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2023

May 4 - 6,
Cairo Egypt

ECONOMIC RESEARCH FORUM
منتدى البحوث الاقتصادية

ERF 29th Annual Conference

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Abstract

This paper investigates the integrated paradigm between economic growth, income inequality, climate change and natural disasters by considering the bi-directional causality. Each of those causes the other and meaningful policy recommendations must involve a concerted effort to affect all of them at once. This paper estimated simultaneous equations consisting of three models, namely neoclassical stochastic growth, income inequality, and natural disaster damage models. This paper constructs a panel database of 160 countries from the years 1990- 2020 by matching country-level datasets, and climate variables. This new endeavor enhances the existing attempts that integrate these dimensions in the climate change-macroeconomic modelling studies. A carefully designed mix of policy solutions that tackles the interrelated issues simultaneously is no longer a luxury, given that our time to reverse global megatrend such as climate change and its catastrophic impacts is about to run out.

Keywords: Natural disasters, inequality, climate change, economic growth, simultaneous equations, megatrends.

JEL Classifications: C33, C55, O11, Q54

1. Introduction & background

The interrelationship relationship between economic growth, income inequality, climate change and natural disasters is a complex one. Climate change is defined as the change in weather patterns resulting from human-induced greenhouse gas (GHG) emissions. These weather changes include global warming and unpredictable and unprecedent variations in the temperature that can have dangerous effects on the livelihood. Climate change is one of the global megatrends that is expected to have a significant effect on the development and growth of many countries today and in the future. Figure 1 depecits the global warming through the timeplot of the monthly global temperature anomaly. It shows that global temperature has an increasing trend. Meanwhile, Kuznets inverted U-shaped hypothesis affirms that income inequality within a nation will first rise and then fall as its income grows, this is no longer considered an accurate representation of how the distribution of income changes with growth (Piketty and Saez, 2003; Saez and Zucman, 2020). Convergence of income levels and decline in inequality between nations is also far from guaranteed and depends crucially on whether productivity enhancing policies, institutional frameworks are adopted, cumulative impacts of repeated disasters and climate change adaptation measures (Sachs and Warner 1995; Abou-Ali and Abdelfattah, 2013; Acemoglu and Robinson, 2013).

Therefore, there is an urgent need for more systematic research into the connections between climate change, frequency of natural disasters, economic growth, and socioeconomic vulnerability. This joint assessment of the influence of the role of inequality on the relative vulnerability to damages due to disasters, of natural disasters on inequality, and of the impact of climate change along with economic vulnerability and disaster intensity on growth can shed light into the trend of increasing damages first reported by Coronese et al. (2019) and Cappelli et al. (2021).

The purpose of the present paper is to untangle the connection between economic growth, disasters, climate change, and economic vulnerability by accounting for both directions of causality. We do so by means of a simultaneous equations approach on a panel of 160 countries from year 1990 to 2020. Additionally, the panel analysis brings to the fore the dynamic nature of these phenomena, whereby the cumulative impacts of repeated disasters on some locations trigger a vicious cycle, that we label disaster-inequality trap (Cappelli et al., 2021). We recognize the existence of reverse causality between all the three variables. Inequality within a country is not only a consequence of disastrous events, but also affects how a country can deal with those events when they occur. The level of development as well can be affected by climate change, but also determines the country's adaptation and mitigation capabilities. The main finding is that the more prevalence of income inequality, measured by the Gini index, relates to a greater number of people affected by natural disasters. At the same time, the greater the human toll the larger is the inequality gap. While economic growth is negatively affected by climate change, its relationship with inequality implies that on average countries are in their early stages of economic development.

Therefore, countries that are in their early stages of development may grow faster as inequality rises.

The remainder of the paper is organized as follows. Section 2 reviews key literature on the causal relations between natural disasters and income inequality as well as paper value added. Section 3 outlines the panel databases, modelling framework, and relevant econometric details. Section 4 discusses the main results and Section 5 concludes with key relevant policy implications for future adaptation strategy design.

2. Key literature review

Since the 1980s, research on global warming has demonstrated that the expected changes would have significant impacts and implications for all world regions. Hence, it is recognized that climate change is one of the significant "megatrends" in future scientific research and future studies. This means that it has a long-life cycle of many years and is expected to be much longer, a global phenomenon that will significantly affect virtually all economic sectors, individuals, and institutions. With engagement with other megatrends and shifts, such as changing demographics, migration, and rapid urbanization, climate change is predicted to raise severe threats to all countries of the World (Abdelfattah et al., 2021).

The effect of climate change on economic growth is not a relationship that has been presented only by the economics of climate change literature. The literature on 'economic geography' taught us some things about how economic growth in a region is affected by its climate (Clark et al., 2018). Nordhaus (2013) estimated that a doubling of the atmospheric concentration of GHG emissions will lead to temperature increase that will cause a loss equivalent to a year of growth of the global economy. Carraro (2016) forecasted the effect of climate change on economic growth, agreed that an increase in the atmospheric concentration of GHG emissions will lead to a loss in economic growth.

In its essence, the neoclassical growth model does not explicitly introduce climate change as a determinant of growth (Rubio, García, and Hueso, 2009). It is merely treated as a depreciation stimulator, where the destruction caused by the increasing frequency of extreme weather events can hinder capital accumulation and production. Likewise, other streams of literature, built upon the neoclassical growth models, offered several theoretical frameworks exploring the relationship between economic growth and environmental problems. The broad focus of this literature is on questions related to environmental degradation and externalities (see John and Pecchenino, 1994; Rubio, García, and Hueso, 2009), and not the more comprehensive issue of climate change. However, Tol (2009) claims that climate change is the mother of all externalities. It is large, more tangled, and more debatable than any other environmental problem (Bretschger and Karydas 2019).

Some theoretical endeavors have been directed toward explaining theoretically the effect of climate change on growth. Fankhauser and Tol (2005) provided a framework using the Ramsey-Cass-Koopmans model to illustrate the impact of climate change on economic growth. This model is built on the idea that growth happens over two periods with different generations. Two factors have been identified as main channels explaining this dynamic relation. The first dynamic effect is capital accumulation. If savings are held constant and climate change has a negative impact on output, investment in the economy will be reduced. This will lead to a reduction in capital stock, output, and consumption. Lower investments, in the endogenous growth models, will also lead to a slow-down in technical progress, labor productivity and human capital accumulation. The second dynamic outcome is related to savings. Forward-looking agents are likely to change their saving behavior as climate change starts to negatively materialize in their returns on investments. This will then affect accumulation of capital and growth. The direction in which saving will be affected is not, however, clear. Savings may fall because, faced with lower rates of return, people may prefer to consume now rather than save. People may also decide to increase their saving to compensate for the shortfall in future income. Piontek et al. (2019) also discussed lessons from growth literature and showed that the destruction of factors of production, capital and labor can also affect long-run equilibrium growth. On the other hand, Acemoglu, Aghion, and Hémous (2014) endogenized technological change in the growth model to show how technical progress, induced by environmental policy, can mitigate the effect of climate change by adopting more environmentally friendly energy sources. Although the authors were not explicitly exploring the impact of growth on the climate, they highlighted the central role played by the market size. A larger market that can encourage innovation is associated with how this economy is growing and its development level.

There is an increasing body of literature studying the effects of climate change on growth. Schlesinger, et al. (2015) point to the fact that a modest increase in temperature will have some benefits, followed by losses as temperature increases further[1]. Dell et al. (2009) showed that a one-degree Celsius increase in temperature can cause an 8.5% decrease in GDP per capita on average in countries over the world. However, action must be taken to avoid or mitigate the negative impacts that are expected to occur at 1.1 degrees C (James Oguntuase, 2020). Last but not the least, Kahn et al. (2021) used data for 174 countries between 1960 and 2014. They found that per-capita real output growth is adversely affected by persistent changes in temperature above and below the historic norm, but they did not find significant effects for precipitation.

On the other side, natural disasters have devastating impacts on societies and impose exorbitant tolls in terms of casualties, material deprivation and altered power relations. From Figure 2 to Figure 4, we can see the different kinds of natural disasters and their intensity during the period from 1990 to 2020 as well as the number of people exposed to these disasters. The frequency and intensity of natural disasters has been on the rise since the 1970s (Yamamura, 2015; Coronese et al., 2019) and is expected to increase exponentially in the coming years (Bae, 2018; IPCC, 2018, 2021). This can be seen from Figure 5 to Figure 7. While developing countries may not have been the most egregious polluters historically, they have become the most responsible for it now and are also the most likely suffer from it (Samson et al., 2011; Busch, 2015). Developing countries are more disadvantaged than developed countries in terms of the frequency of occurrence of these events, and their ability to deal with them (Roberts, 2001) (See Figure 7). Many of these developing countries rely on agriculture and other natural resource-based industries or are at risk from rising sea levels, all of which are intensifying with climate change (IPCC 2018, 2021). From a neoclassical model perspective, climate change induced destructive events will increase the depreciation rate of the existing stock of technology and assets within a country (Qureshi et al., 2019), resulting in slower growth, more protracted convergence, and ultimately higher inequality between nations.

There is a general belief that preventing the consequences of climate change and developmental policies are mutually exclusive (Rao & Min, 2018). However, some of these preventive policies

[1] There are no estimates of the impacts of warming above 3 degrees C.

can ease the destructive consequences of climate change in developing countries, and at the same time, are necessary for the country's general development (Alano and Lee, 2016). These measures include reducing inequality within the country. Higher levels of inequalities within a country can increase the country's vulnerability to catastrophic events, and hence reduce its adaptability and mitigation capacities (Klomp & Valckx, 2014). Therefore, the relationship between disastrous events and inequality is becoming a hot topic are discussed (Dang et al., 2013; Zhang & Zhang, 2021; Hailemariam et al., 2020; Rojas-Vallejos & Lastuka, 2020; Wu & Xie, 2020; Cappelli et al., 2021). For example, in his seminal study, Khan (2005) finds that death tolls of catastrophic events are lower in richer countries, due to stricter law enforcement and the availability of preventive measures. Anbarci et al. (2005) also conclude that catastrophic events are purely a natural phenomenon, but the resulting death toll is a result of the economic, political, and institutional factors. Even gender inequality can affect the uneven distribution of disasters' incidence (Huyer et al., 2020). For example, women suffer more from the reduced mobility to the non-agriculture sector, and hence have less chances to adapt to climate change. There is another microeconomic stream of literature that consists of case studies based on experimental methods to compare inequality before and after specific disastrous events (Belasen & Polachek, 2009; Baez et al., 2010; Thiede, 2014).

The prevailing orientation of literature is to consider disasters as exceptional and independent events from each other. This literature falls short of explaining the growth of the frequency and increasing magnitudes associated with damage (Cappelli et al., 2021; Rao & Min, 2018). Figure 4 demonstrated the adjusted total damage distribution per disaster from the year 1990-2020 which calculated to be around 4.6 billion dollars worldwide. We explicitly take into consideration the climate change context for each country by also controlling for factors that reflect a change in their climatic conditions, even if they do not have disastrous effects, such as changes in the precipitation levels or heat waves. To our knowledge, no paper has previously observed the interrelationship between growth, inequality, and natural disaster between and within countries, mediated by the problem of climate change.

3. Empirical framework

This paper investigates the integrated paradigm of inequality, economic growth, climate change and natural disasters through a system of simultaneous equations. The proposed system of equations consists of three models, namely inequality, neoclassical stochastic growth, and disaster damage models. Economic growth is a function of country-specific climate variables, a set of macroeconomic indicators, inequality, and disaster damage. While, disaster damage is a function of inequality, climate variables, socioeconomic variables representing the adaptation demand and public budget related to the adaptation supply. Inequality is a function of natural disasters, institution quality and a vector of control variables. Therefore, this paper constructs a panel database of 160 countries from the years 1990- 2020 by matching country-level datasets and climate variables yearly time series. This includes income inequality, macroeconomic data, climate variables and finally natural disasters.

Though this integrated strategy offers a more complete picture of the triangular relationship it entails some major tradeoffs. For instance, there are many macroeconomic indicators that explain growth that are difficult to account for in the integrated approach.

3.1 Simultaneous equations system

A general framework, including a growth equation, an inequality equation, and disaster equation, is adopted. This empirical framework is based on estimating a simultaneous equations system using panel data based on the following h^{th} equation that can be represented as:

$$\boldsymbol{y}_{\boldsymbol{h}_{NT\times 1}} = \left(\boldsymbol{Y}_{\boldsymbol{h}_{NT\times(g_h-1)}} \middle| \boldsymbol{X}_{\boldsymbol{h}_{NT\times k_h}}\right)\binom{\gamma_h}{\beta_h} + \boldsymbol{\varepsilon}_{\boldsymbol{h}_{NT\times 1}}$$

$$= \boldsymbol{Z}_{\boldsymbol{h}_{NT\times(g_h-1+k_h)}} \boldsymbol{\delta}_{\boldsymbol{h}_{(g_h-1+k_h)\times 1}} + \boldsymbol{\varepsilon}_{\boldsymbol{h}_{NT\times 1}} \quad \boldsymbol{h} = 1,2,\ldots,\boldsymbol{g} \tag{1}$$

Where $\boldsymbol{y_h}$ is the column vector of data on the dependent endogenous variable, $\boldsymbol{Y_h}$ is the matrix of data on the $g_h - 1$ explanatory endogenous variables, $\boldsymbol{X_h}$ is the matrix of data on the included exogenous variables, $\boldsymbol{\delta_h}$ summarizes all the coefficients to be estimated in the equation and $\boldsymbol{NT}$ is the number of observations where $\boldsymbol{N}$ represents the number of countries included in the analysis and $\boldsymbol{T}$ is time. The $\boldsymbol{\varepsilon_h}$ is an NT×1 vector of error terms,

$$\boldsymbol{\varepsilon_h} = (\boldsymbol{I_N} \otimes \boldsymbol{\iota_T})\boldsymbol{\alpha_h} + \boldsymbol{u_h} \qquad (2),$$

with $\boldsymbol{\alpha_h}$ =($\boldsymbol{\alpha_{1h}}, \dots \dots \dots \dots, \boldsymbol{\alpha_{Nh}}$)′ and $\boldsymbol{u_h}$=($\boldsymbol{u_{11h}}, \dots \dots \dots, \boldsymbol{u_{1Th}}, \dots \dots \dots . \boldsymbol{u_{NTh}}$)′ where $\boldsymbol{\alpha_h}$ denotes the unobservable individual specific effect, $\boldsymbol{u_h}$ denotes the remnant disturbance, $\boldsymbol{I_N}$ isan N dimension identity matrix, $\boldsymbol{\iota_T}$ is a vector of ones of dimension T and $\otimes$ denotes Kronecker product. The objective of using simultaneous equations model is to explain the potential endogeneity of several explanatory variables. The endogeneity of the right-hand regressors is a serious econometric problem. It leads to the inconsistency and bias of the usual ordinary least squares (OLS) estimates since OLS doesn't differentiate between which of the explanatory variables in the equation are endogenous and which are exogenous. The problem evolves when applying least squares directly to estimate this equation using explanatory endogenous variables Y_h which are correlated with the stochastic disturbance termsε_h, even in probability limit. If these variables could be replaced by appropriate instruments, (i.e., related variables that are uncorrelated) in the probability limit, with the stochastic disturbance terms, the resulting estimator would be consistent. It is often difficult to find such instruments, however, the two-stage least squares (2SLS) method accomplishes this by replacing explanatory endogenous variables with their estimated values. It can be noticed that 2SLS distinguishes between explanatory endogenous variables Y_h and included exogenous variableX_h. The significance of 2SLS could be tested using Hausman test, where Y_h is exogenous under the null hypothesis. If 2SLS is utilized in the case of cross-section regression, the estimated parameters are consistent, but not efficient. At this point, the results of the analysis obtained from 2SLS need to be improved; the three stage least squares (3SLS) method can be adopted. The 3SLS technique is an improvement over 2SLS. While both are consistent, 3SLS is asymptotically more efficient than 2SLS. Since, the basic rationale for 3SLS, as opposed to 2SLS, is its use of information on the correlation of the stochastic disturbance terms of the structural equations in order to improve asymptotic efficiency (Maddala 1992; Intriligator et al. 1996; Wooldridge, 2010; Hsiao, 2022). On the other side, the estimation of simultaneous equations using panel data is considered a weighted combination of between cross-section, between time-period and within simultaneous equations system estimates (Baltagi 2008; Baltagi and Liu2009). Baltagi (1981) derived simultaneous panel data models, named as simultaneous equations with error components. Baltagi (1984) proved that simultaneous equations with error components have efficiency gains in terms of the mean squared error when performing error component two-stage least squares (EC2SLS) and error component three-stages least squares (EC3SLS) over the standard simultaneous equation counterparts, 2SLS and 3SLS, respectively. Therefore, this paper utilizes three different panel econometric techniques namely separate models, error components two stage least squares, and error components three stage least squares as potential estimation techniques for the simultaneous equations.

3.2 Integrated model

The unambiguous model specification of equation (1) that will be adopted, allowing the interrelationship of inequality, economic growth, climate change and natural disasters is described in equations (3a) and (3c), respectively. Following the work of Kahn et al. (2021) and Aiyar & Ebeke (2020), neoclassical stochastic growth model is as follows:

$$EG_{it} = \alpha_0 + \alpha_1 Gini_{\,it-1} + \alpha_2 Hit_{it-1} + \alpha_3 Intial\ GDP_{it} + \alpha_4 Invest_{it} + \alpha_6 urban_{it} + \alpha_7 climate_{it} + \alpha_8 instit_{it} + u_{it} \quad (3a)$$

Following the work of Cappelli et al. (2021), inequality model is as follows:

$$Gini_{it} = \gamma_0 + \gamma_1 Hit_{it-1} + \gamma_2 GDP_{t-1} + \gamma_3 HDI_{t-1} + \gamma_4 Exp_{t-1} + \gamma_5 Inst_t + v_{it} \quad (3b)$$

and natural disasters damage model is as follows:

$$Hit_{it} = \beta_0 + \beta_1 Gini_{\,it-1} + \beta_2 GDP_{it-1} + \beta_3 GDP_{t-1}^2 + \beta_4 Exp_{it-1} + \beta_5 Invest_{it-1} + + \beta_6 No.\ of\ disaster_{it} + \beta_7 No.\ of\ disaster_{it-1} + e_{it} \quad (3c)$$

Different econometric techniques under simultaneous equations system are adopted namely error components two-stage least squares, and error components three stage least squares, along with Hausman test to test if the three stage least squares is robust. In passing, note that not each and every variable needs to appear in each equation of the system described in equations 3a-3c. As a matter of fact, some variables need to be excluded in order to ensure identification. For the use of 3SLS, the system must meet the identification condition, according to which the number of excluded exogenous variables is greater than or equal to the number of included endogenous variables:

$$m_i \leq (K - k_i) \quad (4)$$

where m_i is the number of endogenous variables of the model; K is the sum of the number of exogenous variables in all equations (k_i) and the number of excluded exogenous variables (instruments) in all equations.

3.3. Data Sources

This paper constructs a panel database of 160 countries from year 1980- 2020 by matching country-level datasets and climate variables yearly time series. This includes income inequality, macroeconomic data, climate variables and finally climate-induced natural disasters. The World Income Inequality Database (WIID) and world development indicator are the sources of inequality variables. Climate variables, in our dataset, are terrestrial air temperature (°C), and precipitation (mm) obtained from Climate Change Knowledge Portal, World Bank Group. Our macroeconomic indicators, which we collected from World Bank Development Indicators (WDI) databases. Information on natural disasters comes from the Emergency Events Database (EM-DAT), which is a service of the Centre for Research on the Epidemiology of Disasters (CRED). The EMDAT reports the number of people killed, injured, or rendered homeless as well as the estimated monetary damage. A disaster is defined as an incident meeting any of the following criteria: (a) ten or more people reported killed; (b) 100 people reported affected; (c) declaration of a state of emergency; or (d) call for international assistance. Our primary measures for natural disasters are the intensity of the disasters and the estimated number of people affected by natural disasters. The EM-DAT divides natural disasters into six subgroups: biological (epidemic, pandemic, insect infection, and animal accident); geophysical (earthquake, volcanic activity, and mass movement); climatological (drought, glacial lake outburst, and wildfire); hydrological (flood, landslide, and wave action), meteorological (storm, extreme temperature, and fog); and extraterrestrial disasters (impact and space weather). The wet disasters are covering floods, landslides, and storms. The dry disasters are droughts, extreme temperatures, and wildfires. As we assume that the impact of natural disasters on inequality depends on the magnitude of disasters, we standardize our disaster measures as the estimated number of people affected by all disasters. Since the current year's population has been affected by the disaster itself, we divide the measures for the number of people affected by the population size in the year prior to the disaster (Cappelli et al., 2021; Moustafa and El-Shal, 2021).

4. Estimation Results and discussion

The simultaneous equation system illustrated in equations 3a-3c is estimated using EC2SLS, and EC3SLS. Furthermore, the Hausman test is used to investigate which method of estimation provides consistent and efficient estimators. Results of this test lead to the rejection of the null hypothesis, asserting that the differences in coefficients are not systematic at a one percent level of significance. Therefore, the 3SLS technique is an enhancement over 2SLS. This finding supports the existence of an interlocking relationship between economic growth, economic inequality, and natural disasters. Hence, they should not be treated separately as proposed by Cappelli et al. (2021) for economic inequality, and natural disasters. Baltagi (1981) demonstrated that EC3SLS reduces inefficiency in the EC2SLS if the disturbances of the different structural equations are uncorrelated with each other. This is different from the equivalence conditions between 2SLS and 3SLS in the classical simultaneous equations model (Baltagi, 2008).

The estimated models use the panel data described in the previous section. Discussion on the obtained results of the preferred model namely, EC3SLS is provided below.

The economic growth equation is based on GDP per capita growth as a function of Initial GDPPC, Gini index, Government effectiveness, lagged gross fixed capital formation, lagged HIT, urban population percentage of the total population, temperature anomalies and precipitation analogies. Gini index equation is a function of No. death toll + affected normalized by previous year population, lagged logarithmic function of GDP per capita PPP, lagged logarithmic function of square value of GDP PPP, lagged government expenditure as percentage of GDP, Number of dry disasters and Number of wet disasters. Finally, natural disaster is calculated using number of death toll + affected normalized by previous year population as a dependent variable and lagged logarithmic function of GDP per capita PPP, lagged logarithmic function of square value of GDP PPP, lagged government expenditure as percentage of GDP, Number of dry disasters and Number of wet disasters.

In EC2SLS, Initial GDPPC is added to the growth equation as proposed by the neoclassical theory of the long run growth model as it represents conditional rate of convergence (Barro 1991; Barro 1998; Barro and Sala-i-Martin 2004; Carlin and Soskice 2006, and Islam 1995). This kind of convergence highlights the fact that countries are not expected to converge to the same living standards unless they have similar important aspects such as saving rate and population growth. This implies that poor countries will not catch up and achieve the living standards of rich countries unless the former are able to change the determinants of their steady state. The Initial GDPPC estimate was significant. The Initial GDPPC is equal to -0.803 given all other variables remaining constant. The temperature anomalies are significantly negatively related to temperature. In the inequality equation, L.LnGDPpc is found to be significant. According to our results, both variables have a significant effect and the expected sign of coefficients. Hence the EC2SLS method of estimation embraces the existence of economic growth and inequality on one side and the existence of natural disaster and climate.

5. Conclusion and Expected Policy Implications

The results of this research will provide unique insight into the complex and intertwined relationships between growth, inequality, climate change and natural disasters. The main conclusion is that an interlocking relationship exists between these growth and inequality under the moderation of climate change on one side and inequality and natural disaster on the other side. Therefore, inequality is the mediating effect between natural disasters and economic growth. Each of those causes the other, while at the same time, being affected by it and therefore meaningful policy recommendations must involve a concerted effort to affect all three at once. Reducing inequality may hinder growth but can also boost it depending on the incentive structures and institutional regulations. Insisting on low environmental degradation may slow down growth but can also boost it through emphasis on green technologies that may ultimately be even more labor intensive, and hence more equitable. Lower inequality will ultimately reduce the intensity of economic losses from natural disasters, sparing countries even more severe losses as the frequency of such events intensifies. Moreover, the investment rate is found to directly force higher level of economic growth. Consequently, countries must have higher levels of gross capital formation. A carefully designed mix of policy solutions that tackles the three interrelated issues simultaneously is no longer a luxury, even for developing countries, given that our time to reverse climate change and its catastrophic impacts is about to run out. Last but not least, after the analysis of the results, we urge future studies to take into consideration the endogeneity problem and adopt panel datasets in order to improve the efficiency of econometric estimates.

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Tables

Table 1: Summary Statistics and data source

Variable	Variable description	Source	Obs.	Mean	Std. Dev.	Min	Max
HIT	No. death toll + affected normalized by previous year population	EM-DAT	6,715	0.02	0.07	0	1.2
Gini index	Gini index	WDI & WIID	1,728	38.33	9.01	20.7	65.8
GDPgrowth	GDP per capita growth	WDI	5,796	3.3	6.35	-64.05	149.97
GDPpc	GDP per Capita (PPP)	WDI	5,705	18065.5	20465.9	436.72	161972
HDI	Human development index	HDI	5,220	0.66	0.17	0.2	0.96
Govt. Exp	Government expenditure (% GDP)	WDI	5,216	16.89	8.86	0.91	147.72
Investment	Gross capital formation (% of GDP)	WDI	5,225	23.56	8.58	-12.88	79.4
Urban Pop (%)	Urban population (%)	WDI	6,871	56.91	24.55	5.34	100
N_Total	Total number of natural disasters	EM-DAT	7,744	0.87	1.17	0	7
N_Dry	Number of dry disasters	EM-DAT	7,744	0.23	0.53	0	4
N_Wet	Number of wet disasters	EM-DAT	7,744	0.52	0.74	0	3
Temperature anomaly	Yearly mean temperature anomalies	WB	5,888	0	8.5	-39.52	10.63

Precipitation anomaly	Yearly mean precipitation anomalies	WB	6,016	0	820.8	-1145.2	3521.2

Source: Authors' calculations

Table 2: Estimated regressions for separate models.

	Fixed Effects			Random effects		
	HIT	Gini	GDPgrowth	HIT	Gini	GDPgrowth
Gini index	-0.0003	-0.0003	0.1337**	0.0003	0.0003	0.0239
	0	0	-0.041	0	0	-0.021
L.lnGDPpc	0.0056	0.0056		0.0213	0.0213	
	-0.028	-0.028		-0.02	-0.02	
lnGDPpcsq	-0.0011	-0.0011		-0.0016	-0.0016	
	-0.002	-0.002		-0.001	-0.001	
L.Gov Exp	-0.0001	-0.0001		-0.0001	-0.0001	
	0	0		0	0	
L.N_DRY	-0.0040*	-0.0040*		-0.0023	-0.0023	
	-0.002	-0.002		-0.002	-0.002	
L.N_WET	-0.0004	-0.0004		0.0015	0.0015	
	-0.002	-0.002		-0.002	-0.002	
HIT			-1.8877			-3.9394
			-2.927			-2.379
Initial GDPPC						-1.0993***
						-0.316
L.Investment			-0.0091			0.0244
			-0.023			-0.018
Urban population (%)			-0.0699			-0.0189
			-0.037			-0.013
Government Effectiveness			-0.7248			-0.1085
			-0.562			-0.259
Precipitation anomaly			0.0003			0.0002
			-0.001			0
Temperature anomaly			-0.6273**			-0.0957***
			-0.224			-0.028

Constant	0.0753	0.0753	1.2347	-0.0577	-0.0577	13.1232***
	-0.134	-0.134	-3.48	-0.089	-0.089	-2.733
R2	0.0073	0.0073	0.0366			
N						

Source: Authors' estimation. * indicates significance at the 10 percent level, ** indicates significance at the 5 percent level, and *** indicates significance at the 1 percent level.

Table 3: Estimated regressions for the simultaneous model.

	EC2SLS			EC3SLS		
	HIT	Gini	GDPgrowth	HIT	Gini	GDPgrowth
Gini index	0.002		1.450***	0.007***		1.360***
	(0.002)		(0.253)	(0.002)		(0.227)
L.LnGDPpc	0.004	-0.983		0.026**	-2.608***	
	(0.012)	(0.850)		(0.011)	(0.626)	
L.LnGDPpc sq.	-0.020			-0.018*		
	(0.014)			(0.011)		
L.Govt. Exp	0.000	-0.065		0.001	-0.099**	
	(0.001)	(0.049)		(0.001)	(0.039)	
L.N_Dry	-0.003*			-0.002		
	(0.002)			(0.001)		
L.N_Wet	-0.002			0.001		
	(0.002)			(0.001)		
HIT		36.868**			51.511***	

		(18.358)			(15.063)	
L.HDI		-19.114***			-8.133**	
		(4.774)			(3.318)	
Government effectiveness		-0.108	0.143		0.070	0.171
		(0.486)	(0.798)		(0.381)	(0.790)
L.HIT			1.129			-1.154
			(3.369)			(2.930)
Initial GDPPC			-0.706***			-0.803***
			(0.169)			(0.125)
L.Investment			0.109***			0.068***
			(0.032)			(0.025)
Urban Pop (%)			0.114*			0.088*
			(0.064)			(0.050)
Precipitation anomaly			-0.000			-0.000
			(0.000)			(0.000)
Temperature anomaly			-0.048*			-0.106***
			(0.026)			(0.020)
Constant	0.001	0.254***	7.016***	0.000	0.193**	7.766***
	(0.001)	(0.098)	(1.545)	(0.001)	(0.096)	(1.143)
N						

Source: Authors' estimation. * indicates significance at the 10 percent level, ** indicates significance at the 5 percent level, and *** indicates significance at the 1 percent level.

Figures

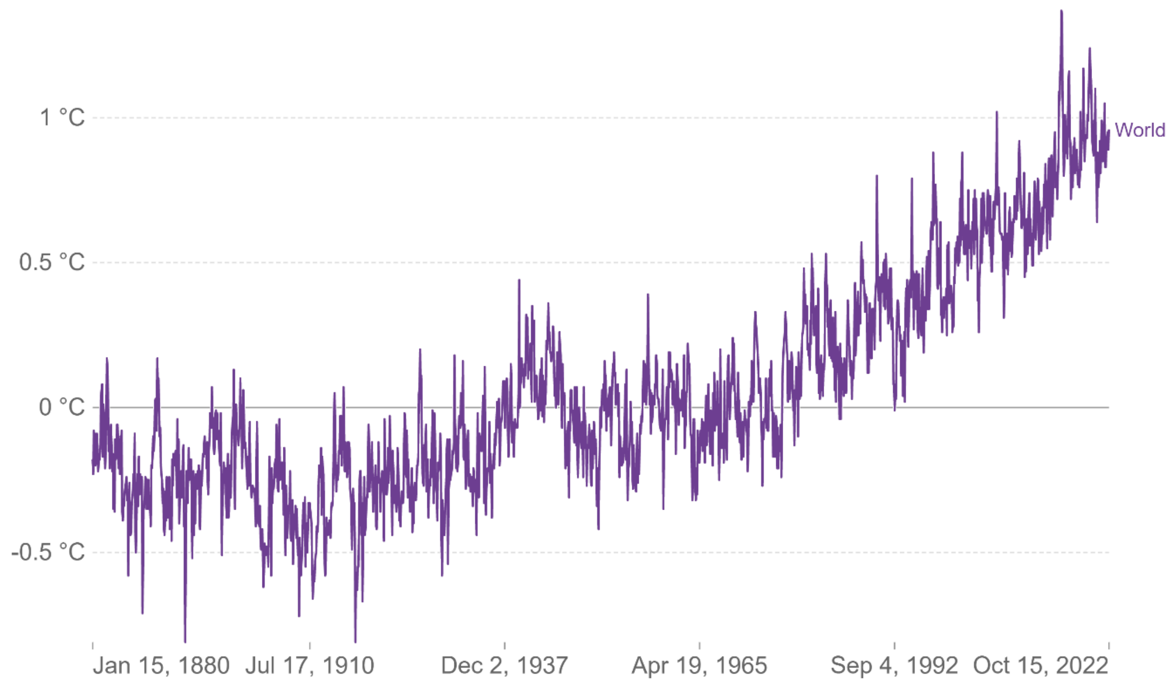

Figure 1: Global warming: monthly temperature anomaly (derivation from1951-1980 mean)

Source: National Aeronautics and Space Administration (NASA), Goddard Institute for Space Studies (GISS) (2022).

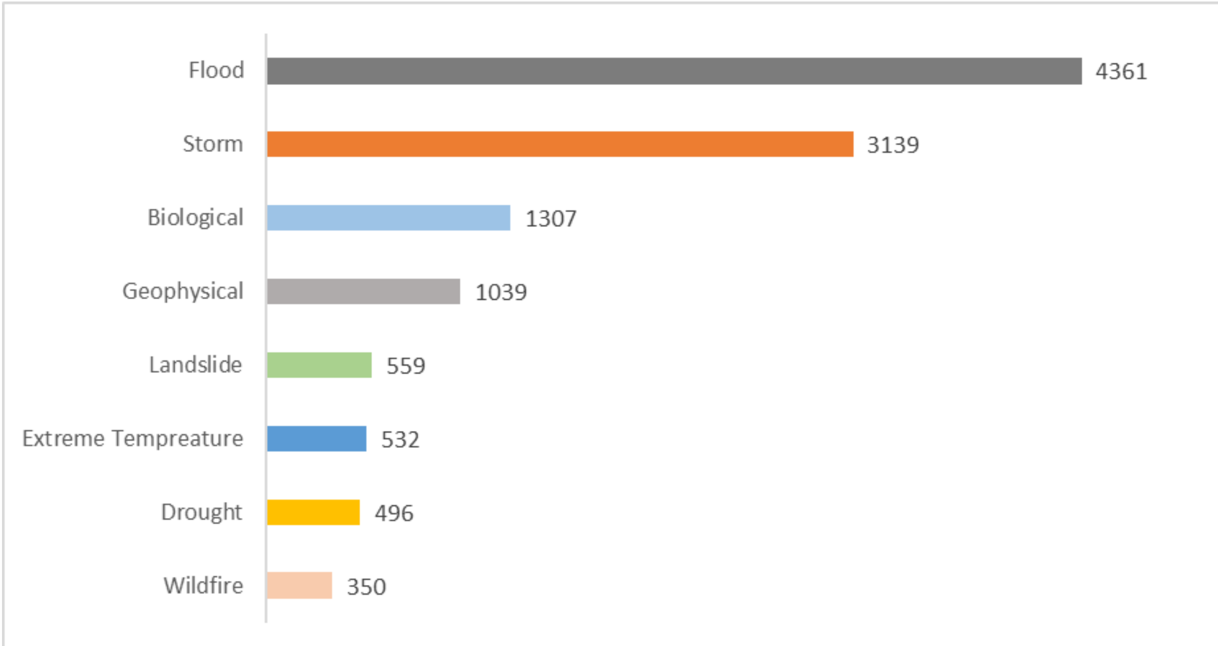

Figure 2: Number of Events per disaster 1990-2020.

Source: authors' calculations based on data from EM-DAT database (2022).

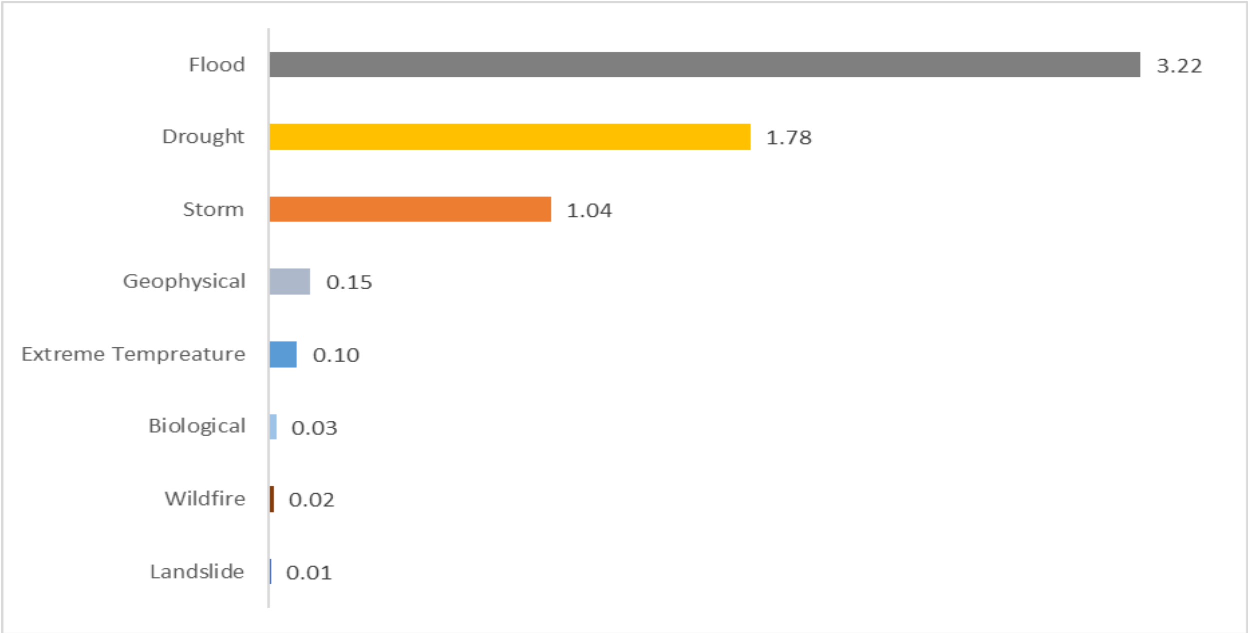

Figure 3: Number of persons hit by disaster 1990-2020 (in Billions).

Source: authors' calculations based on data from EM-DAT database (2022).

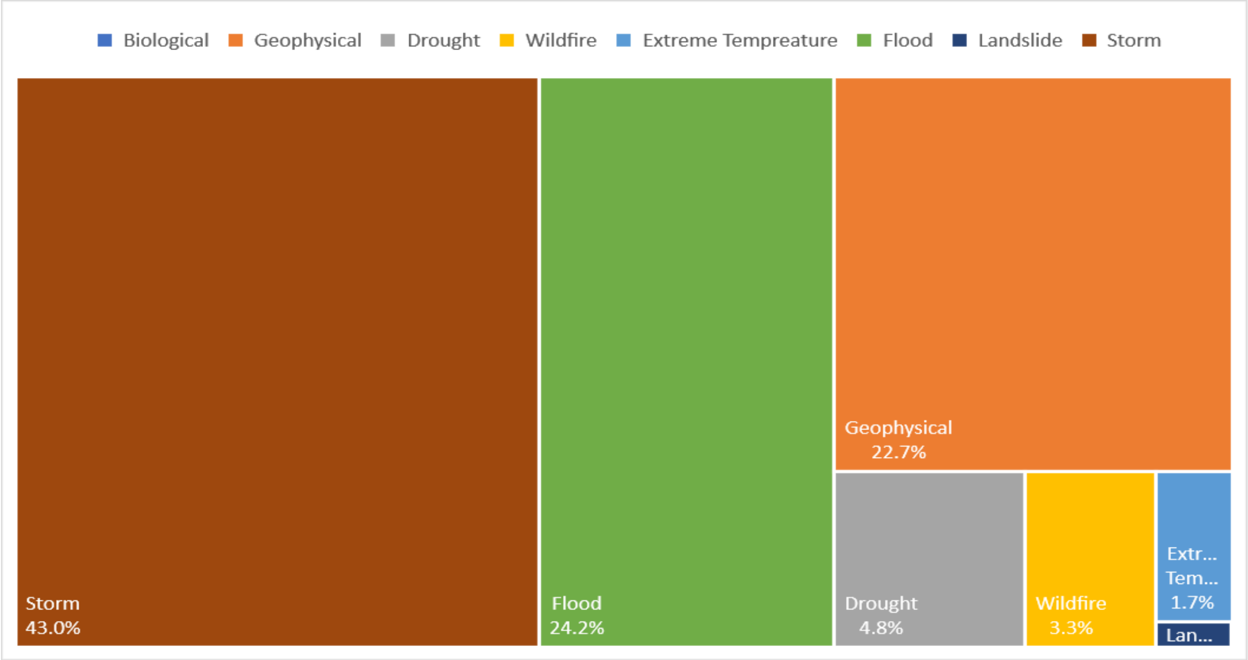

Figure 4: Adjusted total damage distribution per disaster 1990-2020 [Total = 4.6 billion dollars].

Source: authors' calculations based on data from EM-DAT database (2022).

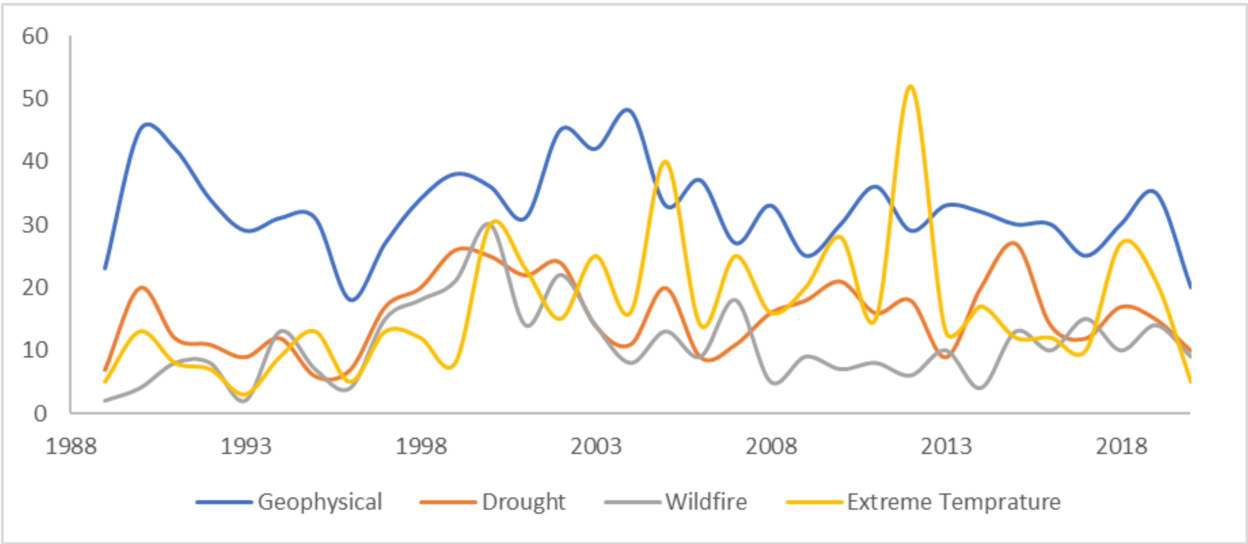

Figure 5: Time series plot for dry disasters count – Categorized

Source: authors' calculations based on data from EM-DAT database (2022).

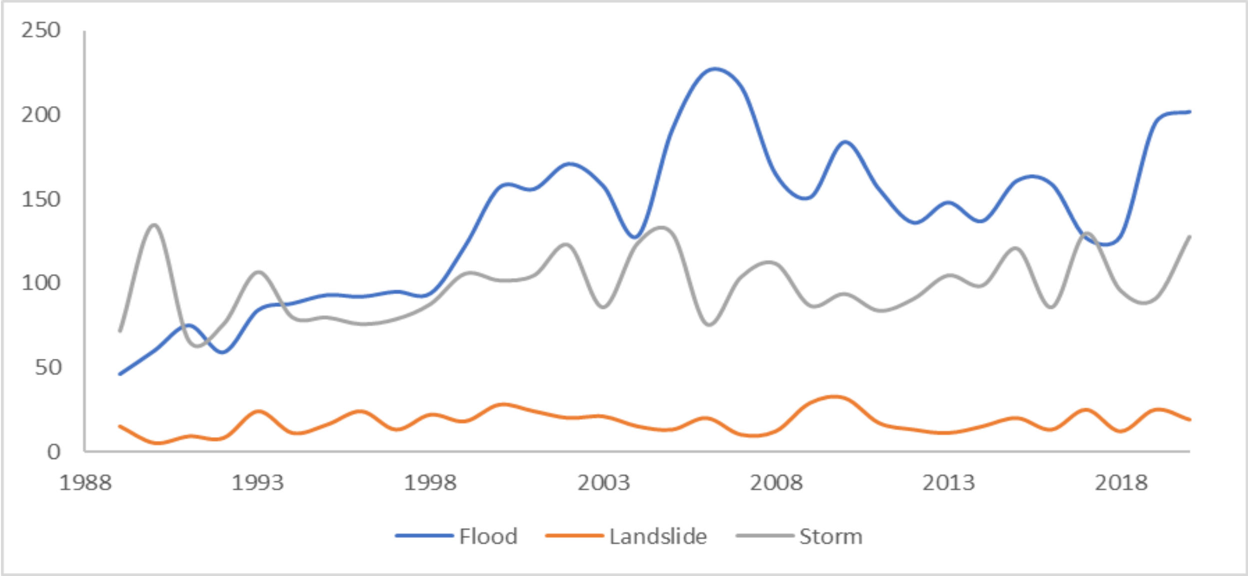

Figure 6: Time series plot for wet disasters count – Categorized

Source: authors' calculations based on data from EM-DAT database (2022).

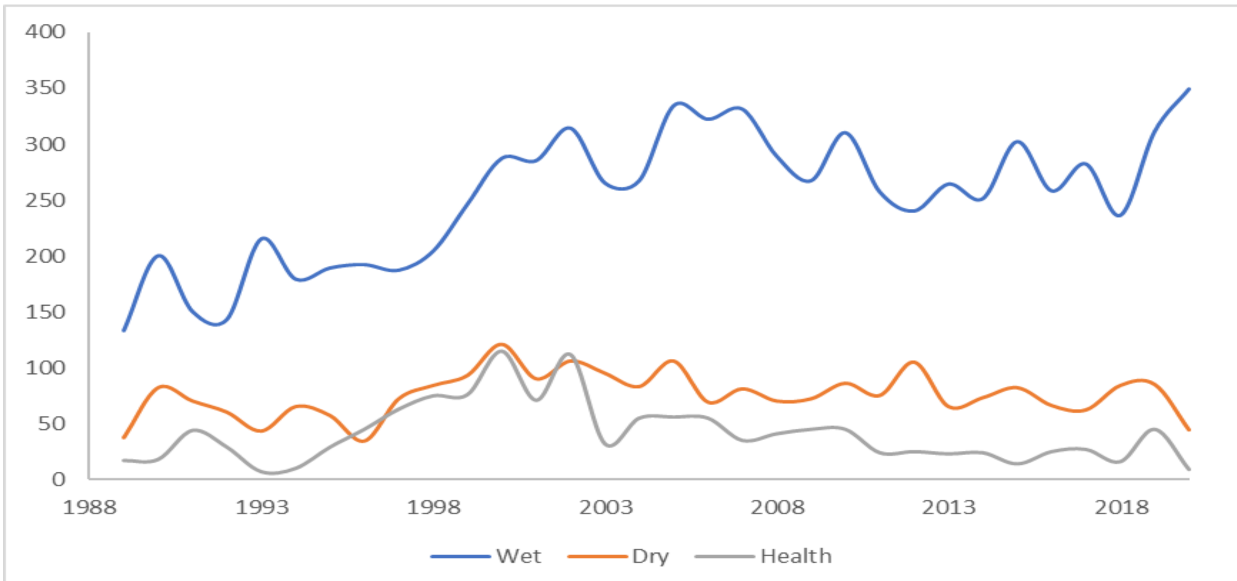

Figure 7: Time series plot for disasters count – Categorized

Source: authors' calculations based on data from EM-DAT database (2022).

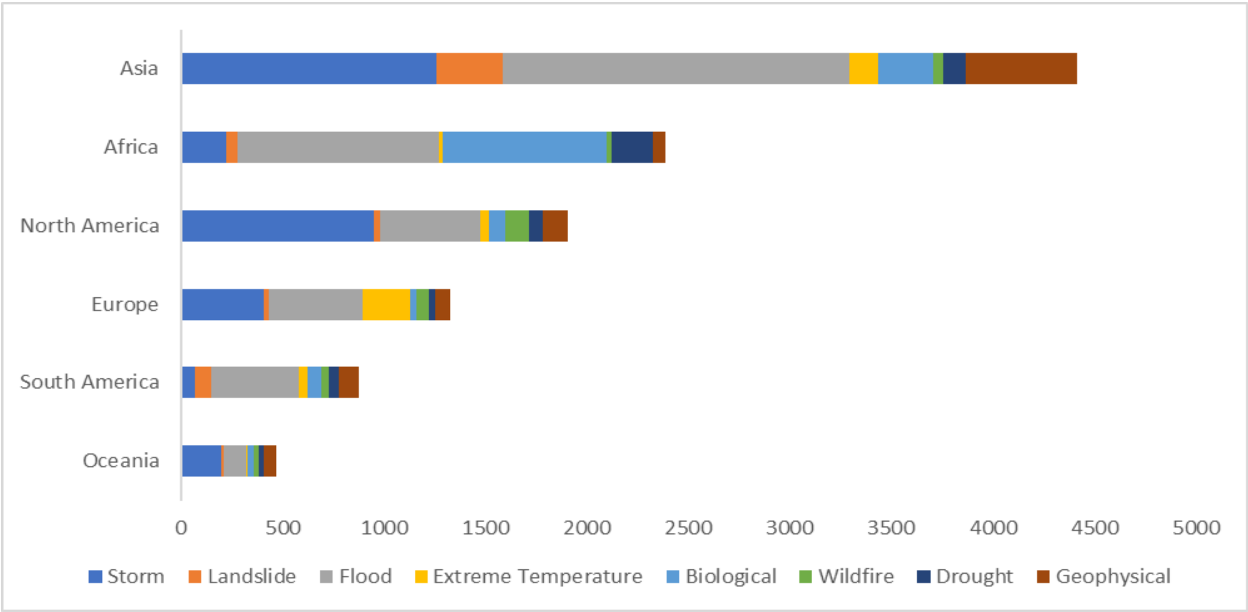

Figure 8: Number of disasters by continent 1989-2020

Source: authors' calculations based on data from EM-DAT database (2022).