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

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Abstract

The average country in Asia-Pacific experiences more natural disasters than the average country 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, 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 country 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 smooth consumption. 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.

Keywords

natural disasters, shocks, debt, human development

JEL Classification

O4, F3, Q54, H6

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

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by

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Abstract: The average country in Asia-Pacific experiences more natural disasters than the average country 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, 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 country 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 smooth consumption. 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.

Contribution of the paper: 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.

Key Words: Natural Disasters, Shocks, Debt, Human Development
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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 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 these 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.

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 socio-economic 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 to guide 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 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 socio-economic 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.

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 socio-economic crises. A careful balance, therefore, needs to be struck, and optimal conditions identified 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 eight 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 analysis 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 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, the paper is divided into several sections. After discussing related literature in the next section, we move on to present stylized facts in Section 3. Section 4 contains a discussion of the econometric model estimates. Section 5 presents case studies. Section 6 concludes.

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.

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 low birth weight. 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. (2016) examined the impact of the 2004 Niigata-Chuetse 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 the tsunami, 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 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 the Louisiana public schools. The likelihood of displaced students attending

colleges declined as well. The negative effects on human capital were not restricted to very large disasters, as shown by Husted et al. (2023). 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 through 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 infant exposure to natural disasters on long-term education outcomes. Caruso and Miller (2015) found that the earthquake exposure in utero led to less schooling, and Paudel and Ryu (2018) revealed that infants born in more affected areas by earthquakes were less likely to complete middle and 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 the 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 level 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 (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 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 the actual debt service payment can be endogenous, as governments may adjust their debt service payments to accommodate pressing needs, and therefore, it may not reflect the degree of the liquidity constraint. 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 had 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 expenditures, 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 data set 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 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, Dogan 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, Zaghdoudi (2018) examined the impact of external debt on the composite HDI index. Using panel data for 95 developing countries between 2002 and 2015, Zaghdoudi (2018) identified a non-linear 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 Zaghdoudi (2018) and our paper is that we control for country and time fixed effects as well as the lagged dependent variable, while Zaghdoudi's controls only for country fixed effects (but not time fixed effects and lagged HDI, which in the context of external debt are both very important control variables). In contrast to Zaghdoudi 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 the Official Development Assistance (ODA) after disasters had a positive effect on economic growth, and the effect increased in disaster severity, suggesting that ODA is an effective post-disaster recovery instrument.

A closely related paper by Melecky and Raddatz (2015) finds 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. Stylized Facts

This section presents stylized facts on external debt, human development and natural disasters for developing Asia-Pacific. The section begins by discussing summary statistics on external debt-to-GDP ratios and the associated debt servicing costs. A key finding of this section is that external debt to-GDP-ratios in developing Asia-Pacific are similar to other developing regions, and so is the burden associated with debt as measured by debt servicing costs as a percent of GDP.

Section 3.2 shows cross-country scatter plots of the relationship between external debt-to-GDP ratios and the human development index. The main takeaway from Section 3.2 is that in Asia-Pacific human development is not significantly associated with external debt-to-GDP ratios. Section

3.2 also presents and discusses descriptive statistics of the human development index for Asia-Pacific, and compares these to other developing regions.

Section 3.3 examines a specific component of the human development index: GDP per capita. GDP per capita in Asia-Pacific is significantly lower than in LAC and MENA, but significantly higher than in SSA. The section shows evidence that these differences emerge due to differences in capital per worker as well as differences in total factor productivity.

Section 3.4 presents descriptive statistics on the incidence and severity of natural disasters. The descriptive statistics show that Asia-Pacific suffers from more natural disasters than other regions. The severity of natural disasters is also greater in Asia-Pacific. Natural disasters in Asia-Pacific have become more frequent and more severe over the past two decades.

Section 3.5 shows that there is a significant negative cross-country relationship between natural disasters and development. Countries in Asia-Pacific with a greater mean incidence of natural disasters have a lower human development index, less capital per worker, lower total factor productivity, and higher poverty rates.

Section 3.6 discusses trends in external debt-to-GDP ratios, the human development index, and natural disasters. The three main takeaways from this section are that: (i) external debt-to-GDP ratios in Asia-Pacific are lower during the early 2020s than they were in the late 1990s; (ii) countries in Asia-Pacific experienced sustained progress in the human development index during 1990-2020; (iii) temperatures and the incidence of natural disasters are on the rise.

3.1 External Debt and Debt Servicing Costs

During 1990-2020, the average external debt-to-GDP ratio in Asia-Pacific was about 46 percent. This is not a particularly large value by international comparison. In other developing regions in the world, such as Latin America and the Caribbean, Middle East and North Africa, and Sub-Saharan Africa the average external-to-GDP ratios during 1990-2020 were about 62, 55, and 72 percent respectively.[1] Noteworthy is that the debt servicing cost was quite a bit lower for Asia-Pacific than for these other developing regions. For Asia-Pacific, the average annual debt servicing cost as a fraction of GDP was around 4 percent. In Latin America and the Caribbean servicing costs of external debt were about 6 percent on average during 1990-2020 while in the Middle East and North Africa the annual costs of servicing external debt amounted to about 7 percent on average. The lower debt servicing cost as a percent of GDP in Asia-Pacific relative to Latin America and the Caribbean and the Middle and North Africa are mostly due to the lower external debt-to-GDP ratios in the former region.

External debt-to-GDP ratios varied considerably across countries in Asia-Pacific and throughout time during 1970-2020. The median external debt-to-GDP ratio was around 35 percent, with an interquartile range of 35 percentage points. At the bottom 25th percentile, the debt-to-GDP ratio was around 19 percent while at the top 25th percentile it was around 54 percent. The standard deviation of the debt-to-GDP ratio in Asia-Pacific during 1970-2020 is around 39 percent. The top 1 percent of countries in Asia-Pacific had at times an external debt-to-GDP ratio in excess of 200 percent. This includes Laos during the late 1980s, Vietnam during the early 1990s, and Mongolia during the late 2010s. At the other extreme of the distribution, the bottom 1 percentile, the external debt-to-GDP was less than 1 percent. The country in Asia-Pacific with an external debt-to-GDP ratio of less than 1 percent was Myanmar during the 2000s. As is apparent from these extremes at the distribution, high values of external debt-to-GDP ratios are not necessarily associated with underdevelopment. Or vice versa: a low value of an external debt-to-GDP ratio does not necessarily mean that the country is highly developed.

3.2 External Debt and Human Development

The top panel of Figure 1A plots the cross-country relationship between external debt-to-GDP ratios and the human development index for countries in Asia-Pacific. On the x-axis is the country-average

[1]These statistics are for low and middle income countries only. High income countries are excluded.

external debt-to-GDP ratio, in percent, during 1990-2020; on the y-axis is the country-average HDI index during 1990-2020. One can see from the figure that a least-squared fitted line is mostly flat. The slope coefficient is 0.02 with a standard error of 0.061. The R-squared is 0.005. Hence, within Asia-Pacific there is no apparent cross-country relationship between external debt-to-GDP ratios and human development. This is different when the sample includes all countries in the world for which data are available. As shown in the bottom panel of Figure 1A, there is a significant negative cross-country relationship between the external-debt-to-GDP ratio and the human development index for the world sample. When all countries in the world are included in the sample, the slope coefficient on the external debt-to-GDP is -0.043 with a standard error of 0.023. The R-squared for this bi-variate regression is 0.018.

The average Human Development Index in Asia-Pacific during 1990-2020 is around 60. This is slightly lower than the average HDI for developing countries in Latin America and the Caribbean and Middle East and North Africa. In LAC and MENA the average HDI during 1990-2020 is 68 and 63, respectively. Asia-Pacific's average HDI during 1990-2020 is slightly higher than that of the average country in Sub-Saharan Africa. During 1990-2020 the average HDI in SSA was about 47. These number imply that during 1990-2020 the average HDI of countries in Asia-Pacific is about 8 percent below the average HDI of countries in LAC, 3 percent below the average HDI of countries in MENA, and 13 percent above the average HDI of countries in SSA.

Within Asia-Pacific, there is also quite a bit of variation in the HDI across different groups of countries belonging to different sub-regions of Asia-Pacific. For the Least Developed Countries in Asia-Pacific, the average HDI during 1990-2020 was around 52. This is about 8 percent below the average HDI in Asia-Pacific. South Asia's average HDI during 1990-2020 was around 57 percent below the Asia-Pacific-wide average. The average HDI is highest in East-Asia Pacific. In East-Asia Pacific the average HDI during 1990-2020 was 62; 61 in East Asia and 63 in the Pacific. These numbers imply that the average HDI during 1990-2020 was about 2, 1 and 3 percent higher in these sub-regions relative to the Asia-Pacific average.

Asia-Pacific's average HDI is between the average HDI of lower middle income countries and upper middle income countries. Asia-Pacific, on average, is more advanced in human development than the average low income country and the average lower middle income country. During 1990-2020 the average HDI of the low and lower-middle income countries was 42 and 56, respectively. These numbers imply that the average HDI in Asia-Pacific during 1990-2020 was about 40 percent higher than the average HDI of low income countries, and about 7 percent higher than the average HDI of lower middle income countries.

Asia-Pacific's average HDI is lower than the HDI of the average upper-middle income country as well as high income country. During 1990-2020 the average HDI of upper middle income countries and high income countries was 70 and 84, respectively. These numbers imply that the average HDI in Asia-Pacific during 1990-2020 was about 14 percent below the average HDI of upper middle income countries, and about 29 percent below the average HDI of high income country.

There is quite a bit of variation in average external debt-to-GDP ratios across different groups of countries belonging to different sub-regions in Asia-Pacific (see Table 2). For the Least Developed Countries in Asia-Pacific, the average external debt-to-GDP ratio during 1990-2020 was around 47 percent. This is about 1 percent above the average external-debt-to-GDP ratio in Asia-Pacific. South Asia's external-debt-to-GDP ratio during 1990-2020 was around 37 percent, 9 percent below the Asia-Pacific average. In Asia-Pacific the external debt-to-GDP ratio was highest in the group of countries belonging to East-Asia Pacific. In East-Asia Pacific the average external debt-to-GDP ratio during 1990-2020 was 51 percent; 59 percent in East Asia and 38 percent in the Pacific. These numbers imply that the average external debt-to-GDP ratio in East-Asia Pacific during 1990-2020 was about 5 percent higher than the average external debt-to-GDP ratio in Asia-Pacific.

3.3 GDP per capita: An Important Component of the HDI

One important component of the HDI is Gross Domestic Product per capita. GDP is a summary measure of all the value added created by the people of a country in terms of goods and services

produced. For GDP per capita, the gap between Asia-Pacific and other developing regions is more pronounced than for the HDI. During 1990-2020, the average GDP per capita in developing countries of Asia-Pacific was about $5950. This is about 42 percent less than the average GDP per capita of developing countries in LAC and MENA. During 1990-2020 average constant-price PPP GDP per capita of developing countries in LAC and MENA was about $10263and $10353, respectively. GDP per capita in developing countries of Asia-Pacific is on average about 50 percent large than the average GDP per capita in developing countries in Sub-Saharan Africa. During 1990-2020 average constant-price PPP GDP per capita of developing countries in Sub-Saharan Africa was about $3856.

Why is GDP per capita in Asia-Pacific significantly lower than in LAC and MENA, but higher than in SSA? The classic approach in economic growth theory for providing an answer to this question is to consider the production function where output per worker can be broken down into three components: labor force participation, capital per worker, and total factor productivity. Table 2 shows that capital per worker is lower, on average, in Asia-Pacific than in developing LAC and MENA -- and so is total factor productivity. Capital per worker in Asia-Pacific during 1990-2020 was about $58145. This is about 25 percent below LAC and 45 percent below MENA. Capital per worker is about 60 percent higher in Asia-Pacific than in SSA. Total factor productivity in Asia-Pacific is about 14 percent less than in LAC and 34 percent less than in MENA. Total factor productivity in Asia-pacific during 1990-2020 was about 9 percent higher than in SSA.

3.4 Natural Disasters and Climate: Incidence and Severity

During 1990-2020 the average country in Asia-Pacific experienced 6 natural disasters per year. By international comparison, Asia-Pacific experiences significantly more natural disasters than other regions in the world. During 1990-2020, the average country of Asia-Pacific experienced about twice as many natural disasters as the average country in LAC, about three times as many natural disasters as the average country in SSA, and six times as many natural disasters as the average country in MENA.

Natural disasters that occur in Asia-Pacific cause more deaths than natural disasters that occur in other regions. During 1990-2020, total deaths in a year due to natural disasters were on average about 1574. This is about three times as much as the total number of deaths due to natural disasters in a year in developing countries in Latin America and the Caribbean; about five times as much as in developing countries in the Middle East and North Africa, and about eight times as much as in developing countries of Sub-Saharan Africa.

Natural disasters that occur in Asia-Pacific are associated with a larger economic damage than in other developing regions. During 1990-2020, the average country in Asia-Pacific incurred a damage per year due to natural disasters of about $1.4 billion. This is about fives times as much as in Latin America and the Caribbean, about ten times as much as in the Middle East and North Africa, and about eighty times as much as in Sub-Saharan Africa.

Despite the higher incidence and greater severity of natural disasters in Asia-Pacific the region is not that different from other developing regions with regard to climate. During 1990-2020, the mean temperature in Asia-Pacific was around 22 degrees Celsius. This is about three degrees less than the mean temperature in Latin America and the Caribbean, or sub-Saharan Africa. Mean temperature in Asia-Pacific is about the same as the mean temperature in the Middle East and North Africa. Countries in Asia-Pacific received, on average, during 1990-2020 as much rainfall in a year as countries in Latin America and the Caribbean. Annual precipitation in Asia-Pacific was, on average, about eight times higher than in the Middle East and North Africa; and about sixty percent higher than in sub-Saharan Africa.

The average country in Asia-Pacific has a higher incidence and greater severity of natural disasters than the average country in any of the four income categories. The average incidence of natural disasters in Asia-Pacific is about three times as high as the average incidence of natural disasters in the group of low income countries, about twice as high as in the group of lower middle-income countries, upper middle-income countries, and high income countries. Natural disasters cause

on average about three times as many deaths in Asia-Pacific than in the average low income country, about twice as many deaths as in the average lower and upper middle-income country, and about eleven times as many deaths as in the average high income country.

Natural disasters cause a greater economic damage, on average, in Asia-Pacific than what is typical for the average country in the low-, lower-middle, and upper-middle-income category. The average economic damage due to natural disasters in Asia-Pacific is about twenty times larger than the average economic damage of natural disasters in the group of low income countries. It is about five times larger than the average economic damage in the group of lower middle-income countries; and about sixty percent larger than the average economic damage in the group of upper middle-income countries. The average economic damage of natural disasters in Asia-Pacific is about half the average economic damage of natural disasters in high income countries. The message from these stylized facts is that: (i) natural disasters cause a greater economic damage in more developed countries; (ii) given its level of economic development, the economic damage caused by natural disasters in Asia-Pacific is atypically high. The second point is consistent with the fact that the incidence and severity of natural disasters is higher in Asia-Pacific than in other parts of the world.

There is significant variation in the incidence of natural disasters across time and countries belonging to Asia-Pacific. While during 1970-2020 the average country in Asia-Pacific experienced about 5 natural disasters per year, it is noteworthy that during the past two decades this number has increased. During 2000-2020, the average country in Asia-Pacific experienced about 6 natural disasters per year; during 1970-1999 the average country in Asia-Pacific experienced about 4 natural disasters per year. The median country in Asia-Pacific experienced during 1970-2020 about 2 natural disasters per year. A country at the bottom 25th percentile experienced about 1 natural disaster per year, while a country at the top 25th percentile experienced about 6 natural disasters per year. At the extremes of the distribution, the annual incidence is as large as 30 per year (at top 1st percentile), and as low as 0 per year (at the bottom 1st percentile). The standard deviation in Asia-Pacific during 1970-2020 of the per annum incidence of natural disasters is 6.

There is significant variation in the severity of natural disasters across time and countries as well. The distribution of the severity of natural disasters exhibits fat tails. Consider first the distribution of total deaths per annum due to natural disasters in Asia-Pacific during 1970-2020: Mean total deaths per annum due to natural disasters in Asia-Pacific during 1970-2020 were about 1952; but median total deaths per annum were only about 75. At the bottom 25th percentile, natural disasters caused about 4 deaths per annum while at the top 75th percentile deaths per annum amounted to about 418. At the extremes of the distribution, annual deaths due to natural disasters are as large 31500 (at the top 1st percentile), and as low as 0 per year (at the bottom 1st percentile). The standard deviation of the per annum total deaths due to natural disasters in Asia-Pacific during 1970-2020 is 15368.

The distribution of total damage caused by natural disasters exhibits fat tails as well. Many natural disasters do not cause a significant economic damage, but some disasters, which occur infrequently, do cause a significant economic damage. From Table 1, one can see that the mean total damage per annum due to natural disasters in Asia-Pacific during 1970-2020 was about $1.0 billion; the median per annum total damage was only about $1.5 million. At the bottom 25th percentile, natural disasters caused no economic damage at all, while at the top 75th percentile the total economic damage per annum amounted to about $0.2 billion. At the extremes of the distribution, the total damage per annum due to natural disasters is as large as $23 billion (at the top 1st percentile), and $0 (at the bottom 1st percentile). The standard deviation of the per annum total damage due to natural disasters in Asia-Pacific during 1970-2020 is about $5.1 billion.

Table 4 provides a top-5 list of the countries most affected by natural disasters. In column (1) of Panels A-C the criteria are the incidence, deaths, and damage of natural disasters, respectively. One issue with these criteria is that large countries (in terms of land area) have, all else equal, more natural disaster than small countries. Another issue is that more people die due to natural disasters in countries with large populations, all else equal, than countries with small population. To adjust for this, columns (2) and (3) of Panels A-C show a top-five list using as criteria the incidence, deaths, and damage of natural disasters per 1 million people and per 1 thousand square KM, respectively.

In terms of the total number of natural disasters per annum, China takes the first place in Asia-Pacific: During 1990-2020 there were on average 24 natural disasters per year in China. Second place goes to India, which had about 15 natural disasters per year on average during 1990-2020. Other countries in the top five list are Philippines (14 natural disasters per year), Indonesia (13 natural disasters per year), and Bangladesh (7 natural disasters per year).

The top-5 list in terms of natural disasters incidence looks quite different when scaling by population size and land area. All of the countries in the top five list are so-called small island countries. The country in Asia-Pacific with the highest incidence of natural disasters per capita is Tuvalu, followed by Marshal Islands, Samoa, Tonga, and Micronesia. When scaling by land area, the country in Asia-Pacific with the highest incidence of natural disasters per square KM is Tuvalu, followed by Marshal Islands, Samoa, Maldives, and Tonga.

Panel B of Table 4 lists the top-5 countries in Asia-Pacific with the highest average deaths per annum due to natural disasters during 1990-2020. In terms of the total deaths per annum due to natural disasters, Indonesia makes the top of the list with a mean total deaths per annum due to natural disasters of 6320. Followed by Bangladesh, which had on average 5211 total deaths per annum due to natural disasters. Other countries in this top-5 list are Myanmar (5007 deaths), China (4609 deaths), and India (4309 deaths).

The top-5 list in terms of deaths due to natural disasters looks quite different when scaling by population size and land area. The country in Asia-Pacific with the higher number of deaths due to natural disasters per capita is Samoa. Samoa had on average about 180 annual deaths per 1 million population. At ranks 2 to 5 are Myanmar, Micronesia, Sri Lanka, and Bhutan. In these countries, average annual deaths per 1 million population amounted to 103, 75, 63, and 59, respectively. When scaled by land area, the country in Asia-Pacific with the most deaths due to natural disasters per square KM is Samoa; followed by Maldives, Bangladesh, Sri Lanka, and Micronesia.

Panel C of Table 4 lists the top-5 countries with the highest average economic damage due to natural disasters in Asia-Pacific. China takes first place in this list: During 1990-2020 China had a mean annual damage due to natural disasters of $18 billion. Place 2 goes to India, which had a mean annual damage due to natural disasters of about $4 billion. Other countries in the top five list in terms of mean annual damage are Thailand ($1.6 billion), Indonesia ($1.0 billion), and North Korea ($1 billion).

The top-5 list with regard to economic damage due to natural disasters looks quite different when scaling by population size and land area. The country in Asia-Pacific with the highest economic damage due to natural disasters per capita is Samoa. For Samoa the mean annual damage due to natural disasters amounted to about $899 per capita. At ranks 2 to 5 are Tonga, Maldives, Vanuatu, and Fiji. In these countries, the mean annual economic damage due to natural disasters per capita amounted to $232, $159, $95 and $59, respectively. When scaling by land area, the country in Asia-Pacific with the largest economic damage due to natural disasters per square KM is Samoa; followed by Maldives, Tonga, North Korea, and Bangladesh.

3.5 Natural disasters and development

This section shows that there is a negative cross-country relationship between the mean incidence of natural disasters and development. Countries in Asia-Pacific with a greater mean incidence of natural disasters tend to have a lower human development index, less capital per worker, lower total factor productivity and higher poverty rates. Before discussing these scatter plots, an important point regarding causality. The average incidence of natural disasters is exogenous to the development of a country. However, the number of deaths and the economic damage caused by natural disasters is not. This section exclusively presents cross-country scatter plots of the relationship between natural disaster incidence and development. These scatter plots can be interpreted as describing a causal relationship. The direction of causality is as follows: if the mean incidence of natural disasters increases by x, the country is expected to have a lower human development index of y.

Figure 1B shows that in Asia-Pacific during 1990-2020 there is a negative relationship

between mean natural disaster incidence and the human development index. Countries in which natural disasters are more frequent tend to have a lower human development index. However, the R-squared is very low, around 0.0003, meaning that less than 1 percent of cross-country variation in the human development index can be explained by cross-country variation in the mean incidence of natural disasters.

The negative cross-country relationship between natural disaster incidence and human development is more pronounced for the sub-set of countries with a mean annual incidence of natural disasters disasters between 0 and 10. This sub-sample comprises all countries in Asia-Pacific where data are available, and it excludes China, India, Indonesia and the Philippines. For this sub-set of countries in Asia-Pacific, see the bottom panel of Figure 1B, the R-squared is 0.065: i.e. nearly 7 percent of the cross-country variation in the human development index is due to cross-country variation in the mean incidence of natural disasters. A linear fit yields a slope of -1.2 with a standard error of 0.9. This slope gives the marginal effect of the mean incidence of natural disasters on the human development index. Quantitatively, the least squares estimate of -1.2 means that for each one-unit increase in the mean incidence of natural disasters, a country is expected to have a lower human development index by about 1.2 percentage points. (Note that this statement is for the average country in the sample. And that it is with regard to a cross-country relationship. In Section 2, we will explore how external debt affects the within-country relationship between natural disaster incidence and the human development index. This is conceptually different from the cross-country results.)

3.6 Trends:

3.6.1 External Debt-to-GDP Ratios: Similar Patterns in Asia-Pacific's Median Country and the Median Country in Other Developing Regions

Figure 2A shows that during 1970-2020 the time-series of the external debt-to-GDP ratio for Asia Pacific's median country displays a similar pattern as the time-series of the external debt-to-GDP ratio of the median country in the world. There was an increase in the external debt-to-GDP ratio for the median country in Asia Pacific throughout the 1970s, 1980s and 1990s. Between 1970-2000 the external debt-to-GDP ratio more than doubled for the median country in Asia Pacific. At the beginning of the 1970s external debt was about 20 percent of GDP; by 1997 at the wake of the Asia financial crisis the external debt-to-GDP ratio for the median country in Asia-Pacific was nearly 60 percent. During the 2000s there was a sharp decrease of the external debt-to-GDP ratio for the median country in Asia-Pacific. The external debt-to-GDP ratio remained mostly flat during the 2010s, hovering at around 30 percent. In the later part of the 2010s the external debt-to-GDP ratio increased. By 2020, the external debt-to-GDP ratio in the Asia-Pacific's median country was around 40 percent.

While for Asia-Pacific the median country's external debt-to-GDP ratio displays a similar time-series pattern to the external debt-to-GDP ratio of the median country in the world it is important to be aware that within Asia-Pacific there is substantial variation in external debt-to-GDP ratios across countries in any given year. To illustrate this, Figure 2B plots the time-series for the country in Asia-Pacific with the smallest debt-to-GDP ratio (referred to as "minimum", see the green line) and the largest debt-to-GDP ratio (referred to as "maximum", see the red line). One can see that in any given year during 1970-2020, the minimum country's external debt-to-GDP in Asia-Pacific never exceeded 15 percent; and most of the time it was in the range of 1 to 5 percent. In contrast, the maximum country's external debt-to-GDP ratio exceeded 100 percent in all years during 1990-2020. In 2020, the country in Asia-Pacific with the largest external debt-to-GDP ratio was Mongolia – standing at an astonishing 275 percent. In 2020, Mongolia was the country in the world with the highest external debt-to-GDP ratio.

Figure 2C shows that the time-series pattern of the external debt-to-GDP ratio in the median country of Asia-Pacific is similar to the time-series pattern of the external debt-to-GDP ratio of the median country in other developing regions. In the beginning of the 1970s, the external debt-to-GDP ratio was about the same in the median country of Asia-Pacific as in the median country of LAC, MENA, and SSA – around 20 percent. During the 1970s and 1980s, the external debt-to-GDP ratio increased in the median country of LAC, MENA and SSA. The increases in external debt-to-GDP

ratios were larger in the median country of LAC, MENA and SSA during the 1970s and 1980s than in the median country of Asia-Pacific. Between 1970-1990, external debt-to-GDP ratios for the median country in LAC, MENA, and SSA more than tripled. During this time period the external debt-to-GDP ratio about doubled in the median country of Asia-Pacific. During the 1990s the region with the highest external debt-to-GDP ratio was SSA where in the median country external debt peaked at around 100 percent of GDP. In all developing regions the median country's external debt-to-GDP ratio declined significantly during the 2000s. During the early part of the 2010s external debt-to-GDP ratios were in the range of around 25 to 40 percent in the median country of all of the four developing regions. In the later part of the 2010s external debt-to-GDP ratios increased in all four developing regions. For the year 2020, Asia-Pacific is the region where the median country has the lowest external debt-to-GDP ratio. In 2020, the external debt-to-GDP ratio was 57 percent in the median country of LAC, 70 percent in the median country of MENA, and 42 percent in the median country of SSA. In 2020, the median country in Asia-Pacific had an external debt-to-GDP ratio of 41 percent.

3.6.1 Sustained Progress in Human Development for All Countries... But Most of the Initial Gaps Across Countries Remain

There was sustained progress in human development throughout Asia-Pacific during 1990-2020. This can be seen from Figure 3A. The figure plots the time-series of the median, minimum, and maximum Human Development Index in Asia-Pacific. The country in Asia Pacific that had the lowest HDI in 1990 was Afghanistan. In 1990 Afghanistan's HDI was 27. By 2020 Afghanistan's HDI was 48. During 1990-2020 the HDI of Afghanistan increased by over 70 percent – this is the largest percent increase in the region, despite years of war during the 2000s. The HDI of the median country in Asia-Pacific increased during 1990-2020 by around 32 percent. In 1990, the median country in Asia-Pacific had an HDI of 49. By 2020 the median country's HDI in Asia-Pacific was 65. There was also a sustained increase in the HDI for the country in Asia-Pacific that had the highest initial HDI. Malaysia is the country in Asia-Pacific with the highest HDI. In 1990, Malaysia's HDI was 64. In 2020, Malaysia's HDI was 81. Between 1990-2020 the HDI of Malaysia increased by around 26 percent.

Noteworthy is that gaps in human development across countries in Asia-Pacific did not narrow significantly during 1990-2020. This can seen, for example, from Figure 3A by comparing the countries in Asia-Pacific with the minimum, median, and maximum HDI in any given year. In the group of countries in Asia-Pacific, the minimum, median, and maximum HDI was 27, 48, and 64, respectively, in the year 1990. In 1990, there was a gap of 21 percentage points between the country that had the lowest HDI in Asia-Pacific and the median country. The gap between the country with the lowest HDI and the country with the highest HDI was 37 percentage points. And the gap between the country with the highest HDI and the median country was 16 percentage points. Over three decades -- despite progress in the HDI for the minimum, median and maximum -- these gaps remain. In the group of countries in Asia-Pacific, the minimum, median, and maximum HDI was 48, 66, and 81, respectively, for the year 2020. This means that, in 2020, the gap between the country in Asia-Pacific with the lowest HDI and the country with the median HDI was 22 percentage points. The year 2020 gap between the country in Asia-Pacific with the lowest HDI and the highest HDI was 33 percentage points. And the gap between the country with the highest HDI and the median was 15 percentage points.

Figure 3B shows that the HDI of the median country in the world increased during 1990-2020. For the median country in the world, the HDI increased between 1990-2020 by around 17 percent. In 1990, the HDI of the median country in the world was 63. By 2020, it was 74. The HDI of the median country in Asia-Pacific thus increased during 1990-2020 at a faster pace than the HDI of the median country in the world. Recall that the HDI of the median country in Asia-Pacific increased during 1990-2020 by around 32 percent. In 1990, the median country in Asia-Pacific had an HDI of 49. By 2020 the median country's HDI in Asia-Pacific was 65. The gap between the HDI of the median country in the world and the median country in Asia-Pacific thus somewhat narrowed during 1990-2020. In 1990, this gap was 14 percentage points; in 2020, it was only 9 percentage points.

Progress in human development was also made during 1990-2020 in other developing regions. In 1990, the HDI for the median country in LAC, MENA and SSA, was 64, 62, and 40, respectively. Thirty years later, in 2020, the HDI for the median countries in these regions was 76, 74, and 53, respectively. This means that in LAC the median country's HDI increased during 1990-2020 by nearly 18 percent. In MENA the median country's HDI increased during 1990-2020 by around 19 percent. And in SSA the median country's HDI increased during 1990-2020 by around 33 percent. These numbers imply that during 1990-2020 the HDI index for the median country in Asia-Pacific increased at a faster pace than for the median countries in LAC and MENA. The percent increase in the HDI of the the median country in Asia-Pacific is slightly less than the percent increase in the HDI of the median country in SSA. Noteworthy is also that gaps in the HDI between the median country in Asia-Pacific, LAC, MENA, and SSA remain.

3.6.3 Rising Temperatures and a Rising Incidence of Natural Disasters

Temperatures in Asia-Pacific and the world, in general, are rising. Figure 4 shows the mean annual temperature for the median country in Asia-Pacific. Between 1970-2020, the mean annual temperature for the median country in Asia-Pacific increased by about half a degree Celsius. This is somewhat less than the increase in mean annual temperature for the median country in the world. During 1970-2020 mean annual temperature increased by about 1 degree Celsius for the median country in the world. Noteworthy is that in all years during 1970-2020 mean annual temperatures in the median country of Asia-Pacific are about 2 degrees above the median country in the world. Mean annual temperatures in the median country of Asia-Pacific were about 25.4 degrees Celsius. An increase of just half a degree during 1970-2020, even though less than for the median country in the world, is still worrisome, since the economic costs of rising temperatures are non-linear. Increases in temperatures are particularly costly at high temperatures.[2]

Temperatures have also increased during 1970-2020 for the countries in Asia-Pacific with the lowest and the highest mean annual temperatures. Mongolia is the country in Asia-Pacific with the lowest mean annual temperatures. In 1970, Mongolia had a mean annual temperature of -1.3 degrees Celsius. In 2020, Mongolia's mean annual temperature was about 1.2 degrees Celsius. Between 1970-2020 mean annual temperatures in Mongolia increased by about 2 degrees Celsius. The country in Asia-Pacific with the highest mean annual temperatures is Kiribati. Between 1970-2020 mean annual temperatures in Kiribati increased by about 1 degrees Celsius. In 1970, Kiribati's mean annual temperature was 28.1 degrees Celsius. In 2020, Kiribati's mean annual temperature was 28.9 degrees Celsius. Since Kiribati's mean annual temperatures were initially already very high, the increase in temperatures likely has severe negative effects on this country's population.

Figure 5 shows that the incidence of natural disasters has increased in Asia-Pacific during 1970-2020. In the early 1970s, the median country in Asia-Pacific had about 1.5 natural disasters per year. By 2020, the median country in Asia-Pacific had about 3 natural disasters per year. For the median country in Asia-Pacific, the annual incidence of natural disasters doubled during 1970-2020. A doubling of the annual incidence of natural disasters also occurred in the median country in the world. In the early 1970s, the median country in the world experienced about 1 natural disaster per year. In 2020, the median country in the world experienced about 2 natural disasters per year.

Appendix Figure 1 shows that the cross-country distribution of natural disaster incidence in Asia-Pacific increased its mass to the right-side of the tail. One can also see from the figure that the tail of distribution expanded to the right. This means that: (i) the average incidence of natural disasters per year has increased in Asia-Pacific during 1970-2020, and (ii) the maximum incidence of natural disasters per year was higher in 2020 than in 1970. In 1970, the maximum number of natural disasters in a country belonging to the Asia-Pacific region was 9. In 2020, the maximum number of natural disasters in a country belonging to the Asia-Pacific region was 29.

[2]See Burke et al. (2015).

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

4.1 Econometric Model

The econometric model is described by equation (1):

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

where *HD* is a measure of human development. *Disaster* is the incidence of natural disasters. *Debt* is the external debt-to-GDP ratio. 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: $\alpha + \gamma*Debt_{it-1}$. The coefficient γ measures by 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: $(\alpha + \gamma*Debt_{it-1})/(1-\theta)$.

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.

4.2. Baseline Results: Human Development Index

Column (1) of Table 5 shows least squares estimates of equation (1) where the dependent variable is the human development index. One can see in column (1) of Table 5 that the estimated coefficient (α) on natural disaster incidence is negative and significantly different from zero at the 5 percent significance level. The estimated coefficient (γ) on the interaction between natural disaster incidence and the external debt-to-GDP ratio is positive and significantly different from zero at the 10 percent significance level. The estimated coefficient (β) on the external debt-to-GDP ratio is negative but not significantly different from zero at the 10 percent level or higher. The estimated coefficient (θ) on the lagged dependent variable is positive and significantly different from zero at the 1 percent level.

The estimates in column (1) of Table 5 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 is the external debt-to-GDP ratio, the smaller are 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 5 also imply that, the higher is the incidence of natural disasters the (less negative) more positive are 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: $\beta + \gamma*Disaster_{it}$. The estimated β coefficient is negative and the estimated coefficient γ 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 $\beta + \gamma*Disaster_{it}$ is positive and significantly different from zero 0 at the 10 percent significance level or higher

4.2.1 Quantitative Result I: Effects of Natural Disasters on the HDI

Quantitatively, the estimates in column (1) of Table 5 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 6 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*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,..., t+n,...,t+∞* (equal to the effect of the shock on the HDI in year *t* times 0.95, 0.95^2, 0.95^3, …,0.95^n,...,0.95^∞ for periods *t+1, t+2, t+3,..., t+n,...,t+∞*, respectively; note that the last term, 0.95^∞, is equal to zero).

According to the estimates in column (1) of Table 5 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. 10 additional natural disasters (equal to about 1.6 standard deviations 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 with regard to the external-debt-to-GDP ratio. Let's 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 5, 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*(1-0.946^10)/(1-0.946). And 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' 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.[3]

Another country example that is useful to illustrate 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 comparison. Afghanistan is at about the 10th percentile in Asia-Pacific with regard to the external debt-to-GDP ratio in 2020. Let's 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*(1-0.946^10)/(1-0.946). And 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. 100 natural disasters cut Afghanistan's human development index in half – to about 28 percent.

Figure 6A plots the effects of natural disaster 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. And more so, the lower is a country's external debt-to-GDP ratio.

4.2.2 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 5 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 1 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 5, 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 4 natural disasters in year *t*, the HDI in year *t* increases by 0.00066 percentage points for each 1 percentage point (0.01) increase in the year *t-1* external debt-to-GDP ratio. I.e. If there are 4 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 5, the HDI in year *t* would increase by around 0.026 percentage points. The long-run effect is larger: If there are 4 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.

4.3 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.

4.3.1 Human Capital Index

Column (2) of Table 5 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

[3]This calculation, of course, does not mean that Indonesia's HDI will decrease in the future to the values computed here. The calculations merely serves 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.

can expect to acquire by age 18, given the risks of poor health and poor education that prevail in the country where she lives.

One can see in column (2) of Table 5 that the estimated coefficient on natural disaster incidence is negative and significantly different from zero at the 5 percent significance level. The estimated coefficient on the interaction between natural disaster incidence and the external debt-to-GDP ratio is positive and significantly different from zero at the 1 percent significance level. The estimated coefficient on the external debt-to-GDP ratio is negative and significantly different from zero at the 5 percent level.

The estimates in column (2) of Table 5 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, say 10 percent (0.1). For a country with external debt-to-GDP 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 5 can be interpreted as follows. The higher is the incidence of natural disasters the (less negative) more positive are 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 the 10 percent level or higher. For a country in Asia-Pacific that has an incidence of natural disasters equal to 5 per year, the effects of external debt-to-GDP on the HCI are positive and significantly different from zero at the 10 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 1 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 5 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 5 natural disasters in year *t*, the HCI in year *t* increases by 0.00034 percentage points for each 1 percentage point (0.01) increase in the year *t-1* external debt-to-GDP ratio. I.e. If there are 5 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 5 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 5 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.

4.3.2 Life Expectancy

Column (3) of Table 5 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 5 that the estimated coefficient on natural disaster incidence is negative and significantly different from zero at the 5 percent significance level. The estimated coefficient on the interaction between natural disaster incidence and the external debt-to-GDP ratio is positive and significantly different from zero at the 5 percent significance level. The estimated coefficient on the external debt-to-GDP ratio is negative but not significantly different from zero at the 10 percent level or higher.

The estimates in column (3) of Table 5 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 5 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, say 10 percent (0.1). For a country with external debt-to-GDP 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 decrease 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 5 can be interpreted as follows. The higher is the incidence of natural disasters the (less negative) more positive are 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 the 10 percent level or higher. For the median country in Asia-Pacific that has an incidence of natural disasters equal to 4 per year, the effects of external debt-to-GDP on life expectancy are positive but not significantly different from zero at the 10 percent level. For a country with 10 natural disasters per year or more the effects of increasing external debt-to-GDP ratios are positive and significantly different from zero at the 10 percent level.

Quantitatively, the effects of external debt-to-GDP ratios on life expectancy are sizable: For a country with a country with zero natural disasters, increasing the external debt-to-GDP ratio by 10 percentage points decreases life expectancy by about 0.1 years in the long-run. For a country at the median (4 natural disasters per year), increasing the external debt-to-GDP ratio by 10 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.

4.3.3 GDP Growth

Column (4) of Table 5 reports estimates of equation (1) where the dependent variable is real GDP per capita growth. One can see in column (4) of Table 5 that the estimated coefficient on natural disaster incidence is negative and significantly different from zero at the 5 percent significance level. The estimated coefficient on the interaction between natural disaster incidence and the external debt-to-GDP ratio is positive and significantly different from zero at the 1 percent significance level. The estimated coefficient on the external debt-to-GDP ratio is negative and significantly different from zero at the 10 percent level. The later result is in line with literature (e.g. Reinhart and Rogoff, 2010)

that higher external debt-to-GDP ratios are a drag on GDP growth.[4]

The estimates in column (4) of Table 5 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 are external debt-to-GDP ratios, the less negative are 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, say 10 percent (0.1). For a country with external debt-to-GDP 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 the GDP growth, the estimates in column (5) of Table 5 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 1 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 5 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 1 percentage point (0.01) increase in the year *t-1* external debt-to-GDP ratio. I.e. If there are 5 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 5 GDP growth in year *t* would decrease by around 0.05 percentage points.

4.4 Interpretation of the Econometric Results

External debt-to-GDP is a measure of international risk sharing. When financial markets are incomplete, countries with higher external debt-to-GDP ratios tend to be also those countries with access to (less costly) international financial intermediation.[5] In contrast, countries with low external debt-to-GDP ratios tend to be also 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.[6] But 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 the

[4]We have also estimated models that include a squared term of the external-debt-to-GDP ratio. The estimates on the natural disasters and the interaction with external debt were similar to the ones reported in Table 6. The coefficient on squared debt was insignificant.

[5]See Maggiori (2022). "International macroeconomics with imperfect financial markets." *Handbook of International Economics*, Volume 6.

[6]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 the 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.

natural disasters destroys good -- or capital, which is 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 is 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 loose business) and the good survives and expands (productive firms enter the market and/or existing productive firms increase market size).

Table 6A 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 Table 6A one can see that the estimated coefficients on natural disasters are negative and significantly different from zero at the conventional significance levels. The estimated coefficients 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 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).[7]

According to the factsheet: "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.

Table 6B shows that natural disasters have a significant effect on the growth rates of external debt and net current transfers. From column (1) of Table 6B one can see that the coefficient on natural disaster incidence is positive and significantly different from zero at the 5 percent level. The interaction between natural disaster incidence and external debt-to-GDP is positive and significantly different from zero at the 1 percent level. These estimates imply that when a natural disaster strikes countries with low external debt to GDP ratio significantly increase international borrowing but not so in countries with intermediate to high external debt-to-GDP ratios. In column (2) of Table 6B 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 sub-optimally (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.

[7] See https://www.imf.org/en/About/Factsheets/Sheets/2023/Catastrophe-containment-relief-trust-CCRT

4.5 Further Econometric Results on Risk Sharing

4.5.1 Public External Debt vs. Private External Debt

Table 7 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.

One can see from columns (2) and (3) of Table 7 that, qualitatively, results are similar for public external debt and private external debt. In both columns (2) and (3) the estimated coefficient on natural disasters is negative; the coefficient on 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 7, the estimated coefficient on the public external debt-to-GDP ratio is significantly different from zero at the 10 percent level (p-value 0.08); the estimated coefficient on the interaction between the public external debt-to-GDP ratio and the incidence of natural disasters is not significantly different from zero at the conventional significance levels (p-value 0.17). In column (3) of Table 7, the estimated coefficient on the private external debt-to-GDP ratio is not significantly different from zero at conventional significance levels (p-value 0.19); the estimated coefficient on the interaction between the private external debt-to-GDP ratio and the incidence of natural disasters is significantly different from zero at the 10 percent level (p-value 0.08). For comparison: in the baseline estimates that use total external debt, the coefficient on the external debt-to-GDP ratio is significantly different from zero at the 5 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 the 10 percent level (p-value 0.06).

The quantitative interpretation of the estimates for public external debt, see column (2) of Table 7, 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 10thth percentile where the public external debt-to-GDP ratio is 6 percent. According to the estimates in column (2) of Table 7, for a country with a public external debt-to-GDP equal to 6 percent ten additional natural disasters in year *t* decreases 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* decreases 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* decreases 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 7, is as follows. If private external debt-to-GDP ratios were zero, then ten additional natural disasters in year *t* decreases 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 relatively low private external debt-to-GDP, e.g. at the 10thth percentile where the private external debt-to-GDP ratio is 0.1 percent. According to the estimates in column (3) of Table 7, for a country with a private external debt-to-GDP equal to 0.1 percent ten additional natural disasters in year *t* decreases 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* decreases 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* decreases the HDI in year *t* by 0.02 percentage points; in the long-run the HDI decreases by 0.4 percentage points.

4.5.2 Central Government Debt vs. Private Sector Debt

Table 8 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 definition a foreign liability. External debt-to-GDP 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 8 that, qualitatively, results are similar for central government debt and private sector debt. In both columns (1) and (2) of Table 8 the estimated coefficients on natural disaster incidence are negative; the coefficients on 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 8, the estimated coefficient on central government debt-to-GDP is not significantly different from zero at conventional significance levels (p-value 0.14); the estimated coefficient on the interaction between the central government debt-to-GDP ratio and the incidence of natural disasters is also not significantly different from zero at the conventional significance levels (p-value 0.27). In column (2) of Table 7, the estimated coefficient on the private sector debt-to-GDP ratio is not significantly different from zero at conventional significance levels (p-value 0.14); the estimated coefficient on the interaction between the private sector debt-to-GDP ratio and the incidence of natural disasters is significantly different from zero at the 10 percent level (p-value 0.07).

The quantitative interpretation of the estimates for central government debt, see column (1) of Table 8, 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) decreases 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 relatively low central government debt-to-GDP, e.g. at the 10thth percentile where the central government debt-to-GDP ratio is 12 percent. According to the estimates in column (1) of Table 8, 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 8 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 8, 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, e.g. at the 10thth percentile where the private sector debt-to-GDP ratio is 5 percent. According to the estimates in column (2) of Table 8, for a country with a private sector debt-to-GDP 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 6-8 suggest that international risk sharing is more effective in reducing the HDI cost 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.

4.5.3 Financial Market Depth

A country's external debt-to-GDP ratio is just one, although a very important, component of the depth of financial markets. The IMF has put together an index of financial market depth[8] that combines data on the size of the stock market (capitalization, or the value of listed shares) and how active it is (stocks traded), the outstanding volume of international debt securities of sovereigns and international and domestic debt securities of financial and nonfinancial corporations.

Table 9 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 9 that the estimated coefficient on natural disaster incidence is negative and significantly different from zero at the 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 the 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.

The quantitative interpretation of the estimates in Table 9 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 9 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.

4.5.4 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 10 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 10 that, qualitatively, results are similar for both categories. In both columns (1) and (2) the estimated coefficient on natural disasters is negative and significantly different from zero at the 10 percent level. The coefficient on the interaction between the grants-to-GDP ratio is positive and significantly different from zero at the 10 percent level. Qualitatively, the message of the estimates displayed in Table 10 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).

The quantitative interpretation of the estimates in column (1) of Table 10 is as follows. If the ratio of grants excluding technical assistance over GDP were zero, then ten additional natural disasters

[8]See IMF WP 16/5 "Introducing a New Broad-based Index of Financial Development".

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 10thth percentile where this ratio is equal to 0.03 percent. According to the estimates in column (1) of Table 10, 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 10 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 10 is as follows. If the ratio of technical assistance over GDP were 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 10thth percentile where this ratio is equal to 0.02 percent. According to the estimates in column (2) of Table 10, 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 in year *t* HDI 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.

5. Case Studies

This section presents case studies for particular countries of developing Asia-Pacific. A total of eight countries are studied. The selected countries are: Afghanistan, Bangladesh, India, Indonesia, Pakistan, Philippines, Thailand, and Vietnam. All of these countries have experienced a significant number of natural disasters in the past. While in none of these countries external debt-to-GDP ratios are high, there is variation across these countries and across time in the external debt-to-GDP ratio. This variation can be used to make comparisons across countries and across time. These comparisons enable a deeper understanding of the role that external debt plays in shaping the effect that natural disasters have on human development.

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 are done.

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. Figure 7 plots the effects that natural disasters had on the HDI. This effect is referred to in Figure 7 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 5 and the incidence of natural disasters for a particular country that serves as a case study during 2010-2020.

Afghanistan

One can see from Panel A of Figure 7 (left-hand-side y-axis, blue line) that the effects of natural disasters on Afghanistan's human development during 2010-2020 were negative; that is, there was a positive HDI cost. At peak, in 2012, when according to EM-DAT there were 11 natural disasters in Afghanistan the HDI cost was about 2.3 percentage points. For the other years during 2010-2020, when the incidence of natural disasters was in the range of 3 to 7 per year, the HDI cost was in the range of 0.6 to 1.5 percentage points.

Afghanistan's external debt-to-GDP ratio is relatively low by international comparison. During 2010-2020, Afghanistan's external debt was in the range of around 12 to 15 percent of its GDP. External debt-to-GDP ratios first decreased in Afghanistan during the first half of the 2010s and then increased during the second half of the 2010s. In 2010, Afghanistan's external debt-to-GDP ratio was around 15 percent. The trough during 2010-2020 was reached in 2014, when external debt was around 12 percent of GDP. In 2020, the external debt-to-GDP ratio was about 15 percent – i.e. about the same as in 2010.

If Afghanistan had more access to international borrowing, then this is likely to have significantly reduced the HDI cost of natural disasters. Suppose Afghanistan would have borrowed more, so that its external debt-to-GDP ratio would have been 40 percent of GDP (recall that 40 percent is about the median in Asia-Pacific). According to the estimates in column (1) of Table 5, at an external debt-to-GDP ratio of 40 percent, the peak HDI cost in the year 2012 -- when Afghanistan was hit by 11 natural disasters -- would have been about 1.2 percentage points. This is less than half the actual HDI cost of natural disasters that Afghanistan incurred in the year 2012 (2.3 percentage points; computed for the actual external debt-to-GDP ratio, which for Afghanistan in 2012 was around 13 percent). For the other years during 2010-2020, Afghanistan's HDI cost due to natural disasters would have been around 0.3 to 0.8 percentage points if external debt-to-GDP ratios would have been around 40 percent of GDP.

For Afghanistan during 2010-2020 there is no visible trend relationship between external debt-to-GDP ratios and the human development index. Afghanistan's HDI increased between 2010-2020 by around 3 percentage points. The external debt-to-GDP ratio in 2020 was about the same as in 2010.

Bangladesh

Panel B of Figure 7 (left-hand-side y-axis, blue line) shows that the effects that natural disasters had on Bangladesh's human development were negative during 2010-2020, i.e. there was a positive HDI cost. At peak, in 2015, when according to EM-DAT there were 8 natural disasters in Bangladesh the HDI cost was about 1.5 percentage points. For the other years during 2010-2020, when the incidence of natural disasters in Bangladesh was in the range of 2 to 6 per year, the HDI cost was in the range of 0.4 to 1.2 percentage points.

Bangladesh's external debt-to-GDP ratio is relatively low by international comparison. During 2010-2020, Bangladesh's external debt was in the range of around 16 to 21 percent of its GDP. External debt-to-GDP ratios first decreased in Bangladesh during the first half of the 2010s and then increased during the second half of the 2010s. In 2010, Bangladesh's external debt-to-GDP ratio was around 21 percent. The trough during 2010-2020 was reached in 2016, when external debt was around 16 percent of GDP. In 2020, the external debt-to-GDP ratio was about 20 percent – i.e. about the same as in 2010.

If Bangladesh had more access to borrowing, then this could have significantly reduced the HDI cost of natural disasters. Suppose Bangladesh would have borrowed more, so that its external debt-to-GDP ratio would have been 40 percent of GDP. According to the estimates in column (1) of Table 5, at an external debt-to-GDP ratio of 40 percent, the peak HDI cost in the year 2015 -- when Bangladesh was hit by 8 natural disasters -- would have been about 0.9 percentage points. This is about 40 percent less than the actual HDI cost of natural disasters that Bangladesh incurred in the year 2015 (which was 1.5 percentage points; computed for the actual external debt-to-GDP ratio of 17 percent in the year 2015). For the other years during 2010-2020, the HDI cost due to natural disasters that occurred in Bangladesh during this time period would have been around 0.2 to 0.7

percentage points if external debt-to-GDP ratios would have been around 40 percent of GDP.

For Bangladesh during 2010-2020 there is no visible trend relationship between external debt-to-GDP ratios and the human development index. Bangladesh's HDI was increasing throughout 2010-2020 while external debt-to-GDP ratios decreased during 2010-2015 and increased during 2015-2020.

India

Panel C of Figure 7 (left-hand-side y-axis, blue line) shows that the effects of natural disasters on India's human development were negative during 2010-2020, i.e. there was a positive HDI cost. At peak, in 2018, when according to EM-DAT there were 23 natural disasters in India the HDI cost was about 4.2 percentage points. For the other years during 2010-2020, when the incidence of natural disasters in India was in the range of 10 to 22 per year, the HDI cost was in the range of 1.9 to 3.8 percentage points.

India's external debt-to-GDP ratio is relatively low by international comparison. During 2010-2020, India's external debt was in the range of around 18 to 23 percent of its GDP. External debt-to-GDP ratios increased in India during the first half of the 2010s, from 18 percent in 2010 to about 23 percent in 2015. India's external debt-to-GDP ratio followed a v-shaped pattern during the second half of the 2010s. At the end of the decade, external debt was about 21 percent of GDP.

If India would have borrowed more from the international channels, then this could have significantly reduced the HDI cost of natural disasters. Suppose India would have borrowed more, so that its external debt-to-GDP ratio would have been 40 percent of GDP. According to the estimates in column (1) of Table 5, at an external debt-to-GDP ratio of 40 percent, the peak HDI cost in the year 2018 -- when India was hit by 23 natural disasters -- would have been about 2.5 percentage points. This is about 40 percent less than the actual HDI cost of natural disasters that India incurred in the year 2018 (which was 4.2 percentage points; computed for the actual external debt-to-GDP ratio of 20 percent in the year 2018). For the other years during 2010-2020, the HDI cost due to natural disasters that occurred in India during this time period would have been around 1.1 to 2.4 percentage points if external debt-to-GDP ratios would have been around 40 percent of GDP.

For India during 2010-2020 there is a positive trend relationship between external debt-to-GDP ratios and the human development index. Between 2010 and 2020 the external debt-to-GDP ratio increased by about 4 percentage points; the HDI increased by around 7 percentage points. It is noteworthy that most of this increase occurred during the first half of the past decade. Between 2010 and 2015 India's external debt-to-GDP ratio increased by 5 percentage points while the HDI increased by 5 percentage points.

Indonesia

Panel D of Figure 7 (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 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 D of Figure 7 (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' 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.

Pakistan

Panel E of Figure 7 (left-hand-side y-axis, blue line) shows that the effects of natural disasters on Pakistan's human development were negative during 2010-2020, i.e. there was a positive HDI cost. At peak, in 2019, when according to EM-DAT there were 12 natural disasters in Pakistan the HDI cost was about 1.7 percentage points. For the other years during 2010-2020, when the incidence of natural disasters in Pakistan was in the range of 2 to 10 per year, the HDI cost was in the range of 0.3 to 1.6 percentage points. Noteworthy is that the incidence of natural disasters in Pakistan increased during the second half of the past decade. During 2010-2014, there were a total of 22 disasters (on average about 4.4 disasters per year); during 2015-2020, there were a total of 46 disasters (7.6 disasters per year on average).

In Pakistan during 2010-2020, external debt-to-GDP ratios significantly decreased in the first half of the decade and then significantly increased. External debt was about 36 percent of Pakistan's GDP in 2010. During 2010-2015 Pakistan's external debt-to-GDP ratio declined by around 10 percentage points. In 2015 external debt in Pakistan was about 26 percent of GDP. In the second half of the past decade, Pakistan's external debt-to-GDP ratio significantly increased – by about 20 percentage points during 2015-2020. In 2020 Pakistan's external debt-to-GDP ratio was about 45 percent, which is slightly above the median in Asia-Pacific.

The increase in external debt-to-GDP ratios that occurred in Pakistan during the second half of the past decade reduced the HDI cost of natural disasters. During 2015-2020 Pakistan experienced a total of 46 disasters: 10, 9, 6, 2, 12, and 7 natural disasters in the year 2015, 2016, 2017, 2018, 2019, and 2020, respectively. The cumulative HDI cost of these 46 disasters at Pakistan's external debt-to-GDP ratios during 2015-2020 was 6.8 percentage points. (The HDI cost was 1.6, 1.5, 0.9, 0.3, 1.7, and 0.8 percentage points in the year 2015, 2016, 2017, 2018, 2019, and 2020, respectively. External debt-to-GDP ratios during 2015-2020 were 26, 28, 31, 32, 39, and 45 percent, respectively.) Suppose that external debt-to-GDP would have remained in Pakistan at the 2015 value, i.e. 26 percent. In that case Pakistan's cumulative HDI cost during 2015-2020 would have been 7.4 percentage points.

For Pakistan during 2010-2020 there is no visible negative trend relationship between external debt-to-GDP ratios and the HDI. If anything, the trend relationship is positive: Between 2010 and 2020, external debt-to-GDP ratios increased by around 9 percentage points and the HDI increased by 4 percentage points.

Philippines

Panel F of Figure 7 (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 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 comparison. 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, so that its external debt-to-GDP ratio would have been 40 percent of GDP. According to the estimates in column (1) of Table 5, 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 the 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.

Thailand

Panel G of Figure 7 (left-hand-side y-axis, blue line) shows that the effects of natural disasters on Thailand's human development were negative during 2010-2020, i.e. there was a positive HDI cost. At peak, in 2014, when according to EM-DAT there were 8 natural disasters in Thailand, the HDI cost was about 0.9 percentage points. For the other years during 2010-2020, when the incidence of natural disasters in Thailand was in the range of 0 to 7 per year, the HDI cost was in the range of 0 to 0.9 percentage points.

Thailand's external debt in 2020 was about 42 percent of its GDP. This puts Thailand close to median in Asia-Pacific. During 2010-2020, Thailand's external debt-to-GDP ratio was in the range of around 32 to 42 percent. External debt-to-GDP ratios have increased in Thailand over the course of the past decade by around 10 percentage points.

If Thailand would have borrowed less internationally, then the HDI cost of natural disasters could have been larger. Consider, for example, the natural disasters that occurred in 2014. In that year Thailand's external debt-to-GDP ratio was around 38 percent. According to the econometric model estimates, the HDI cost associated with the 8 natural disasters that occurred in 2014 for an external debt-to-GDP ratio of 38 percent is 0.9 percentage points. Suppose now that Thailand would have borrowed less in international capital markets so that the external debt-to-GDP ratio would have been only around 20 percent in 2014. In that case the HDI cost of the 8 natural disasters that occurred during 2014 would have been around 1.5 percentage points. At an external debt-to-GDP of only around 20 percent the HDI cost of natural disasters would have been around 60 percent larger.

It is also noteworthy that tor Thailand there is a positive trend relationship between the external-debt-to-GDP ratios and the human development index. Between 2010 and 2020, the external-debt-to-GDP ratio increased by around 10 percentage points. The HDI increased during this period by 6 percentage points.

Vietnam

Panel H of Figure 7 (left-hand-side y-axis, blue line) shows that the effects of natural disasters on Vietnam's human development were negative during 2010-2020, i.e. there was a positive HDI cost. At peak, in 2013, when according to EM-DAT there were 10 natural disasters in Vietnam, the HDI cost was about 1.1 percentage points. For the other years during 2010-2020, when the incidence of natural disasters in Vietnam was in the range of 3 to 11 per year, the HDI cost was in the range of 0.3 to 1 percentage points.

Vietnam's external debt in 2020 was about 49 percent of its GDP. This puts Vietnam at about the 70^{th} percentile in Asia-Pacific. During 2010-2020, Vietnam's external debt-to-GDP ratio was in the range of around 40 to 50 percent. External debt-to-GDP ratios have increased in Vietnam over the course of the past decade by around 9 percentage points.

If Vietnam would have borrowed less internationally, then the HDI cost of natural disasters

could have been larger. Consider, for example, the natural disasters that occurred in 2013. In that year Vietnam's external debt-to-GDP ratio was around 40 percent. According to the econometric model estimates, the HDI cost associated with the 10 natural disasters that occurred in 2013 for an external debt-to-GDP ratio of 40 percent is about 1.0. Suppose now that Vietnam would have borrowed less in international debt markets so that the external debt-to-GDP ratio would have been only around 20 percent. In that case the HDI cost of the 10 natural disasters that occurred in 2013 would have been around 1.9 percentage points. Hence, at an external debt-to-GDP of only around 20 percent the HDI cost of natural disasters would have been around 90 percent larger.

For Vietnam there is a positive trend relationship between the external-debt-to-GDP ratios and the human development index during 2010-2020. Between 2010 and 2020, the external-debt-to-GDP ratio and the HDI increased by around 9 and 5 percentage points, respectively.

Summary of Case Studies

There are three main findings from the case studies:

1.) **External debt reduces the adverse effects that natural disasters have on the Human Development Index.** For each of the 8 countries studied during 2010-2020, the effects that natural disasters have on the HDI are less negative when external debt-to-GDP ratios increase. For example: Vietnam in the year 2019 had an external debt-to-GDP ratio of 48 percent. In 2020 Vietnam experienced 11 natural disasters which incurred an HDI cost of 0.9 percentage points. Seven years prior to that, when Vietnam's external debt-to-GDP ratio was about 40 percent, the country experienced 11 natural disasters that incurred an HDI cost of 1.1 percentage. This is about 20 percent larger than the HDI the country incurred in 2020 (when a similar number of natural disasters struck and the country engaged less in international risk sharing).

2.) **No evidence of systematic direct negative effects of external debt on the Human Development Index**. For the 8 countries studied during 2010-2020: the trend relationship between external debt-to-GDP ratios and the HDI is positive in 4 countries (India, Indonesia, Thailand, Vietnam); zero in three countries (Afghanistan, Bangladesh, Pakistan); and negative in one country (Philippines).

3.) **No evidence of systematic direct negative effects of external debt on the Human Development Index for countries with initially higher external debt-to-GDP ratios.** For the 8 countries studied during 2010-2020: in one country (the Philippines) where there was a negative trend relationship between the external debt-to-GDP ratio and the HDI, the 2010 external debt-to-GDP ratio was 21 percent. In the other 3 countries (Afghanistan, Bangladesh, Pakistan), where there was a near zero trend relationship between the external debt-to-GDP ratio and the HDI, the 2010 external debt-to-GDP ratio was 15, 21, and 36 percent, respectively. In the 4 countries (India, Indonesia, Thailand, Vietnam), where there was a positive trend relationship between the external debt-to-GDP ratio and the HDI, the 2010 external debt-to-GDP ratio was 18, 27, 33, and 40 percent, respectively.

6. Summary and Policy Implications

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 disasters 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 in 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 credit markets. At the same time, there is also a need for reform in the international financial mechanism 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 international finance access. 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 market, 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 for reforming the international financial system, including reforms of the multilateral development banks[9] 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.

[9] See https://odi.org/en/insights/multilateral-development-bank-reform-can-and-must-benefit-both-low-and-middle-income-countries/ and https://www.brookings.edu/articles/strengthening-multilateral-development-banks-a-response-to-critics/

References

Albala-Bertrand, J. M. (1993). Political economy of large natural disasters. *Clarendon Press*, Oxford.

Aguiar, M. (2023). The costs and consequences of sovereign borrowing. *Mundell Fleming Lecture*.

Armenian, H. K., Melkonian, A. K., & Hovanesian, A. P. (1998). Long-term mortality and morbidity related to the degree of damage following the 1988 earthquake in Armenia. *American Journal of Epidemiology*, 148(11), 1077-1084.

Burke, M., Hsiang, S. & Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, 527, 235–239.

Caruso, G., & Miller, S. (2015). Long-run effects and intergenerational transmission of natural disasters: A case study on the 1970 Ancash Earthquake. *Journal of Development Economics*, 117, 134-150.

Cavallo, E., Galiani, S., Noy, I., & Pantano, J. (2013). Catastrophic natural disasters and economic growth. *Review of Economics and Statistics*, 95(5), 1549-1561.

Checherita-Westphal, C., & Rother, P. (2012). The impact of high government debt on economic growth and its channels: An empirical investigation for the euro area. *European Economic Review*, 56(7), 1392-1405.

Clements, B., Bhattacharya, R., & Nguyen, T. Q. (2003). External debt, public investment, and growth in low-income countries. *IMF Working Paper,* No. 03/249.

Currie, J., & Rossin-Slater, M. (2013). Weathering the storm: Hurricanes and birth outcomes. *Journal of Health Economics*, 32(3), 487-503.

Dessy, S. E., & Vencatachellum, D. (2007). Debt relief and social services expenditure: The African experience, 1989–2003. *African Development Review*, 19(1), 200-216.

Doğan, İ., & Bilgili, F. (2014). The non-linear impact of high and growing government external debt on economic growth: A Markov regime-switching approach. *Economic Modelling*, 39, 213-220.

Felbermayr, G., & Gröschl, J. (2014). Naturally negative: The growth effects of natural disasters. *Journal of Development Economics*, 111, 92-106.

Frankenberg, E., Sumantri, C., & Thomas, D. (2020). Effects of a natural disaster on mortality risks over the longer term. *Nature Sustainability*, 3(8), 614-619.

Fosu, A. K. (2007). Fiscal allocation for education in sub-Saharan Africa: Implications of the external debt service constraint. *World Development*, 35(4), 702-713.

Fosu, A. K. (2008). Implications of the external debt-servicing constraint for public health expenditure in sub-Saharan Africa. *Oxford Development Studies*, 36(4), 363-377.

Hallegatte, S., & Dumas, P. (2009). Can natural disasters have positive consequences? Investigating the role of embodied technical change. *Ecological Economics*, 68(3), 777-786.

Ho, J. Y., Frankenberg, E., Sumantri, C., & Thomas, D. (2017). Adult mortality five years after a natural disaster. *Population and Development Review*, 43(3), 467-490.

Howard, E., Murphy, K., Nientker, W., El-Ouaghlidi, K., & Schmidt, H. (2020). The effectiveness of debt relief in mitigating the macroeconomic consequences of natural disasters (Master's thesis), *Barcelona School of Economics.*

Husted, L., Opper, I. M., & Park, J. R. (2022). The Impact of natural disasters on human capital. *Annenerg Brown University Edworking Paper*, No. 22-548.

Kahn, M. E. (2005). The death toll from natural disasters: The role of income, geography, and institutions. *Review of Economics and Statistics*, 87(2), 271-284.

Kim, B., Carruthers, C. K., & Harris, M. C. (2017). Maternal stress and birth outcomes: Evidence from the 1994 Northridge earthquake. *Journal of Economic Behavior & Organization*, 140, 354-373.

Loko, B., Mlachila, M., Nallari, R., & Kalonji, K. (2003). The impact of external indebtedness on poverty in low-income countries. *IMF Working Paper*, No. 03/61.

Maggiori, M. (2022). International macroeconomics with imperfect financial markets. In *Handbook of International Economics* (Vol. 6, pp.199-236). Elsevier.

Melecky, M. and Raddatz, C. E. (2015. Fiscal Responses after Catastrophes and the Enabling Role of Financial Development. *World Bank Economic Review* 29, 479-522.

Nakagawa, I., Nakamura, K., Oyama, M., Yamazaki, O., Ishigami, K., Tsuchiya, Y., & Yamamoto, M. (2009). Long-term effects of the Niigata-Chuetsu earthquake in Japan on acute myocardial infarction mortality: An analysis of death certificate data. *Heart*.

Noy, I. (2009). The macroeconomic consequences of disasters. *Journal of Development Economics*, 88(2), 221-231.

Oliveira, V. H. de, Lee, I., & Quintana-Domeque, C. (2023). Natural disasters and early human development: Hurricane Catarina and infant health in Brazil. *Journal of Human Resources*, 58(3), 819-851.

Özek, U. (2023). Examining the educational spillover effects of severe natural disasters: The case of Hurricane Maria. *Journal of Human Resources*, 58(2), 421-451.

Pane, J. F., McCaffrey, D. F., Tharp-Taylor, S., Asmus, G. J., & Stokes, B. R. (2006). Student displacement in Louisiana after the hurricanes of 2005: Experiences of public schools and their students. *RAND Corporation*, Santa Monica, CA.

Pattillo, C. A., Poirson, H., & Ricci, L. A. (2002). External debt and growth. *IMF Working Paper*, No. 02/69.

Paudel, J., & Ryu, H. (2018). Natural disasters and human capital: The case of Nepal's earthquake. *World Development*, 111, 1-12.

Sacerdote, B. (2012). When the saints go marching out: Long-term outcomes for student evacuees from Hurricanes Katrina and Rita. *American Economic Journal: Applied Economics*, 4(1), 109-135.

Skidmore, M., & Toya, H. (2002). Do natural disasters promote long-run growth? *Economic Inquiry*, 40(4), 664-687.

Strobl, E. (2011). The economic growth impact of hurricanes: Evidence from US coastal counties. *Review of Economics and Statistics*, 93(2), 575-589.

Tol, R., & Leek, F. (1999). Economic analysis of natural disasters. *Climate Change and Risk*, 308-327.

Torche, F. (2011). The Effect of Maternal Stress on Birth Outcomes: Exploiting a natural experiment. *Demography*, 48, 1473–1491.

Toya, H., & Skidmore, M. (2007). Economic development and the impacts of natural disasters. *Economics Letters,* 94(1), 20-25.

Zaghdoudi, K. (2018). Is the relationship between external debt and human development non-linear? A PSTR approach for developing countries. *Economics Bulletin*, 38(4), 2194-2216.

Table 1 Descriptive Statistics
Debt, Development, Climate and Natural Disasters in Asia-Pacific During 1970-2020

	Average	Median	Interquartile range	Bottom 1st Percentile	Top 1st Percentile	Standard Deviation
	Panel A: Debt					
External Debt, % of GNI	43	35	[19,54]	1	206	39
External Debt, % short term	11	6	[1,15]	0	69	15
External Debt, % public	73	81	[58,93]	9	100	24
External Debt service cost, % of GNI	4	3	[1,5]	0	17	5
Central Government Debt, % of GNI	44	39	[25,54]	3	193	32
	Panel B: Development					
Human Development Index	60	61	[52, 68]	32	80	11
Poverty Ratio, 2.15$ per day	15	8	[1,22]	0	72	18
GDP per capita, PPP constant price USD	5950	4038	[2898, 7658]	854	21289	4629
Capital per worker	44154	21176	[9897, 56188]	828	277754	55158
Total factor productivity (US=100)	50	45	[38,60]	27	100	17
	Panel C: Climate and Natural Disasters					
Temperature	22	25	[21,27]	0	29	8
Rainfall, mm/month	1805	1871	[1152, 2466]	197	3621	924
Natural disasters, total number within a year	5	2	[1,6]	0	30	6
Natural disasters, total deaths within a year	1952	75	[4, 418]	0	31500	15368
Natural disasters, total damage within a year ('1000 USD)	996211	1500	[0,150000]	0	23100000	5107387

Table 2A. Debt, Development, Climate and Natural Disasters
Averages During 1990-2020 for Different Developing Regions in the World

Region	Asia-Pacific	South-Asia	East Asia and Pacific	Latin America and Caribbean	Middle East and North Africa	Sub-Saharan Africa
Classification	UNDP	World Bank	World Bank	World Bank	World Bank	World Bank
Period	1990-2020	1990-2020	1990-2020	1990-2020	1990-2020	1990-2020
Statistic Reported	Average	Average	Average	Average	Average	Average
	Panel A: Debt					
External Debt, % of GNI	46	41	51	62	55	72
External Debt service cost, % of GNI	4	3	4	6	6	3
	Panel B: Development					
Human Development Index	60	55	61	68	63	47
Poverty Ratio, 2.15$ per day	13	18	13	9	4	46
GDP per capita, PPP constant price USD	5950	5568	5658	10336	10356	3856
Capital per worker	58145	44771	54046	77115	105284	36306
Total factor productivity (US=100)	49	54	45	57	74	45
	Panel C: Climate and Natural Disasters					
Temperature	22	19	23	25	22	25
Rainfall	1806	1297	2053	1858	226	1098
Natural disasters, total number within a year	6	6	5	3	1	2
Natural disasters, total deaths within a year	1574	2336	1224	585	302	189
Natural disasters, total damage within a year ('1000 USD)	1358928	930048	1616524	258296	141497	15990

Note: the regions listed under the World Bank classification exclude high income countries.

Table 2B. Debt, Development, Climate and Natural Disasters
Averages During 1990-2020 for Different Developing Regions in Asia-Pacific

Region	Asia-Pacific	Asia-Pacific LDC	South Asia	East Asia and Pacific	East Asia	Pacific
Period	1990-2020	1990-2020	1990-2020	1990-2020	1990-2020	1990-2020
Classification	UNDP	UNDP	UNDP	UNDP	UNDP	UNDP
Statistic Reported	Average	Average	Average	Average	Average	Average
	Panel A: Debt					
External Debt, % of GNI	46	47	37	51	59	38
External Debt service cost, % of GNI	4	2	3	4	5	3
	Panel B: Development					
Human Development Index	60	52	57	62	61	63
Poverty Ratio, 2.15$ per day	13	20	14	13	14	12
GDP per capita, PPP constant price USD	5950	3102	6436	6074	7296	5060
Capital per worker	58145	27724	63780	54046	54889	45619
Total factor productivity (US=100)	49	41	61	45	41	69
	Panel C: Climate and Natural Disasters					
Temperature	22	21	19	23	20	26
Rainfall	1806	1750	1178	2073	1753	2465
Natural disasters, total number within a year	6	3	6	5	7	2
Natural disasters, total deaths within a year	1574	1631	2343	1222	1824	30
Natural disasters, total damage within a year ('1000 USD)	1358928	147409	921950	1612541	2417241	18919

Table 3. Debt, Development, Climate and Natural Disasters
Averages During 1990-2020 by Income Status

Income Status	Low Income	Lower Middle Income	Higher Middle Income	High Income, Debtor
Period	1990-2020	1990-2020	1990-2020	1990-2020
Statistic Reported	Average	Average	Average	Average
	Panel A: Debt			
External Debt, % of GNI	73	64	52	72
	Panel B: Development			
Human Development Index	42	56	70	84
Poverty Ratio, 2.15$ per day	52	19	7	1
GDP per capita, PPP constant price USD	1649	4606	11712	39813
Capital per worker	16431	50041	106103	318757
Total factor productivity (US=100)	36	49	59	79
	Panel C: Climate and Natural Disasters			
Temperature	24	22	20	15
Rainfall	994	1230	1404	1054
Natural disasters, total number within a year	2	3	3	3
Natural disasters, total deaths within a year	553	653	555	138
Natural disasters, total damage within a year ('1000 USD)	64201	239854	812430	2092205

Table 4. List of Top-5 Most Affected Countries from Natural Disasters in Asia-Pacific During 1990-2020

Panel A: Average total number of natural disasters in a year					
Country	Total number of disasters	Country	Total number of disasters per 1 million people	Country	Total number of disasters per 1 thousand sq Km.
China	24	Tuvalu	82	Tuvalu	28
India	15	Marshall Islands	19	Marshall Islands	6
Philippines	14	Samoa	18	Samoa	5
Indonesia	13	Tonga	13	Maldives	2
Bangladesh	7	Micronesia	10	Tonga	2
Panel B: Total deaths due to natural disasters in a year					
Country	Total deaths due to disasters	Country	Total deaths due to disasters, per 1 million people	Country	Total deaths due to disasters, per 1 thousand sq Km.
Indonesia	6320	Samoa	180	Samoa	50
Bangladesh	5211	Myanmar	103	Maldives	44
Myanmar	5007	Micronesia	75	Bangladesh	40
China	4609	Sri Lanka	63	Sri Lanka	20
India	4309	Bhutan	59	Micronesia	11
	Panel C: Total damage due to natural disasters				
Country	Total damage due to disasters in '1000 USD	Country	Total damage due to disasters in '1000 USD) per 1 million people	Country	Total damage due to disasters in '1000 USD, per 1 thousand sq Km.
China	18200000	Samoa	899939	Samoa	250000
India	4142863	Tonga	231975	Maldives	185222
Thailand	1646073	Maldives	158703	Tonga	32271
Indonesia	1063141	Vanuatu	94804	North Korea	7895
North Korea	990331	Fiji	58986	Bangladesh	4047

Table 5. Effects of Natural Disasters on Human Development: The Role of External Debt

Dependent Variable is:	Human Development Index (in %)	ΔHuman 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 * External Debt-to-GDP, t-1	0.020* (0.011)	0.011*** (0.003)	0.021** (0.010)	0.237*** (0.092)
External Debt-to-GDP, 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. *, **, ***, denotes that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

Table 6A. Effects of Natural Disasters on International Trade: The Role of External Debt

Dependent Variable is:	Imports of Goods and Services (Growth Rate, in %)	Exports of Goods and Services (Growth Rate, in %)
Natural Disasters, t	-0.277** (0.133)	-0.287* (0.157)
Natural Disasters, t * External Debt-to-GDP, t-1	0.815** (0.307)	0.797** (0.321)
External Debt-to-GDP, t-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

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

Table 6B. Effects of Natural Disasters on External Debt and Net Current Transfers

Dependent Variable is:	External Debt (Growth Rate, in %)	Net Current Transfers (Growth Rate, in %)
Natural Disasters, t	0.353** (0.151)	-1.681*** (0.587)
Natural Disasters, t * External Debt-to-GDP, t-1	-1.085*** (0.279)	2.572* (1.467)
External Debt-to-GDP, t-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. *, **, ***, denotes that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

Table 7. Effects of Natural Disasters on Human Development: Public vs. Private External Debt

Dependent Variable is:	Human Development Index (in %)		
External Debt Variable:	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 * External Debt-to-GDP, t-1	0.020* (0.011)	0.018 (0.012)	0.076* (0.042)
External Debt-to-GDP, 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. *, **, ***, denotes that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

Table 8. Effects of Natural Disasters on Human Development:
Central Government Debt vs. Private Sector Debt

Dependent Variable is:	Human Development Index (in %)	
Debt Variable:	Central Government Debt	Private Sector Debt
Natural Disasters, t	-0.006 (0.008)	-0.012 (0.008)
Natural Disasters, t * Debt-to-GDP, t-1	0.007 (0.007)	0.013* (0.007)
Debt-to-GDP, 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. *, **, ***, denotes that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

Table 9. 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 * 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. *, **, ***, denotes that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

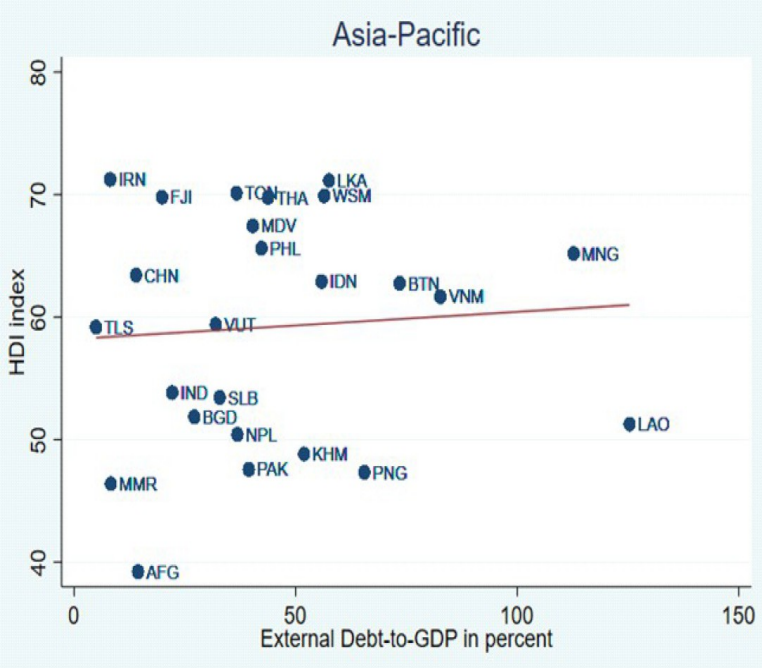
Table 10. Effects of Natural Disasters on Human Development:
The Role of Grants

Dependent Variable is:	Human Development Index (in %)	
Grants Variable:	Grants, Excluding Technical Cooperation	Technical Cooperation Grants
Natural Disasters, t	-0.010* (0.006)	-0.010* (0.005)
Natural Disasters, t * Grants-to-GDP, t-1	0.168* (0.101)	0.921* (0.515)
Grants-to-GDP, 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. *, **, ***, denotes that the estimated coefficient is significantly different from zero at the 10, 5, and 1 percent level, respectively.

Figure 1A. External Debt and Human Development

Panel A: Asia-Pacific



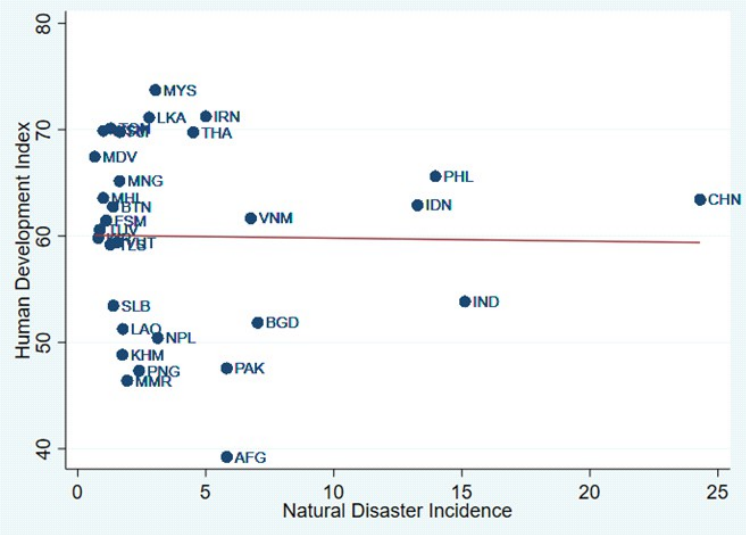
Note: The figure plots the country average external debt-to-GDP ratio in percent during 1990-2020 (x-axis) and the country average HDI index during 1990-2020 (y-axis) for all countries in Asia-Pacific. The red line is the least squares fit. The slope coefficient on the external-to-GDP is 0.022 with a standard error of 0.061. The R-squared is 0.005.

Panel B: World Sample

Note: The figure plots the country average external debt-to-GDP ratio in percent during 1990-2020 (x-axis) and the country average HDI index during 1990-2020 (y-axis) for all countries in the world. The red line is the least squares fit. The slope coefficient on the external-to-GDP is -0.043 with a standard error of 0.023. The R-squared is 0.018.

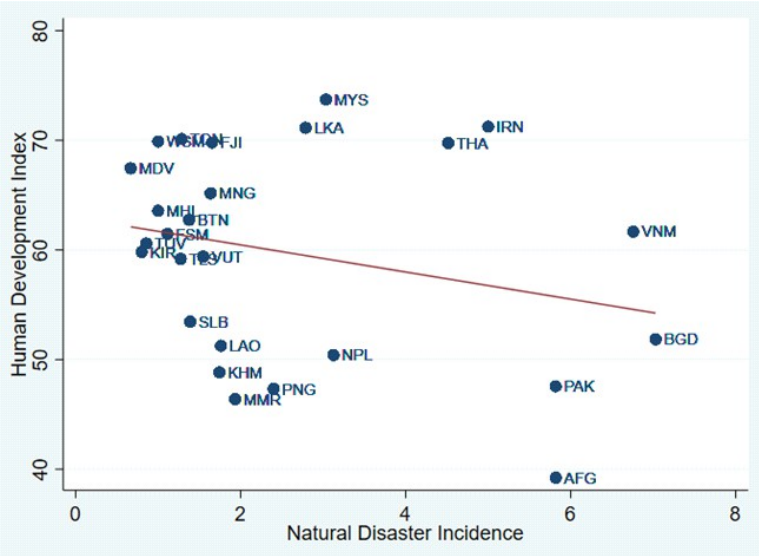
Figure 1B. Natural Disasters and Human Development in Asia-Pacific

Panel A: All Countries in Asia-Pacific



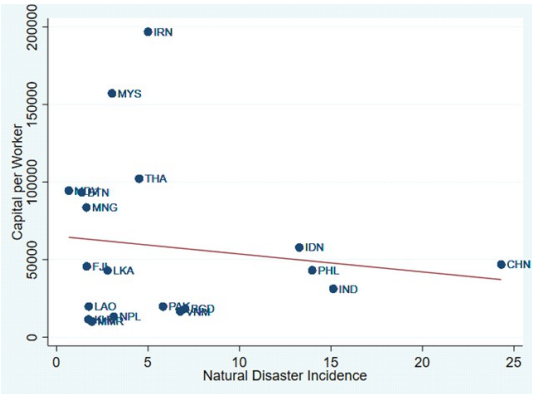
Note: The figure plots the country average human development index during 1990-2020 (y-axis) and the country average incidence of natural disasters during 1990-2020 (x-axis) for all countries in Asia-Pacific. The red line is the least squares fit. The slope coefficient is -0.029 with a standard error of 0.188. The R-squared is 0.0003.

Panel B: Countries with less than 10 natural disasters per year on average during 1990-2020



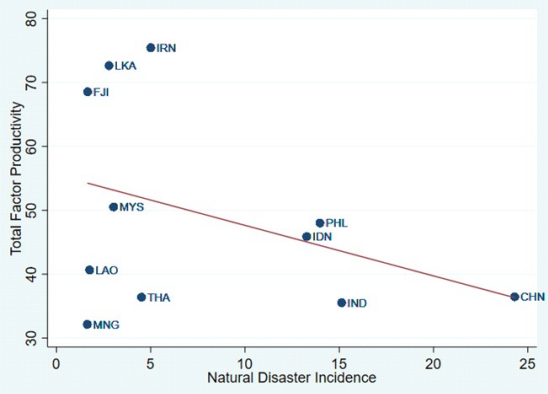
Note: The figure plots the country average human development index during 1990-2020 (y-axis) and the country average incidence of natural disasters during 1990-2020 (x-axis) for all countries in Asia-Pacific excluding those with an mean annual natural distaster incidence of ten or more. The red line is the least squares fit. The slope coefficient is -1.236 with a standard error of 0.922. The R-squared is 0.065.

Figure 1C. Natural disasters and capital per worker in Asia-Pacific



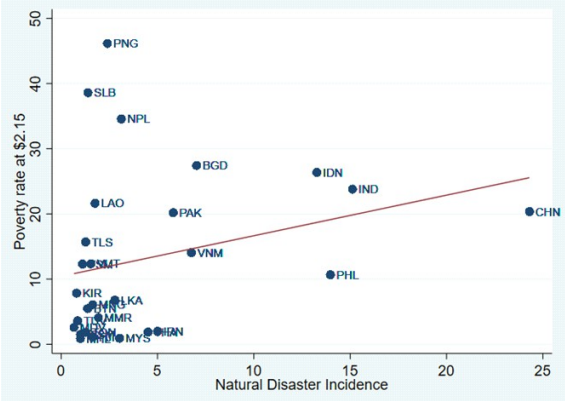
Note: The figure plots the country mean incidence of natural disasters during 1990-2020 (x-axis) and the country mean capital per worker during 1990-2020 (y-axis) for all countries in Asia-Pacific. The red line is the least squares fit. The slope coefficient is -1153with a standard error of 994. The R-squared is 0.019.

Figure 1D. Natural disasters and total factor productivity in Asia-Pacific



Note: The figure plots the country mean incidence of natural disasters during 1990-2020 (x-axis) and the country mean total factor productivity during 1990-2020 (y-axis) for all countries in Asia-Pacific. The red line is the least squares fit. The slope coefficient is -0.791 with a standard error of 0.455. The R-squared is 0.143.

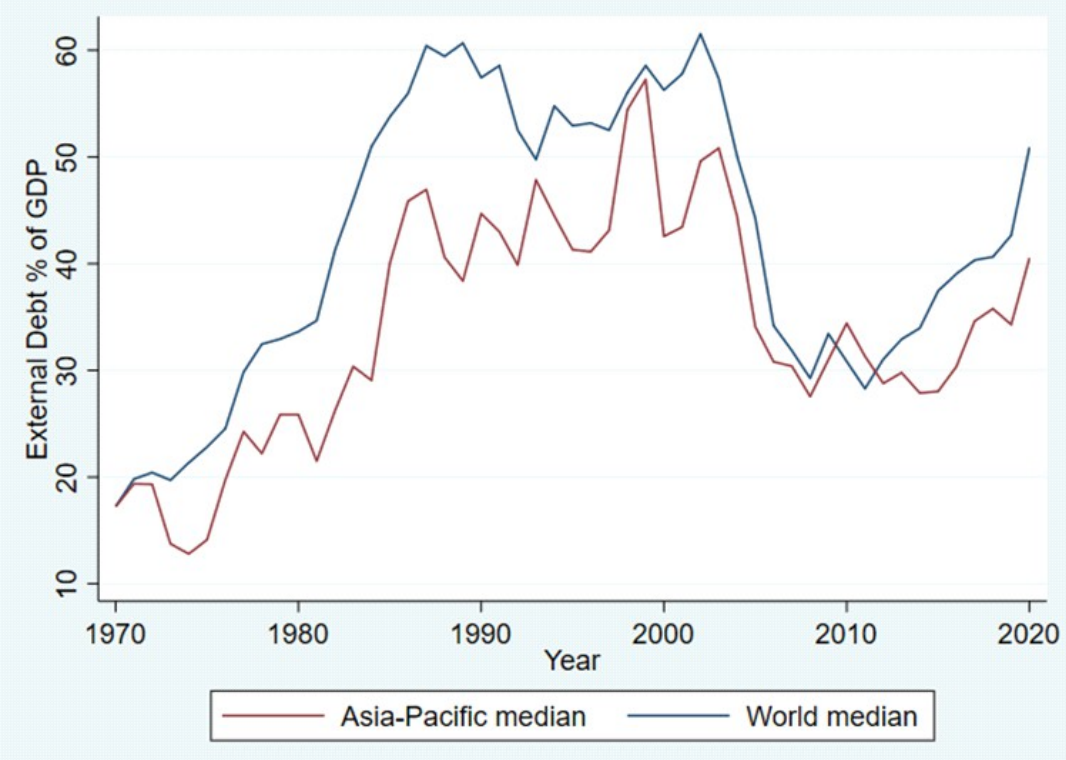
Figure 1E. Natural disasters and poverty in Asia-Pacific



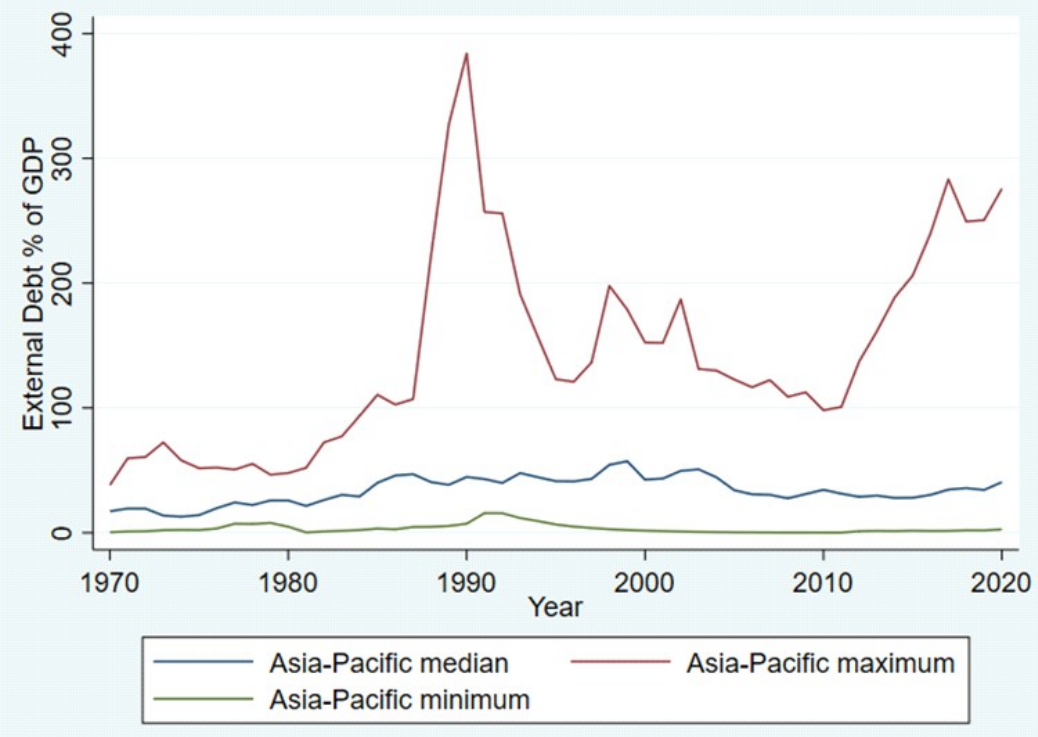
Note: The figure plots the country mean incidence of natural disasters during 1990-2020 (x-axis) and the country mean poverty rate at $2.15 (y-axis) for all countries in Asia-Pacific. The red line is the least squares fit. The slope coefficient is 0.623 with a standard error of 0.261. The R-squared is 0.077.

Figure 2. Trends in the External Debt-to-GDP Ratio

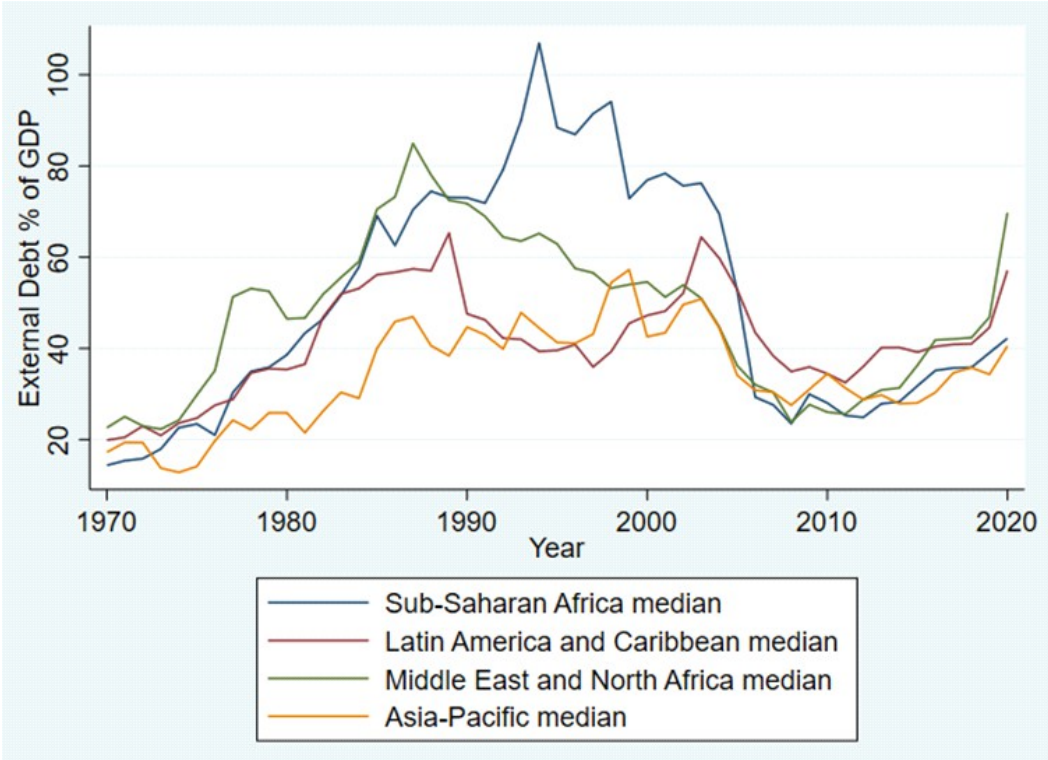
Panel A: Trends in the External Debt-to-GDP Ratio in Asia-Pacific and the World



Panel B: Trends in the Median, Maximum, and Minimum External Debt-to-GDP Ratio in Asia-Pacific



Panel C: Trends in the External Debt-to-GDP Ratio in other Regions



Panel D: Trends in the External Debt-to-GDP Ratio by Income Status

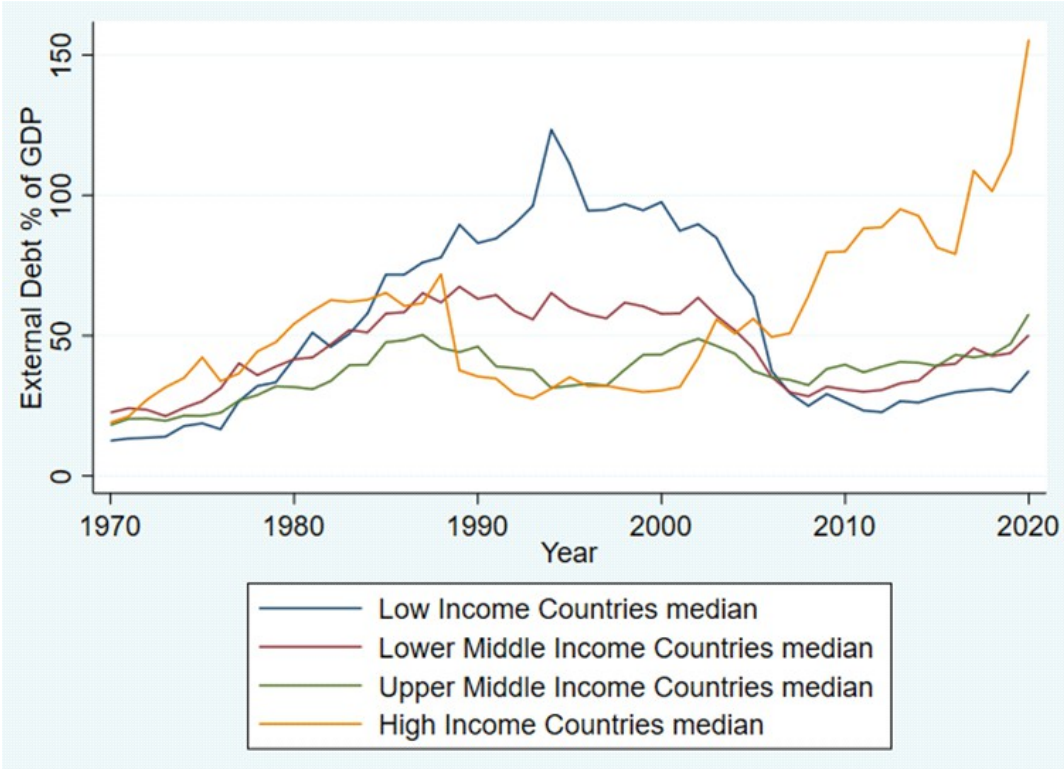
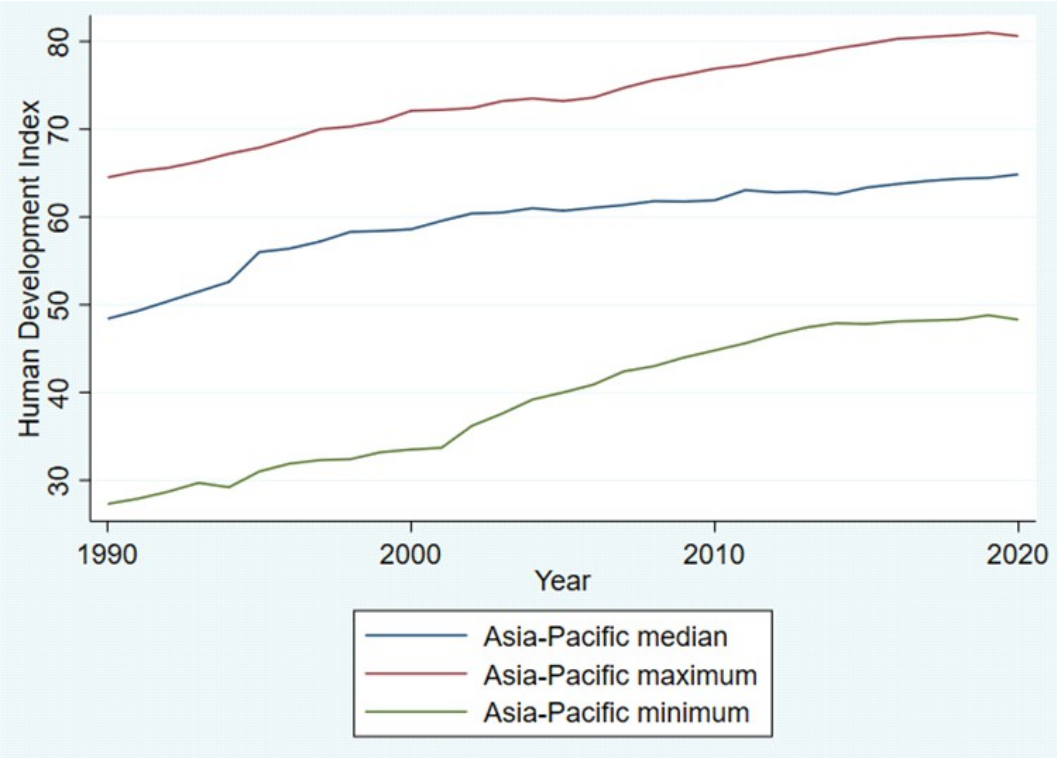
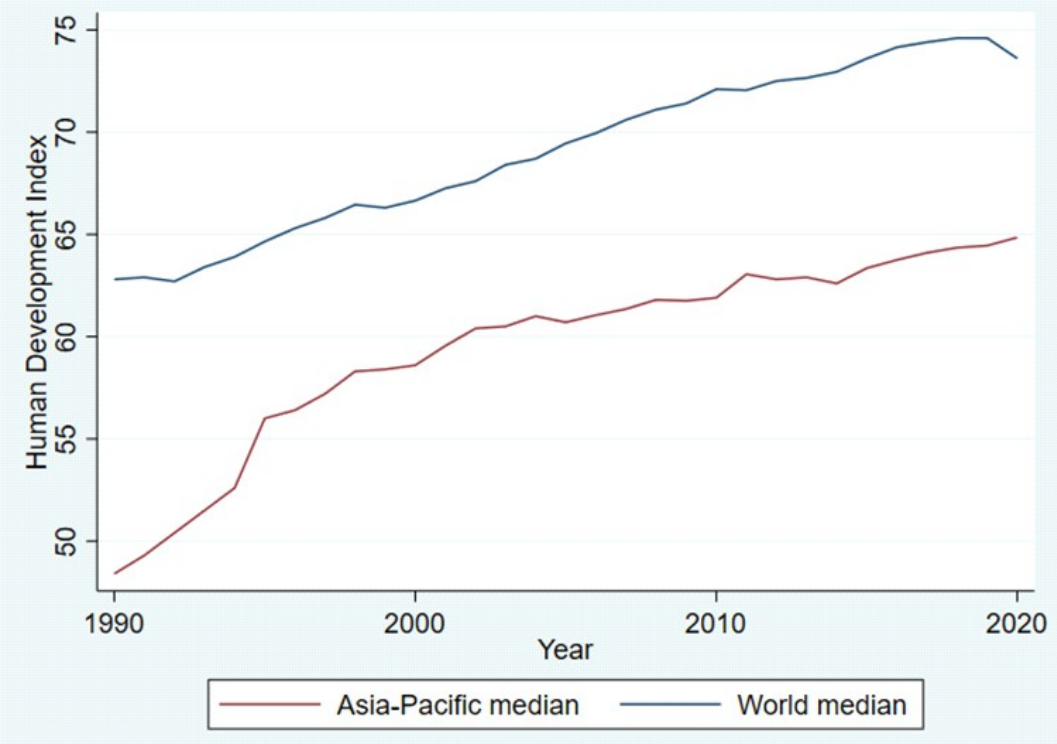


Figure 3. Trends in the Human Development Index

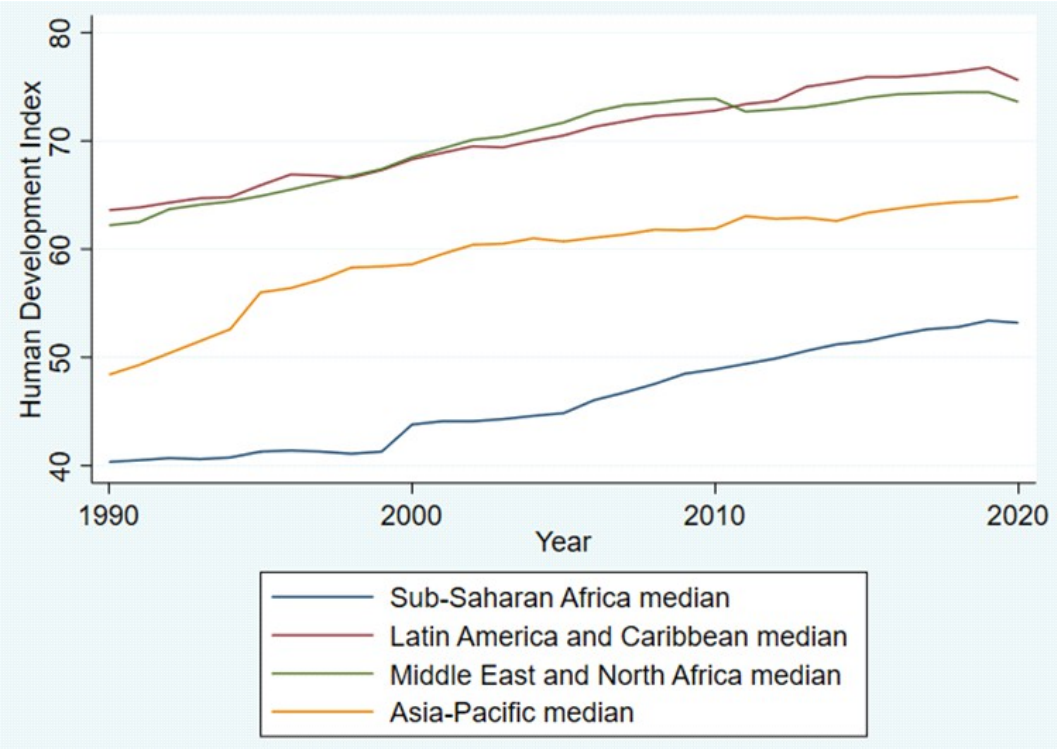
Panel A: Trends in the Median, Maximum, and Minimum Human Development Index in Asia-Pacific



Panel B: Trends in the Global Human Development Index



Panel C: Trends in the Human Development Index for Other Regions



Panel D: Trends in the Human Development Index by Income Status

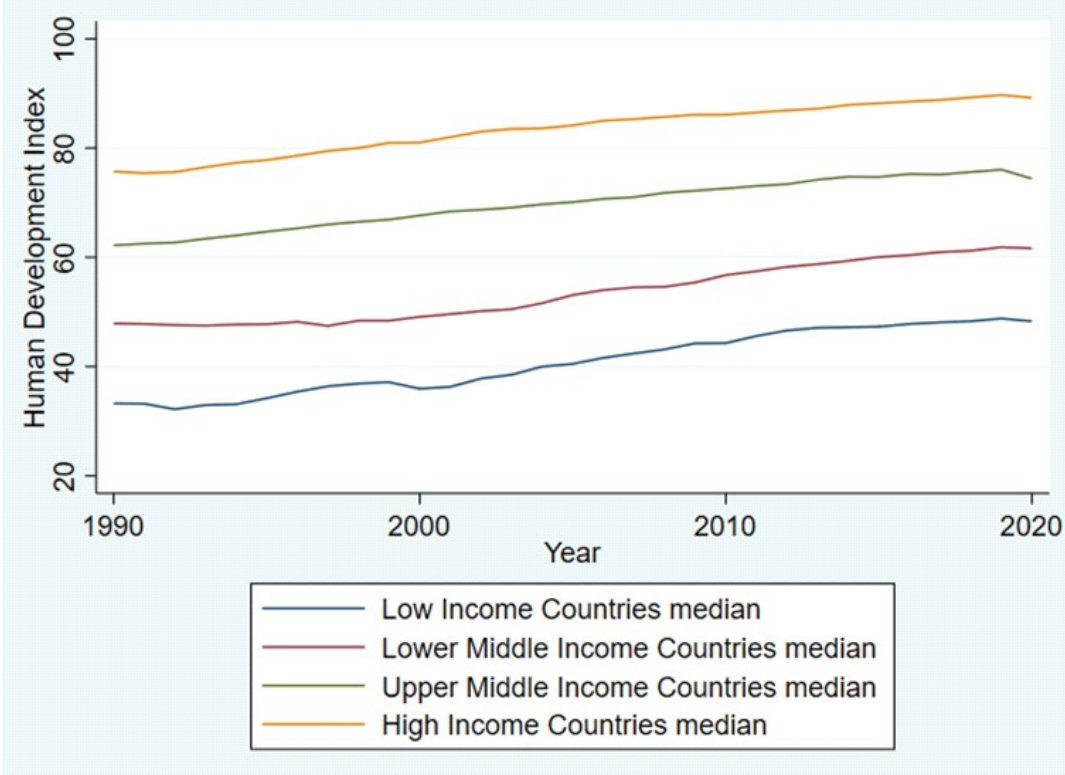
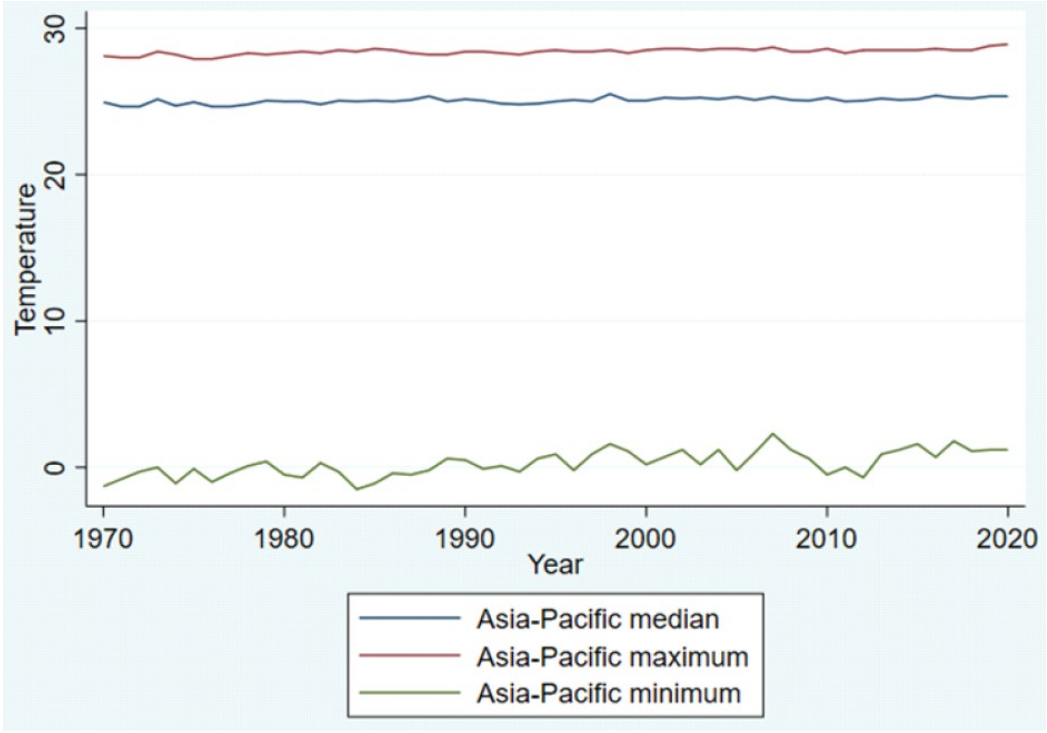
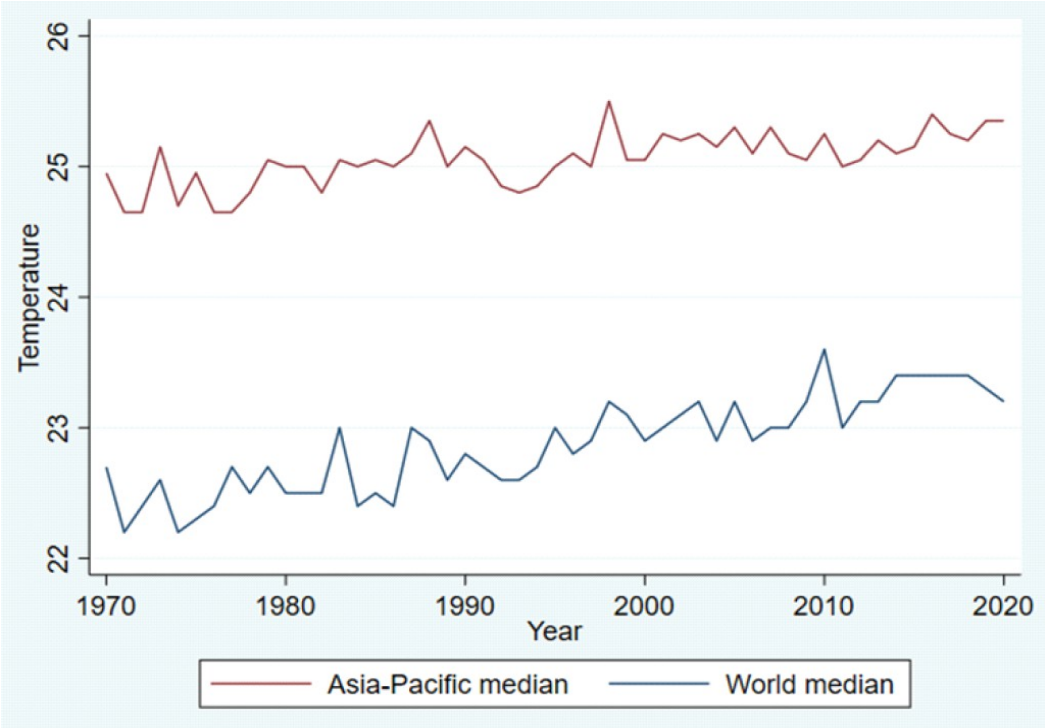


Figure 4. Trends in Temperatures

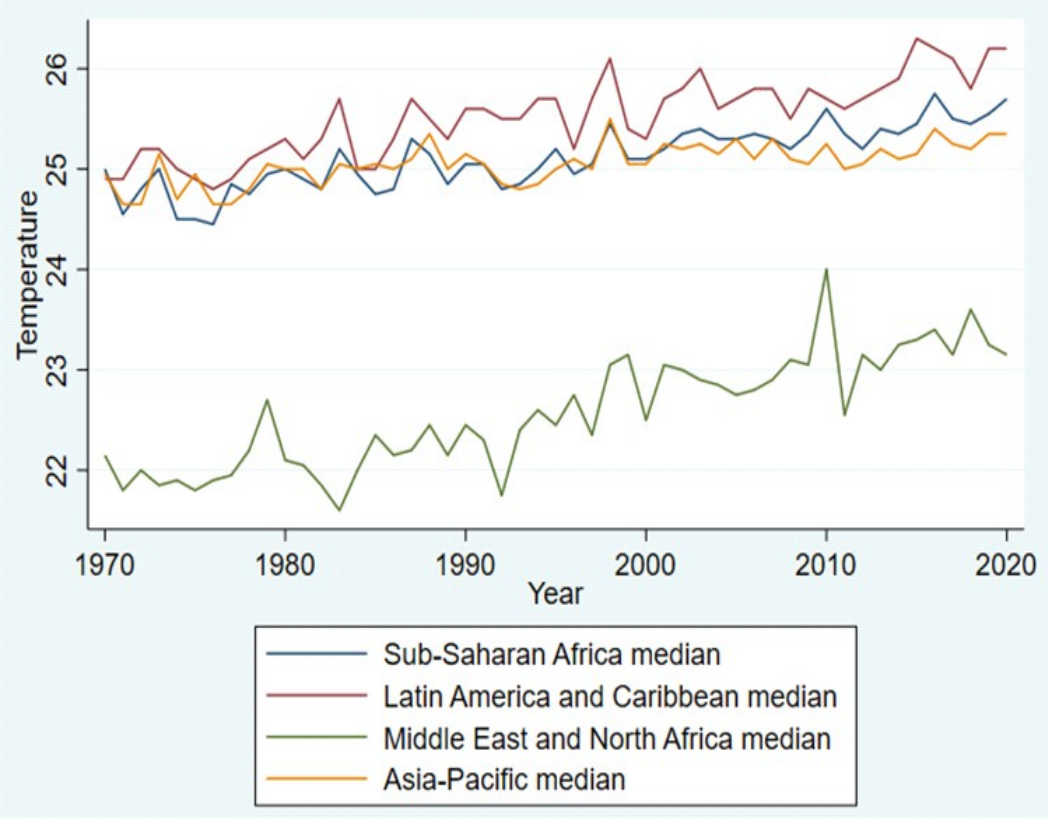
Panel A: Trends in the Median, Maximum, and Minimum Country-Mean Annual Temperatures in Asia-Pacific



Panel B: Trends in Country-Mean Annual Temperatures for the Median Country in the World



Panel C: Trends in Median Annual Temperatures for Other Regions



Panel D: Trends in Median Annual Temperatures by Income Status

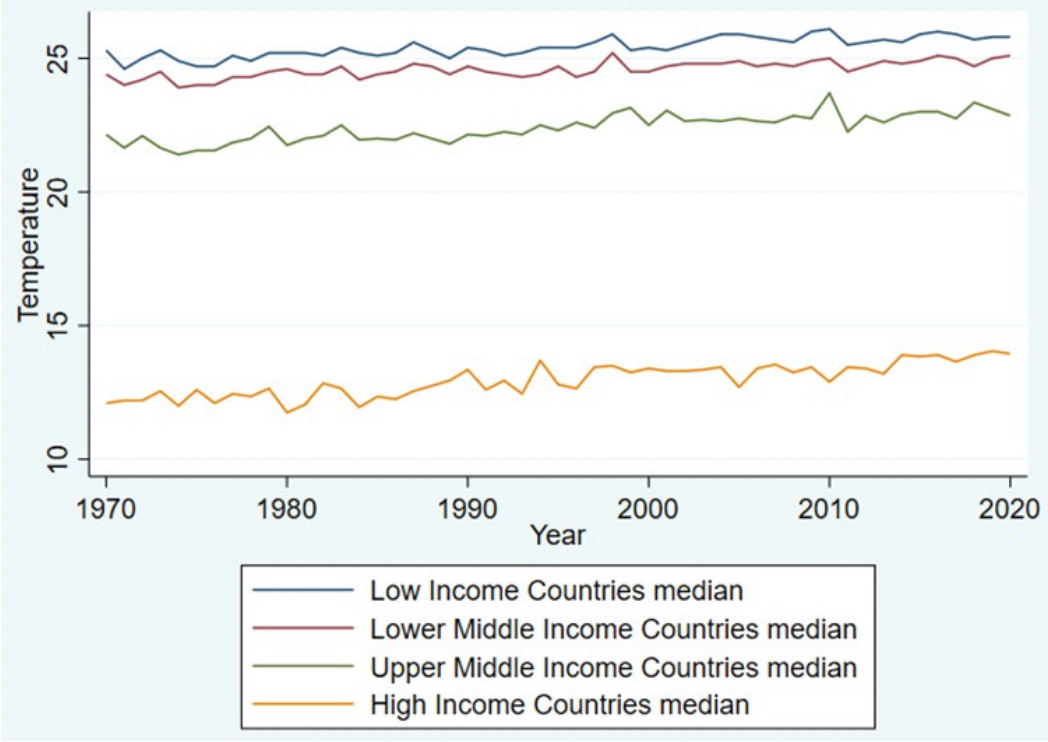
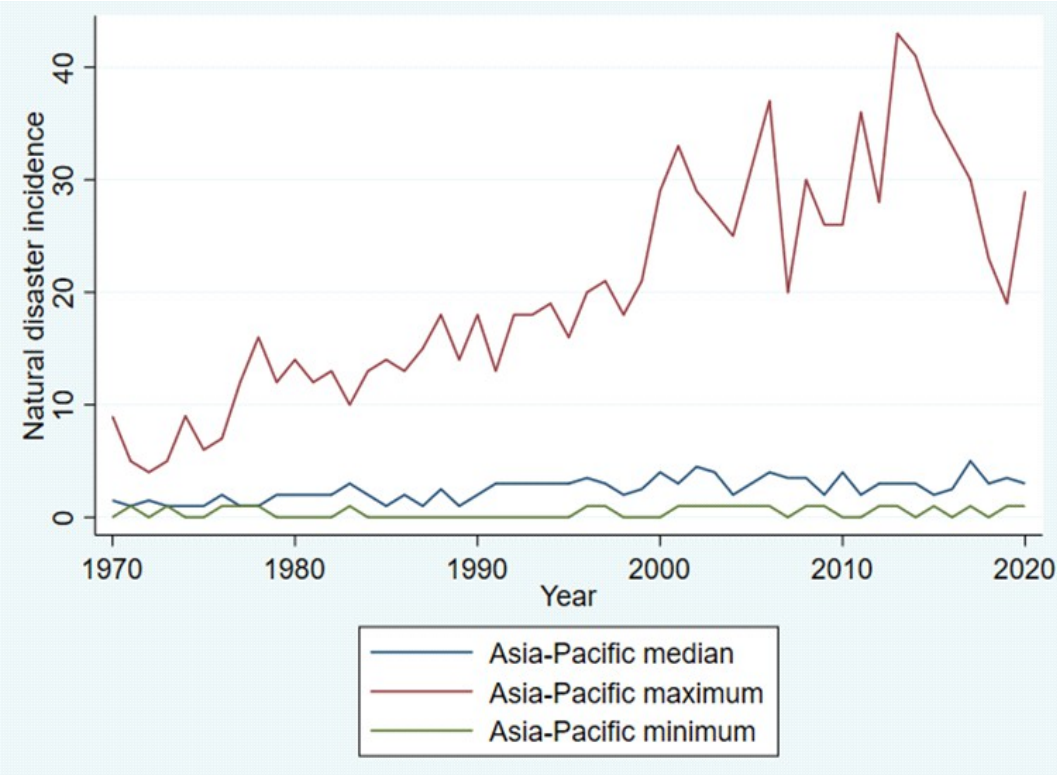
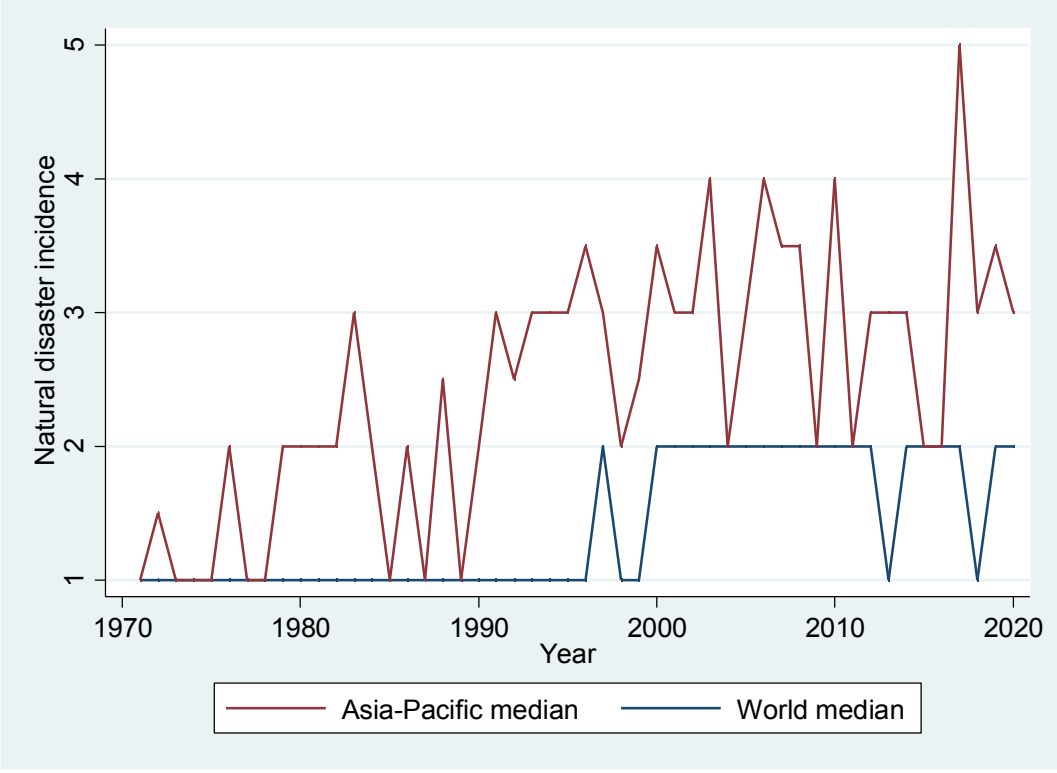


Figure 5. Trends in the Annual Incidence of Natural Disasters

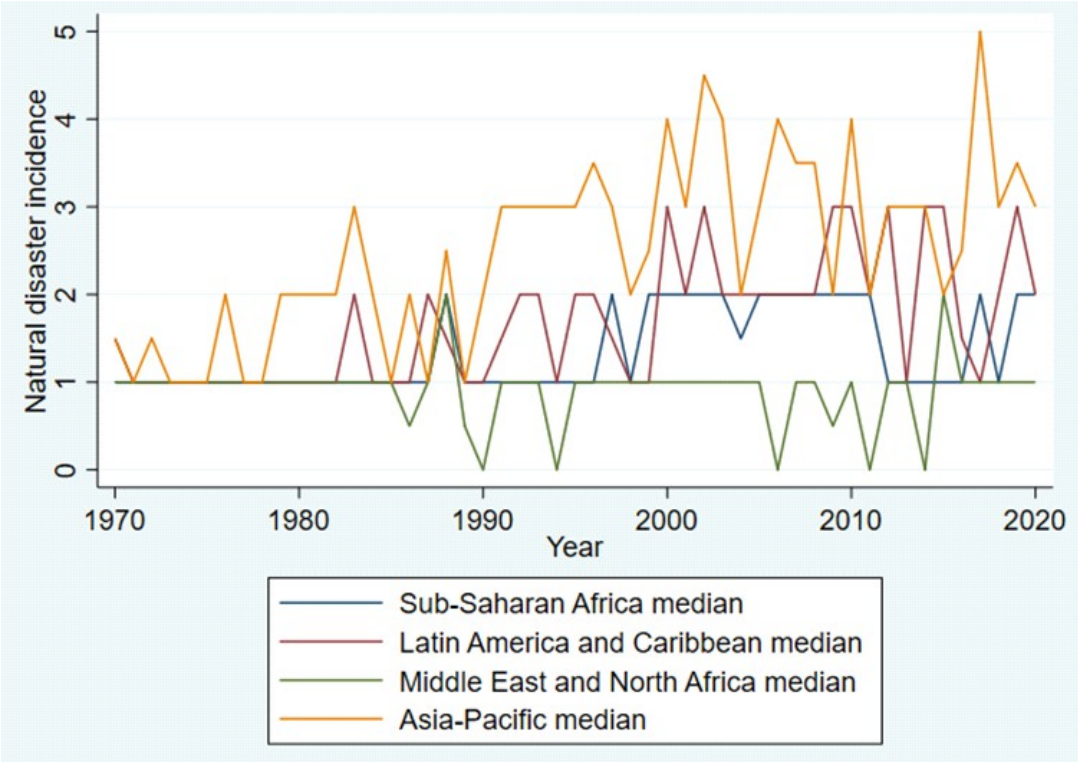
Panel A: Trends in the Annual Incidence of Natural Disasters in Asia-Pacific



Panel B: Trends in the Annual Incidence of Natural Disasters for the Median Country in the World



Panel C: Trends in the Annual Incidence of Natural Disasters for the Median Country in Other Developing Regions



Panel D: Trends in the Annual Incidence of Natural Disasters for the Median Country by Income Status Group

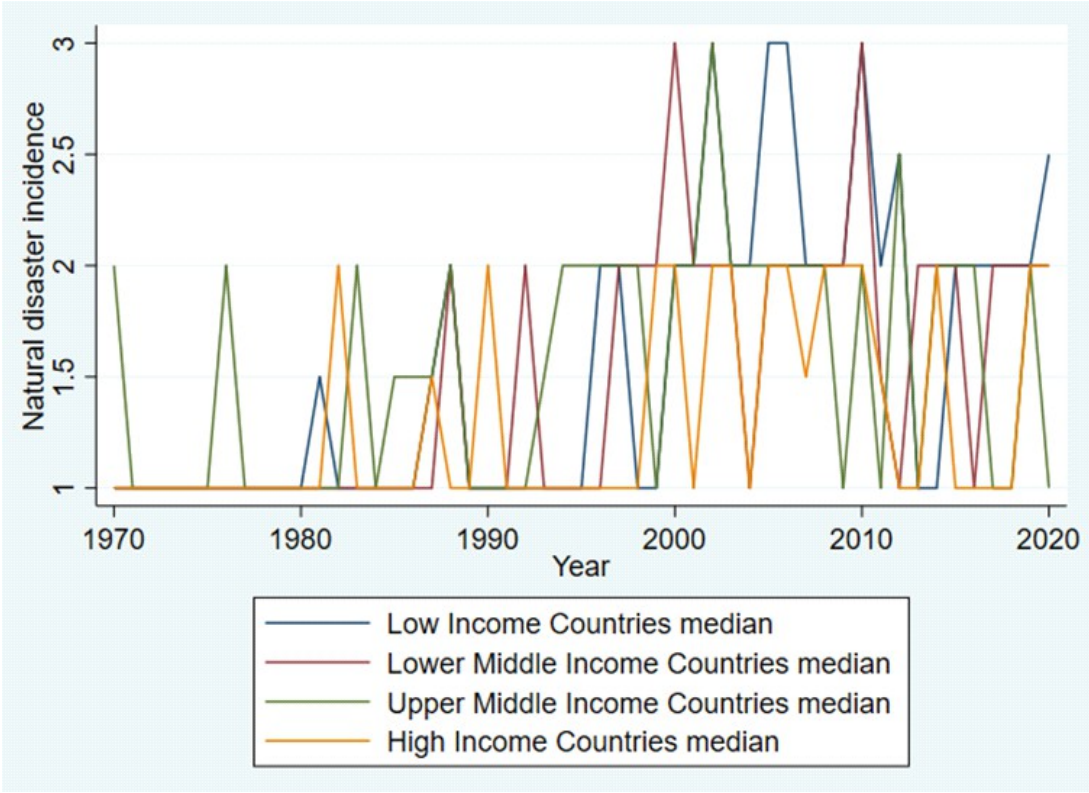
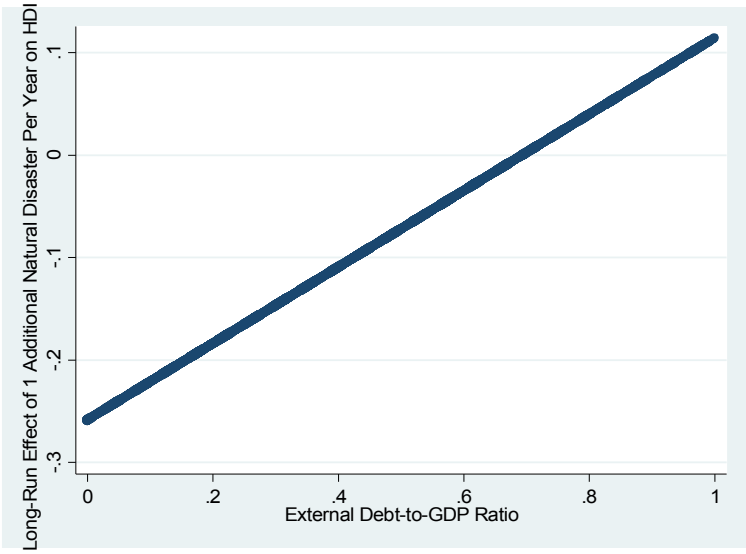


Figure 6. Effects of Natural Disasters on the Human Development Index: the Role of External Debt



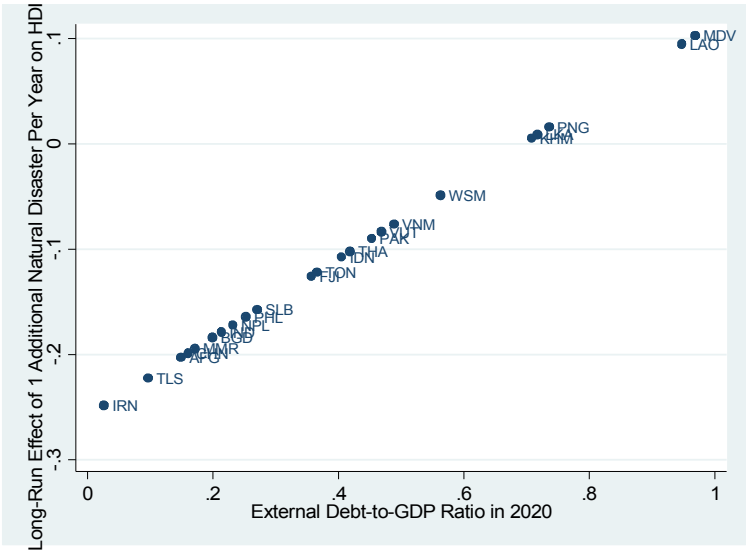
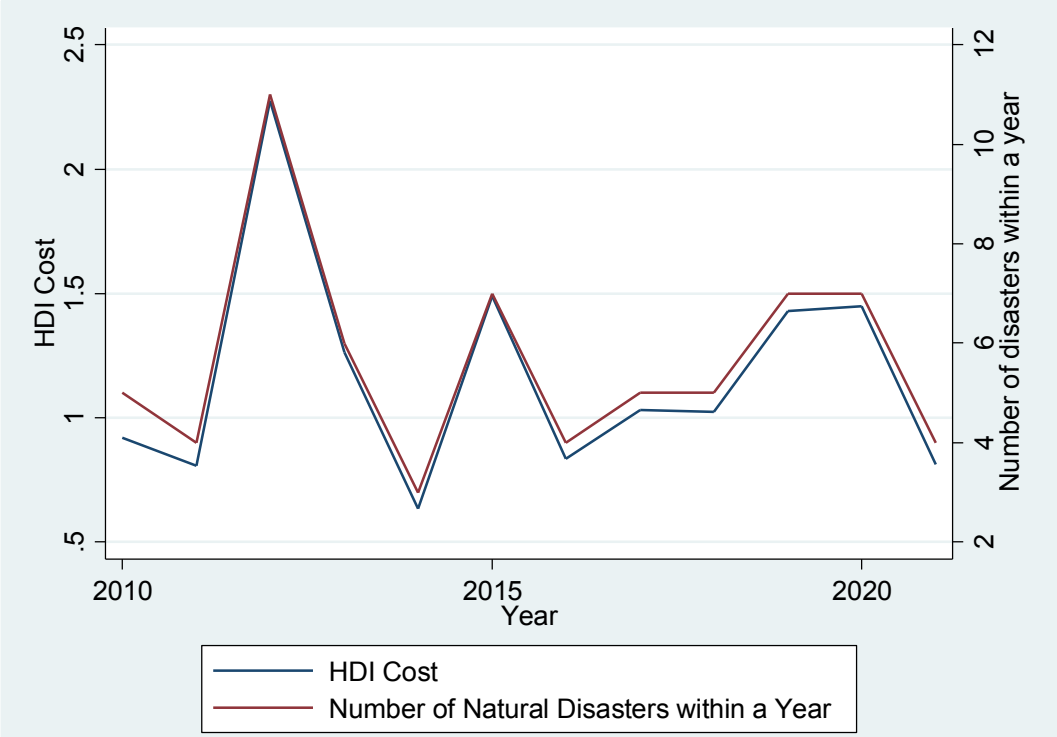
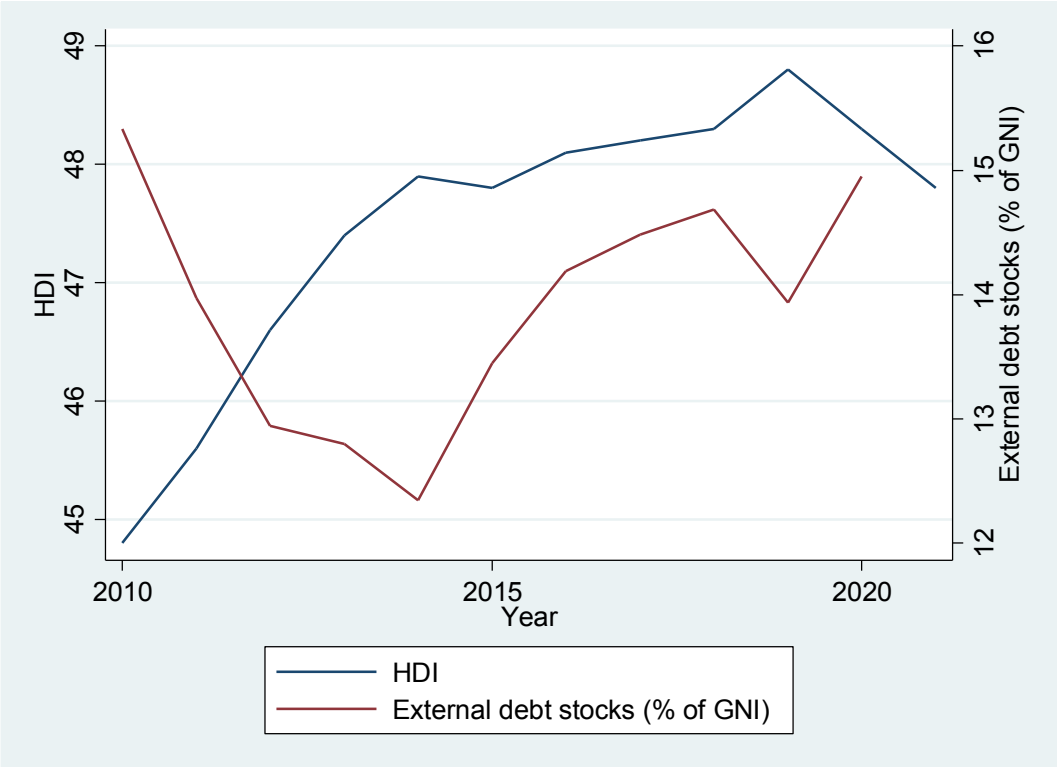


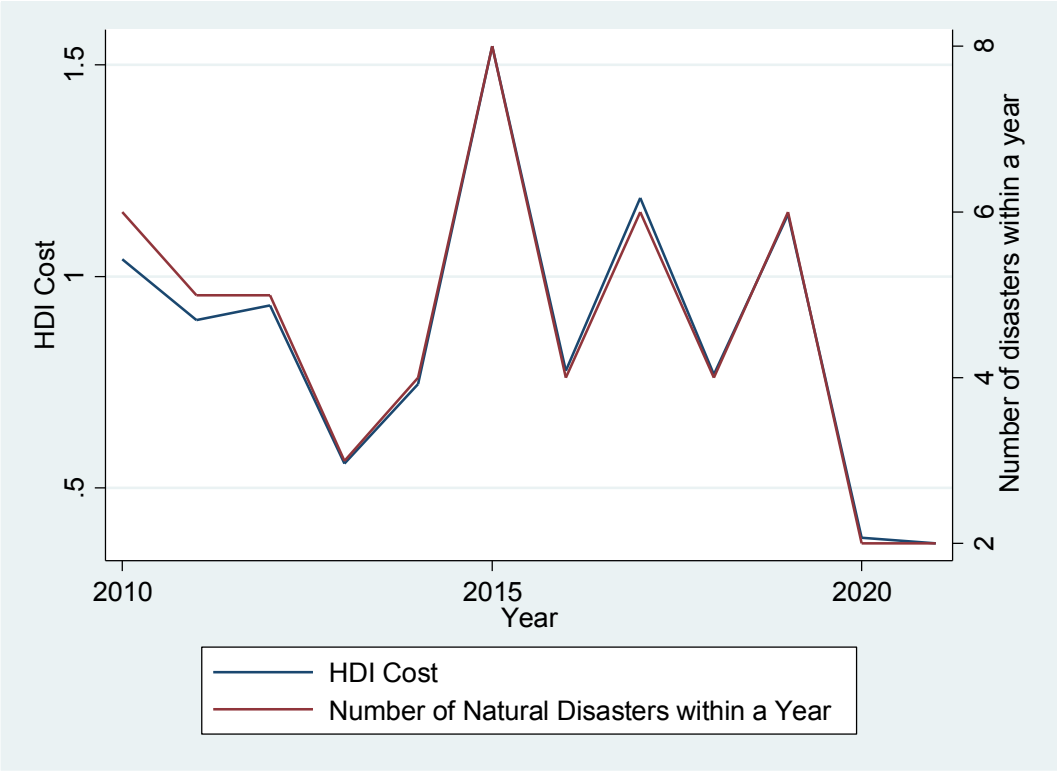
Figure 7. The HDI Cost of Natural Disasters for Selected Countries

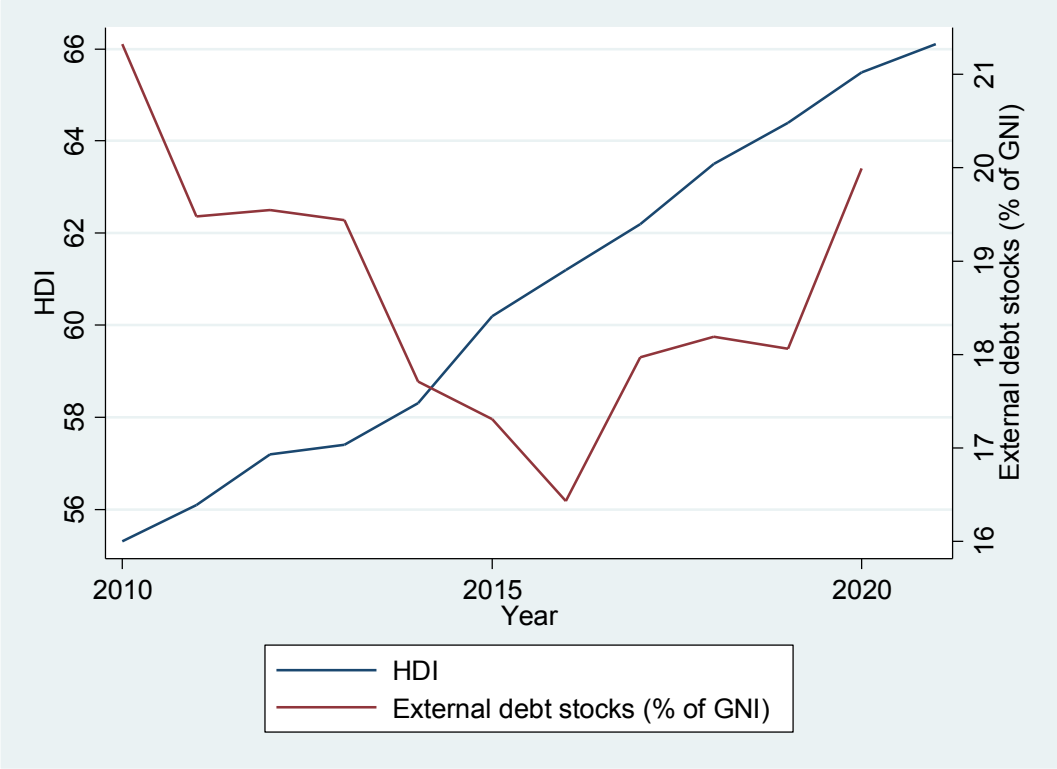
Panel A: Afghanistan



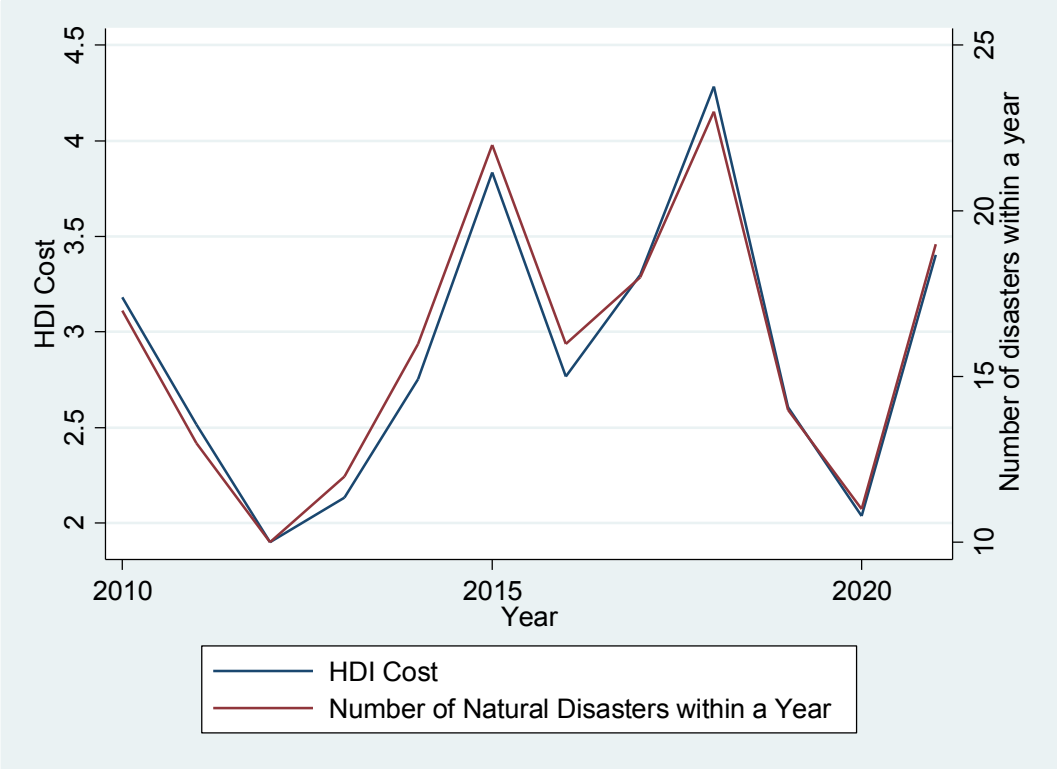


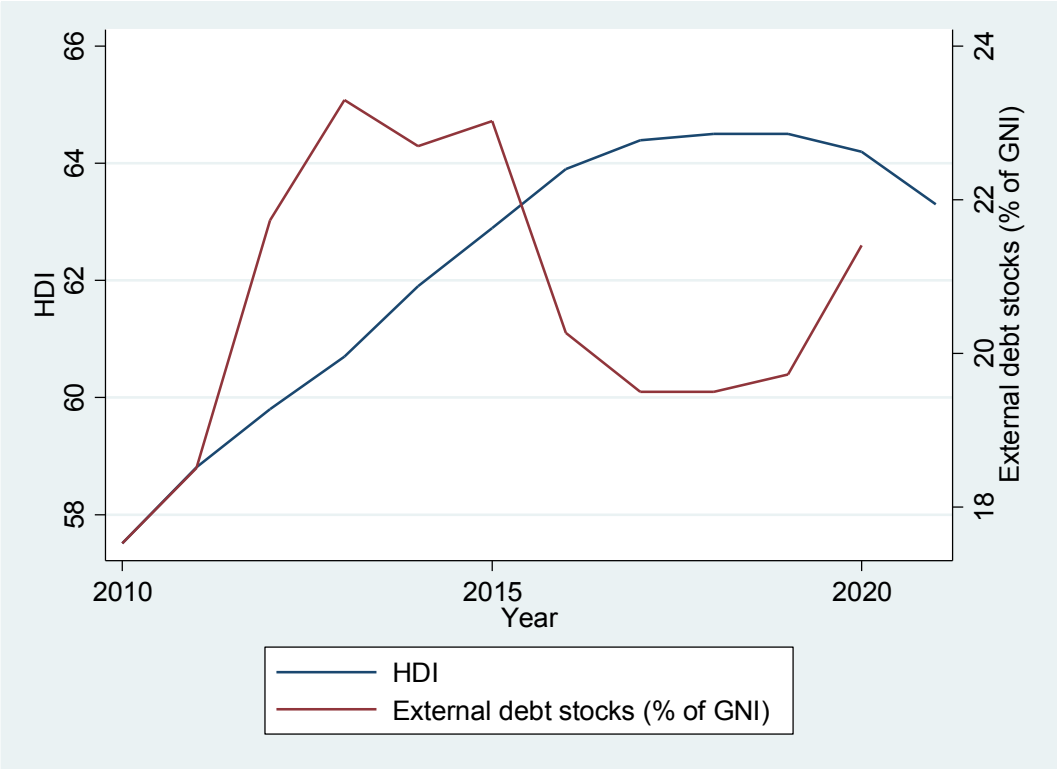
Panel B: Bangladesh



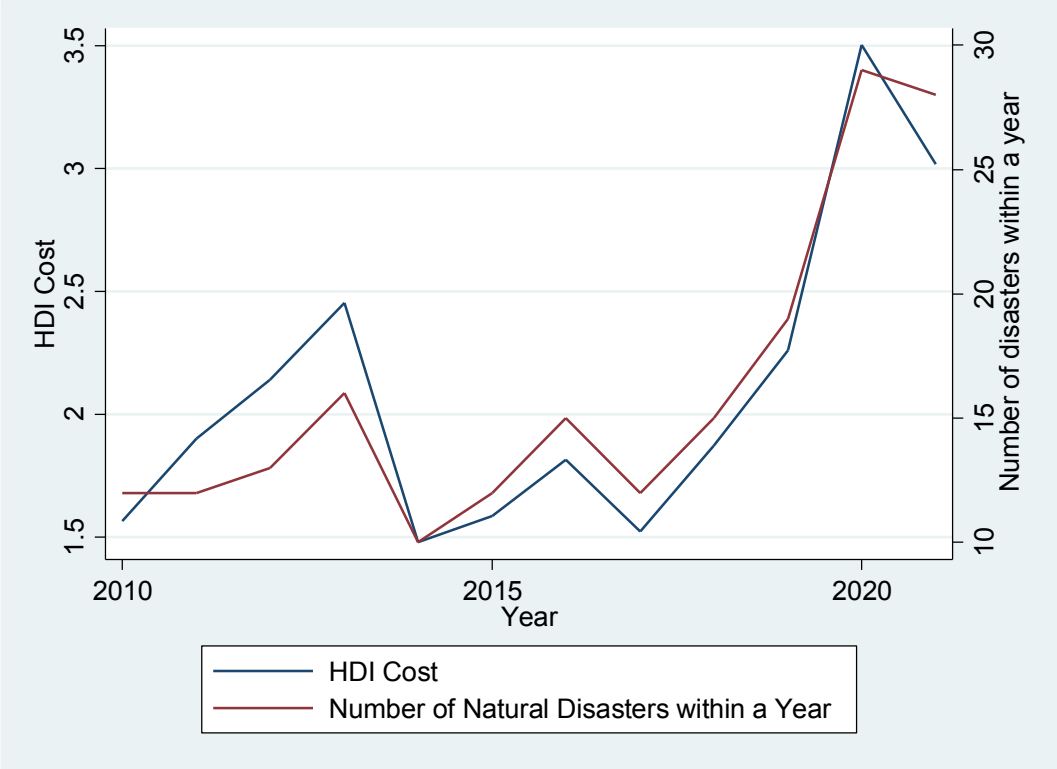


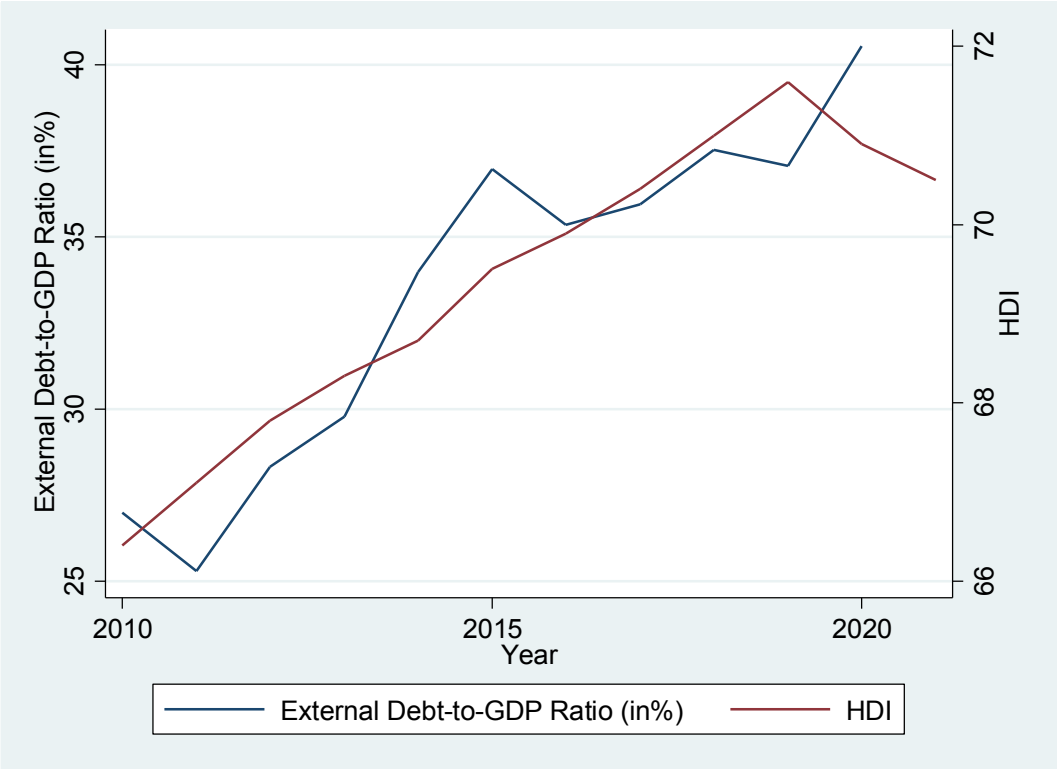
Panel C: India



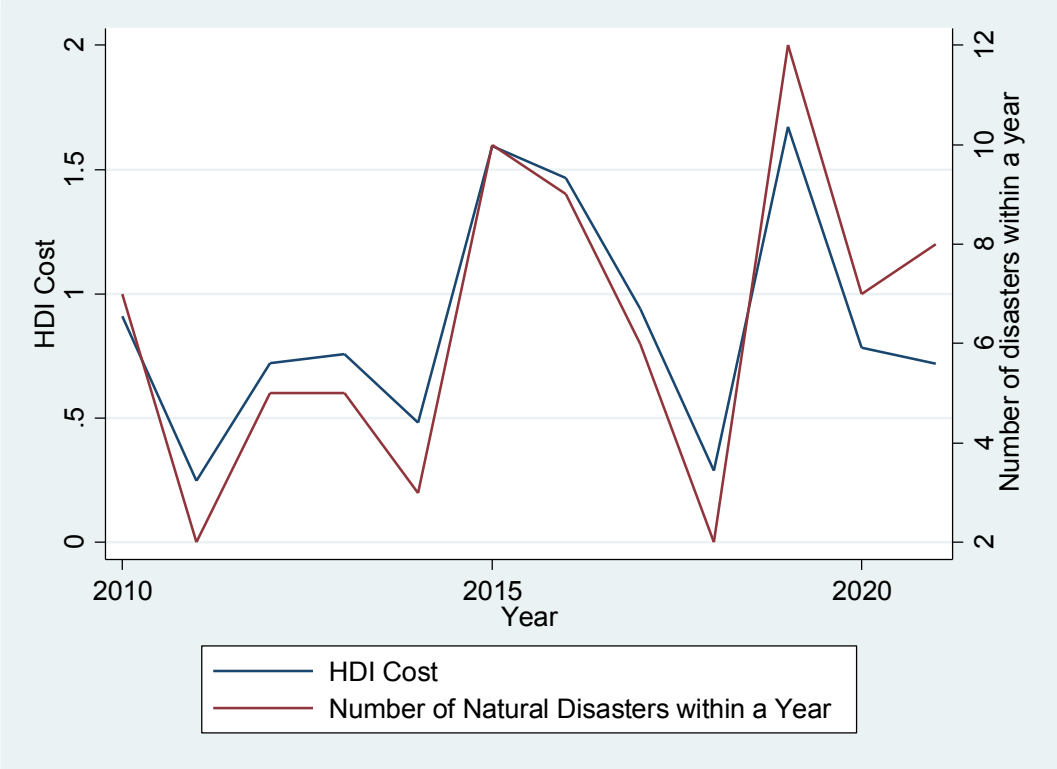


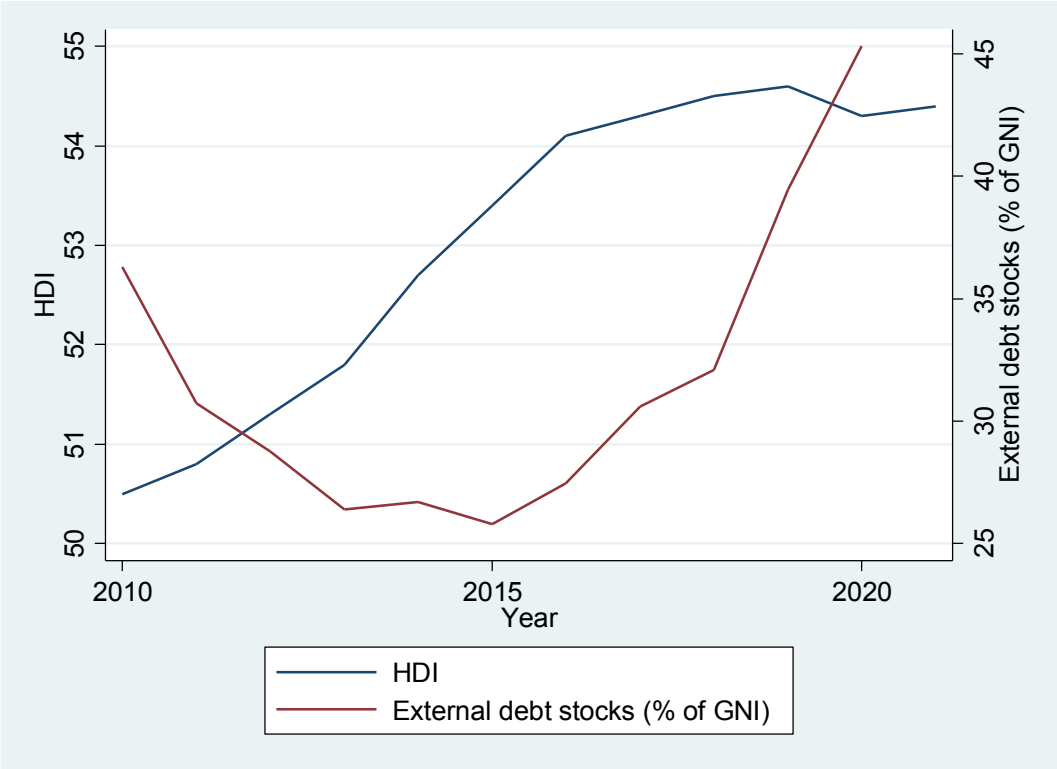
Panel D: Indonesia



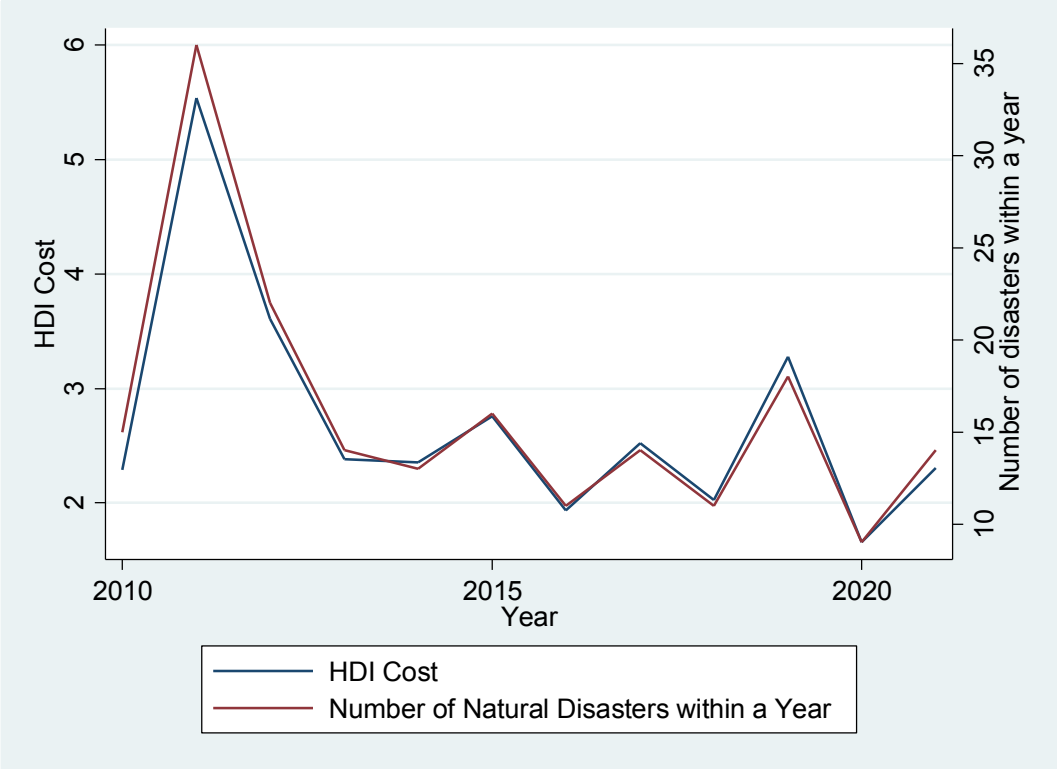


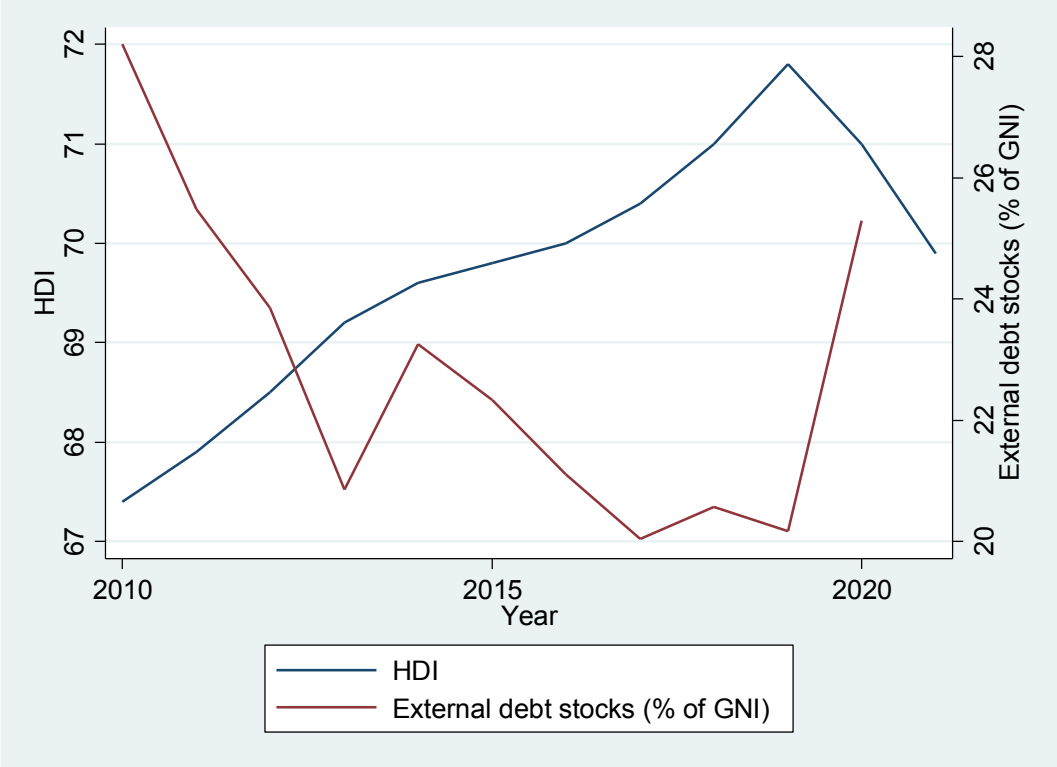
Panel E: Pakistan



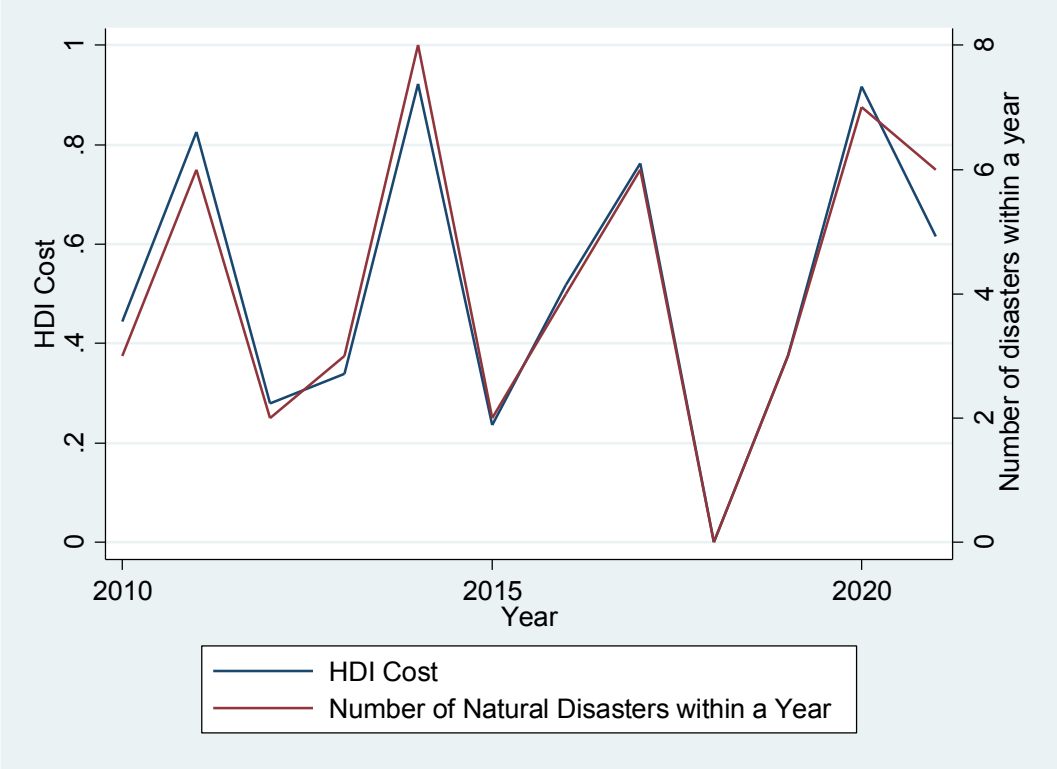


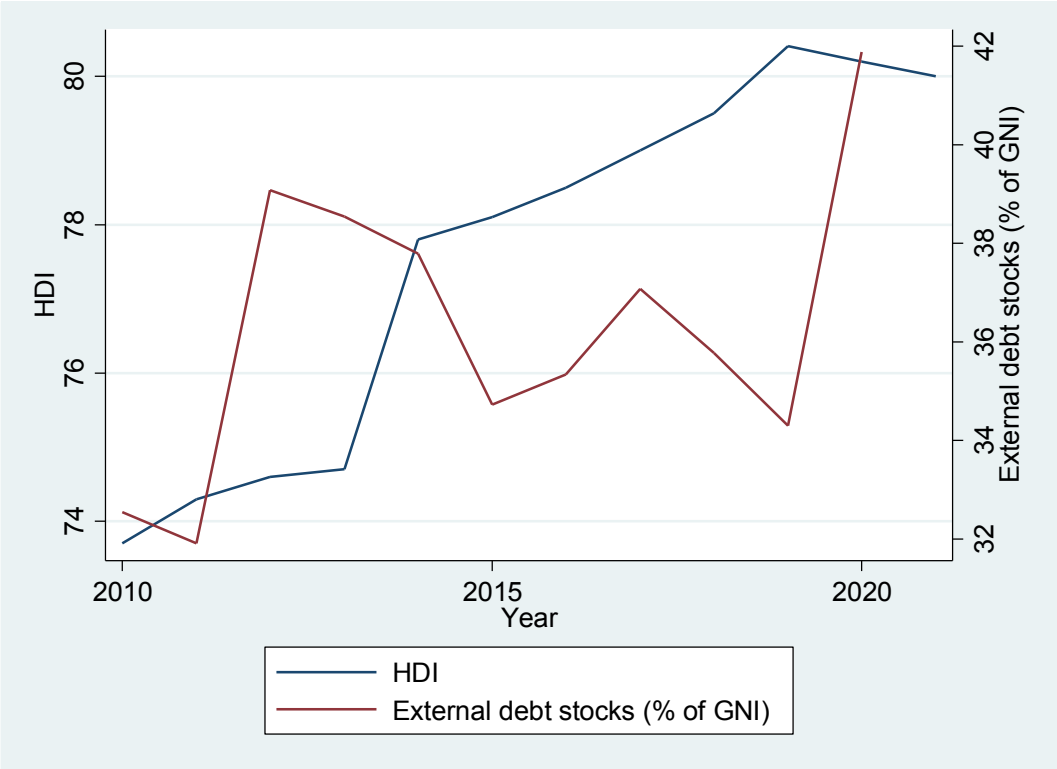
Panel F: Philippines



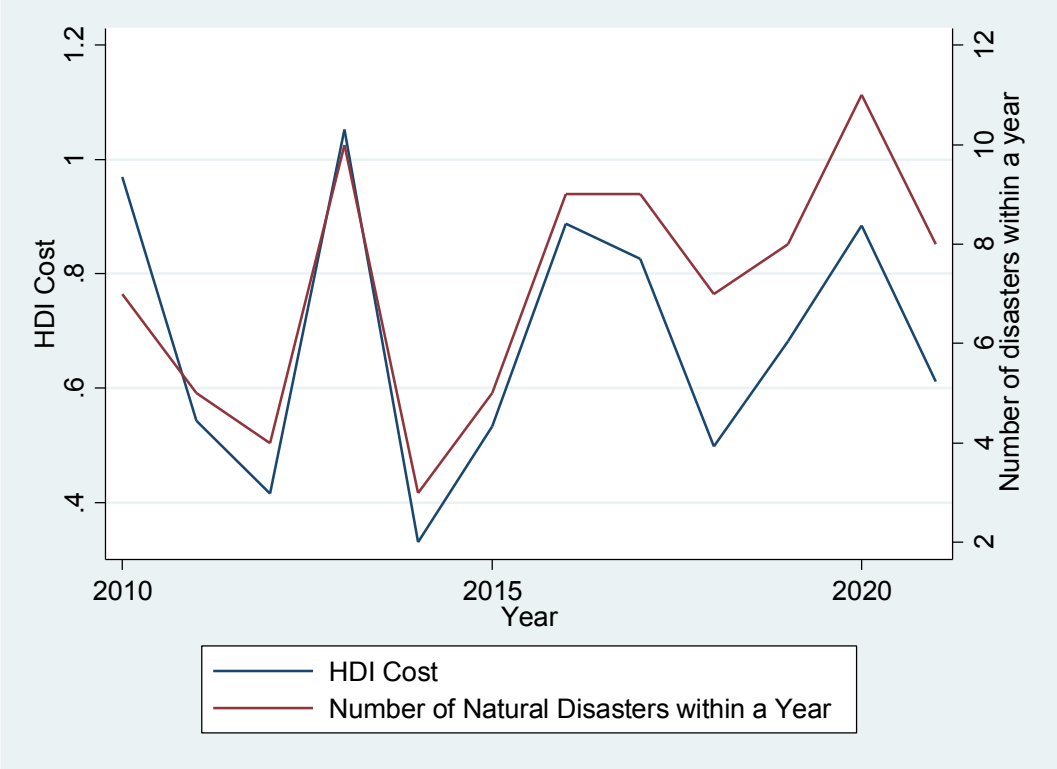


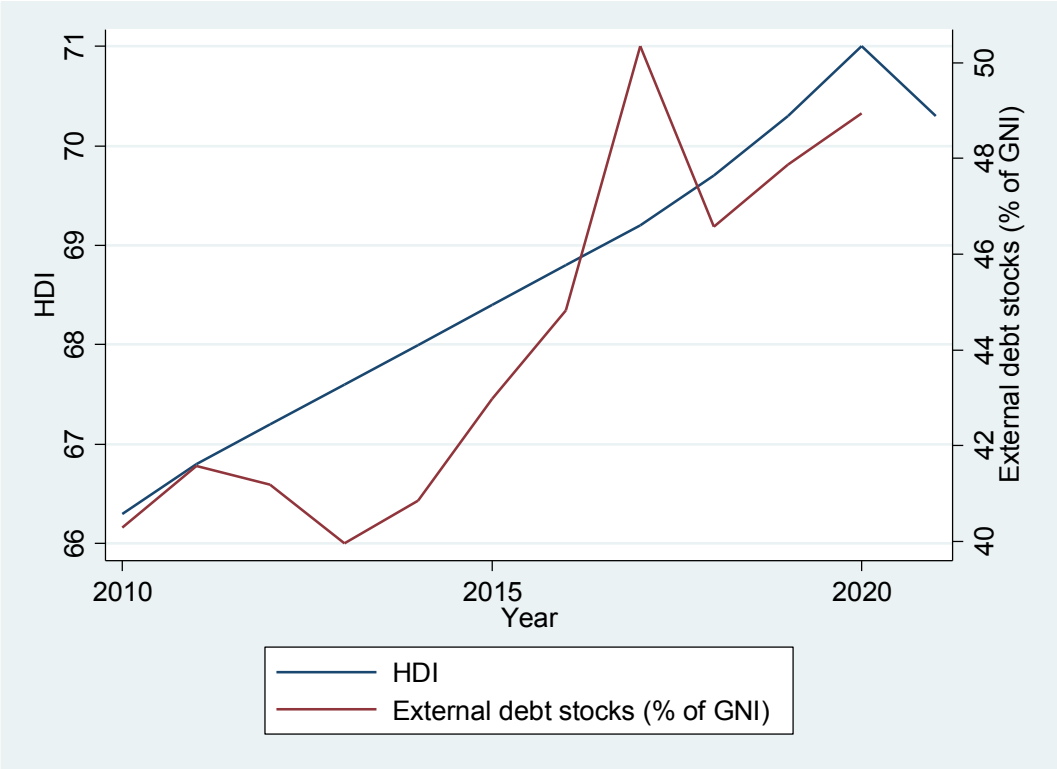
Panel G: Thailand





Panel H: Vietnam





Appendix Figure 1. The distribution of natural disaster incidence in Asia-Pacific