

Are We Adapting to Floods? Evidence from Global Flooding Fatalities

ABSTRACT

There has been a growing interest in understanding whether and how people adapt to extreme weather events in a changing climate. This paper presents one of the first empirical analyses of adaptation to flooding on a global scale. Using a sample of 97 countries between 1985 and 2010, we investigate the extent and pattern of flood adaptation by estimating the effects of a country's climatological risk, recent flood experiences, and socioeconomic characteristics on its flood-related fatalities. Our results provide mixed evidence on adaptation: countries facing greater long-term climatological flooding risks do not necessarily adapt better and suffer fewer fatalities; however, after controlling for the cross-country heterogeneity, we find that more recent flooding shocks have a significant and negative effect on fatalities from subsequent floods. These findings may suggest the short-term learning dynamics of adaptation and potential inefficacy of earlier flood control measures, particularly those that promote increased exposure in floodplains. Our findings provide important implications for climate adaptation policymaking and climate modeling.

Keywords: Adaptation; floods; climate change; natural disasters; weather anomalies.

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1. INTRODUCTION

With the preponderant scientific evidence on the occurrence of climate change, increased attention has been focused on the question: “how should society adapt to the unavoidable climate impacts?” Adaptation is not necessarily a new phenomenon—there is a common belief that humans always try to adapt to their living environment. However, the anthropogenic climate change caused by massive greenhouse gas emissions has occurred more rapidly than anything observed before and will likely worsen certain extreme weather events including floods, severe storms, tropical cyclones, and heatwaves (Intergovernmental Panel on Climate Change [IPCC], 2012). Studying how well societies cope with their exposure to climatic hazards provides insights into the likely extent and pattern of climate adaptation as well as projections of future climate change damage (de Bruin, Dellink, & Tol, 2009; Patt et al., 2009). In this paper, we offer one of the first empirical analyses of adaptation to flooding risks by examining the factors influencing nation-level flood-related fatalities (Jongman et al., 2015).

Flooding is a common environmental hazard and a leading cause of natural disaster fatalities and economic damages worldwide (Smith, 2013; Miller, Muir-Wood, & Boissonnade, 2008; Jonkman, 2005; Kousky, 2014). It has been estimated that floods caused approximately 6.8 million deaths throughout the 20th century and more than 500,000 fatalities between 1980 and 2009 (Kousky, 2014; Doocy et al., 2013). Recent decades have also seen a steady increase in frequency and economic losses of flooding events (Tanoue, Hirabayashi, & Ikeuchi, 2016; Do, Westra, & Leonard, 2017). This raises the question of what factors contribute to the changes in flood impacts, with possible causes including increases in the exogenous flood hazard (e.g., extreme precipitation or high streamflow events) or increased vulnerability of populations and assets to flood hazards (IPCC, 2012; Do, Westra, & Leonard, 2017). The ongoing climate change has further raised the need for adaptation. Hallegatte et al.

(2013) estimate that average global flood losses will increase from \$6 billion per year in 2005 to more than \$60 billion per year in 2050, considering the risks from sea level rise, as well as if adaptation maintains constant flood probabilities.

Economists have long sought to understand the factors in enabling adaptation to climate change and natural disasters. Many have empirically examined the determinants of disaster losses in cross-country studies, considering both the magnitude of natural hazards and a society's ability to protect against these shocks (e.g., Kahn, 2005; Toya & Skidmore, 2007; Rashky, 2008; Anbarci, Escaleras, & Register, 2005; Fankhauser & McDermott, 2014; Kellenberg & Mobarak, 2008; Keefer, Neumayer, & Plumper, 2011). The underlying reasoning is that effective adaptation can reduce the social impacts of natural disasters. These research efforts have generally found that (1) countries with higher incomes and stronger institutions tend to suffer fewer losses from natural disasters (Kahn, 2005; Toya & Skidmore, 2007; Rashky, 2008; Anbarci, Escaleras, & Register, 2005; Fankhauser & McDermott, 2014; Kellenberg & Mobarak, 2008); and (2) countries more frequently exposed to natural hazards are more capable of mitigating their exposure to and losses from such hazards (Keefer, Neumayer, & Plumper, 2011; Schumacher & Strobl, 2011; Hsiang and Narita; 2012; Neumayer, Plumper, & Barthel, 2014; Bakkensen and Mendelsohn, 2016).

While these findings shed light on the drivers of adaptation, it is important to recognize that each type of natural hazard has its own intricacies, and the extent to which a society adapts to these hazards may vary from case to case. Flood-induced losses heavily depend on the pattern of human settlement and land use, as well as the efficacy of mitigation and response systems. It has been long recognized that many traditional flood control measures such as large-scale protection infrastructure and flood warnings “might help build higher catastrophe potential by promoting complacency and a tolerance for floodplain use” in the long run (White, 1975:88). For instance, Burby (2006) attributed the flooding losses from

Hurricane Katrina to the over-reliance on local defense infrastructure and excessive development in the floodplains, which he framed as the “safe development paradox.” This argument may suggest that countries at higher risk of flooding may not necessarily adapt better if they constantly rely on structural protection measures while continuing development in floodplains. Overall, the extent to which hazard exposure drives adaptation could be a more nuanced question in the flooding context and deserves more careful investigation.

In this research, we conceptualize adaptation broadly as actions that can reduce the expected losses from natural disasters. Building upon the prior adaptation literature (Hsiang and Narita, 2012; Neumayer, Plumper, & Barthel, 2014; Bakkensen and Mendelsohn, 2016), we test for adaptation by modeling a country’s human losses from floods as a function of its physical exposure, climatological and socioeconomic characteristics. Moreover, our study takes a unique perspective by considering the learning dynamics of adaptation and examining the effect of recently-experienced weather shocks on current losses, after controlling for the time-invariant heterogeneity across countries. By doing so, this paper provides additional insights into both long-term and short-term patterns of flood adaptation.

Our research is different from the existing adaptation and flooding studies in several ways. First, we recognize that the occurrence of floods is endogenous to a country’s flood protection system and socioeconomic characteristics (Kahn, 2005). Similar weather-related shocks or hazards (e.g., extreme rainfall shocks) that may cause floods in some areas may not necessarily result in flooding in countries or regions with effective mitigation measures. The endogenous nature of flood incidents implies that modeling losses conditional on observed flooding events (e.g., using events as the unit of observation) is inappropriate because of the sample selection problem (i.e., this approach omits possible floods that would have occurred absent good mitigation systems). We address this issue by creating a balanced panel data set including country-years with zero observed flood fatalities.

Second, compared to other natural hazards whose physical intensities can be easily measured (e.g., Richter scale for earthquakes), the magnitude of flooding hazard is more ambiguous to identify. Many recent studies have failed to control for the intensity of flooding conditions in explaining flood-induced losses. The exceptions include Neumayer, Plumper, & Barthel (2014) and Ferreira, Hamilton, & Vincent (2013), both of which rely on the absolute precipitation levels. In this paper, we use objective meteorological data, including annual precipitation and tropical storm duration, to construct weather anomalies which are highly predictive of a country's flooding fatalities.

Our empirical analysis, using a balanced panel of 97 countries between 1985 and 2010, provides mixed evidence of adaptation to floods around the world. We find that the climatological characteristics that may increase a country's flooding risks do not necessarily lead to better adaptation and fewer losses from floods. However, recent flooding shocks are shown to have significantly reduced fatalities from current floods, after controlling for the time-invariant cross-country heterogeneity. Our results suggest the learning dynamics of adaptation: specifically, a society's tendency to adapt is not autonomous and constant, but discontinuously affected by its recent disaster experiences and exposure. Our results also shed light on the complexity of flood adaptation, which involves maladaptation practices, updating and learning, and the diminishing effect of earlier adaptation responses.

The article proceeds as follows. The next section provides an overview of the prior empirical literature related to adaptation and determinants of natural disaster losses. Section 3 describes our data sources and measurement of variables. Section 4 discusses the empirical methods and estimation results. Section 5 concludes with a discussion of findings.

2. PRIOR LITERATURE

A growing body of research has investigated adaptation to natural disasters by exploring the factors that influence national or regional disaster losses, measured by either fatalities or monetary losses (e.g., Kahn, 2005; Toya & Skidmore, 2007; Rashky, 2008; Anbarci, Escaleras, & Register, 2005; Fankhauser & McDermott, 2014; Keefer, Neumayer, & Plumper, 2011; Schumacher & Strobl, 2011; Hsiang and Narita; 2012). These studies commonly identify income or political institutions as the social determinant of adaptation, or examine whether countries that experience more frequent natural disasters have lower losses (Hsiang and Narita; 2012; Bakkensen and Mendelsohn, 2016). Because adaptation can take various forms and include numerous possible measures people can utilize to mitigate risks, this line of research does not directly quantify adaptation activities, but rather infers adaptation based on a negative relationship between disaster losses and long-term hazard exposure. The underlying rationale is that populations with higher levels of exposure to natural hazards would likely invest more in risk mitigation measures (as a rational decision) and therefore, are better adapted to the hazard relative to other populations with lower exposure. For example, Hsiang and Narita (2012) examine adaptation to tropical cyclones (TC) by comparing countries with different levels of climatological exposure (measured by the long-term average annual maximum wind speed and energy dissipated by storms). They find that countries more exposed to TC climate suffer lower marginal fatalities and economic losses. Bakkensen and Mendelsohn (2016) make a distinction between higher and lower intensity storms and find that countries that experience more frequent and intense TCs have lower damages, while frequent weak storms could still increase TC damages, which they attribute to warning fatigue. In another study, Jongman et al. (2015) find a global decline in human vulnerability to river floods for the 1980-2010 period, which coincided with the increase in

income. Their work largely focuses on the role of income in adaptation and does not account for long-term hazard exposure.

The adaptation hypothesis has also been tested in other disaster studies (Keefer, Neumayer, & Plumper, 2011; Schumacher & Strobl, 2011; Ferreira, Hamilton, & Vincent, 2013; Neumayer, Plumper, & Barthel, 2014), although they did not explicitly use the term “adaptation.” For example, Neumayer, Plumper, & Barthel (2014) use quantile regression to show that a country’s long-term disaster exposure (measured by frequency and intensity) has a significant and negative effect on economic damage from large-scale disaster events such as earthquakes, floods, and TCs.¹ Keefer, Neumayer, & Plumper (2011) find that countries more prone to earthquakes generally suffer fewer deaths from similar-magnitude earthquakes, also providing support for the adaptation hypothesis. They also show this effect is larger in developed and less corrupt nations.

Notably, all these studies identify adaptation by using a variable summing up all disaster shocks in a country over an extended period as a proxy for long-term disaster exposure propensity.² This intuitive approach however raises several issues. First, using the same value covering the entire study period implies constant tendency to adapt and does not consider the possible learning effect of more recent disaster events. Although most natural disasters have a repetitive nature, the exact timing of their occurrence is often uncertain and unpredictable even in those high-risk areas. Hence, using a summed value which can only be

¹ Our study is different from Neumayer, Plumper, & Barthel (2014) in several ways. First, we use a different disaster database and our dependent variable is flood-induced fatalities, while they use economic losses data from Munich Re. Second, Neumayer, Plumper, & Barthel (2014) measure the flood hazard magnitude using the absolute level of local precipitation in flood-affected regions. This could be problematic because they match local rainfall with country-level flooding damage. Third, their analysis aggregates damage from individual flood events at the country-year level, but only includes country-years when a flood event is reported, which could still result in a selected sample.

realized at the end of the entire period is problematic. Second, testing adaptation using the cross-country variation may introduce omitted variable bias because the time-invariant hazard exposure variable may correlate with other unobserved country characteristics that would simultaneously affect their losses from disasters.

In this paper, our investigation of flood adaptation draws upon another strand of literature exploring the learning dynamics associated with adaptation. These studies show that extreme weather events can often induce private adaptation and adoption of new risk management policy (Berrang-Ford, Ford, & Paterson, 2011; Brody et al., 2009; Næss et al., 2005). Many have examined the role of risk perceptions and availability heuristic (i.e., people perceive greater risk when it is salient or can be easily brought to mind) in explaining individual or societal adaptation behaviors (Grothmann & Patt, 2005; Tversky & Kahneman, 1982; Kellens, Terpstra, & De Maeyer, 2013; Keller, Siegrist, & Gutscher, 2006). In particular, some researchers use panel data and fixed effects models to examine the updating effect of disaster shocks when controlling for unobserved cross-sectional heterogeneity. For example, Gallagher (2014) uses U.S. community-level data to show that large flooding events immediately increase household flood insurance take-ups in the affected regions. But this spike is short-lived, thereby suggesting a Bayesian learning model that incorporates forgetting. Similar learning patterns are also found in other studies examining the impacts of recent flooding events on risk-taking behavior and housing values (Kousky, 2016; Atreya, Ferreira, & Kriesel, 2013; Kousky, 2010; Sadowski and Sutter, 2008).

Despite the aforementioned empirical evidence, very few studies have examined the implication of recent disaster shocks for adaptation. One exception is Sadowski and Sutter (2008) that use U.S. county-level data to investigate adaptation to hurricanes. They find that

² For example, Neumayer, Plumper, & Barthel (2014) use the long-run sum of transformed Richter scale to measure the earthquake propensity and long-run sum of cumulative precipitation within flood-affected areas and durations to measure a country's flooding propensity.

the occurrence of a hurricane in only the past ten years that covered at least half of the current storm's path can significantly reduce damages in a county. Our study takes a further step to distinguish the impacts of the long-term climatological risk and past flooding experiences on flooding losses. Based on the economic theory of risk mitigation, we hypothesize that countries with greater exposure to climatological flooding risks tend to adapt better and suffer fewer fatalities from floods. Also considering the learning implications of disaster shocks, we expect that flood adaptation may not increase monotonically with the hazard exposure but rather depend on the timing of more recent flood events.

3. DATA

3.1. Flooding Losses

The dependent variable in this paper is flood-induced fatalities, with the data drawn from the Dartmouth Flood Observatory's (DFO) Global Active Archive of Large Flood Events. The DFO dataset collects information on flood events (e.g., locations, causes, duration, and losses including reported deaths and property damage) that have occurred worldwide since 1985.³ We aggregate the raw data on fatalities from individual flood events to create a country's annual sum of deaths, and construct a balanced panel of 97 countries over the period between 1985 and 2010. We include a country in our sample if it has reported at least five flooding events over our study period and has non-missing data for the independent variables of our interest.⁴ If no floods are reported for a country during a given year, the dependent variable is coded as zero. As discussed earlier, this approach is different from prior studies using flooding events as the unit of analysis (Neumayer, Plumper, & Barthel, 2014; Ferreira, Hamilton, & Vincent, 2013). By including the country-years with zero losses, we

³ <http://floodobservatory.colorado.edu/Archives/index.html>, last accessed in August 2015.

⁴ The online appendix provides a full list of our sample countries.

aim to address the sample selection issue and account for the flood hazards that were prevented from turning into a disaster due to effective adaptation.

Fig. 1 displays the total annual deaths caused by flooding in developing and developed countries, respectively, over the 1985-2010 period, based on the DFO dataset. It shows that developing countries have substantially more fatalities than their developed counterparts, suggesting their higher levels of vulnerability to flooding risks.⁵ The global total reached record high in 1999, which was largely driven by Venezuela's Vargas tragedy which killed more than 20,000 people. The five countries with the highest death tolls from floods during this period are India, China, Venezuela, Philippines, and Bangladesh.

[Fig. 1 about here]

Several things are important to note about using fatalities to measure flooding losses. First of all, the DFO flood losses data were retrieved from news and governmental sources and may likely have the same reporting bias as other disaster databases such as EM-DAT. Specifically, Bakkensen and Mendelsohn (2016) discuss the problem of strategic self-reporting in disaster research, which could occur in both directions. While some countries or governments may under-report their actual disaster losses to "appear more capable," others (particularly low-income countries) may choose to over-report their damage in order to attract more international aid. Other than strategic reporting, researchers also note that there has been continuous improvement in disaster losses reporting and information gathering in recent years, which may make disaster damage data less comparable across years (Kousky, 2014; Tanoue, Hirabayashi, & Ikeuchi, 2016).

Another source of reporting bias and measurement error is related to the fatalities indirectly caused by natural disasters. In particular, almost all disaster databases that rely on

⁵ Over our study period, the average annual number of flood-related deaths in developed countries is 325, while developing countries report an average annual of 7,914 deaths from flooding.

self-reported data provide information on direct losses (i.e., those caused by the physical destruction of a natural disaster), but fail to account for the delayed and indirect losses. For example, a recent study using household survey data estimates that more than 4,000 people died in Puerto Rico after hurricane Maria, which was far beyond the official death count of 64 (Kishore et al., 2018). A large proportion of the indirect fatalities were attributed to delayed or interrupted health care. In another study, Jonkman et al. (2009) find that about two-thirds of the reported deaths after Hurricane Katrina were directly caused by flooding (e.g., drowning), while one-third were caused by the adverse public health situations. Taken altogether, the failure to include indirect fatalities from natural disasters would likely cause under-reporting and measurement error in our dependent variable, thereby biasing our estimates downward.

Secondly, while fatalities are used as a common measure of disaster losses in prior research (e.g., Kahn, 2005), more studies have incorporated economic damage as another measure, mostly drawing data from the EM-DAT (Schumacher & Strobl, 2011; Hsiang and Narita, 2012; Neumayer, Plumper, & Barthel, 2014; Bakkensen and Mendelsohn, 2016). While the two measures are often correlated, they tend to capture different aspects of a disaster's actual impact on society and economic systems. Specifically, there has been a downward trend in the global death tolls from natural disasters over the past few decades, whereas disaster-related economic damage has been growing, particularly in industrialized countries (Tanoue, Hirabayashi, & Ikeuchi, 2016; Kousky, 2014). The general understanding is that although economic development enables better preparation for disasters and reduces fatalities, it may increase the exposure of wealth and physical assets to the risk of natural hazards, and make disasters more expensive. Within this context, we should acknowledge the limitation of using fatalities to test the adaptation hypothesis, especially for developed

countries where disaster fatalities are relatively low and economic damage is substantially high.

It is also noteworthy that some adaptation measure might be useful for reducing fatalities but less effective for reducing economic damage. For example, early warning systems and emergency responses (e.g., evacuation and rescue efforts) can effectively reduce disaster fatalities by moving people out of the disaster-stricken area. However, these measures can hardly prevent a disaster from destroying immobile buildings and infrastructure and incurring economic losses. To mitigate the economic damage of disaster, in the case of floods, would require more proactive adaptation measures such as elevating and fortifying houses, land use and zoning policy that restricts excessive development in flood-prone areas.

Finally, we note that compared to disaster fatalities, the estimates of economic damage provided by DFO has relatively lower quality, which seems to be a common problem across disaster damage databases. Nearly a quarter of the observations in our entire sample (predominantly developing countries) have non-zero deaths but zero economic damage from floods, which makes the damage data less reliable. But for comparison purpose, we still use economic damage (normalized by a country's GDP) as an alternative measure of flooding losses and report our findings in the online appendix.

3.2. Physical Magnitude of Flood Hazards

To characterize the physical intensity of flooding hazards, we use the precipitation data from the Tyndall Center for Climate Change Research to create a rainfall anomaly variable, following the approach in Felbermayr and Groschl (2014). The Tyndall dataset contains country-level monthly and annual mean precipitation weighted by area (in millimeters) from 1900 onward. We measure the precipitation anomaly by computing the number of standard deviations of a country's annual precipitation from its long-run average over the period

between 1950 and 2000, as indicated in equation 1. Thus, positive values of anomaly indicate excessive rainfall in a given country year.

$$\text{Rain Anomaly}_{it} = \frac{\text{RAIN}_{it} - \text{Mean_RAIN}_i}{\text{Std_RAIN}_i} \quad (1)$$

It is important to acknowledge that the annual rainfall anomaly is a coarse intensity measure of exogenous flooding hazards, and it may not fully capture the local and temporal precipitation extremes within a country. Nonetheless, we use this measure for several reasons. First, as discussed earlier, our empirical analysis uses a balanced panel of flooding fatalities at the country-year level instead of modeling based on flooding events. This means we have to create an aggregated rainfall measure for the same unit of observation (i.e., country-years). Therefore, we cannot use local precipitation as Neumayer, Plumper, & Barthel (2014) did to measure the intensity of a single flooding event. Second, the anomaly measure captures deviations of rainfall from long-run means and is conceptually a better proxy for disaster shocks than the absolute level of precipitation.⁶ Measuring anomalies requires using fixed geographic units and timescales to obtain repeated observations every year; therefore, we cannot obtain the anomaly measure using local precipitation only within the reported flooded areas.⁷

Because a certain proportion of the flooding events recorded in the DFO dataset are associated with tropical storms, we follow Miao and Popp (2014) and use storm exposure as another intensity measure of flood hazards. We draw the storm data from the International Best Track Archive for Climate Stewardship (IBTrACS) dataset.⁸ Because the IBTrACS

⁶ We have also used alternative anomaly measures, such as aggregating the positive differences in monthly rainfall anomalies in a year. We find the annual rainfall anomaly has stronger explanatory power in nearly all models.

⁷ We also note that some hydrology studies have used streamflow modeled results or data as an alternative measure of the magnitude of flood hazards (Do, Westra, & Leonard, 2017) Nonetheless, this approach might have data quality problem. The streamflow measurement is more subject to local catchment scale and human factors, and therefore less exogenous as the climatic factors such as extreme precipitation.

⁸ The IBTrACS dataset includes tropical storms, subtropical storms and extratropical storms. Therefore, the storm exposure considered in this paper is only limited to these categories of events, although we refer to them

tracks a storm's position at 6-hour intervals, we map individual storms to affected countries in ArcMAP and calculate the duration of a single storm (in hours) after it made landfall within a country (using the recorded frequency of the storm's track above a country's boundary). We then compute a country's annual cumulative duration of storm exposure and use equation (1) to construct the storm anomaly measure. Both the annual rainfall and storm anomalies not only control for the contemporaneous flooding conditions, but are also used to characterize a country's prior weather disturbance and flooding shocks, with more details provided in the next section.

3.3. Climatological Flood Risks

We measure a country's climatology related to flooding risk using its average annual precipitation and storm duration over the period between 1950 and 2010. We expect that countries with more climatological rainfall and greater storm exposure are generally more susceptible to flood hazards and may have a stronger incentive for adaptation. In addition to the absolute level of precipitation, we create another variable measuring the long-term intra-annual rainfall variability for each country over the same period, which is the mean of computed standard deviation of a country's monthly values of rainfall within a year. The rationale is that countries with larger seasonal rainfall variability such as monsoons should better adapt to the anticipated changes in precipitation (e.g., by building water reservoirs). It should be noted that all the climatology variables are time-invariant and only reflect cross-country differences.

as storms for simplicity throughout the paper. It should also be noted that we did not include the wind speed variable, which was used in other studies modeling adaptation to tropical cyclones (Hsing and Narita, 2012, Bakkensen and Mendelsohn, 2016). Strong tropical cyclones often bring with them high winds, torrential rain, and storm surges. While wind speed is a strong predictor of storm damage associated with high wind, it is less relevant for flooding damage. We instead use the cumulative duration of storms, assuming that the longer a storm event lasts, the more likely it would cause intense precipitation and coastal flooding due to storm surges.

3.4. Socioeconomic, Institutional, and Geographical Characteristics

Drawing upon the prior disaster and adaptation literature, we include control variables for a country's socioeconomic conditions, political institutions, and geographical characteristics by compiling data from various sources. We measure national income using the real GDP per capita (adjusted at constant 2005 dollars), with the data retrieved from the World Bank World Development Indicators. We collect data on a country's total population, urban population, and openness to international trade (the sum of exports and imports of goods and services measured as a share of GDP) also from the World Bank. We measure institutional quality using the political rights index from Freedom House, which takes a value from one to seven to rank a country's status on freedom of participation in the political process. Higher values suggest a less open and democratic institution. With regard to geographic attributes, we include a country's total land area, ocean coastline length, and inland water volume, using the data from the Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT) and the World Factbook of the Central Intelligence Agency.⁹ Table I reports the summary statistics of the main variables used in our regression analyses.

[Table I about here]

4. MODEL AND RESULTS

In this section, we begin with a pooled cross-sectional model to examine the effect of a country's contemporaneous and climatological flood exposure on its flooding losses. We then move to a country fixed effects model by incorporating past flooding shocks to examine short-term adaptation. We further investigate the heterogeneity in national sensitivity to flooding risks, by allowing the effect of the contemporaneous weather shocks to vary across different country groups.

⁹ We acknowledge that there could be other factors that may influence a country's capacity to adapt to floods, such as dam and drainage capacity. We collected data on country-level dam capacity, which are only available for certain years, and find this variable is statistically insignificant in explaining flood-related fatalities.

4.1. Cross-national Model of Flooding Losses

We first specify the following cross-country model with i indexing countries, and t indexing years:

$$\text{Death}_{it} = f(\text{Anom}_{it}, \text{Clim}_i, \text{Geog}_i, X_{it-1}, \eta_{con}, \Phi_t, \varepsilon_{it}). \quad (2)$$

The dependent variable, Death_{it} is the number of fatalities caused by floods. Anom_{it} denotes the precipitation and storm anomalies that capture the physical intensity of contemporaneous flood hazards. Clim_i denotes a country's climatological flood risks, including its long-run annual rainfall (in logs) and storm duration (in logs) as well as intra-annual rainfall variability. Geog_i includes variables related to a country's geography (including total land area, ocean coastline length and inland water volume). All other controls, represented by vector X , include a country's real GDP per capita, political rights, population, urbanization, openness to international trade. To avoid the endogeneity problem, we lag these variables by one year. Following prior studies (Kahn, 2005; Anbarci, Escaleras, & Register, 2005), we use the continent fixed effects η_{con} to control for geopolitical heterogeneity. We also include the year fixed effects Φ_t to control for the time-varying factors that are common to all countries (e.g., the improvement in data reporting over the years, global technological advancement in flood control systems).¹⁰ ε_{it} is the error term.

Given the count-data nature of our dependent variable, we estimate the equation using the negative binomial model which allows for data over-dispersion. We cluster standard errors at the country level to correct for heteroscedasticity and autocorrelation.

We present the baseline results in Table II, column 1. Both the annual precipitation and storm anomalies are statistically significant with the expected positive sign, suggesting their strong predictive power of fatalities. We interpret the coefficients as that one-standard-

¹⁰ Some studies have noted that natural disasters including floods have increased in frequency in recent decades, and such increases are partially attributed to the improvement in reporting (Kousky, 2014). That is why we need the year dummies to control for the general trend in information gathering.

deviation increase in a country's annual rainfall and storm exposure relative to its long-term mean is expected to increase the country's flood-related death counts in the same year by a factor of 1.65 and 1.58, respectively. We find that the climatological variables are largely insignificant for explaining flood fatalities except the long-term storm exposure. Its estimated coefficient is positive and marginally significant, suggesting that countries more often exposed to tropical storms suffer more flood fatalities, which seems to counter the adaptation hypothesis.

[Table II about here]

In terms of geography, we find that countries with smaller geographic areas or longer ocean coastlines on average suffer more fatalities from floods. One possible explanation for this finding, as well as the positive effect of climatological storm exposure, is that rapid development and high concentration of population in coastal regions, due to their attraction for human settlement, may increase a society's vulnerability to flood risks, particularly when effective flood mitigation measures are lacking.

As for other control variables, we find that a country's income or economic development has a significant and negative effect on flood fatalities, which is consistent with the previous findings in the disaster literature. Additionally, larger size of populations is associated with more deaths. The political right variable has a negative estimated coefficient (statistically significant at the 10 percent level), indicating that more politically open and democratic nations tend to suffer more flood fatalities, when everything else is held constant. This finding seems to contradict the existing literature, and might be associated with the use of a different disaster database. Finally, comparing flooding losses across continents, we find that Asia and Latin America have significantly more fatalities from floods relative to Africa (the omitted continent).

As discussed earlier, it is important to include the country-years with zero flood events or losses, considering the endogeneity of flood occurrence (e.g., effective flood mitigation measures may help prevent floods from occurring). As an extension to model flooding losses

conditional on its occurrence, we estimate a negative binomial-logit maximum-likelihood hurdle regression, which first models whether or not a country has zero flood fatalities in a given year using a logit regression (Table II, column 2) and then models the non-zero fatalities using a truncated negative binomial model (Table II, column 3).¹¹ This novel approach is useful for dealing with samples with excessive zeros, but it does not assume two separate data-generating processes for zero and non-zero values, like the zero-inflated negative binomial model.

According to our estimation results from the hurdle model, the contemporaneous weather anomalies are still highly significant for explaining both the likelihood of flooding and the extent of flood losses. The climatological storm variable has a positive and significant effect in both stages of the hurdle model. The climatological rainfall seems to have little impact on flood occurrence, but it negatively correlates with flood fatalities in the second stage, which might be suggestive of adaptation (i.e., higher levels of exposure drives adaptation and thus reduces disaster losses). The inland water variable is negatively correlated with both flood occurrence and fatalities, suggesting that higher volumes of inland water can help reduce flooding risk. This finding may provide another layer of evidence on adaptation, as people could employ this resource endowment in adaptation to floods, for example, by channeling excessive water. It is also worth noting that the effect of coastline length becomes insignificant in both two stages of the hurdle model.

Regarding other explanatory variables, income seems to have no effect on the probability of flooding, but can significantly reduce the extent of flooding fatalities conditional on its occurrence, which resonates with the findings in Ferreira et al. (2013). The political right variable has a negative estimated coefficient in predicting flooding probability (which is

¹¹ This regression is executed using the “hnblogit” command in Stata (Hilbe, 2005).

consistent with the results in column 1 and suggests that more democratic countries are more likely to experience floods), but the variable shows little effect in the second stage. One possible explanation is that more democratic nations have more transparent reporting systems that make it easier for their flooding events to be included in the DFO database. It is also possible that the political institution variable may correlate with other unobserved country characteristics that are not captured in the cross-country model.

4.2. Country Fixed Effects Model

While the cross-country model allows us to examine long-term adaptation to climatological flood risks, it may not adequately control for the unobserved climatic, topographical and geological characteristics that may simultaneously affect a country's actual flood losses (for example, countries located downstream in large river systems might be more vulnerable to repeated flooding losses). Therefore, we resort to a country fixed effects model and add a country's prior flood shocks (measured by a distributed lag of precipitation and storm anomalies) to test whether recently-experienced floods have an updating effect on short-term adaptations that reduce fatalities from subsequent flood events nationwide.

Two things are important to note here. First, although disaster shocks might drive adaptation, it is unclear how long it would take a recent shock to actually affect future losses, and this may likely depend on the type of adaptation measures undertaken in response to the shock. For example, flood events may drive governments to build or enhance their levee infrastructure or change their land-use decisions. It would take a relatively longer period for these measures to be implemented, completed and to effect a change in flood protection. By contrast, some flood adaptation measures could be implemented more easily and at lower costs, for instance, better warning and evacuation systems, and flood-proofing of houses. Given the wide range of flood adaptation options, we focus on their aggregate impacts on risk

reduction. But our analysis including different year lags may shed light on the efficacy of short-term and medium-term adaptations.

Second, in terms of estimation strategy, we switch to the Poisson fixed-effects model with clustered standard errors that controls for the time-invariant heterogeneity across countries (Cameron & Trivedi, 2005). We do not use a negative binomial fixed-effects model, because this model does not truly control for unobserved individual effects (Allison & Waterman, 2002; Paulo, 2008). Our estimation equation is as below:

$$\text{Death}_{it} = f(\text{Anom}_{it}, \sum_{n=1}^N \text{Anom}'_{it-n}, X_{it-1}, \eta_i, \Phi_t, \varepsilon_{it}) \quad (3)$$

where $\sum_{n=1}^N \text{Anom}'_{it-n}$ is a distributed lag of past weather anomalies a country has experienced and η_i denotes the country fixed effects. To examine the effect of longer stretches of abnormal precipitation and storm exposure without incorporating too many lags, we combine the weather anomalies into five-year bins and measure the months in which a country's precipitation and years its storm duration were at the 90th percentile or above during each period, respectively.¹² We first use a 20-year history of weather anomalies, which are subsequently divided into four periods. Table III, column 1 reports the estimation results.

[Table III about here]

First, the contemporaneous precipitation and storm anomaly variables are consistently statistically significant in the fixed-effects model, although the magnitude of coefficients is slightly lower than those in the cross-country model. The significance of weather anomalies reinforces our confidence in using these variables to measure previous exposure to floods. Including recent shocks in a distributed lag structure, we find that more recent weather shocks seem to matter more for current flooding losses. Specifically, we show that experiencing a month in which national precipitation reaches or exceeds the 90th percentile

¹² We conduct a set of sensitivity tests using different thresholds of extreme including 75th, 90th and 95th percentiles and finally choose the 90th percentile because it yields the best goodness of fit. We provide the results of sensitivity analysis in the online appendix.

between six and ten years ago is expected to lower flood fatalities by 11.4 percent, while excessive storm exposure (at the 90th percentile or above) in the past five years would decrease the number of fatalities by 62 percent.¹³ We also find that the lagged weather anomalies become insignificant beyond the ten-year lag.

This result seems to resonate with the finding in Sadowski and Sutter (2008) that only hurricanes that occurred in the past ten-year window can significantly reduce current hurricane damage. While they attribute this finding to forgetting, the underlying causal mechanisms could be more complicated. Admittedly, it is possible that people's memory of earlier events wears off over time, thereby causing a pause in adaptation. In the meantime, the knowledge people had learned from prior disasters might depreciate over time and become gradually obsolete, especially when there is no "nudge" from a new shock for a long period. It is also possible that the effect of earlier adaptation efforts might be offset by increased human exposure and development in floodplains due to the misperception of safety (Burby, 2006; Pinter, 2005).

To assess the explanatory power of past flooding conditions, we conduct a likelihood ratio test and find that including the past weather anomalies results in a statistically significant improvement in model fit. Concerning other control variables, we find that both the income and political rights variables are now statistically insignificant, presumably because of the lack of within-country variation over time. The estimated coefficients on a country's total population and particularly, the percentage of the urban population are both statistically significant with positive signs, which may suggest that rapid urbanization in hazardous areas may exacerbate flooding risks.

Since our findings suggest that more recent shocks matter more, we re-estimate the model by focusing only on the past ten years' weather anomalies (in column 2), which are combined into two-year bins. We show that prior excessive rainfall anomalies that occurred over the years -7 through -10 would significantly reduce current flood fatalities, while storm exposure anomalies appear to have a more immediate mitigating effect. Additionally, the storm

¹³ Because we use the Poisson model for estimation, we are able to interpret the coefficients in a semi-elasticity form.

anomalies in the years -7 through -8 also exhibit a statistically significant and negative effect on current flooding fatalities. By computing the sum of the coefficients on all the lagged anomaly variables, we find that shocks in the past ten-year window have a significant cumulative effect on adaptation. Specifically, having an additional month in which the national precipitation reaches or exceeds the 90th percentile would lower flood fatalities in the following ten years by 26 percent, while experiencing excessive storm exposure (at the 90th percentile or above) would decrease the expected number of fatalities by a factor of 2.4.

We also perform additional tests using flood-related monetary damage as an alternative dependent variable and report our estimation results in the online appendix. Using both cross-country and country fixed effects models, our estimates provide similar evidence on the long-term and short-term adaptation to floods. Nonetheless, due to data quality issue as mentioned earlier, we have more faith in our results using flood fatalities. We have further examined the robustness of our findings by re-estimating the models weighted by a country's population (with results also presented in the online appendix). Our estimates from weighted and unweighted models are highly consistent, which help alleviate concerns over the failure to model the heterogeneous effects.

4.3. Heterogeneity in Sensitivity to Flood Hazards

Depending on the effectiveness of adaptation, different countries and regions could exhibit different levels of sensitivity to exogenous weather shocks. In this paper, we follow the approach in Keefer, Neumayer, & Plumper (2011) to examine the heterogeneity in national sensitivities to flood hazards. Specifically, we estimate the effects of weather anomalies on fatalities separately for different countries grouped according to their income and climatological attributes. We may expect that countries with higher incomes or higher climatological flood risks would adapt better and therefore, are less sensitive to similarly strong flooding shocks.

To test these hypotheses, we divide our sampled countries into two groups based on different criteria and interact the group indicators with the contemporaneous weather anomalies. All specifications are still estimated using the Poisson fixed effects model

incorporating the same set of explanatory variables in equation 3. In Table IV column 1, we create a binary variable that equals one if a country is a developed country (based on the World Bank classifications) and zero otherwise; and another dummy that equals one for a developing country, and then we interact both variables with the precipitation and storm anomaly variables, respectively. As can be seen, the weather anomalies can well predict flood-related fatalities in developing countries, whereas their effects become statistically insignificant for developed countries. This comparison indicates that developing countries are more sensitive to the weather disturbances, and resonates with the prior literature by suggesting economic development as one determinant of adaptation.

[Table IV about here]

In columns 2 and 3, we estimate separate rainfall anomaly coefficients for countries with above the median long-term annual precipitation level *versus* those below the median level, and for countries with above median climatological rainfall variability and those below the median level. In column 2, we find that both groups of countries are sensitive to increased weather anomalies, but the estimated effect for countries with higher climatological rainfall is only marginally significant. Comparing the magnitudes of the two coefficients, we find that extreme precipitation shocks result in more fatalities in countries with lower climatological rainfall, which seems to support the adaptation hypothesis. Results in column 3 suggest that countries classified as having lower rainfall variability would suffer 10 percent more fatalities with one-unit increase in the rainfall anomaly measure, compared to countries with higher rainfall variability, although their difference is statistically insignificant.

In column 4, we estimate separate storm anomaly coefficients for countries with above median climatological storm exposure versus those below the median level (sample confined to countries with nonzero values). Interestingly, we find that longer storm durations can significantly increase flood fatalities only in countries that are more often exposed to storms.

While this finding contradicts the adaptation hypothesis, it seems to be consistent with our results from the cross-country model that higher climatological storm exposure is associated with more losses. By contrast, the storm anomaly variable is statistically insignificant for less-exposed countries. This finding may relate to the lack of variation in annual storm shocks, because a large proportion of countries in this group are landlocked nations and rarely affected by tropical storms.

5. DISCUSSION AND CONCLUSION

Are we adapting to floods? What makes some societies more resilient to floods relative to others? To answer these questions, we take a worldwide view in investigating the extent and pattern of adaptation to floods by linking a country's climatological risk and recent flooding experiences with its flooding fatalities. This paper contributes to the disaster and climate economics scholarship in several ways. First, we not only test for long-term flood adaptation across countries but also examine short-term adaptation by considering the learning dynamics induced by recent shocks. Second, we address the pitfall in recent flooding research (i.e., selection of sample including only observed flood events) by using a balanced country-year panel. Third, we construct weather anomalies using objective precipitation and storm data to measure the physical intensity of flooding hazard, which overcomes the "exogeneity assumptions" in many flood-related empirical studies (Noy, 2009).

To summarize, our study provides mixed evidence of flood adaptation. Unlike the previous studies that suggest long-term risk exposure increases adaptation, we find that higher climatological flooding risk does not necessarily lead to better adaptation and fewer flood fatalities. Our results indicate that countries with more climatological rainfall suffer fewer flood-induced fatalities, and these countries seem less sensitive to exogenous rainfall shocks than countries with less climatological rainfall. However, we also find that countries more prone to tropical storms suffer more fatalities from floods and exhibit higher sensitivity to

storm shocks. These findings do not necessarily imply that people fail to adapt, but adaptation is not fully rational in the long term, at least in the case of floods (particularly, coastal flooding). In this sense, more policy interventions should be taken at the national and local levels to encourage more effective long-term adaptations. When controlling for country fixed effects, we find that weather shocks that have occurred in the past ten years can significantly reduce current flood-related fatalities. This result suggests the presence of short-term adaptation, and in particular, some adaptation measures can be adopted quickly following disaster shocks and provide immediate benefits.

Then why do earlier flooding events no longer matter? Prior studies examining post-disaster behavioral changes show that the learning effects often are short-lived, possibly because of forgetting and people's declining risk perceptions over time (Gallagher, 2014). In the case of floods, it is also possible that earlier-built flood-control infrastructure may promote complacency and excessive development in floodplains that in turn increase human exposure to floods. For example, Pinter (2005) notes that the 1993 Midwestern flood in the U.S. resulted in more public buyouts of floodplain properties, followed by dramatic increases in urban construction on the floodplains. Boustan et al. (2012) find that large flooding events triggered net in-migration across U.S. counties during the early twentieth century, partially as a result of the establishment of protective infrastructure. While most of these discussions center on the U.S. policy context, similar problems could cause even worse consequences in developing countries. Kellenberg and Mobarak (2008) argue that lower-income countries generally have a higher tolerance of risk and tend to place more emphasis on development and urbanization than risk mitigation. Taken together, if earlier adaptation efforts are offset by increased exposure in risky areas, this may suggest that government should avoid relying solely on structural protection in floodplains but also adopt other non-structural mitigation measures such as zoning and land use policy.

The findings of this paper should also be valuable for estimating future climate change damage and particularly the representation of adaptation in climate models. Although most climate models treat adaptation as autonomous, our results show that the tendency to adapt is not constant over time but discontinuously affected by recent extreme events. This implies that adaptation could potentially be treated as a function of previous climate damage, which simultaneously incorporates learning and discounting of earlier disaster experiences (Patt et al., 2009).

Finally, it is important to acknowledge the limitations of this research. First, in this paper we focus on a country's domestic flood exposure and do not account for the potential cross-border impact. It is possible that some countries are more easily affected by the rainfall shocks in their neighboring countries (e.g., due to the downstream location in the river system). In this regard, the rainfall-fatality link may likely extend beyond country borders. If we assume that countries in the same geographic region experience similar weather shocks during a year, and one's excessive rainfall increases the flood losses in its neighboring countries, then not including the foreign shocks may cause our estimates of domestic weather anomalies to be positively biased. Second, in this study we focus on the aggregate adaptation to flood losses and do not distinguish all possible adaptation measures (e.g., warning and response systems, land use and zoning policy, structural protection works). Considering the differences among these measures, an important task for future research is to evaluate the cost-effectiveness of various adaptation measures over different time horizons to inform climate adaptation policies (e.g., Davlasheridze, Fisher-Vanden, and Klaiber, 2017). It is also important to further examine the pattern of human settlement and migration in response to flood shocks to assess the efficacy of long-term adaptation to floods.

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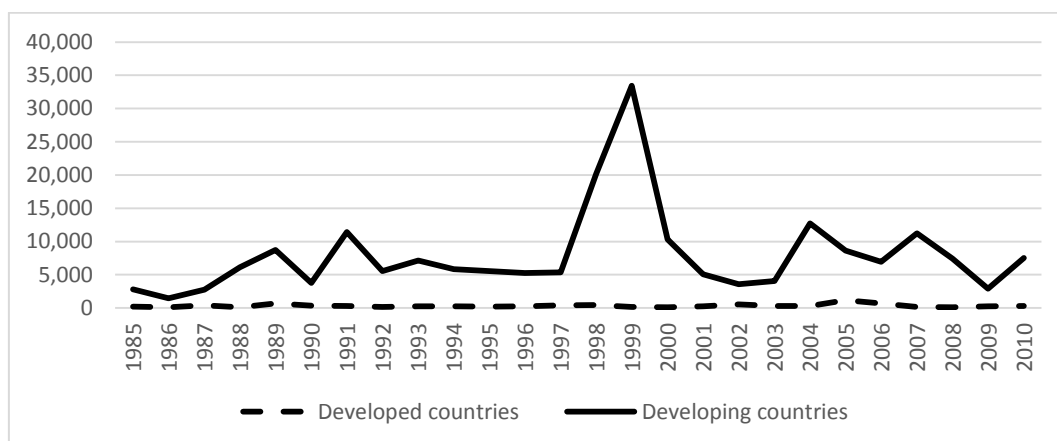
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Figure 1. Annual Global Deaths from Floods by Year



Source: DFO database

Table I. Summary Statistics

Variables	N	Mean	Std. Dev.	Min	Max
Number of flood-related deaths	2386	89.48	615.04	0	20006
Contemporaneous rainfall anomaly	2386	-0.01	0.98	-2.67	4.26
Contemporaneous storm anomaly	2386	0.02	0.76	-2.27	11.13
Climatological annual precipitation (in log)	2386	6.75	0.87	3.76	8.04
Climatological intra-annual rainfall variability	2386	57.80	38.97	2.75	216.03
Climatological annual storm duration (in log)	2386	1.12	1.73	0	5.99
GDP per capita (in log)	2386	7.42	1.53	4.62	10.62
Political Rights	2386	3.48	2.06	1.00	7.00
Population (in log)	2386	16.71	1.35	13.49	21.01
Urban population share (%)	2386	51.75	22.83	4.99	97.42
Openness to international trade (%)	2386	33.49	18.12	5.42	140.18
Geographic area (log)	2386	12.82	1.52	9.11	16.62
Inland water volume (log)	2386	12.59	3.55	0	18.31
Coastline length (log)	2386	6.06	3.40	0	12.22

Note: The sample includes 97 countries from 1985 to 2010.

Table II. Pooled Cross-sectional Model of Flood Fatalities

	<i>Negative binomial</i>	<i>Negative binomial-logit hurdle</i>	
	<i>model</i>	<i>Model</i>	
	(1)	Logit (2)	Truncated NB (3)
Rain anomaly _(it)	0.502*** (0.0741)	0.483*** (0.0660)	0.210*** (0.0596)
Storm anomaly _(it)	0.459*** (0.130)	0.185*** (0.0611)	0.361*** (0.113)
Climatological rainfall _(i)	-0.405 (0.295)	0.0536 (0.227)	-0.365** (0.160)
Rainfall variability _(i)	0.00468 (0.00644)	-0.00191 (0.00357)	0.00448 (0.00393)
Climatological storm _(i)	0.135* (0.0752)	0.158** (0.0664)	0.137** (0.0624)
Area _(i)	-0.195* (0.113)	0.0134 (0.0810)	-0.209*** (0.0751)
Inland water _(i)	-0.0274 (0.0396)	-0.0568** (0.0286)	-0.0392* (0.0227)
Coastline _(i)	0.0696* (0.0376)	0.0345 (0.0331)	0.0322 (0.0274)
GDP per capita _(it-1)	-0.420*** (0.139)	-0.105 (0.111)	-0.481*** (0.126)
Political right _(it-1)	-0.116* (0.0607)	-0.136*** (0.0500)	-0.0575 (0.0423)
Population _(it-1)	1.071*** (0.157)	0.943*** (0.129)	0.729*** (0.111)
Urban population _(it-1)	-0.0115 (0.00845)	-0.0123* (0.00646)	-0.00526 (0.00712)
Openness _(it-1)	-0.00618 (0.00699)	-0.00484 (0.00480)	0.000224 (0.00516)
Asia	0.757*** (0.256)	0.927*** (0.270)	0.488** (0.219)
Europe	-0.428 (0.369)	-0.189 (0.357)	-0.255 (0.271)
Latin America	1.735*** (0.377)	1.051*** (0.263)	1.397*** (0.326)
North America	0.0419 (0.947)	-0.480 (0.779)	0.736 (0.569)
Oceania	0.309 (0.473)	0.612 (0.582)	-0.0982 (0.407)
Constant	-6.979*** (2.177)	-15.34*** (1.534)	-0.381 (1.712)
Observations	2,386	2,386	2,386
Number of countries	97	97	97
Log likelihood	-6869	-6537	-6537

Notes: All models include year fixed effects. Standard errors, shown in the parentheses, are clustered at the country level.

*** p<0.01, ** p<0.05, * p<0.1

Table III. Country Fixed-effect Model of Flood-induced Fatalities

	(1)		(2)
Lagged rainfall anomalies (90 th percentile and above)			
Year -1~ -5	0.0238 (0.0330)	Year -1~ -2	0.0706 (0.0567)
Year -6~ -10	-0.114** (0.0500)	Year -3~ -4	-0.0315 (0.0600)
Year -11~ -15	0.0108 (0.0258)	Year -5~ -6	0.0342 (0.0750)
Year -16 ~ -20	0.0540 (0.0424)	Year -7 ~ -8	-0.174*** (0.0564)
		Year -9 ~ -10	-0.162** (0.0824)
Lagged storm anomalies (90 th percentile and above)			
Year -1~ -5	-0.619** (0.267)	Year -1~ -2	-0.794** (0.311)
Year -6~ -10	-0.141 (0.315)	Year -3~ -4	-0.295 (0.293)
Year -11~ -15	0.0198 (0.141)	Year -5~ -6	-0.0857 (0.410)
Year -16 ~ -20	-0.121 (0.0988)	Year -7 ~ -8	-0.933** (0.470)
		Year -9 ~ -10	-0.321 (0.312)
Rain anomaly _(it)	0.349** (0.148)		0.350*** (0.136)
Storm anomaly _(it)	0.220** (0.105)		0.242* (0.125)
GDP per capita _(it-1)	-0.691 (0.431)		-0.685* (0.413)
Political right _(it-1)	-0.105 (0.0995)		-0.0715 (0.0956)
Population _(it-1)	2.869* (1.716)		2.687** (1.329)
Urban population _(it-1)	0.0584*** (0.0218)		0.0615*** (0.0228)
Openness _(it-1)	-0.0139 (0.0166)		-0.0189 (0.0181)
Observations	2,386		2,386
Number of countries	97		97
Log likelihood	-183935		-183370

Notes: All models include country and year fixed effects. Standard errors, shown in the parentheses, are clustered at the country level.

*** p<0.01, ** p<0.05, * p<0.1

Table IV. Country Fixed-effect Model: Heterogeneity in National Sensitivities to Flood Risks

	(1)	(2)	(3)	(4)
Developed * Rain anomaly _(it)	0.285 (0.206)			
Developing * Rain anomaly _(it)	0.353** (0.153)			
Developed * Storm anomaly _(it)	0.121 (0.218)			
Developing * Storm anomaly _(it)	0.226** (0.109)			
Higher rainfall * Rain anomaly _(it)		0.314* (0.178)		
Lower rainfall * Rain anomaly _(it)		0.444*** (0.164)		
Storm anomaly _(it)		0.222** (0.105)	0.222** (0.105)	
Higher rain variability* Rain anomaly _(it)			0.321* (0.178)	
Lower rain variability* Rain anomaly _(it)			0.425*** (0.162)	
Rain anomaly _(it)				0.366** (0.152)
More storms * Storm anomaly _(it)				0.376*** (0.131)
Fewer storms * Storm anomaly _(it)				-0.176 (0.215)
Observations	2,386	2,386	2,386	2,386
Number of countries	97	97	97	97
Log likelihood	-186879	-186706	-186803	-181144

Notes: All models include country and year fixed effects and all other explanatory variables (e.g., all the lagged rainfall and storm anomalies) that are included in Table III. Standard errors, shown in the parentheses, are clustered at the country level. We provided the full results of other independent variables in the online appendix. *** p<0.01, ** p<0.05, * p<0.1