sector debt. In both columns (1) and (2) of Table 4, the estimated coefficients of natural disaster incidence are negative; the coefficients of the interaction between debt and natural disasters are positive. Qualitatively, the message of column (1) is that, in countries with higher central government debt-to-GDP ratios, natural disasters have a less negative effect on the human development index. Similarly for column (2), in countries with higher private-sector debt-to-GDP ratios, natural disasters have a less negative effect on the human development index.

Statistically, results for central government debt and private-sector debt are less significant than in the baseline model, where total external debt is used as the right-hand-side variable. In column (1) of Table 4, the estimated coefficient of natural disaster incidence is not significantly different from zero at conventional significance levels (p -value 0.14); the estimated coefficient of the interaction between the central government debt-to-GDP ratio and the incidence of natural disasters is also not significantly different from zero at conventional significance levels (p -value: 0.27). In column (2) of Table 4, the estimated coefficient of natural disaster incidence is not significantly different from zero at conventional significance levels (p -value: 0.14); the estimated coefficient of the interaction between the private sector debt-to-GDP ratio and the incidence of natural disasters is significantly different from zero at a 10 percent level (p -value: 0.07).

Table 4. Effects of natural disasters on human development: central government debt vs. private-sector debt.

| Dependent Variable | Human Development Index (in %) | |
|---|--------------------------------|---------------------|
| | Central Government Debt | Private-Sector Debt |
| Natural disasters, t | −0.006 (0.008) | −0.012 (0.008) |
| Natural disasters, $t \times$ debt-to-GDP ratio, $t - 1$ | 0.007 (0.007) | 0.013 * (0.007) |
| Debt-to-GDP ratio, $t - 1$ | −0.096 ** (0.044) | −0.185 (0.152) |
| Human development index, $t - 1$ | 0.942 *** (0.011) | 0.940 *** (0.012) |
| Country-fixed effects | Yes | Yes |
| Time-fixed effects | Yes | Yes |
| Observations | 2335 | 2273 |

Note: Huber robust standard errors (shown in parentheses) are clustered at the country level. *, **, and *** denote that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

The quantitative interpretation of the estimates for central government debt, see column (1) of Table 4, is as follows: If central government debt-to-GDP ratios were zero, then ten additional natural disasters in year t (equal to about 1.6 standard deviations in the sample of developing countries of Asia–Pacific) decrease the HDI in year t by 0.06 percentage points; in the long run, the HDI decreases by 1.0 percentage points. Consider now a developing country in Asia–Pacific with a relatively low central government debt-to-GDP ratio, e.g., at the 10th percentile, where the central government debt-to-GDP ratio is 12 percent. According to the estimates in column (1) of Table 4, for a country with a central government debt-to-GDP equal to 12 percent, ten additional natural disasters in year t decrease the HDI in year t by 0.05 percentage points; in the long run, the HDI decreases by 1.0 percentage points. For a central government debt-to-GDP ratio at the 25th percentile, which is 24 percent, ten additional natural disasters in year t decrease the HDI in year t by 0.04 percentage points; in the long run, the HDI decreases by 0.8 percentage points. For the median

central government debt-to-GDP ratio, which is 38.5 percent, the estimates in column (1) of Table 4 imply that ten additional natural disasters in year t decrease the HDI in year t by 0.03 percentage points; in the long run, the HDI decreases by 0.6 percentage points.

The quantitative interpretation of the estimates for private-sector debt, see column (2) of Table 4, is as follows: If private-sector debt-to-GDP ratios were zero, then ten additional natural disasters in year t decrease the HDI in year t by 0.12 percentage points; in the long run, the HDI decreases by 2.0 percentage points. Consider now a country with a relatively low private-sector debt-to-GDP ratio, e.g., at the 10th percentile, where the private-sector debt-to-GDP ratio is 5 percent. According to the estimates in column (2) of Table 4, for a country with a private-sector debt-to-GDP ratio equal to 5 percent, ten additional natural disasters in year t decrease the HDI in year t by 0.11 percentage points; in the long run, the HDI decreases by 1.9 percentage points. For a private-sector debt-to-GDP ratio at the 25th percentile, which corresponds to a value of 11 percent, ten additional natural disasters in year t decrease the HDI in year t by about 0.10 percentage points; in the long run, the HDI decreases by 1.7 percentage points. For a private-sector debt-to-GDP ratio at the median, which is 22 percent, the estimates in column (2) imply that ten additional natural disasters in year t decrease the HDI in year t by 0.09 percentage points; in the long run, the HDI decreases by 1.5 percentage points.

The results in Tables 1–4 suggest that international risk sharing is more effective in reducing the HDI costs of natural disasters than domestic risk sharing. This is plausible. International financial markets are much deeper than domestic financial markets. When natural disasters strike and significant economic damage is done, domestic resources may be insufficient to fully buffer the shock.

3.5.3. Financial Market Depth

A country’s external debt-to-GDP ratio is just one, although very important, component of the depth of financial markets. The IMF has put together an index of financial market depth⁵ that combines data on the size of a stock market (capitalization, or the value of listed shares), how active it is (stocks traded), the outstanding volume of international debt securities of sovereigns, and international as well as domestic debt securities of financial and nonfinancial corporations.

Table 5 reports estimates where the incidence of natural disasters is interacted with the IMF’s index of financial market depth. One can see from the results displayed in Table 5 that the estimated coefficient of natural disaster incidence is negative and significantly different from zero at a 5 percent level (p -value: 0.04). The interaction between natural disaster incidence and the index of financial market depth is positive and significantly different from zero at a 10 percent level (p -value: 0.06). The qualitative interpretation of these estimates is that natural disasters have a less negative effect on human development in countries with deeper financial markets.

Table 5. Effects of natural disasters on human development: the role of financial market depth.

| Dependent Variable | Human Development Index (in %) |
|---|--------------------------------|
| Natural disasters, t | −0.016 ** (0.008) |
| Natural disasters, $t \times$ financial market depth, $t - 1$ | 0.031 * (0.016) |
| Financial market depth, $t - 1$ | −0.502 (0.320) |
| Human development index, $t - 1$ | 0.943 *** (0.012) |
| Country-fixed effects | Yes |
| Time-fixed effects | Yes |
| Observations | 2609 |

Note: Huber robust standard errors (shown in parentheses) are clustered at the country level. *, **, and *** denote that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

The quantitative interpretation of the estimates in Table 5 is as follows: If the index of financial market depth is zero, then ten additional natural disasters in year t (equal to about 1.6 standard deviations in the sample of developing countries of Asia–Pacific) decrease the HDI in year t by 0.16 percentage points; in the long run, the HDI decreases by 2.8 percentage points. According to the IMF data, about one-quarter of countries in Asia–Pacific have an index of financial market depth equal to zero (the index ranges from 0 to 1, with higher values denoting deeper financial markets). For the median country in Asia–Pacific (where the index of financial market depth is equal to 0.08), the estimates in Table 5 imply that ten additional natural disasters in year t reduce the HDI in year t by about 0.14 percentage points; in the long run, the HDI decreases by 2.4 percentage points.

3.5.4. Grants

In this section, we provide estimates of how grants impact the effect that natural disasters have on human development. From a risk-sharing perspective, grants should have similar effects to external debt: Both provide the (financial) means for imports. When a country is struck by an unexpected, exogenous event that adversely affects output, such as a natural disaster, it can smooth consumption by increasing imports. While with external debt the country has an obligation to repay in the future, there is no such obligation with grants—i.e., grants come without a quid pro quo.

Table 6 reports estimates where the incidence of natural disasters is interacted with the grants-to-GDP ratio. Grants are split into two categories: total grants, excluding technical assistance (column (1)), and technical assistance only (column (2)). One can see from columns (1) and (2) of Table 6 that, qualitatively, results are similar for both categories. In both columns (1) and (2), the estimated coefficient of natural disasters is negative and significantly different from zero at a ten percent level. The coefficient of the interaction between the grants-to-GDP ratio is positive and significantly different from zero at a 10 percent level. Qualitatively, the message of the estimates displayed in Table 6 is that, in countries with higher grants-to-GDP ratios, natural disasters have a less negative effect on the human development index (i.e., are associated with a smaller HDI cost).

Table 6. Effects of natural disasters on human development: the role of grants.

| Dependent Variable | Human Development Index (in %) | |
|--|---|------------------------------|
| | Grants, Excluding Technical Cooperation | Technical Cooperation Grants |
| Natural disasters, t | −0.010 * (0.006) | −0.010 * (0.005) |
| Natural disasters, $t \times$ grants-to-GDP ratio, $t - 1$ | 0.168 * (0.101) | 0.921 * (0.515) |
| Grants-to-GDP ratio, $t - 1$ | 0.291 (0.413) | −0.020 (1.633) |
| Human development index, $t - 1$ | 0.939 *** (0.011) | 0.937 *** (0.011) |
| Country-fixed effects | Yes | Yes |
| Time-fixed effects | Yes | Yes |
| Observations | 2647 | 2646 |

Note: Huber robust standard errors (shown in parentheses) are clustered at the country level. *, **, and *** denote that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

The quantitative interpretation of the estimates in column (1) of Table 6 is as follows: If the ratio of grants excluding technical assistance over GDP is zero, then ten additional natural disasters in year t decrease the HDI in year t by 0.10 percentage points; in the long run, the HDI decreases by 1.7 percentage points. Consider now a developing country in Asia–Pacific with a relatively low ratio of grants excluding technical assistance over GDP, e.g., at the 10th percentile, where this ratio is equal to 0.03 percent. According to the estimates in column (1) of Table 6, for a country with a ratio of grants excluding technical assistance equal to 0.03 percent, ten additional natural disasters in year t decrease the HDI in year t by 0.10 percentage points; in the long run, the HDI decreases by 1.7 percentage

points. For a GDP ratio of grants excluding technical assistance at the 25th percentile, which is 0.2 percent, ten additional natural disasters in year t decrease the HDI in year t by 0.09 percentage points; in the long run, the HDI decreases by 1.6 percentage points. For the median GDP ratio of grants excluding technical assistance, which is 2.0 percent, the estimates in column (1) of Table 6 imply that ten additional natural disasters in year t decrease the HDI in year t by 0.07 percentage points; in the long run, the HDI decreases by 1.1 percentage points.

The quantitative interpretation of the estimates in column (2) of Table 6 is as follows. If the ratio of technical assistance over GDP is zero, then ten additional natural disasters in year t decrease the HDI in year t by 0.10 percentage points; in the long run, the HDI decreases by 1.7 percentage points. Consider now a developing country in Asia–Pacific with a relatively low ratio of technical assistance over GDP, e.g., at the 10th percentile, where this ratio is equal to 0.02 percent. According to the estimates in column (2) of Table 6, for a country with a ratio of technical assistance over GDP equal to 0.02 percent, ten additional natural disasters in year t decrease the HDI in year t by 0.10 percentage points; in the long run, the HDI decreases by 1.7 percentage points. For a GDP ratio of technical assistance at the 25th percentile, which is 0.06 percent, ten additional natural disasters in year t decrease the HDI in year t by 0.09 percentage points; in the long run, the HDI decreases by 1.5 percentage points. For the median GDP ratio of technical assistance, which is 0.5 percent, the estimates in column (2) imply that ten additional natural disasters in year t decrease the HDI by 0.05 percentage points; in the long run, the HDI decreases by 0.8 percentage points.

3.6. Current Account Deficit vs. Current Account Surplus

In this section, we split countries into two groups: those with a current account deficit (group 1) and those with a current account surplus (group 2). We then re-estimate our baseline econometric model separately for group 1 and group 2.

Table 7 shows the relevant results. In column (1), we present estimates for the group of countries with current account deficits. The total number of country–year observations for this subsample is 1788. In column (2), we show estimates for the group of countries with a current account surplus. For group (2), the number of country–year observations is 514.

Table 7. Effects of natural disasters on human development: the role of external debt (current account surplus vs. current account deficit).

| Dependent Variable | Human Development Index (in %) | |
|---|--------------------------------|-------------------------|
| | Current Account Deficit | Current Account Surplus |
| Natural disasters, t | −0.017 * (0.010) | −0.013 ** (0.006) |
| Natural disasters, $t \times$ external debt-to-GDP ratio, $t - 1$ | 0.020 (0.016) | 0.050 *** (0.016) |
| External debt-to-GDP ratio, $t - 1$ | 0.014 (0.034) | −0.265 *** (0.087) |
| Country-fixed effects | Yes | Yes |
| Time-fixed effects | Yes | Yes |
| Lagged dependent variable | Yes | Yes |
| Observations | 1788 | 514 |

Note: Huber robust standard errors (shown in parentheses) are clustered at the country level. *, **, and *** denote that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

From the estimates in Table 7, one can see that in both group 1 and 2 (i) natural disasters have a negative effect on human development; (ii) external debt reduces the negative effects that natural disasters have on human development. Effect (ii) is stronger and more statistically significant in group 2, i.e., the countries with a current account surplus.

4. Case Studies

This section presents case studies for two selected countries of developing Asia–Pacific: Indonesia and the Philippines. Both countries have experienced a significant number of natural disasters in the past. The period covered in the case studies is 2010–2020; the time period of the analysis thus spans the entire past decade. The selection of this time period is motivated by two main goals; First, the case studies should uncover medium-term effects. For uncovering medium-term effects, a time span of one decade is an appropriate time window. (As opposed to cyclical, short-run effects, where the appropriate time window would be one or just a few years, or long-term effects, where the appropriate time window would be half a century or longer.) Second, the case studies should uncover the most recent medium-term effects, i.e., effects during the last decade. These two goals motivate the choice of 2010–2020 as the time period during which the case studies took place.

One can use the estimates from the econometric model to compute the effects that natural disasters have on the human development index for specific countries during 2010–2020. This effect is referred to in Figure 2 as the “HDI cost”. Note that, if the effects of natural disasters on the HDI are negative, the HDI cost is positive. The HDI cost is computed using the estimates in column (1) of Table 1 and the incidence of natural disasters for a particular country that serves as a case study during 2010–2020.

Panel A: Indonesia.

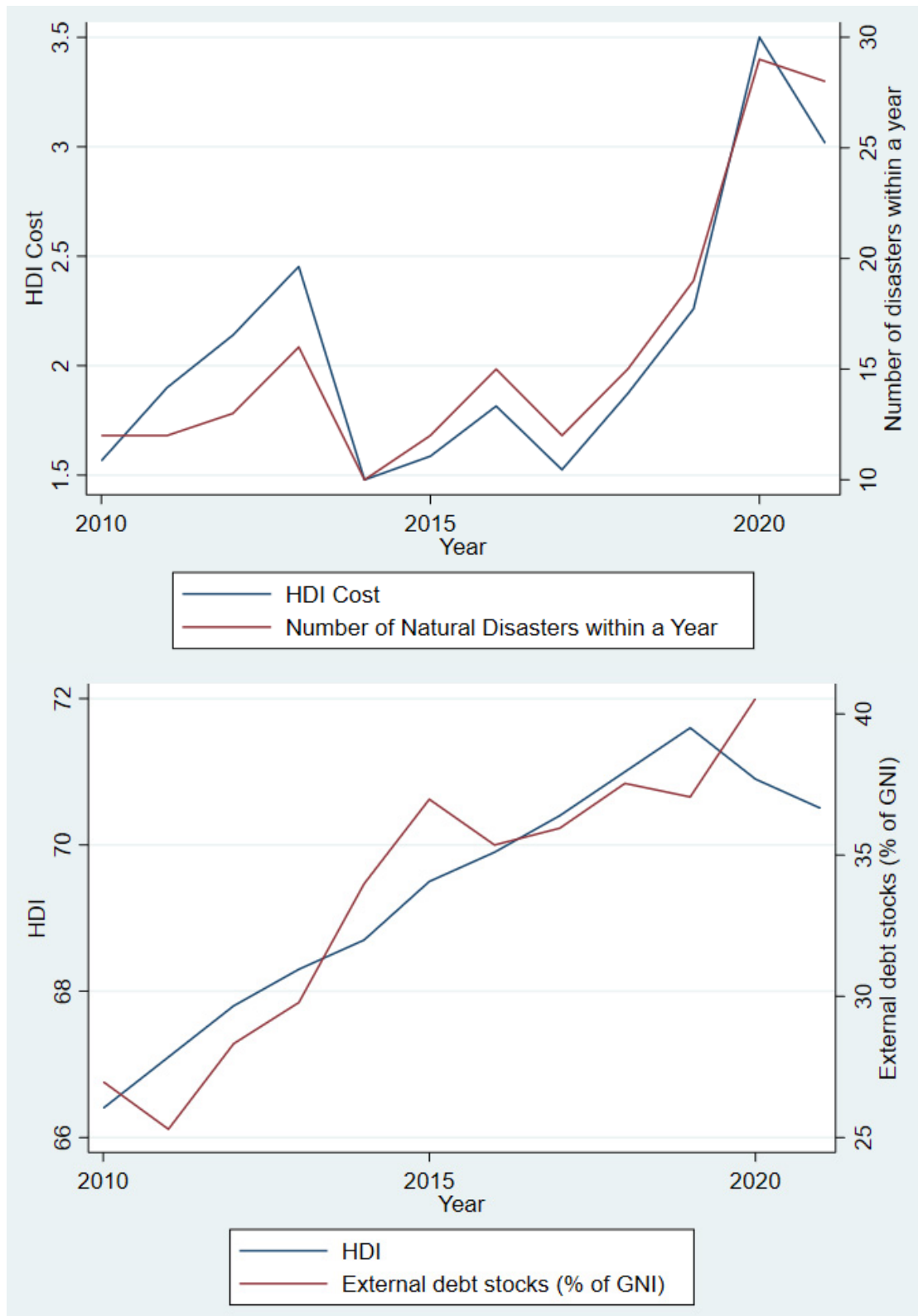


Figure 2. Cont.

Panel B: Philippines.

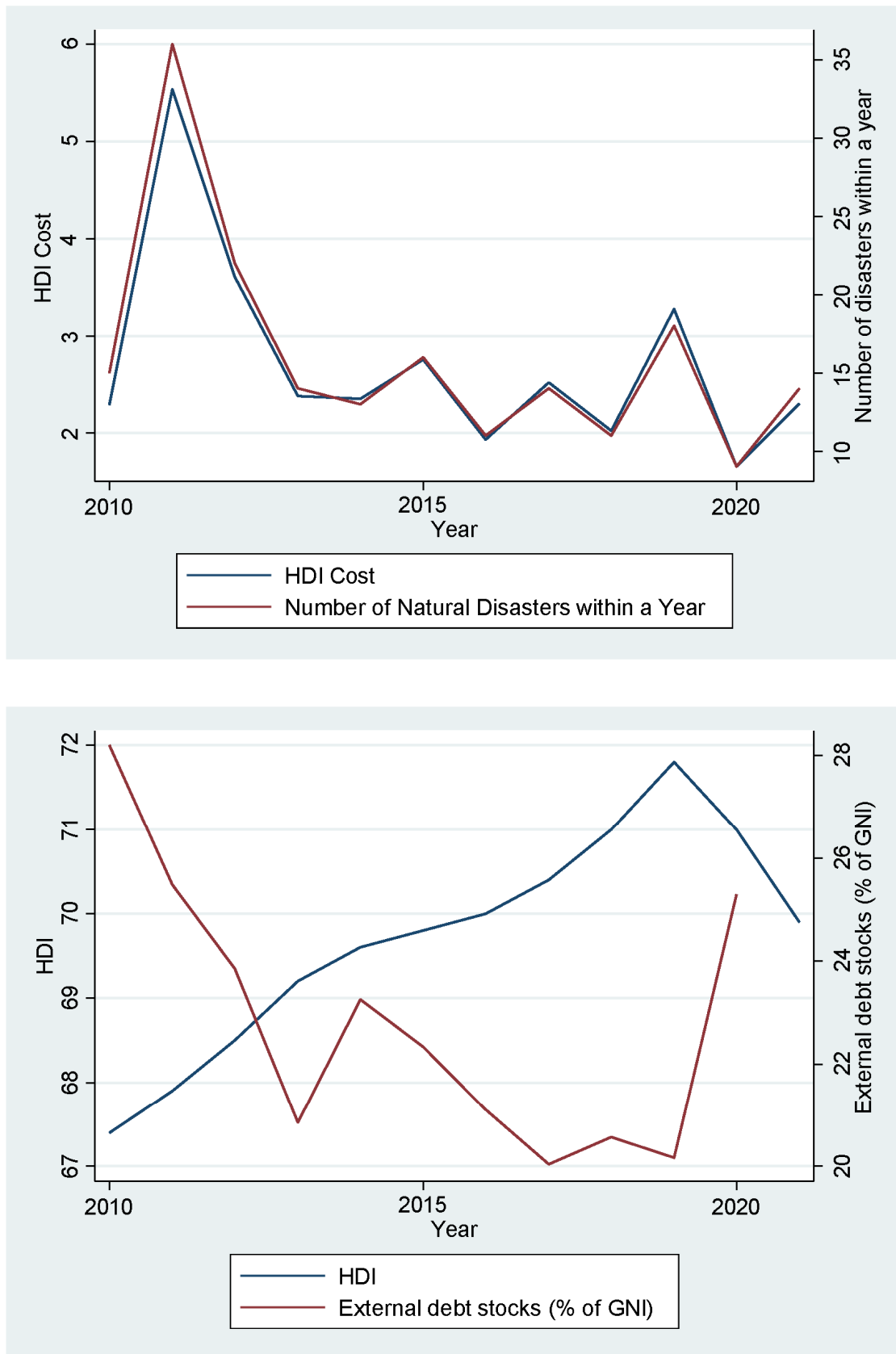


Figure 2. The HDI cost of natural disasters for selected countries.

4.1. Indonesia

Panel A of Figure 2 (left-hand-side y-axis, blue line) shows that the effects of natural disasters on Indonesia's human development during 2010–2021 were negative; that is, there was a positive HDI cost. At the peak, in 2020, when according to EM-DAT there were 29 natural disasters in Indonesia, the HDI cost was about 3.5 percentage points. In the early 2010s, when the incidence of natural disasters was relatively low, the HDI cost was about 1.5 to 2 percentage points. In the late 2010s, when the incidence of natural disasters was relatively high, the HDI cost of natural disasters was about 3 to 3.5 percentage points.

The increase in the HDI cost in Indonesia is mostly due to the increase in the incidence of natural disasters in that country. As one can see from Panel A of Figure 2 (right-hand-side y-axis, red line), during the past decade the incidence of natural disasters has increased in Indonesia. At the beginning of the 2010s, Indonesia experienced about 10 to 15 natural disaster per year. Towards the end of the 2010s, Indonesia experienced about 20 to 30 natural disasters—about double the rate of natural disasters that the country experienced 10 years earlier.

External debt-to-GDP ratios have increased in Indonesia during the past decade. At the beginning of the 2010s, Indonesia's external debt stood at slightly above 25 percent of GDP. Ten years later, in 2020, external debt was about 40 percent of GDP. According to the estimates of the econometric model, the increase in Indonesia's external debt reduced the adverse effects that natural disasters had on the HDI. If external debt would have remained at the 2010 value (i.e., not increased during the 2010s), the HDI cost of natural disasters would have been considerably larger towards the end of the last decade, about 4 to 5 percentage points.

For Indonesia, there is a positive trend relationship between external debt-to-GDP ratios and the human development index during 2010–2020. Between 2010 and 2020, the external debt-to-GDP ratio increased by about 15 percentage points; the HDI increased by around 5 percentage points.

4.2. Philippines

Panel B of Figure 2 (left-hand-side y-axis, blue line) shows that the effects of natural disasters on the Philippines's human development were negative during 2010–2020, i.e., there was a positive HDI cost. At the peak, in 2011, when according to EM-DAT there were 36 natural disasters in the Philippines, the HDI cost was about 5.5 percentage points. For the other years during 2010–2020, when the incidence of natural disasters in the Philippines was in the range of 9 to 22 per year, the HDI cost was in the range of 1.7 to 3.6 percentage points.

The Philippines's external debt-to-GDP ratio is relatively low by international standards. During 2010–2020, the Philippines's external debt was in the range of around 20 to 28 percent of its GDP. External debt-to-GDP ratios decreased in the Philippines sharply at the beginning of the decade, and then increased towards the end of the 2010s. The Philippines's external debt-to-GDP ratio was around 28 percent in 2010 and 25 percent in 2020.

If the Philippines would have borrowed more internationally, then this could have significantly reduced the HDI cost of natural disasters. Suppose the Philippines would have borrowed more, such that its external debt-to-GDP ratio would have been 40 percent of GDP. According to the estimates in column (1) of Table 1, at an external debt-to-GDP ratio of 40 percent, the peak HDI cost in the year 2011—when the Philippines were hit by 36 natural disasters—would have been about 4.0 percentage points. This is almost 30 percent less than the actual HDI cost of natural disasters that the Philippines incurred in the year 2011 (which was 5.5 percentage points, computed for the actual external debt-to-GDP ratio in the year 2011). For the other years during 2010–2020, the HDI cost due to natural disasters that occurred in the Philippines during this time period would have been around 1 to 2.4 percentage points if external debt-to-GDP ratios would have been around 40 percent of GDP.

For the Philippines, there is a negative trend relationship between external debt-to-GDP ratios and the human development index. Between 2010 and 2020, the external debt-to-GDP ratio decreased by about 3 percentage points and the HDI increased by 3 percentage points.

5. Summary and Policy Implications

The econometric model estimates showed that an unexpected increase in the incidence of natural disasters has a less negative effect on human development in countries with a higher external debt-to-GDP ratio. In countries with very low external debt-to-GDP ratios, i.e., less than 20 percent, natural disaster shocks are associated with significant decreases in the human development index, the human capital index, life expectancy, and GDP growth. In countries with median and above-median external debt-to-GDP ratios, there are no significant negative effects of natural disaster shocks on these outcome variables.

The econometric model estimates also showed that the benefits of international borrowing are significantly increasing with the number of natural disasters. For countries with a high frequency of natural disasters, there is a significant positive effect of external debt-to-GDP ratios on the HDI, the HCI, and life expectancy; there is an insignificant effect of external debt-to-GDP ratios on GDP growth. In contrast, in disaster-free countries there is a significant negative effect of external debt-to-GDP ratios on GDP growth, and a negative but statistically insignificant effect on the HDI, the HCI, and life expectancy.

Developing countries of Asia–Pacific that wish to reduce the adverse effects of natural disasters on human development should put effort into integrating more into international financial system. At the same time, there is also a need for reform in international financial mechanisms so that access to finance is easier for developing countries because countries with high incidences of disaster per capita are also the ones being locked out from access to international finance. A hallmark result in international economics is that welfare increases due to international risk sharing when countries are hit by exogenous, country-specific shocks, such as natural disasters. Higher external debt-to-GDP ratios indicate that there is more international risk sharing. International risk sharing is beneficial for human development when countries are faced with an exogenous, adverse country-specific shock, such as a natural disaster. The econometric model estimates showed that, in countries with a higher number of natural disasters, increasing external debt-to-GDP ratios has positive effects on life expectancy and human capital. There are no significant effects on GDP growth. Hence, one would expect a positive effect on human development of higher external debt-to-GDP ratios in disaster-prone countries that materializes through higher life expectancy (i.e., improved health outcomes) and greater human capital.

In order to increase international risk sharing, governments of disaster-prone countries can pursue two broad strategies. The first strategy is to increase integration into the international financial system, including concessional financing. To do so, governments of developing countries in Asia–Pacific need to carry out domestic reforms; however, it will also be equally important to reform the international financial system, including reforms of the multilateral development banks⁶ so that more finance is available from agencies such as the IMF, World Bank, Asian Development Bank or governments of large economies. A second indirect strategy is to reduce barriers to international borrowing faced by the private sector. Reducing these barriers would likely lead to an increase in private-sector borrowing.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/jrfm17060246/s1>, Table S1: Descriptive Statistics Debt, Development, Climate and Natural Disasters in Asia-Pacific During 1970–2020; Table S2A: Debt, Development, Climate and Natural Disasters Averages During 1990–2020 for Different Developing Regions in the World; Table S2B: Debt, Development, Climate and Natural Disasters Averages During 1990–2020 for Different Developing Regions in Asia-Pacific; Table S3: Debt, Development, Climate and Natural Disasters Averages During 1990–2020 by Income Status; Table S4: List of Top-5 Most Affected Countries from Natural Disasters; Figure S1A: External Debt and Human Development; Figure S1B: Natural Disasters and Human Development in Asia-Pacific; Figure S1C: Natural disasters and capital

per worker in Asia-Pacific; Figure S1D: Natural disasters and total factor productivity in Asia-Pacific; Figure S1E: Natural disasters and poverty in Asia-Pacific; Figure S2: Trends in the External Debt-to-GDP Ratio; Figure S3: Trends in the Human Development Index; Figure S4: Trends in Temperatures; Figure S5: Trends in the Annual Incidence of Natural Disasters; Figure S6: The distribution of natural disaster incidence in Asia-Pacific.

Author Contributions: Conceptualization, M.B. and S.D.; methodology, M.B. and S.D.; software, M.B. and H.L.; validation, M.B. and H.L.; formal analysis, M.B.; investigation, M.B., S.D. and H.L.; resources, M.B., S.D. and H.L.; data curation M.B. and H.L.; writing—original draft preparation, M.B., S.D. and H.L.; writing—review and editing, M.B., S.D. and H.L.; visualization, M.B., S.D. and H.L.; supervision, M.B. and S.D.; project administration, M.B., S.D. and H.L.; funding acquisition, S.D. All authors have read and agreed to the published version of the manuscript.

Funding: The research was funded by UNDP, contract number IC-2022/212. A background paper was written for the UNDP Regional Human Development Report for which the funding was received. The findings, analysis, and recommendations of the paper published this journal are those of the authors and do not represent the official position of the UNDP or of any of the UN Member States that are part of its Executive Board.

Data Availability Statement: All data are publicly available.

Acknowledgments: Feedback from two anonymous referees, the journal’s editor, as well as Philip Schellekens, Lars Jensen, Vikram Nehru, Mizuho Okimoto-Kaewtathip, and Amos Peters is gratefully acknowledged. Any views and opinions expressed in this paper are those of the author and do not necessarily reflect the views or positions of any entities the authors represent.

Conflicts of Interest: The authors declare no conflict of interest.

Notes

- ¹ This calculation, of course, does not mean that Indonesia’s HDI will decrease in the future to the values computed here. The calculations merely serve to illustrate the quantitative effects that natural disasters have on the human development index for a country like Indonesia. There are many other things (unrelated to natural disasters) that affect Indonesia’s HDI.
- ² We have also estimated models that include a squared term of the external-debt-to-GDP ratio. The estimates of the natural disasters and the interaction with external debt were similar to the ones reported in Table 2. The coefficient of squared debt was insignificant.
- ³ External debt is a financial obligation to pay back (borrowed) resources in the future. When such a financial obligation exists, a country can obtain resources (imports) from abroad at the time that a disaster strikes. There are other ways to finance imports, e.g., by selling foreign assets (as opposed to increasing foreign liabilities). If a country sells foreign assets (there is a decrease in net foreign assets), the decrease in the trade balance that arises from the increase in imports would be fully reflected in a deterioration of the country’s current account. It should also be noted that, in the context of developing countries, another way to obtain imports is through net current transfers, i.e., foreign aid or remittances. If the imports come in the form of foreign aid or remittances, there is a deterioration in the trade balance, but the current account, as well as net foreign assets, would be unchanged. A deeper dive into these issues goes beyond this paper, which is devoted to the role that external debt may have with regard to shaping the relationship between natural disasters and development.
- ⁴ See <https://www.imf.org/en/About/Factsheets/Sheets/2023/Catastrophe-containment-relief-trust-CCRT> (accessed on 18 May 2023).
- ⁵ See IMF WP 16/5 “Introducing a New Broad-based Index of Financial Development”.
- ⁶ See <https://odi.org/en/insights/multilateral-development-bank-reform-can-and-must-benefit-both-low-and-middle-income-countries/> (accessed on 1 June 2023) and <https://www.brookings.edu/articles/strengthening-multilateral-development-banks-a-response-to-critics/> (accessed on 1 June 2023).

References

- Aguiar, Mark. 2023. *The Costs and Consequences of Sovereign Borrowing*. Mundell Fleming Lecture. Available online: <https://link.springer.com/article/10.1057/s41308-024-00248-9> (accessed on 1 June 2023).
- Albala-Bertrand, Jose Miguel. 1993. *Political Economy of Large Natural Disasters*. Oxford: Clarendon Press.
- Armenian, Haroutune K., Arthur K. Melkonian, and Ashot P. Hovanesian. 1998. Long-term mortality and morbidity related to the degree of damage following the 1988 earthquake in Armenia. *American Journal of Epidemiology* 148: 1077–84. [CrossRef] [PubMed]
- Caruso, Germán, and Sebastian Miller. 2015. Long-run effects and intergenerational transmission of natural disasters: A case study on the 1970 Ancash Earthquake. *Journal of Development Economics* 117: 134–50. [CrossRef]
- Cavallo, Eduardo, Sebastian Galiani, Ilan Noy, and Juan Pantano. 2013. Catastrophic natural disasters and economic growth. *Review of Economics and Statistics* 95: 1549–61. [CrossRef]

- Checherita-Westphal, Cristina, and Philipp Rother. 2012. The impact of high government debt on economic growth and its channels: An empirical investigation for the euro area. *European Economic Review* 56: 1392–405. [CrossRef]
- Clements, Benedict, Rina Bhattacharya, and Toan Quoc Nguyen. 2003. *External Debt, Public Investment, and Growth in Low-Income Countries*. IMF Working Paper, No. 03/249. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=880959 (accessed on 1 June 2023).
- Currie, Janet, and Maya Rossin-Slater. 2013. Weathering the storm: Hurricanes and birth outcomes. *Journal of Health Economics* 32: 487–503. [CrossRef] [PubMed]
- de Oliveira, Victor Hugo, Ines Lee, and Climent Quintana-Domeque. 2023. Natural disasters and early human development: Hurricane Catarina and infant health in Brazil. *Journal of Human Resources* 58: 819–51. [CrossRef]
- Dessy, Sylvain, and Désiré Vencatachellum. 2007. Debt relief and social services expenditure: The African experience, 1989–2003. *African Development Review* 19: 200–16. [CrossRef]
- Doğan, İbrahim, and Faik Bilgili. 2014. The non-linear impact of high and growing government external debt on economic growth: A Markov regime-switching approach. *Economic Modelling* 39: 213–20. [CrossRef]
- Felbermayr, Gabriel, and Jasmin Gröschl. 2014. Naturally negative: The growth effects of natural disasters. *Journal of Development Economics* 111: 92–106. [CrossRef]
- Fosu, Augustin Kwasi. 2007. Fiscal allocation for education in sub-Saharan Africa: Implications of the external debt service constraint. *World Development* 35: 702–13. [CrossRef]
- Fosu, Augustin Kwasi. 2008. Implications of the external debt-servicing constraint for public health expenditure in sub-Saharan Africa. *Oxford Development Studies* 36: 363–77. [CrossRef]
- Frankenberg, Elizabeth, Cecep Sumantri, and Duncan Thomas. 2020. Effects of a natural disaster on mortality risks over the longer term. *Nature Sustainability* 3: 614–19. [CrossRef]
- Ho, Jessica Y., Elizabeth Frankenberg, Cecep Sumantri, and Duncan Thomas. 2017. Adult mortality five years after a natural disaster. *Population and Development Review* 43: 467–90. [CrossRef]
- Howard, Emma, Kean Murphy, Wouter Nientker, Karim El-Ouaghli, and Harry Schmidt. 2020. The Effectiveness of Debt Relief in Mitigating the Macroeconomic Consequences of Natural Disasters. Master's thesis, Barcelona School of Economics, Barcelona, Spain.
- Husted, Lucas, Issac M. Opper, and R. Jisung Park. 2022. *The Impact of Natural Disasters on Human Capital*. Annenberg Brown University Edworking Paper, No. 22-548. Providence: The Annenberg Institute for School Reform at Brown University.
- Kahn, Matthew E. 2005. The death toll from natural disasters: The role of income, geography, and institutions. *Review of Economics and Statistics* 87: 271–84. [CrossRef]
- Khan, Muhammad, Sofia Anwar, Samuel Sarkodie, Muhammad Yaseen, and Adbul Nadeem. 2023. Do natural disasters affect economic growth: The role of human capital, foreign direct investment, and infrastructure dynamics. *Heliyon* 9: e12911. [CrossRef] [PubMed]
- Kim, Bongkyun, Celeste K. Carruthers, and Matthew C. Harris. 2017. Maternal stress and birth outcomes: Evidence from the 1994 Northridge earthquake. *Journal of Economic Behavior & Organization* 140: 354–73.
- Loko, Boileau, Montfort Mlachila, Raj Nallari, and Kadima Kalonji. 2003. *The Impact of External Indebtedness on Poverty in Low-Income Countries*. IMF Working Paper, No. 03/61. Washington: International Monetary Fund.
- Maggiore, Matteo. 2022. International macroeconomics with imperfect financial markets. In *Handbook of International Economics*. Amsterdam: Elsevier, vol. 6, pp. 199–236.
- Melecky, Martin, and Claudio Raddatz. 2015. Fiscal Responses after Catastrophes and the Enabling Role of Financial Development. *World Bank Economic Review* 29: 479–522. [CrossRef]
- Nakagawa, Izumi, Kazutoshi Nakamura, Mari Oyama, Osamu Yamazaki, Kazuo Ishigami, Yasuo Tsuchiya, and Masaharu Yamamoto. 2009. Long-term effects of the Niigata-Chuetsu earthquake in Japan on acute myocardial infarction mortality: An analysis of death certificate data. *Heart* 95: 1972–73. [CrossRef]
- Noy, Ilan. 2009. The macroeconomic consequences of disasters. *Journal of Development Economics* 88: 221–31. [CrossRef]
- Özek, Umut. 2023. Examining the educational spillover effects of severe natural disasters: The case of Hurricane Maria. *Journal of Human Resources* 58: 421–51. [CrossRef]
- Pane, John, Daniel McCaffrey, Shannah Tharp-Taylor, Garry Asmus, and Billi Stokes. 2006. *Student Displacement in Louisiana after the Hurricanes of 2005: Experiences of Public Schools and Their Students*. Santa Monica: RAND Corporation.
- Pattillo, Catherine, Helene Poirson, and Lucca Ricci. 2002. *External Debt and Growth*. IMF Working Paper, No. 02/69. Washington: International Monetary Fund.
- Paudel, Jayash, and Hanbyul Ryu. 2018. Natural disasters and human capital: The case of Nepal's earthquake. *World Development* 111: 1–12. [CrossRef]
- Reinhart, Carmen, and Kenneth Rogoff. 2010. Growth in a Time of Debt. *American Economic Review Papers and Proceedings* 100: 573–78. [CrossRef]
- Sacerdote, Bruce. 2012. When the saints go marching out: Long-term outcomes for student evacuees from Hurricanes Katrina and Rita. *American Economic Journal: Applied Economics* 4: 109–35. [CrossRef]
- Skidmore, Mark, and Hideki Toya. 2002. Do natural disasters promote long-run growth? *Economic Inquiry* 40: 664–87. [CrossRef]

-
- Strobl, Eric. 2011. The economic growth impact of hurricanes: Evidence from US coastal counties. *Review of Economics and Statistics* 93: 575–89. [[CrossRef](#)]
- Torche, Florencia. 2011. The Effect of Maternal Stress on Birth Outcomes: Exploiting a natural experiment. *Demography* 48: 1473–91. [[CrossRef](#)] [[PubMed](#)]
- Toya, Hideki, and Mark Skidmore. 2007. Economic development and the impacts of natural disasters. *Economics Letters* 94: 20–25. [[CrossRef](#)]
- Zaghdoudi, Khemais. 2018. Is the relationship between external debt and human development non-linear? A PSTR approach for developing countries. *Economics Bulletin* 38: 2194–216.

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.