# Climate Risk and FDI
# A proposal — please do not cite or circulate

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**Abstract**

The frequency of extreme weather events has increased in recent decades. This paper explores whether multinational firms react to such events by reducing their presence in countries that are more affected. We measure this by looking at foreign direct investment (FDI) dynamics. We conjecture that the decline in FDI in response to extreme weather events reflects firms' upward update of perceived probability of such events due to climate change. We also explore the impact of climate policy on FDI. Preliminary results using data from 94 countries (1970-2019) show that extreme weather events in host countries have a significantly negative effect on FDI inflows to advanced countries and emerging markets but a positive effect on FDI inflows to low-income countries. We also find that most of the effect is concentrated in the later part of the sample, when there is more climate change awareness.

Keywords: climate change, weather, foreign direct investment

JEL codes: F21, F23, F64

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# 1 Introduction

It is well documented in the science literature that the frequency of extreme weather events increases due to climate change (Hsiang and Kopp, 2018). Events that once were thought to be extraordinary have become an annual occurrence. In the world of rational expectations, this implies that every occurrence of extreme weather events increases perceived risks of climate change, both physical risks, due to destructive effects of such events, and transition risks which arise from increased awareness of these risks and political will to mitigate them. Is this change in the distribution of weather event occurrence incorporated in behavior of multinational companies? While most literature focuses on pricing of climate-related risks by asset markets, we evaluate the response of foreign direct investments to extreme weather events and climate policies.

We conduct our analysis at different aggregation levels. First, we focus on FDI flows at country level, controlling for economic determinant of FDI flows and allowing for the models to be different for advanced, emerging, and low-income economies. Next, we collect FDI data at country-industry level to allow for impact of weather events and climate policies to vary across industries for a given country, depending on how exposed industries are to physical as well as transitional climate-related risks. Finally, we focus on a number of multinational companies with global presence and evaluate their reaction to extreme weather events and climate policies in the countries where they operate.

Preliminary country-level results show that extreme weather events in host countries have a significantly negative effect on FDI inflows to advanced countries and emerging markets but a positive effect on FDI inflows to low-income countries. Different types of extreme weather events affect FDI inflows to different degrees. In particular, droughts and floods show significant and negative impact. When using Kyoto agreement (1997) as a landmark for the rise of global awareness of climate change risks and thus a proxy for the change of beliefs on climate risks, we find that FDI inflows become more negatively affected by extreme weather events during the post-1997 period than the period before. This is especially true for emerging markets and low-income countries.

Our paper fits into the broader context of the literature on the impact of climate change on international financial markets and international capital flows. The approach of using weather shocks as a proxy for climate change exposure is not new, as summarized in the survey paper by Dell et al. (2014). Since the survey, the use of weather shock gained further popularity in the literature due to their exogenous nature, at least in short and medium run.[1] Substantial literature already exists in this context, but to the best of our knowledge,

[1] As integrated analysis models show, economic activity affects emissions and therefore climate change,

there is no comprehensive analysis of the effect of climate change on FDI.

Two recent papers are closely related to our analysis. In the study of FDI patterns, Barua et al. (2020) show that long-run changes in average temperatures lower FDI flows to developing countries, but increase them for developed economies. In contrast with their analysis, we look at weather disasters rather than changes in trends. Pankratz and Schiller (2021) show that climate-change risks as measured by extreme heat and floods, affect global customer-supplier relationships. Importantly, when climate shocks exceed expectations, a substantial portion of the supplier relationships are terminated. While this study focuses on international trade, we expect to find similar dynamics with respect to multinational affiliate locations.

An important question is whether the FDI response we find is commensurate with actual or expected future damages from climate change (physical risks) or actual or expected policies for climate change mitigation (transition risks), under the rational expectations assumption. For instance, Pankratz (2019) estimates that increasing heat exposure of firms reduces their financial performance, but is not fully incorporated in analysis forecasts. We calibrate the model to existing climate change scenarios and compare the predictions with our empirical findings.

Our analysis is important for a number of reasons. Given that reliable models exist for geographical impact of climate change, our analysis allows for forecasting the response of FDI to increasingly frequent weather events. In addition, to the extent that we find a smaller response than predicted by the model, our findings are consistent with under-reaction to observed events and therefore with possibility of abrupt changes in the future.

# 2 Data

## 2.1 Weather data

Our first data source is The Emergency Events Database (EM-DAT) housed at the Centre for Research on the Epidemiology of Disasters (CRED), University of Louvain. It provides data of disaster events worldwide from 1900 and present. To be included in the data, at least one of the following criteria must be fulfilled: 10 or more human deaths; 100 or more people injured or left homeless; declaration by the country of a state of emergency and/or

which in turn increases frequency of weather shocks. However, this feedback mechanism is not internalized by economic agents.

an appeal for international assistance.[2]

This data set provides monthly count of events by disaster subgroups: geophysical, meteorological, hydrological, climatological, and biological, of which we retain climate-related disaster events: climatological, which includes wildfire and drought; meteorological, which includes extreme temperatures and storms; hydrological, which includes flood. The dataset only includes monthly number of deaths, number of people affected, and economic losses in USD. We aggregate these data to country-year level, and for country-years where no disasters are reported we assume that all indicators are zero — no events. We express economic losses in real USD, by dividing the amount by the U.S. CPI.

Figures 1 and 2 show the total number of the events in the world that is reported in our data, by year. Figure 1 breaks down the total into the event types as described above, while Figure 2 breaks it down by advanced and emerging economies. We can see a rapid increase in the number of events, especially due to an increase in emerging markets, until early 2000s, after which the number is stabilized. It is possible that the number of countries covered in the data and the degree of coverage increase over time, leading to an overall increase in total number of events. For this reason, in our regression analysis we include year fixed effects that capture any common trends.

Hsiang (2016) and Lemoine (2021) demonstrate that weather data, when used appropriately, identifies the effects of climate change. While these studies are focusing on average weather characteristics, such as temperature, precipitation, and humidity, we believe the occurrence of extreme weather events tracks impact of climate change in a more transparent way and, therefore, is more likely to affect investors' and firms' behavior. In the future, we plan to supplement our analysis with normal weather characteristics.

We also observe that there is substantial variation of the frequency of climate-related events across regions. Figure 3 shows country-year average of event occurrence across broad geographical regions, broken down by advanced and emerging economies. Finally, we see that weather-related disasters are becoming more costly, as shown in Figure 4, which depicts average damages per disaster for each year, in million USD.

## 2.2 FDI data

We gather information on FDI from a variety of sources. The longest time series at annual frequency are available from World Bank's World Development Indicators (WDI) at country

[2]This data set has been used in a related study by Feng and Li (2021) and is also the main source for the World Meteorological Organization Atlas of Mortality and Economic Losses from Weather, Climate, and Weather Extremes (1970-2019).

level. For the country-industry level data we turn to OECD database. Finally, we obtain firm level data from ORBIS.

**Country level**

Country level data are from WDI and start in 1970 for most of the 94 countries in the sample. The last year for which we observe the data is 2019. According to the World Bank, FDI in our data are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. It shows net inflows (new investment inflows less disinvestment) in the host economy from foreign investors, and is divided by GDP.

**Country-industry level**

Differen industries have different exposures to climate change risks. Therefore, we would expect that the sensitivity of FDI flows to climate risks revealed by the weather disasters vary by industry. To evaluate this, we first need to construct industry-level climate exposures. We are currently considering two options: fist, use existing classifications such as those used in De Haas and Popov (2018); second, follow Rajan-Zingales type approach to aggregate from firm to industry level using information on U.S. firm-level exposures to climate risks, such as constructed by Sautner et al. (2021).

Country-industry data on FDI are obtained from OECD and start, for most countries, in 2000. The industry classification corresponds to ISIC4 codes and is available at a high level of aggregation, generally corresponding to a 2-digit level.

**Firm level**

Firm-level data are obtained from ORBIS. These data go back to 2005 in most cases and are available through 2019. To properly classify all affiliates of multinationals, we rely on vintage ownership data collected for each year. At the first pass, we focus on a binary indicator of a firm's presence in each country and test whether climate-related events are correlated with changes in ownership of firms located in affected countries. We follow the approach of Sautner et al. (2021) to evaluate climate-risk exposures of individual firms.

# 3 Preliminary results

Here we present the results of our country-level analysis. All the regressions include year and country fixed effects and their standard errors are clustered at six-region level (Africa, Asia, Australasia, Europe, North America, and South America). Disaster variables are lagged by one year to reflect possible delays in FDI adjustments. The work on industry- and firm-level analysis is still ongoing.

## 3.1 Country-level Results

We conduct our country-level analysis for the full panel as well as for the subsets of countries. In a recent study, Cevik and ao Tovar Jalles (2020) demonstrate that the impact of climate risks on sovereign credit ratings is larger for developing countries than for advanced economies. They conjecture that this is due to lower-income countries having less fiscal space for adaptation and mitigation measures. We believe these differences can play an important role in the sensitivity of foreign investors to climate risk exposures of FDI host countries, which is consistent with findings by Barua et al. (2020). Through pre-testing we find that it is useful to define three sets of countries: advanced, emerging, and low-income, which we classify according to the IMF definition.

Table 1 shows the impact of total number of disaster events from last year on the share of FDI net inflow in host country GDP. Column (1) is for all countries, column (2) advanced countries, (3) emerging economies, and (4) low-income countries. FDI inflows to all groups of countries are significantly affected by climate events. In particular, if last year's number of disasters increases by one, FDI inflows into advanced countries and emerging markets as a share of GDP would decrease by 0.11 and 0.05 percentage points, respectively. To get a sense of the magnitude, the 2019 median FDI inflow to GDP share among advanced countries in our sample is 2.51 percent, while for emerging economies it is 2.18 percent. A median-sized advanced country would lose about $437 million in FDI inflows in 2019, while a median emerging economy would lose $73 million in FDI inflows.[3]

For low-income countries, however, if the previous year's number of disasters increases by one, FDI inflows would increase by about 0.1 percentage points. The 2019 median FDI inflow to GDP share among low-income countries in our sample is 2.56 percentage points, and a median sized low-income country would gain about $46 million FDI inflows in 2019.[4] We conjecture that much of such increase comes from investments by foreign government-owned

[3]The median nominal GDP for advanced countries (emerging economies) in our sample is $397,000 ($145,000) million in 2019.

[4]The median nominal GDP for low-income countries in our sample is $45,950 million.

enterprises for the purpose of reconstruction following capital loss from the disaster.

Table 2 shows the impact of different types of disaster events from last year on the share of FDI net inflow in host country GDP, using all sample countries. Column (1) is for climatological events, column (2) meteorological events, (3) hydrological events, (4) drought, which drives the climatological event result, and (5) flood, which drives the hydrological event result. Except for meteorological events, all the other disaster types can significantly reduce FDI inflows. For instance, drought can reduce inflow to GDP share by 0.57 percentage points (a 25% decline).

The literature finds the importance of beliefs about climate change in the way that markets incorporate potential risks. While at this stage we do not have cross-country data on such beliefs, we conduct a crude discontinuity test. In particular, we choose Kyoto agreement in 1997 as a moment in time when awareness of climate change risks increased globally. Thus we test for differences in the impact of weather disasters on FDI before and after 1997.

Table 3 shows the post-1997 impact of total number of disaster events from last year on the share of FDI net inflow in host country GDP, since the agreement of Kyoto Protocol in December 1997. Column (1) is for all countries, column (2) advanced countries, (3) emerging economies, and (4) low-income countries. We observe that FDI inflows become more negatively affected by extreme weather events during the post-1997 period than the period before. This is especially true for emerging markets and low-income countries. In particular, FDI inflows to emerging markets were not affected by disasters prior to 1997 but have become increasingly sensitive to disaster events. Low-income countries, however, used to receive more FDI inflows upon disaster events, and now have received less such inflows.

# 4 Next steps

In addition to expanding our analysis to industry and firm levels, we will consider introducing additional climate change measures, such as normal (non-extreme) weather changes (Auffhammer et al., 2013). We will also investigate the impact of climate mitigation policies by host countries and home countries (for bilateral flows).

To evaluate whether the response of FDI to climate risks reflects rational expectations or whether there is under-reaction which could lead to rapid changes in the future, we will introduce climate risks in a standard model of foreign direct investment, such as Markusen (1997) or Markusen and Venables (1998).

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Figure 1: Climate-related disaster events by type

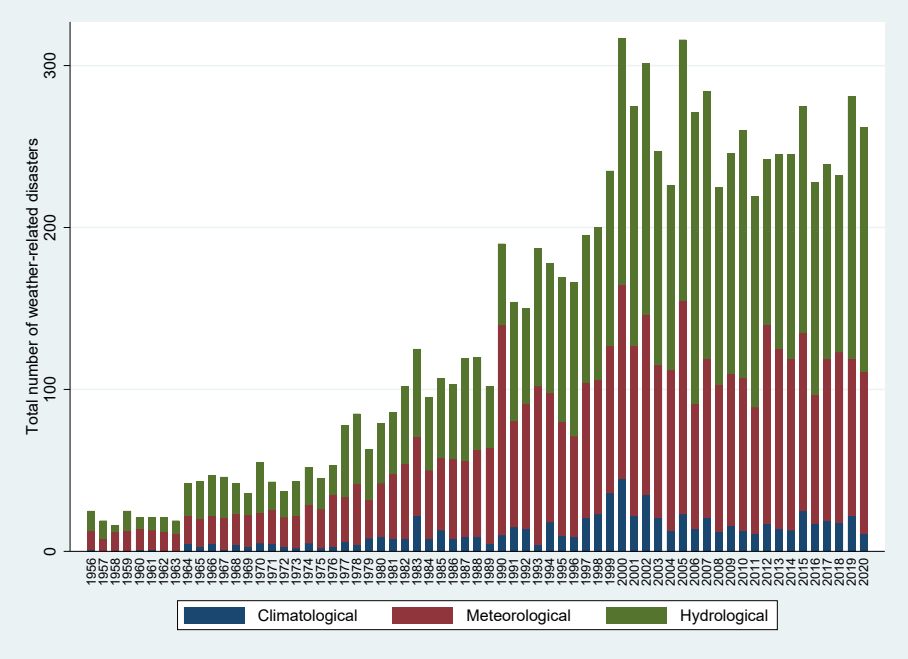



Figure 2: Climate-related disaster events by country group

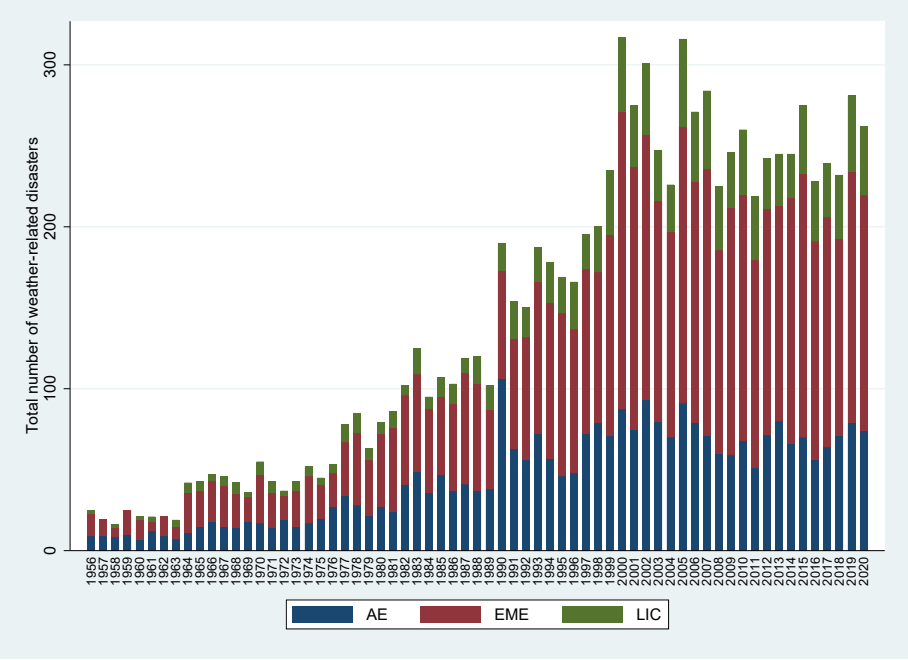


Figure 3: Frequency of climate-related disaster events by region

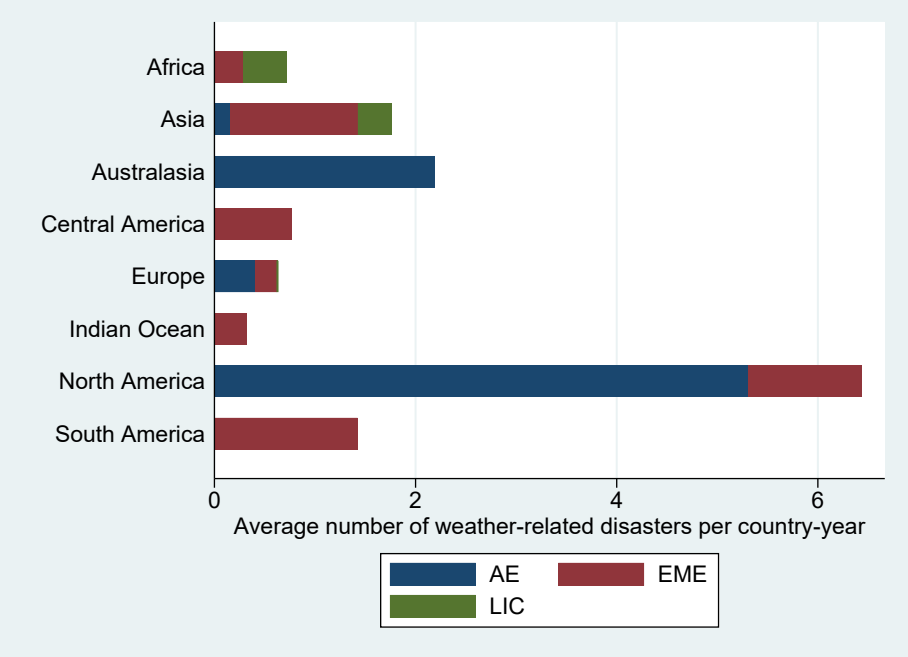



Figure 4: Average monetary damages per disaster

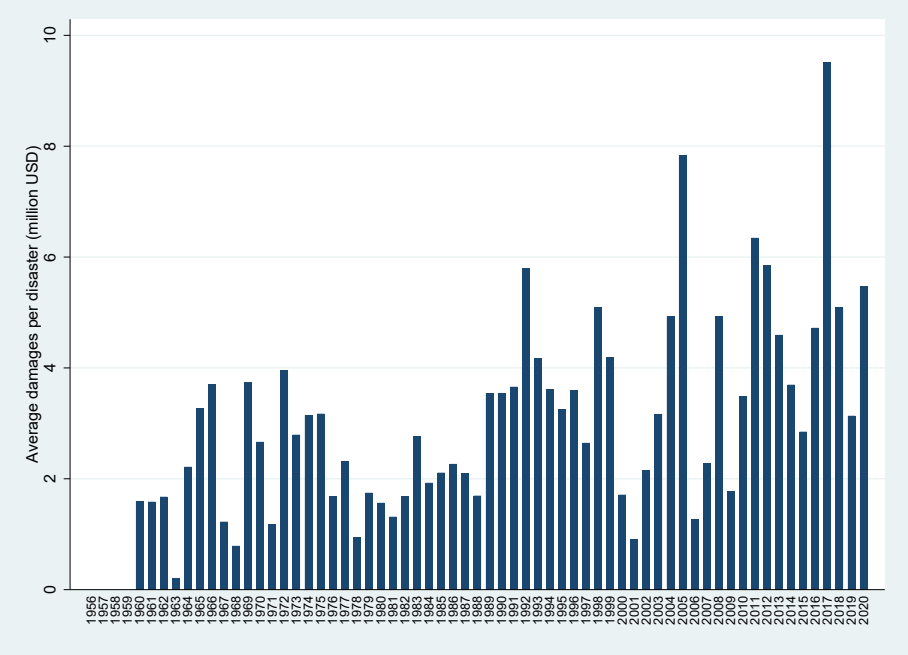


Table 1: All Extreme Weather Disaster Events

Dependent variable is net FDI inflows as a share of GDP in year $t$. All regressions include year and country fixed effects are estimated by OLS. Clustered standard errors are in parentheses $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

| | (1) Full sample | (2) AEs | (3) EMEs | (4) LICs |
|---|---|---|---|---|
| $\text{Disasters}_{t-1}$ | -0.0617$^{*}$ | -0.108$^{*}$ | -0.0479$^{**}$ | 0.0958$^{***}$ |
| | (0.0271) | (0.0425) | (0.0154) | (0.0161) |
| $(\text{EX+IM})/\text{GDP}_t$ | 0.0356$^{***}$ | 0.0529$^{**}$ | 0.0325$^{***}$ | 0.0444 |
| | (0.00873) | (0.0152) | (0.00650) | (0.0245) |
| $\text{PPI inflation}_t$ | -0.000325 | 0.0987$^{***}$ | -0.000317 | -0.00118 |
| | (0.000362) | (0.0161) | (0.000349) | (0.00107) |
| $\log(\text{GDP per capita})_t$ | 0.329 | -0.839 | 0.0460 | -1.889$^{**}$ |
| | (0.549) | (0.383) | (0.666) | (0.394) |
| $\text{Real GDP growth}_t$ | 0.0667$^{***}$ | 0.108$^{*}$ | 0.0651$^{**}$ | 0.0386 |
| | (0.0136) | (0.0386) | (0.0216) | (0.0378) |
| Number of observations | 3811 | 1161 | 2041 | 609 |
| Overall $R^2$ | 0.126 | 0.182 | 0.129 | 0.278 |

Table 2: Climate Disaster Events by Type

Dependent variable is net FDI inflows as a share of GDP in year $t$. All regressions include year and country fixed effects are estimated by OLS. Full sample only. Clustered standard errors are in parentheses $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Climatological disasters$_{t-1}$ | -0.220** | | | | |
| | (0.0802) | | | | |
| Meteorological disasters$_{t-1}$ | | -0.0161 | | | |
| | | (0.0261) | | | |
| Hydrological disasters$_{t-1}$ | | | -0.121* | | |
| | | | (0.0507) | | |
| Drought$_{t-1}$ | | | | -0.574*** | |
| | | | | (0.130) | |
| Flood$_{t-1}$ | | | | | -0.129* |
| | | | | | (0.0539) |
| (EX+IM)/GDP$_t$ | 0.0355*** | 0.0354*** | 0.0355*** | 0.0355*** | 0.0354*** |
| | (0.00870) | (0.00879) | (0.00870) | (0.00853) | (0.00866) |
| PPI Inflation$_t$ | -0.000334 | -0.000333 | -0.000317 | -0.000334 | -0.000318 |
| | (0.000365) | (0.000366) | (0.000362) | (0.000364) | (0.000362) |
| log(GDP per capita)$_t$ | 0.287 | 0.285 | 0.326 | 0.297 | 0.318 |
| | (0.558) | (0.562) | (0.545) | (0.559) | (0.549) |
| Real GDP growth$_t$ | 0.0655*** | 0.0656*** | 0.0671*** | 0.0660*** | 0.0672*** |
| | (0.0138) | (0.0140) | (0.0135) | (0.0137) | (0.0134) |
| Number of observations | 3811 | 3811 | 3811 | 3811 | 3811 |
| Overall $R^2$ | 0.126 | 0.125 | 0.126 | 0.126 | 0.126 |

Table 3: All Extreme Weather Disaster Events: discontinuity

Dependent variable is net FDI inflows as a share of GDP in year $t$. All regressions include year and country fixed effects are estimated by OLS. Clustered standard errors are in parentheses $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

| | (1) Full sample | (2) AEs | (3) EMEs | (4) LICs |
|---|---|---|---|---|
| $\text{Disasters}_{t-1}$ (a) | 0.0619 | -0.0177 | 0.0943 | 0.371** |
| | (0.0460) | (0.0195) | (0.0510) | (0.114) |
| I(Year>1997) (b) | 1.861** | 11.46** | -0.731 | 4.530*** |
| | (0.592) | (2.684) | (2.665) | (0.589) |
| (a) $*$ (b) | -0.134* | -0.113 | -0.139** | -0.364* |
| | (0.0599) | (0.0663) | (0.0468) | (0.123) |
| $(\text{EX+IM})/\text{GDP}_t$ | 0.0358*** | 0.0498* | 0.0332*** | 0.0467 |
| | (0.00857) | (0.0162) | (0.00665) | (0.0251) |
| $\text{PPI inflation}_t$ | -0.000311 | 0.103*** | -0.000306 | -0.00125 |
| | (0.000336) | (0.0147) | (0.000322) | (0.000944) |
| $\log(\text{GDP per capita})_t$ | 0.370 | -0.862 | 0.117 | -1.674** |
| | (0.522) | (0.377) | (0.650) | (0.414) |
| $\text{Real GDP growth}_t$ | 0.0648*** | 0.109* | 0.0632** | 0.0315 |
| | (0.0130) | (0.0384) | (0.0221) | (0.0323) |
| Number of observations | 3811 | 1161 | 2041 | 609 |
| Overall $R^2$ | 0.128 | 0.184 | 0.131 | 0.288 |

# A Appendix

Tables below provide summary statistics of our weather events data for advanced and emerging economics separately. 1 is for advanced countries, 2 is for emerging economies, and 3 is for low-income countries.

Table A.1: Summary Statistics of Climate Disaster Events

| | disaster_m | climatological_m | meteorological_m | hydrological_m |
|---|---|---|---|---|
| 1 | | | | |
| mean | 1.51 | 0.16 | 0.90 | 0.46 |
| sd | 3.61 | 0.61 | 2.48 | 1.05 |
| 2 | | | | |
| mean | 1.53 | 0.10 | 0.51 | 0.92 |
| sd | 3.34 | 0.36 | 1.55 | 2.03 |
| 3 | | | | |
| mean | 1.10 | 0.07 | 0.36 | 0.67 |
| sd | 1.84 | 0.27 | 1.06 | 1.09 |
| Total | | | | |
| mean | 1.44 | 0.11 | 0.59 | 0.74 |
| sd | 3.20 | 0.43 | 1.81 | 1.66 |

Table A.2: Summary Statistics of Climate Disaster Events: Five Categories

| | drought_m | temperature_m | flood_m | storm_m | wildfire_m |
|---|---|---|---|---|---|
| 1 | | | | | |
| mean | 0.03 | 0.12 | 0.41 | 0.78 | 0.13 |
| sd | 0.18 | 0.37 | 1.02 | 2.37 | 0.53 |
| 2 | | | | | |
| mean | 0.06 | 0.10 | 0.78 | 0.41 | 0.04 |
| sd | 0.25 | 0.35 | 1.74 | 1.45 | 0.24 |
| 3 | | | | | |
| mean | 0.06 | 0.04 | 0.60 | 0.32 | 0.01 |
| sd | 0.25 | 0.21 | 1.00 | 0.98 | 0.09 |
| Total | | | | | |
| mean | 0.05 | 0.09 | 0.64 | 0.50 | 0.06 |
| sd | 0.23 | 0.34 | 1.45 | 1.70 | 0.33 |

Table A.3: Summary Statistics of Human Toll

| | totaldeaths_m | noinjured_m | noaffected_m | nohomeless_m | totalaffected_m |
|---|---|---|---|---|---|
| 1 | | | | | |
| mean | 79.33 | 145.46 | 95319.19 | 1810.73 | 97275.38 |
| sd | 822.29 | 2091.42 | 2109682.87 | 33751.94 | 2110252.03 |
| 2 | | | | | |
| mean | 158.34 | 1044.65 | 1879679.38 | 34377.40 | 1915101.43 |
| sd | 1348.82 | 32837.42 | 16661528.49 | 569363.83 | 16878954.74 |
| 3 | | | | | |
| mean | 827.19 | 983.24 | 673372.30 | 21820.10 | 696175.64 |
| sd | 11567.31 | 18470.53 | 3196587.44 | 187320.66 | 3280699.77 |
| Total | | | | | |
| mean | 264.36 | 778.55 | 1143498.37 | 22756.64 | 1167033.56 |
| sd | 5185.02 | 25161.83 | 12233053.62 | 421301.77 | 12393747.25 |

Table A.4: Summary Statistics of Monetary Toll (Real USD)

| | recon_real | insure_real | totdam_real |
|---|---|---|---|
| 1 | | | |
| mean | 33.74 | 4636.37 | 12113.40 |
| sd | 934.21 | 39738.68 | 83603.56 |
| 2 | | | |
| mean | 3.11 | 132.93 | 3546.53 |
| sd | 115.39 | 2096.38 | 23707.78 |
| 3 | | | |
| mean | 1.84 | 2.98 | 734.52 |
| sd | 55.46 | 59.58 | 4239.29 |
| Total | | | |
| mean | 11.53 | 1381.69 | 5429.81 |
| sd | 504.49 | 21282.24 | 47889.14 |

Table A.5: Summary Statistics of Monetary Toll (Share of GDP in Percent)

| | gdp_recon | gdp_insure | gdp_totdam |
|---|---|---|---|
| 1 | | | |
| mean | 0.00 | 0.01 | 0.06 |
| sd | 0.02 | 0.07 | 0.21 |
| 2 | | | |
| mean | 0.00 | 0.00 | 0.20 |
| sd | 0.02 | 0.06 | 2.63 |
| 3 | | | |
| mean | 0.00 | 0.00 | 0.34 |
| sd | 0.01 | 0.03 | 1.69 |
| Total | | | |
| mean | 0.00 | 0.01 | 0.18 |
| sd | 0.02 | 0.06 | 2.03 |