Margin—The Journal of Applied Economic Research 13 : 1 (2019): 109–139
SAGE Publications Los Angeles/London/New Delhi/Singapore/Washington DC/Melbourne
DOI: 10.1177/0973801018800087

Economic Impact of Natural Disasters: An Empirical Re-examination

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Natural disasters cause serious economic and human losses. Yet there remains ambiguity in the existing literature with regard to their impact on the economy at large. This study re-examines the relationship between natural disasters and economic growth. It aims to contribute to a fairly limited literature on the economy-wide and sector-specific consequences of natural disasters in the short-to-medium term (up to 5 years). Further, it examines whether the disaster impacts are dependent on a country's level of development. Based on panel data consisting of 102 (29 developed and 73 developing) countries over the period 1981–2015, it looks at the growth effects of four types of natural disasters, namely, floods, droughts, storms and earthquakes that were explored using the system generalised method of moments (GMM) approach. The results indicate that natural disasters have diverse economic impacts across economic sectors depending on disaster types and their intensity. The study confirms the findings of previous studies that the economic impacts of natural disasters are statistically stronger in developing countries. These findings may stimulate the policymakers especially in developing countries to explore the efficacy of viable ex-ante disaster risk financing tools (such as insurance, micro-insurance and catastrophic bonds). This would not only safeguard population and physical assets but also ensure adherence to the sustainable development goals.

Keywords: *Natural Disasters, Economic Growth, Loss and Damages, Economic Development*
JEL Classification: *Q54, O10*

Acknowledgements: We would like to thank the anonymous reviewer for constructive comments and the editorial team for improving the overall quality of the article.

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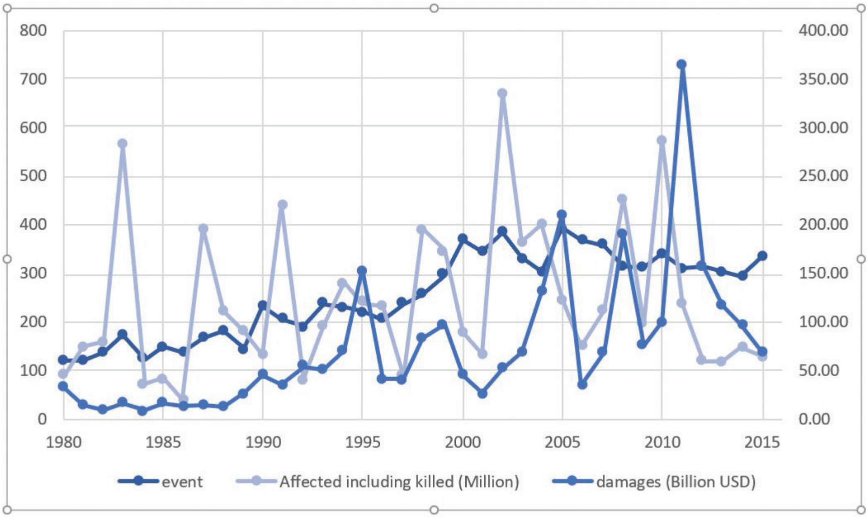
1. Introduction

The inherently destructive and disruptive nature of natural disasters may result in serious economic losses. The disaster literature although largely remains inconclusive, offering limited systematic evidence on how natural disasters affect economic growth (Cavallo & Noy, 2011; Fiala, 2017; Noy & DuPont, 2016). A few studies have examined the sector-specific (namely, agricultural, industrial, etc.) economic impact of natural disasters along with their impact on gross domestic product (GDP) growth (Fomby, Ikeda, & Loayza, 2013; Loayza, Olaberría, Rigolini, & Christiaensen, 2012, among others). The present study re-examines the relationship between natural disasters and economic growth and aims to contribute to the fairly limited disaster literature by estimating the disaster and sector-specific average growth effects in the short-to-medium term (up to 5 years). The motivation for this research was twofold. First, to quantify the short-term, economy-wide and sector-specific impacts of natural disasters which may assist the policymakers in their pre- and post-disaster recovery and reconstruction efforts, and second, to better understand the link between economic development and disaster resilience to enable the convergence of disaster risk reduction and development goals, which can also be the pathway to achieve the United Nation's sustainable development goals (SDGs).

In recent years, a significant rise in the frequency and intensity of natural disasters has resulted in severe loss of human lives and destruction of physical capital (Figure 1). The loss and damages caused by natural disasters are expected to rise further in future largely due to climate change and the increased disaster exposure and vulnerability of our modern societies (IPCC, 2012). In general, the nature of disasters and their impacts are localised. However, the direct damages (human deaths, injuries, property losses, etc.) caused by the initial impact of natural disasters may lead to indirect damages (of potential wages and capital) at the macro level in terms of forgone production and/or agricultural output, thereby affecting the country's GDP in the long term. Therefore, a study of the macroeconomic impact of natural disasters becomes highly relevant. The existing growth theories fail to provide robust inferences on the possible growth effects of natural disasters. The neoclassical theories postulate that natural disasters do not have any significant impact on technological progress. Disasters might increase growth in the short term by shifting economies from their normal growth paths. On the other hand, the endogenous growth models predict negative effects of natural shocks on gross production and subsequently on economic growth. The growth models based on Schumpeter's creative destruction theory advocate

Figure 1 Trends in Damages from Natural Disasters Worldwide, 1980–2015



Source: Authors' calculation using data from Emergency Events Database (EM-DAT) (Guha-Sapir, Below, & Hoyois, 2009).

that there may be positive effects of natural disasters on economic growth,[1] as the physical destruction caused by natural disasters may trigger greater investment in the reconstruction and/or upgradation of existing physical capital. The inconclusiveness of the existing growth models in explaining the growth effects of natural disasters has motivated the earlier empirical research in this area.

Due to similarities in the methodological approach, the results of the present study should either corroborate or diverge from those reported by earlier studies (e.g., Loayza et al., 2012; Noy, 2009). On that note, the present study has the following research objectives and diverse features. First, it contributes to disaster literature on the macroeconomic consequences of natural disasters. We widen the scope of investigation and use rich, updated data on natural disasters, which include some of the major natural disasters (in terms of the economic and human losses) that occurred in recent years, such as the 2015 Nepal earthquake, Chennai (India) floods in 2015, drought of East Africa in 2011–2012 and the Tohoku (Japan) earthquake and tsunami in 2011. These have proved

[1] Philippe Aghion, Howitt, and García-Peñalosa (1998) provided a theoretical explanation of Schumpeter's creative destruction theory. Okuyama (2003), Hallegatte and Dumas (2009), and Loayza et al. (2012) also found evidence in support of this theory, but their findings were limited to moderate or typical natural disasters.

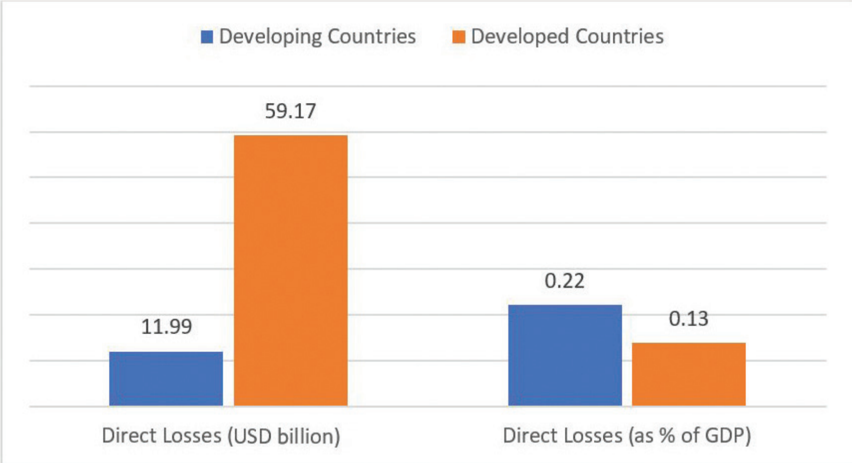
to be useful in drawing robust conclusions regarding the economic impact of natural disasters in developing countries since most of these events occurred in such countries. We use sectoral growth rates along with the overall GDP growth rate to capture the effects of different types of natural disasters (floods, droughts, storms and earthquakes) across economic sectors. For example, to analyse the impact of natural disasters on the agricultural sector we have used gross agricultural value added per capita at constant 2010 prices (valued in US dollar) derived from the *World Development Indicators*. We further classify natural disasters as either moderate or severe to check whether they significantly differ in terms of their economic impact. The classification of the disasters in terms of impact is explained under Section 3.

Second, this study considers two subsamples of countries classified as developed (OECD[2] member countries) and developing (non-OECD countries) to examine whether economic development influences the disaster impact. The preliminary analysis using GDP and disaster data show that in absolute terms, there is more direct economic damage due to natural disasters in developed countries. However, as a percentage of GDP, developing countries look more exposed to natural disasters (Figure 2): direct losses as a percentage of GDP was 0.22 per cent in developing countries over the period from 1980 to 2015, but for developed countries it stood at 0.13 per cent. This may possibly be an underestimate for developing countries since there may be underreporting of disaster losses. Further, estimates from the *World Risk Report* (UNU-EHS, 2016) show that most developing countries fall in the categories of medium-to-extreme high risk of natural hazards compared to developed countries, which mostly fall under the very low-to-low risk categories. Considering this important insight, this study on the effects of natural disasters on economic growth with reference to the level of economic development is relevant. It may assist in examining whether higher economic development helps in mitigating post-disaster damages more efficiently or not.

Third, by quantifying the average growth effects of natural disasters, this study may provide useful inputs to policymakers to ascertain the costs and benefits of investing in disaster risk reduction (DRR) which is one of the core policy objective of the Sendai Framework for Disaster Risk Reduction (SFDRR) (UN-General Assembly, 2015). On the methodological front, this study uses the system generalised method of moments (GMM) approach in dynamic panel settings (where T is smaller than N) to obtain robust estimators which are corrected for the invariably negative bias (refer Nickell, 1981) and endogeneity of regressors. Further, we use both continuous and binary measures of disaster impact to check the influence of these on the results, if any.

[2] Organisation for Economic Co-operation and Development.

Figure 2 Average Economic Damages from Natural Disasters by Country Groups,[3] 1980–2015



Source: Authors' calculation using data from EM-DAT (Guha-Sapir et al., 2009) and the World Bank (2016).

The rest of the article is organised as follows: Section 2 is based on a review of the literature. Section 3 describes the data and variables used in the study. Section 4 presents a review of the most popular estimation techniques used in this research area and the limitations of such techniques along with the empirical model, estimation methodology and test diagnostics used in this study. Section 5 discusses the results of estimation, followed by the concluding remarks in Section 6.

2. Economic Impact of Natural Disasters

The empirical relationship between natural disasters and economic growth has largely remained inconclusive with existing studies reporting positive, negative and even no effects, both in the short and long term. The contradictory results are surprising since most earlier studies were based on 5-year growth rates and used data on disasters primarily from the EM-DAT Database (Guha-Sapir et al., 2009). However, this is still a comparatively niche area, with limited economic research. Table A1 presents a summary of some of the important disaster impact studies conducted at the national level. In this section, we revisit the relationship

[3] The analysis was done using the sample of 29 OECD and 73 non-OECD countries included in this study.

between natural disasters and economic growth. As with Cavallo and Noy (2009), we consider the distinction between the short-to-medium-term impacts (up to 5 years) and the long-term impacts (10 years and beyond) of natural disasters.

2.1 Short-Term Impacts

Natural disasters are expected to disrupt economic activities in the short term due the direct and indirect damages they cause (Hochrainer, 2009; Okuyama, 2003). Direct damages occur in two forms: (a) loss of labour which includes human deaths, disabilities or injuries; and (b) loss of capital which includes loss of physical assets (damage to houses, factories and infrastructure). These direct losses may result in a further loss of potential labour hours (wages) and cause a decrease in the expected production output, say, agricultural or industrial output. The loss of potential wages and subsequent decrease in expected output may indirectly impact economic growth of the country, as the forgone wages would have been added to the country's GDP if the disaster had not happened (Noy & Nualsri, 2007). Most of the current research in this area finds the impact of natural disasters on short-term economic growth to be negative (Hochrainer, 2009; Hsiang & Jina, 2014; López, Thomas, & Troncoso, 2016; Noy, 2009; Raddatz, 2007). The negative impacts of relatively severe natural disaster are observed to be even stronger since large-scale destruction and damage caused by such events are more likely to decelerate economic growth or even trap the economy at a lower-level equilibrium (Fomby et al., 2013; Loayza et al., 2012; Noy, 2009). Developing countries are found to be more sensitive to the economic shocks of natural disasters than developed ones largely due to their limited capacity to cope with the economic and financial consequences of such events (Fomby et al., 2013; Loayza et al., 2012). Further, countries with higher levels of per capita income, better institutional frameworks, higher literacy rates, greater trade openness and more effective ex ante disaster risk financing mechanisms find it easier to absorb the economic shocks of natural disasters (Kahn, 2005; Noy, 2009).

Contrary to the findings that report adverse impacts from disasters, some studies find that natural disasters may also have a positive impact on economic growth in the short-to-medium term. Following a disastrous event, reinvestment in capital stocks and the upgraded technology may accelerate growth. A few older studies support this view (Albala-Bertrand, 1993; Okuyama, 2003; Otero & Martz, 1995) and some recent studies have found that the positive impacts of natural disasters were limited to specific economic sectors (e.g., the agricultural sector) and disaster types (e.g., floods) (Fomby et al., 2013; Loayza et al., 2012).

2.2 Long-Term Impacts

The long-term economic consequences of natural disasters are not clear, both theoretically and empirically. Natural disasters may have negative, positive and even no impact on long-term economic growth and development (Chhibber & Laajaj, 2013; Noy & DuPont, 2016). Like the short-term impact, natural disasters are expected to have a negative impact on long-term economic growth as well. The damage to human and physical capital may shift the growth paths of countries experiencing natural disasters to lower-level equilibriums, thereby causing a permanent negative impact in the long term (Berlemann & Wenzel, 2016; Jaramillo, 2009; Noy & Nualsri, 2007; Raddatz, 2009). Disruptions in health and education services are more likely to hamper the current stock of human capital and the future accumulation of skilled human capital (Baez, De Fuente, & Santos, 2010). More severe natural disasters often create high opportunity costs. The impact is more pronounced for developing countries as the funds mobilised for post-disaster response and recovery could have been used for other social welfare initiatives. Moreover, frequently recurring disasters can create an atmosphere of uncertainty and hamper long-term investment prospects in a country (Keen, Freeman, & Mani, 2003; Fiala, 2017).

The long-term positive impact of natural disasters can be explained by endogenous growth models based on the Schumpeterian creative destruction theory. Such models predict that growth in a disaster-affected location may accelerate following a negative shock due to reconstruction efforts which lead to higher investments and leave 'productivity effects' on the economy in the long term (Chhibber & Laajaj, 2013; Hallegatte & Dumas, 2009; Skidmore & Toya, 2002). Apart from the negative and positive impacts, a few studies have found that the growth effects of natural disasters fade away in the long term (Albala-Bertrand, 1993; Cavallo, Galiani, Noy, & Pantano, 2013; Klomp, 2015).

As mentioned earlier, the macroeconomic consequences of natural disasters remain a relatively niche area of research primarily because of challenges of data and methodology in establishing a statistically robust relationship. A comprehensive analysis in this regard may help in extending the theoretical and empirical framework to analyse the growth effects of natural disasters. This study contributes to the existing literature by providing new empirical evidence of probable short-to-medium-term growth effects of natural disasters and attempts to close the gap in understanding the economic consequences of natural disasters with respect to different stages of economic development.

3. Data and Methodology

3.1 Data and Variables

A panel of 102 countries over the period 1981–2015 was constructed for this study. The sample of selected countries includes 29 OECD (developed) and 73 non-OECD (developing) countries.[4] Following Loayza et al. (2012) and Noy (2009), we have organised the data into 5-year, non-overlapping periods to examine the medium-term growth effects of natural disasters and to control for missing observations. Three dependent variables were identified to represent economic growth: per capita growth rates of real GDP, gross agricultural value-added and gross non-agricultural value-added.[5] The per capita output was obtained by dividing the real value-added of respective sectors by the total population for a country-year since the country-level annual data on the number of workers in these two sectors were not available. All the growth variables were measured as the log differences of the 5-year averaged output. Following the review of literature, we included three sets of explanatory variables broadly classified as (a) natural disasters variables, (b) control variables that is standard determinants of economic growth and (c) proxies of external shocks other than natural disasters. The data on all the variables, except for the natural disasters variables, were obtained from the *World Development Indicators* (The World Bank, 2016). Table 1 presents the descriptive statistics of the economic growth and disaster-intensity variables appearing in the analytical portion of this study.

As with the growth model specifications of Levine, Norman, and Beck (2000) and Dollar and Kraay (2004), we have used the following variables as standard determinants of growth. The logs of the initial outputs corresponding to respective dependent variables were used to control for the initial conditions or lagged effects (refer Loayza et al., 2012). Similarly, the logs of the gross secondary enrolment ratios (for both genders) were taken as a proxy for education conditions at the beginning of each period. This is the ratio of the number of students enrolled in schools to the total number of children of secondary schooling age (13–16 years). Since education attainment is assumed to have a delayed effect on economic growth through technological progress (refer Romer, 1990), this measure seems justifiable. Furthermore, it may be linked with the SDGs since quality education is one of the targets. The log of

[4] The list of countries is presented in Table A2 in the Appendix.

[5] As per the *World Development Indicators*, the non-agricultural value added includes the industrial value added (value added in mining, manufacturing, construction, electricity, water and gas) and services value added (value added in wholesale and retail trade, transport, and government, financial, professional, and personal services).

Table 1 Descriptive Statistics (5-year Average Data)

	Mean	*Std. Dev.*	*Minimum*	*Maximum*
All Countries (*N* = 102, *n* = 714)				
GDP growth (in log-differences)	0.19	0.45	−3.76	1.88
Agricultural growth (in log-differences)	0.31	0.69	−5.64	3.36
Non-agricultural growth (in log-differences)	0.01	0.03	−0.18	0.17
All disasters (in logs)	−6.94	3.66	−17.14	−1.56
Floods (in logs)	−8.71	3.61	−17.48	−1.88
Drought (in logs)	−11.38	4.18	−15.08	−1.56
Storms (in logs)	−11.60	3.83	−19.70	−1.84
Earthquakes (in logs)	−12.44	2.63	−18.96	−2.91
Non-OECD Countries (*N* = 73, *n* = 511)				
GDP growth (in log-differences)	0.21	0.52	−3.76	1.87
Agricultural growth (in log-differences)	0.32	0.78	−5.64	3.36
Non-agricultural growth (in log-differences)	0.01	0.03	−0.18	0.17
All disasters (in logs)	−5.87	3.16	−15.67	−1.56
Floods (in logs)	−7.79	3.43	−17.49	−1.88
Drought (in logs)	−10.51	4.58	−15.08	−1.56
Storms (in logs)	−11.17	3.90	−19.71	−1.84
Earthquakes (in logs)	−12.41	2.67	−18.97	−2.91
OECD Countries (*N* = 29, *n* = 203)				
GDP growth (in log-differences)	0.18	0.18	−0.46	0.98
Agricultural growth (in log-differences)	0.28	0.42	−1.73	1.78
Non-agricultural growth (in log-differences)	0.01	0.01	−0.03	0.07
All disasters (in logs)	−9.63	3.45	−17.14	−1.84
Floods (in logs)	−11.01	2.93	−16.79	−3.69
Drought (in logs)	−13.58	1.39	−13.81	−2.53
Storms (in logs)	−12.67	3.42	−19.08	−3.00
Earthquakes (in logs)	−12.54	2.55	−16.12	−3.28

Source: Authors' own.

government's final consumption expenditure over GDP was taken as a proxy for government's financial burden. Price stability at the macroeconomic level was measured by the log of the annual growth rate of the consumer price index (CPI). Economic openness was denoted as the ratio of (the log of) total trade volume (real imports plus export) to GDP. Similarly, the log of the total domestic credit to the private sector over GDP was taken as a proxy for financial depth, reflecting the development and ease of access to financial services in a country. Following Loayza et al. (2012), to control for external shocks other than natural disasters, the growth rate in the terms of trade (in log difference) and period-specific dummies were used. The former represents the growth rate of export prices relative to import prices for a country.

The data on various variables capturing occurrences, types and frequency of natural disasters were obtained from the EM-DAT database maintained by the Centre for Research on the Epidemiology of Disasters (CRED). This database provides information on disaster-related mortality, total economic damages and number of people affected due to natural and manmade disasters. Despite having few limitations,[6] EM-DAT continues to be the most prominent and reliable disaster database. Since EM-DAT provides data on economic damages, it may be used as a disaster-intensity variable. Most researchers have abstained from using this measure as an independent variable, although a few have used it as a dependent variable (e.g., Cavallo et al., 2013; Toya & Skidmore, 2007). There is a suspicion that the economic damage data may be endogenous to GDP. The disaster loss estimates are mostly recorded based on the relief and recovery expenditures incurred following a natural disaster, and the chances of these estimates being correlated with GDP growth of a particular year are very high. Therefore, using it as an independent variable may result in a spurious regression.

In disaster literature, a more appropriate measure of disaster intensity is the total number of people affected including those killed. Researchers have used this variable as a count measure (Klomp, 2015; Loayza et al., 2012; Noy, 2009) as well as a binary measure (Fomby et al., 2013; McDermott, Barry, & Tol, 2013), with some threshold or decision rule (e.g., 30% of the total people affected).

[6] The disaster-related data obtained from EM-DAT have the following shortcomings which may hamper the robustness of the estimates derived during econometric analysis. First, the disaster data for many events is not reported and, therefore, it is difficult to verify whether it is missing or whether there were no damages that is there are zero economic losses (human and property losses) corresponding to that event. Second, there may be a time bias in the EM-DAT disaster dataset not only due to the increased incidence of natural disasters but also because of improved recording and reporting techniques in recent years. Third, the accuracy of the disaster data depends on the accuracy of the data collection methods used by primary agencies which provide data to EM-DAT.

In this study, both continuous and count disaster intensity measures were used without any decision rule. We have taken the total number of people affected including human deaths over the total population (in logs) as a continuous disaster intensity variable. The population of the lagged year (1-year lag) was used to adjust the disaster intensity variable so that the disaster-affected population for a particular year can be excluded from the total population of that year. We collected data on different disaster types, namely, droughts, floods, earthquakes and storms, and used the binary disaster intensity variables to segregate the growth effects of severe and moderate disasters. Following earlier studies (Fomby et al., 2013; IMF, 2003), we have created disaster intensity dummies for each type of disaster included in this study.

The measure of disaster intensity $D_{i,tt}$ for moderate (typical) natural disasters is given by:

$$D_{i,t}(k) = \sum_{m=0}^{n} \text{Disaster Intensity}\begin{pmatrix} k \\ i,t,m \end{pmatrix} \quad (1)$$

and,

$$\text{Disaster Intensity}\begin{pmatrix} k \\ i,t,m \end{pmatrix} = 1,$$

$$\text{if} \frac{\text{Number of people affected including killed.}_{i,t,m}^{k}}{\text{Population.}_{i,t-1}} > 0.0001$$

$$= 0, \text{otherwise} \quad (2)$$

where, m represents the total number of k type events (floods, droughts, storms and earthquakes) that occurred in country i at time t. The disaster dummies were created to measure the intensity of the disasters, where a variable takes value one if disaster intensity was greater than 0.01 per cent and zero otherwise. The summed-up values of all the disasters result in a combined disaster intensity variable that represents the magnitude of the total number of k type events that occurred in country i at time t. Similarly, for capturing the growth effects of severe natural disasters, we have used a threshold of 1 per cent of the total population instead of 0.01 per cent. The creation of disaster dummies for severe natural disasters follows the same method.

3.2 Estimation Methodology

Panel data techniques have been widely used for the empirical validation of growth theories. Studies exploring the relationship between natural disasters and economic growth have used panel fixed effects models since they allow for controlling the unobserved time-invariant heterogeneity and time-variant shocks that are common for all cross-sectional units (e.g., global business cycles, global financial crises, etc.). In the case of a dynamic panel model, which is also the case for this study, certain estimation difficulties may restrict the robustness of the estimates. One major issue that arises in a dynamic panel setting is the correlation between the regressors and the error term, referred to as the problem of endogeneity. Due to endogeneity, the ordinary least square (OLS) estimates become inconsistent and therefore unreliable (Wooldridge, 2013). Researchers suspect that the use of EM-DAT may also lead to the problem of endogeneity. The extent to which a natural disaster translates into economic damages would depend on many omitted factors which may differ from country to country, such as the ex ante and ex post disaster management and institutional quality, among others. Therefore, it is useful to take endogeneity into account while using the EM-DAT dataset to arrive at robust results.

Another issue that may arise while using fixed effects in dynamic panel models is an invariably negative bias in estimators called the 'Nickell bias'. Nickell (1981) argued that the demeaning process which subtracts the means of dependent and independent variables from their respective values may lead to correlation between the error term and the regressors which results in biased estimators. Loayza et al. (2012) and Klomp (2014) have used the generalised method of moments (GMM) to remove this bias and potential endogeneity problem in dynamic panel models for small *Ts*. Following such studies, we have used the GMM estimation in this study. GMM is based upon differencing regressions and uses the lag values of the dependent and independent variables as instruments. Our model specification follows Noy (2009) and Loayza et al. (2012).

$$Y_{i,t} = \alpha + \beta_0 Y_{i,t-1} + \beta_1 D_{i,t} + \beta_2 X_{i,t} + \mu_i + \theta_t + \varepsilon_{i,t} \qquad (3)$$

where, the subscripts i and t stand for country and year, respectively. $Y_{i,t}$ represents the respective dependent variables and $Y_{i,t-1}$ is the first lag of $Y_{i,t}$. $D_{i,t}$ represents the natural disaster variable/s, and $X_{i,t}$ is the set of control variables; μ_i represents country-specific heterogeneity; θ_t represents year fixed effects; $\varepsilon_{i,t}$ the error term; and α the intercept.

We have used system GMM estimators developed by Arellano and Bover (1995) and Blundell and Bond (1998), over the difference estimators to remove potential biases associated with difference estimators and to avoid the problem of weak instruments which may often lead to poor small sample properties and relatively larger standard errors in fixed effects estimation (Arellano & Bond, 1991; Kiviet, 1995). The system GMM creates one system of equations by combining the regression equations in differences and in levels. The lagged values of explanatory variables were used as instruments for difference estimators and the lagged differences of the explanatory variables were used for equations in levels. It was assumed in that system GMM that there is no serial correlation in the error terms and the regressors are not correlated with the error term that is weakly exogenous regressors. To test the validity of the instruments used, the Hansen test for overidentified restrictions was considered with the null hypotheses supporting the validity of instruments during the estimation. To check whether the error terms were serially correlated, the Arellano–Bond test for AR (1) and AR (2) was used. Failure to reject the null hypotheses in this test supports the estimated model.[7]

3.3 Diagnostic Tests

To obtain consistent and statistically robust results, we conducted a series of diagnostic tests. We started with testing for the poolability of the cross-sectional and time-series data so that it may be declared a panel data. The Chow test (Chow, 2010) was used for this purpose with the null hypothesis supporting the poolability of data. We failed to reject the null at the 10 per cent level of significance. Since the study focuses on a panel data with 35-year time frame, the time-series properties of the data set needed to be examined. To check for a possible non-stationarity problem, the Levin, Lin, and Chu (2002), and Im, Pesaran, and Shin (2003) tests were used. These tests detected the presence of a unit root for the log of the respective dependent variables in levels. The output growth variable (in log-differences), although, seemed to be stationary.[8] To choose between the fixed effects and random effects models, we used the standard Hausman (1978) test, which yielded in favour of the fixed effects model. To check for the presence of time-fixed effects, a joint test of significance for all the period dummies was conducted. The null hypothesis was rejected at the 1 per cent level of significance suggesting the presence of year-fixed effects.

4. Results and Discussion

In this section, we present the models estimated and the results relating to the growth effects of natural disasters under three subsections. Section 4.1 presents a discussion of the results based on the full sample (102 countries). The results obtained from the subsamples of developing (73 countries) and developed

[7] AR(1) and AR(2) are standard usage in time series econometrics.
[8] The unit root tests results are presented in Table A3 in appendix.

countries (29 countries) are presented in Section 4.2. Finally, the growth effects of moderate and severe disasters are discussed in Section 4.3. The Hansen specification and the serial correlation tests were undertaken to validate the statistical robustness of the regression models estimated. The *p*-values of the two tests have been reported.

Table 2 presents the results for the full sample of 102 countries. We have used the same set of control variables and proxy variables for external shocks in all the estimated regression models.[9] The results pertaining to control variables support the existing studies and are observed to be consistent across estimated models. The coefficients of the proxies for the government's financial burden and inflation were negative and significant in most cases (except for agricultural growth in Model 3), indicating an adverse economic impact of fiscal imbalances and price instability at the macroeconomic level. Economic openness showed a positive and significant effect, indicating that a favourable economic climate or regime may have a greater impact on knowledge and technology transfered among countries through trade. The coefficients for financial depth were positive and significant in most cases (except for non-agricultural growth in Model 4), suggesting favourable economic significance of easier access to financial services for households and private businesses in an economy. The gross secondary enrolment ratio reveals a favourable impact on economic growth variables. The coefficients of the terms of trade growth rate were positive and significant in most cases signifying the beneficial impact of better terms of trade on economic growth.

4.1 Growth Effects of Natural Disasters

As in Table 2, the cumulative disaster intensity variable is not significant (Model 1), however, when we segregate the natural disasters into different sub-groups, we observe more insightful estimates. Contrary to expectations, floods have significant positive impact on agricultural growth, although these results are in line with those reported by Loayza et al. (2012) and Fomby et al. (2013) concerning floods. Floods, on average may increase medium-term agricultural growth by 2.13 percentage points (represented as pp. hereafter) (0.43 pp. annually, in Model 3) and GDP growth by 2.68 pp. (0.54 pp. annually, in Model 2). In general, water is critical for agriculture, but excess supply of water may be harmful for crops. In this sense, the positive effects of floods on agricultural growth are quite surprising. As highlighted by Fomby et al. (2013) and Loayza et al. (2012), these effects may be attributed to the timing of the

[9] We have reported the coefficients for the control variables only in Table 2.

Table 2 Growth Effects of Natural Disasters for All Countries in the Sample

		Dependent Variables			
		(1)	*(2)*	*(3)*	*(4)*
Disasters Intensity Variables	*Expected Signs*	*GDP Growth*	*GDP Growth*	*Agricultural Growth*	*Non-agricultural Growth*
By Disaster type					
Floods	(−)		**0.0268****	**0.0213****	0.0020
			(0.0126)	(0.0095)	(0.0014)
Droughts	(−)		−0.001	**−0.0054***	−0.0005
			(0.0125)	(0.0076)	(0.0009)
Storms	(−)		−0.0085	−0.0010	0.0007
			(0.0094)	(0.0084)	(0.0013)
Earthquakes	(−)		0.0165	−0.0086	**0.0043****
			(0.0201)	(0.0111)	(0.0021)
Collective disaster variable	(−)	0.0350			
		(0.0126)			
Control Variables					
Initial output	(+)	0.3816**	0.3679***	0.3118***	2.1468***
		(0.0586)	(0.0646)	(0.0571)	(0.4763)
Education	(+)	0.0805*	0.0688	0.1841**	0.0037
		(0.0426)	(0.0474)	(0.0921)	(0.0052)
Terms of trade	(+)	1.4744***	1.1913**	−0.3602	0.1057***
		(0.3705)	(0.5613)	(0.4012)	(0.0270)
Government financial burden	(−)	−0.0209**	−0.0013*	−0.1023*	−0.0122*
		(0.0598)	(0.0748)	(0.1442)	(0.0089)
Inflation	(−)	−0.2567***	−0.2434***	0.6709**	−0.0436***
		(0.0691)	(0.0490)	(0.2457)	(0.0126)
Economic openness	(+)	0.0449*	0.0737*	0.1793**	0.0013*
		(0.0447)	(0.0447)	(0.0866)	(0.0041)
Financial depth	(+)	0.0501*	0.0425*	0.1410*	−0.0057
		(0.0263)	(0.0241)	(0.0863)	(0.0053)
Number of Instruments		49	52	52	52
Number of Observations		612	612	612	612
Number of Countries		102	102	102	102
Hansen Test for Overidentified Restrictions (*p*-values)		0.514	0.517	0.144	0.487
Arellano-Bond Test for AR (1) in First Differences		0.002	0.002	0.001	0.000
Arellano-Bond Test for AR (2) in First Differences		0.425	0.552	0.358	0.410

Source: Authors' calculations using data from EM-DAT and the World Bank.
Notes: Standard errors are in parentheses. The time (period) fixed effects and constant terms were also included, however, their coefficients are not reported here. [* 10% level of significance, ** 5% level of significance and *** 1% level of significance]
The values in bold are the statistically significant independent variables.

occurrence of floods that is the effects of floods may be on one cropping season out of the multiple cropping seasons, thereby resulting in an abundant supply of water throughout the year. Consequently, they may trigger higher GDP growth through the transmission mechanism especially in agriculture-based economies (Cunado & Ferreira, 2014; Fomby et al., 2013). The possibility of floods having a positive growth effect is referred to as the 'productivity effect', where disasters can only affect production or output levels but cannot affect the economy at large (Hallegatte & Dumas, 2009).

Like floods, earthquakes have a positive relationship with GDP growth and non-agricultural growth, although the effects are significant only for the latter. Earthquakes seem to trigger an increase of 0.4 pp. in non-agricultural growth (Model 4). The positive effects of a natural disaster (in this case floods and earthquakes) find support from Schumpeter's creative destruction theory as well, indicating that the damages and destruction caused by such events may trigger greater investment in reconstruction and/or upgradation of houses and public infrastructure which may ultimately enhance the country's GDP in the short-to-medium term.

The effects of droughts on agricultural growth are observed to be negative. The scarcity of water certainly has a negative impact on agricultural output, indicating the critical importance of water for agriculture. In general, the impact is more severe in subsequent years (or cropping seasons) following a drought event mainly because it is a slow on-set disaster. Further analysis of the same is beyond the scope of this study. The effects are relatively weak in magnitude and significant only for agricultural growth (a reduction of 0.11 pp. annually in Model 3). There are many empirical studies reporting a strong negative impact of droughts on agricultural growth (Berlemann & Wenzel, 2016; Dercon, 2004; Hlavinka et al., 2009, among others). The effects of storms on economic growth variables are mostly negative, however, none of the coefficients are significant. Unlike the findings of Fomby et al. (2013) and Loayza et al. (2012), we did not find any significant impact of droughts and storms on GDP growth and agricultural growth, respectively.

4.2 Influence of the Levels of Development on Disaster Impact

Several studies claim that developing countries are more sensitive to natural disasters largely due to their limited capacities to deal with such events (Mahul et al., 2014). To empirically test this claim, we compared the growth effects of natural disasters in developing and developed countries. Table 3 presents the results relating to developing countries. The growth effects are stronger both in magnitude as well as significance (more variables are significant) in developing countries compared to the full sample of countries and developed countries.

Table 3 Growth Effects of Natural Disasters in Developing Countries

	Dependent Variables			
Disasters Intensity Variables	*(1) GDP Growth*	*(2) GDP Growth*	*(3) Agricultural Growth*	*(4) Non-agricultural Growth*
By Disaster type				
Floods		**0.0331****	**0.0516****	**0.0026****
		(0.0251)	(0.0197)	(0.0016)
Droughts		–0.0103	**–0.0122****	–0.0001
		(0.0138)	(0.0099)	(0.0012)
Storms		**–0.0162***	**–0.0161***	0.0007
		(0.0118)	(0.0112)	(0.0011)
Earthquakes		–0.0165	–0.0039	**–0.0211***
		(0.0255)	(0.0113)	(0.0019)
Collective disaster variable	0.0456			
	(0.0153)			
Controls (same as in Table 2)	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes
Period Fixed Effects	Yes	Yes	Yes	Yes
Number of Instruments	49	52	52	52
Number of Observations	438	438	438	438
Number of Countries	73	73	73	73
Hansen Test for Overidentified Restrictions (*p*-values)	0.737	0.560	0.164	0.263
Arellano-Bond Test for AR (1) in First Differences	0.006	0.002	0.000	0.086
Arellano-Bond Test for AR (2) in First Differences	0.710	0.603	0.520	0.998

Source: Authors' calculations using data from EM-DAT and the World Bank.
Notes: Standard errors are in parentheses. [* 10% level of significance, ** 5% level of significance and *** 1% level of significance].
The values in bold are the statistically significant independent variables.

The impacts of floods and droughts on agricultural growth are relatively stronger in developing countries. Floods on an average may enhance annual GDP growth by 0.67 pp. (Model 2), annual agricultural growth by 1.03 pp. (Model 3) and annual non-agricultural growth by 0.06 pp. (Model 4). Droughts have a statistically significant negative impact on agricultural growth but no significant impact on GDP growth. Droughts may cause an average drop of 0.24 pp. (Model 3) in annual agricultural growth.

As highlighted by Loayza et al. (2012), the stronger growth effects of floods and droughts in developing countries may be due to the fact that they are predominantly agrarian economies. There are limits to financial access in the rural areas of most of the developing countries considered for this study. The absence of financial services may force small farmers to liquidate their assets and livestock to survive in the aftermath of a drought thereby risking their future growth prospects. Storms are observed to have significant negative effects on GDP growth and agricultural growth in developing countries (Models 2 and 3), causing an average annual reduction of about 0.32 pp. in GDP growth and agricultural growth, respectively. Previous studies have also highlighted that storms can severely damage or destroy crops as well as the irrigation facilities, tools and machinery (Fomby et al., 2013; Schumacher & Strobl, 2011, among others). Contrary to our earlier results, earthquakes are found to negatively affect non-agricultural growth in developing countries.

The growth effects of natural disasters in the developed-country sample (Table 4) were comparatively weaker than in the developing countries. The disaster-intensity variables show similar signs as in the earlier estimation. It is however clear from the above set of results that the impact of disasters was relatively weaker in developed countries than in developing countries, both in magnitude and statistical significance. As reported by Noy (2009), developed countries are well equipped to absorb economic shocks following natural disasters due to effective pre-disaster preparedness, disaster risk financing mechanisms, public policy, disaster-resilient infrastructure and proactive private support for disaster risk reduction. These capacities make them less vulnerable and more resilient towards the adverse impacts of natural disasters (Ghesquiere & Mahul, 2010; Mahul et al., 2014). In general, such capacities are either limited or missing in developing countries.

4.3 Moderate Versus Severe Natural Disasters

Table 5 presents the growth effects of moderate and severe natural disasters in developing countries (since this sample was more sensitive to natural disasters). The results for moderate disasters are found to be similar to our earlier estimation using a continuous disaster intensity variable. Therefore, these results further validate our earlier estimated results.

The growth effects of severe natural disasters are either negative or insignificant across growth variables. Unlike moderate disasters, severe disasters show strong negative effects on economic growth with greater magnitude of disaster coefficients across all disaster types. This is true even for floods which had shown positive effects on economic growth in the earlier estimations.

Table 4 Growth Effects of Natural Disasters in Developed Countries

	Dependent Variables			
Disasters Intensity Variables	*(1) GDP Growth*	*(2) GDP Growth*	*(3) Agricultural Growth*	*(4) Non-agricultural Growth*
By Disaster type				
Floods		0.0035	**0.0422***	−0.0013
		(0.0067)	(0.0289)	(0.0010)
Droughts		0.0014	−0.0571	0.0011
		(0.0049)	(0.0702)	(0.0011)
Storms		0.0009	−0.0263	−0.0003
		(0.0062)	(0.0247)	(0.0006)
Earthquakes		**−0.0132***	−0.0720	−0.0004
		(0.0046)	(0.0639)	(0.0005)
Collective disaster variable	−0.0021			
	(0.0036)			
Controls (same as in Table 2)	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes
Period Fixed Effects	Yes	Yes	Yes	Yes
Number of Instruments	49	52	52	52
Number of Observations	174	174	174	174
Number of Countries	29	29	29	29
Hansen Test for Overidentified Restrictions (p-values)	0.975	0.993	0.899	0.999
Arellano-Bond Test for AR (1) in First Differences	0.005	0.009	0.005	0.043
Arellano-Bond Test for AR (2) in First Differences	0.351	0.321	0.116	0.948

Source: Authors' calculations using data from EM-DAT and the World Bank.
Notes: Standard errors are in parentheses. [*10% level of significance, **5% level of significance and ***1 % level of significance]
The values in bold are the statistically significant independent variables.

Severe floods may reduce average annual GDP growth by 1.44 pp. (Model 2). A reduction of 2.82 pp. (Model 3) and 0.28 pp. (Model 4) may be observed in the average annual agricultural and non-agricultural growths, respectively. The seemingly positive effects of moderate floods in the form of abundant water supply for multiple cropping seasons and increased agricultural output in subsequent years were observed to be cancelled by the damage and destruction caused by severe floods. In comparison to moderate droughts, severe droughts on average have very strong negative effects on annual GDP (3.1 pp. compared

Table 5 Growth Effects of Moderate and Severe Natural Disasters (developing countries sample)

Disasters Intensity Variables	*(1) GDP Growth*	*(2) GDP Growth*	*(3) Agricultural Growth*	*(4) Non-agricultural Growth*
Moderate Disasters (73 Countries, 438 Observations)				
Floods		**0.0276****	**0.0372*****	0.0262
		(0.1940)	(0.2754)	(0.0156)
Droughts		**−0.0070***	**−0.0308****	−0.0055
		(0.1058)	(0.1325)	(0.0134)
Storms		−0.0535	−0.0169	−0.0008
		(0.1219)	(0.1736)	(0.0137)
Earthquakes		0.1124	0.4970	**−0.0033****
		(0.2698)	(0.4175)	(0.0148)
Collective disaster variable	−0.0973			
	(0.0602)			
Severe Disasters (73 Countries, 438 Observations)				
Floods		**−0.0719****	**−0.1408*****	**−0.0142***
		(0.1492)	(0.0883)	(0.0100)
Droughts		**−0.155***	**−0.1201****	0.006
		(0.1131)	(0.0930)	(0.0103)
Storms		**−0.0498****	**−0.0540***	−0.0391
		(0.1462)	(0.0988)	(0.0187)
Earthquakes		−0.0788	−0.1899	**−0.0307****
		(0.5425)	(0.0757)	(0.0534)
Collective disaster variable	**−0.1230****			
	(0.0904)			

Source: Authors' calculations using data from EM-DAT and the World Bank.
Notes: Standard errors are in parentheses. Control variables (same as in Table 2), time (period) fixed effects and constant terms were also included for each regression model (coefficients are not reported here). [*10% level of significance, **5% level of significance and ***1% level of significance].
The values in bold are the statistically significant independent variables.

to 0.14 pp.) and agricultural growth (2.4 pp. compared to 0.67 pp.) compared to moderate droughts. Similarly, severe storms have comparatively stronger and more significant negative impacts on agricultural growth and GDP growth than moderate storms. This is true for earthquakes, too, but they fail to have a significant economy-wide and sector-specific impact except on the non-agricultural sector. Interestingly, the combined disaster intensity variable is also significant and negative for severe natural disasters.

The prodigious negative effects of severe natural disasters can be valid because such large events are more likely to decelerate economic growth or even trap it in a lower equilibrium by: (a) inflicting large-scale damages to key infrastructure, private property and human capital stock; and (b) increasing the prospects of exceeding a country's reconstruction capacity (refer Hallegatte & Dumas, 2009). Similar results regarding severe natural disasters were observed by a few earlier studies (Cunado & Ferreira, 2014; Fomby et al., 2013; Loayza et al., 2012, among others).

5. Conclusion

In this study, we have explored the growth effects of four types of natural disasters, namely, floods, droughts, storms and earthquakes using a panel data of 102 countries over the period 1981–2015. We have considered the difference between moderate and severe disasters, and developed and developing countries while tracing the macroeconomic consequences of natural disasters. The use of continuous and binary measures of disaster intensity not only helped us in segregating the moderate and severe natural disasters but also confirmed that the estimation results observed for typical or moderate disasters for both measures are largely similar. Subject to limitations of the disaster data, as discussed in Section 3.1, we summarise the results as follows.

Natural disasters were found to have diverse effects on the macroeconomy, which varies across economic sectors depending on disaster types and their intensity. Typically, normal floods have a positive impact on agricultural growth and even on the growth of other sectors of the economy. The impact of floods was stronger in magnitude in developing countries. However, the growth effects of severe floods were found to be negative, suggesting that the damage and destruction caused outweighs their positive effects on agricultural output. Droughts have negative effects on agricultural growth but failed to show significant impact on any other economic sector. Severe droughts, although, may significantly decrease GDP growth along with agricultural growth in developing countries. Storms have a negative impact on GDP growth and agricultural growth in developing countries. Severe storms showed similar results, and their effects are relatively stronger than typical or moderate storms. Earthquakes seemed to decrease non-agricultural growth in developing countries, but for the full sample of countries, their effects were found to be positive. Severe earthquakes showed a negative impact on non-agricultural growth but failed to indicate a significant impact on any other economic sector. Further, even though the direct disaster damages are more in developed countries (in absolute terms), this study confirms that the macroeconomic impacts of natural disasters are relatively stronger in developing countries.

The results of this study are robust to various checks. We got consistent results (in terms of signs) when we estimated the growth regressions using ordinary least squares methodology. However, this estimation has some econometric limitations as discussed earlier. Using different measures of disaster intensity (continuous and binary) also yielded fairly similar results. The disaster intensity measures carried similar signs while estimating the growth regressions without any control variables, although most of the variables lost their statistical significance.

This study contributes to the fairly limited literature on disasters pertaining to their growth effects and provides further empirical evidences on the same. Instead of using a monetary measure to approximate for disaster losses, this study uses a non-monetary measure (number of people affected including human deaths) and highlights the devastating effects natural disasters may have on the human capital stock which may further translate into macroeconomic losses. This reminds us that saving lives and wellbeing of people should be the main objective of the developmental policies, DRR policies and pathways to SDGs. Nevertheless, policymakers, especially in developing countries should explore the efficacy of viable ex ante disaster risk financing tools (such as insurance, catastrophic bonds, etc.) not only to safeguard physical and human capital but also to ensure adherence to the SDGs.

Overall, the results of this study corroborate with few earlier studies with little deviations in terms of statistical significance and magnitude of estimates. The findings of this study strengthen the argument that the economic impact of natural disasters is disaster- and sector-specific. Therefore, further analysis on the mechanisms through which natural disasters affect economic activities may prove to be useful. For this, there is a need to shift the focus of research on the economic impact of natural disasters from national to subnational (regional) levels to examine their permanent effects.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author received no financial support for the research, authorship, and/or publication of this article.

Appendix

Table A1 Important Literature on the Relationship between Natural Disaster and Economic Growth

Study	*Dependent Variable/s*	*Disaster Variable/s*	*Sample (Size)*	*Data Period*	*Estimation Methodology*	*Key Findings*
I. Short-Term Impact						
Albala-Bertrand (1993)	GDP	Type of disaster: geological/ meteorological	Latin American countries (28)	1960–1979	OLS	No effect/may be positive in long term (increase of 0.4% in average annual GDP)
Kahn (2005)	No. of people killed or affected	Used as dependent variable	Selected countries (73)	1980–2002	Logistic Regression	Negative effects. Rich countries find it easier to absorb disaster losses compared to poor countries.
Raddatz (2007)	GDP growth	Average no. of disaster events per year (climatic, geological, human)	Lower–income countries (40)	1965–1997	Panel VAR	Geophysical events have no effects while climatic events have negative effects (about 2% reduction in average annual GDP).
Toya and Skidmore (2007)	No. of people killed or property damages	Used as dependent variables	OECD and developing countries (151)	1960–2003	OLS (FE)	Negative effects. Factors such as better schooling, effective institutions and sound finances help in mitigating negative effects.

(Table A1 continued)

(Table A1 continued)

Study	*Dependent Variable/s*	*Disaster Variable/s*	*Sample (Size)*	*Data Period*	*Estimation Methodology*	*Key Findings*
Hochrainer (2009)	GDP growth	No. of disaster events	Large disaster events (225)	1960–2005	Time Series Regression (ARIMA)	Negative effects (0.5% reduction in the average annual GDP). Severe disasters have large negative effects
Noy (2009)	GDP growth	No. of people killed or affected, property damages	Developing countries (109)	1970–2003	GMM	Direct losses have negative impacts when measured in monetary terms (damages), but no impact in population terms (killed or affected).
Schumacher and Strobl (2011)	GDP growth	By disaster types: property damages or deaths	Developing countries (181)	1980–2004	Tobit Estimation	Negative effects (0.2% decline in per capita income)
Loayza et al. (2012)	GDP growth, sectoral growth	By disaster type: no. of people killed or affected	OECD and developing countries (94)	1960–2005	System GMM	In developing countries floods have positive effects and droughts have negative effects while storms and earthquakes have no effect. The growth effects vary across economic sectors.
Fomby et al. (2013)	GDP growth, Sectoral growth	Disaster dummies by disaster types using the criterion set by the IMF (2003)	Developing and developed countries (87)	1960–2007	Panel VAR	Floods have positive impacts while droughts have negative effects especially on agricultural growth. The impact is even stronger in developing countries.

Shabnam (2014)	GDP	Deaths or population affected by floods	Selected countries (187)	1960–2010	OLS (FE)	Floods have a negative impact on the livelihood of people but do not cause life loss.
Felbermayr and Gröschl (2014)	No. of people killed, affected or property damages	Used as dependent variable	Selected countries (108)	1979–2010	OLS (FE) and GMM	Lower GDP per capita temporarily. The GeoMet Data set used in the study provided robust estimates compared to EM-DAT.
López et al. (2016)	GDP growth	No. of intense hydro meteorological disasters and carbon accumulation	Selected countries (184)	1970–2013	Negative Binomial Models (FE)	Intense hydro meteorological disasters had a negative impact on GDP growth. 1% atmospheric carbon accumulation was associated with 0.13% decline in GDP growth.
II. Long-Term Impact						
Skidmore and Toya (2002)	GDP growth	No. of disaster events	Selected countries (89)	1960–1990	Ordinary Least Squares (FE)	Geophysical disasters have no effects while climatic disasters may have positive effects in the long term (0.42% increase in average annual GDP).
Noy and Nualsri (2007)	GDP growth	Human deaths: people killed (KILL) and property damages (DAMAGES)	Selected countries (107)	1970–2003	GMM	The KILL variable seemed to be decreasing long-term GDP growth while the DAMAGES variables had no impact.
Raddatz (2009)	GDP growth	Disaster dummies using criterion set by the IMF (2003)	Selected countries (112)	1975–2006	Panel VAR and ARDL	Negative effects of climatic disasters in the long term (0.6% decline) while no impact of geological disasters.

(Table A1 continued)

(Table A1 continued)

Study	*Dependent Variable/s*	*Disaster Variable/s*	*Sample (Size)*	*Data Period*	*Estimation Methodology*	*Key Findings*
Jaramillo (2009)	GDP growth	No. of people killed and affected, property damages, no. of events	Selected countries (113)	1960–1996	OLS	Permanent negative effects in the long term.
Cavallo et al. (2013)	No. of people killed and property damages	Intensity measures (e.g., wind speed for storms, area affected for floods)	Selected countries (196)	1970–2008	OLS (FE) and Case study	No long-term impact on GDP growth unless the disaster triggers an institutional or political change.
Klomp (2015)	Luminosity (change in light patterns)	Count measure of disaster event	Selected countries (140)	1992–2008	System GMM	The reduction in the luminosity was significant in the case of climatic and hydrological disasters in developing countries while that in case of meteorological and geophysical disasters in developed countries. However, these effects of disasters disappeared in the long term.
Berlemann and Wenzel (2016)	GDP growth	Drought indicator based on precipitation data	Selected countries (153)	1960–2002	OLS (FE)	Long-term negative effects of droughts: Lower education level, lower fertility and lower savings rate.

Source: Authors' own preparation.

Note: All GDP measures shown in table are in real per capita terms. OLS: Ordinary Least Square, FE: Fixed Effects, VAR: Vector Auto Regression, ARIMA: Auto Regressive Integrated Moving Average, GMM: Generalised Method of Moments, ARDL: Auto Regressive Distributed Lag

Table A2 List of Countries

Total Number of Countries	102	
Developing Countries (Non-OECD)	73	
Developed Countries (OECD)	29 (marked with '*')	
Albania	Finland*	Namibia
Algeria	France*	Nepal
Angola	Gambia (the)	Netherlands (the)*
Argentina	Georgia	New Zealand*
Australia*	Germany*	Nicaragua
Austria*	Ghana	Nigeria
Bangladesh	Greece*	Norway*
Belgium*	Guatemala	Pakistan
Benin	Guinea	Panama
Bolivia	Honduras	Papua New Guinea
Brazil	Hungary*	Paraguay
Bulgaria	Iceland*	Peru
Burkina Faso	India	Philippines (the)
Burundi	Indonesia	Poland*
Cambodia	Iran (Islamic Republic of)	Portugal*
Cameroon	Ireland*	Romania
Canada*	Israel*	Russian Federation (the)
Central African Republic	Italy*	Senegal
Chad	Jamaica	South Africa
Chile*	Japan*	Spain*
China	Kazakhstan	Sri Lanka
Colombia	Kenya	Sudan (the)
Comoros (the)	Korea (the Republic of) *	Switzerland*
Congo (the Democratic Republic of)	Lao, PDR (the)	Tajikistan
Costa Rica	Madagascar	Tanzania, United Republic of
Cuba	Malawi	Thailand
Czech Republic (the)*	Malaysia	Turkey*
Denmark*	Mali	Uganda
Dominican Republic (the)	Mauritania	Ukraine
Ecuador	Mexico*	United Kingdom *
Egypt	Mongolia	United States of America (the)*
El Salvador	Morocco	Venezuela (Bolivarian Republic of)
Ethiopia	Mozambique	Vietnam
Fiji	Myanmar	Zimbabwe

Table A3 Unit Root Tests

	Levin-Lin-Chu Test (Assumes Common Unit Root)		*Im-Pesaran-Shin Test (Assumes Individual Unit oot)*	
	Adj. t-statistics	*Probability*	*w-Statistics*	*p-Value*
Variables in levels (in logs)				
GDP per capita	11.87	1.00	27.72	1.00
Agricultural value added per capita	17.06	1.00	21.92	0.99
Non-agricultural value added per capita	0.49	0.68	14.94	1.00
Variables as output growth (in log-differences)				
GDP Growth per capita	−12.83	0.00	−24.13	0.00
Agricultural value added per capita	−29.01	0.00	−31.61	0.00
Non-agricultural value added per capita	−19.37	0.00	−25.75	0.00

Source: The World Bank (2016).

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