Pakistan Economic Review
7:2 (Winter 2024), PP. 66-89

Modeling the Economic Impact of Exposure to Natural Disasters: An Empirical Analysis

Awais Riaz[a], Aamir Nawaz[b], Hafiz Muhammad Qasim[a1]

Abstract

There has been a recent shift in economic growth policy discussion and research with increasing attention given to environmental issues. Scholars are now extensively exploring the integration of environmental concerns into economic growth and development theories. This indicates a growing recognition of the interdependence between economic progress and environmental sustainability in modern economic research. Natural disasters, including floods, earthquakes, and other disruptive events, are a crucial aspect of environmental concerns – affecting negatively to economic growth of a country. The current study has emphasized on the investigation of the effects of natural disasters on economic growth and examined the mitigating role of financial development, institutional quality, human capital and others mitigating adverse effect of natural disasters on economic growth. The study has used the global sample of 132 countries for the period 2002-2021. The study used fixed effect model and interaction term for sample of countries. The study concludes the negative impact of natural disasters on economic growth. Moreover, it is also found that financial development, institutional quality and human capital have positive and mitigating the effect of natural disasters in case of all three groups of countries.

Keywords: Natural disaster, economic growth, institutional quality, human capital, infrastructure

JEL Classification: Q54, O47, O43, J24, H54,

[1] [a]Lahore Leads University, Lahore awais.an313@gmail.com
[b]Akhuwat College, Kasur aamir.nawaz@live.com
[a]Lahore Leads University, Lahore hmq.economist@gmal.com

1. Introduction

In the field of macroeconomics, there has been a significant shift in research focus, moving away from a strong emphasis on studying business cycles that dominated the field for many years. This shift is driven by the recognition of the substantial implications of sustained economic growth on overall well-being. Additionally, there is now a renewed interest in understanding the significant disparities in living standards observed across different countries (*Costantini and Monni, 2008*).

Considering these factors, contemporary research in the field of economics places significant importance on economic growth, particularly sustained economic growth. Economic growth or growth of an economic entity is discussed widely in the economics literature and factors affecting it. In this regard, diverse research literature is found that emphasize on different factors having significance in growth mobilizers. Use of energy, capital, labor, trade, human capital development and foreign direct investment (FDI) are considered to be primary factors that positively influence the growth of economy in long run and to some extent in short run (*Mafizur Rahman and Alam, 2021*). Factors affecting the economic growth large and developed economies may differ from the small and less developed economies, however, primarily few factors hold their significance in all seasons.

Additionally, there has been a recent shift in economic growth policy discussions and research, with increasing attention given to environmental issues. Scholars are now extensively exploring the integration of environmental concerns into economic growth and development theories, as evidenced in the existing literature. Numerous environmental factors have been studied in relation to their impact on economic growth. This indicates a growing recognition of the interdependence between economic progress and environmental sustainability in modern economic research.

Natural disasters, including floods, earthquakes, and other disruptive events, are a crucial aspect of environmental concerns. They can cause extensive destruction to physical assets, residential properties, and valuable resources, impacting the well-being of local populations. The existing literature widely supports the belief that natural disasters have a significant negative impact on economic growth. These calamities often disrupt critical infrastructure, hinder productive activities, and disrupt supply chains, leading to substantial economic losses. As a result, researchers emphasize the importance of understanding and addressing the relationship between natural disasters and economic growth to foster resilience and sustainable development in disaster-prone areas. (*Shabnam 2014*).

The significant impact of these calamities can cause a setback of several years in the process of economic recovery and development. The destruction of critical infrastructure and loss of human lives and resources can hinder the nation's ability to reach a state of equilibrium in its economic background. As such, the consequences of natural disasters pose considerable challenges to attaining a stable and prosperous economy. Recent times saw a sharp increase in severe natural disasters worldwide. Pakistan's 2022 floods caused over $30 billion of economic losses. Turkey and Syria's June 2023 earthquake resulted in around $34 billion in losses for Turkey, about 4% of its annual economic output. These examples emphasize the urgent need for effective strategies to reduce the impact of such disasters.

While discussing the economic theories on relationship of natural disasters and economic growth – a diverse opinion is found. According to Solow growth model, the impact of natural disasters in negative on GDP of an economic entity. Whereas, on the other hand, Schumpeter's growth theory advocates a different opinion and states a positive relationship of natural disasters on economic growth.

In light of the aforementioned observations, there has been a notable flow in both the strength and incidence of natural disasters in recent years across the world. Consequently, the costs of these disasters on global economies have been significantly amplified. Therefore, it becomes imperative to thoroughly assess and quantify the effects of natural disasters by exploring into the critical factors such as human capital, financial development and institutional quality. Moreover, it is also imperative to examine the geographical impacts and influences on the regions (*disaster hit areas*) and evaluating the economic loss in context geographical data.

In view of the research problem mentioned above, following are the research objectives developed for the current research study to address the primary research problem of the study.

a. To investigate the impact of natural disaster on economic growth.
b. To investigate the impact of education on economic growth.
c. To assess the role of human capital on economic output.
d. To examine the direct relationship between financial development and economic growth.
e. To evaluate the moderating effect of institutional quality (rule of law) on the economic growth.
f. To determine the contribution of infrastructure investment to long-term economic growth.
g. To explore the impact of gross fixed capital formation on enhancing economic resilience to natural disasters.

As mentioned in the literature, financial development Institutional quality, Foreign Direct Investment (Tariq et al., 2023; Wang et al., 2021a) helps to recover the opposing effects of Natural disasters on economic growth, but no one has investigated the effects of these variables in global perspective, so we are going to investigate the effects of these variables in global perspective.

i. Furthermore, we will explore the threshold level of interacted explanatory variables to investigate the mitigation effect of disasters shocks.
ii. Earlier studies have divided countries into High Income, Low Income and Lower Income groups classified by World Bank. We will choose countries based on geographical location e.g., Overall countries, HLCs and LICs countries etc.

The study will be discussed on the examination of natural disasters in specific regions of the world as mentioned in earlier sections. Therefore, the limitations of the research involve, non-generalization of findings of the study for whole globe. Moreover, the data involved is of limited time period and therefore, study may be viewed in context of that specific time.

This study is divided into five chapters. Chapter One is the introduction. Chapter Two reviews past research on economic growth and natural disasters. Chapter Three explains the data, model, and methods used. Chapter Four presents and discusses the results. Chapter Five gives the main conclusions and suggests policies to improve economic resilience.

2. Literature Review

This chapter will review the empirical work conducted on disasters shocks impact on economic growth. There are two main components of the present study. First, find the influence of natural disaster on economic growth. Secondly, explain interaction natural disaster with explanatory variable to mitigate or cope up natural shocks.

2.1 Economic Growth and Natural disaster

Noy (2007) discovers that natural catastrophes have a detrimental influence on the macroeconomy in the short run. He investigates greater influence of natural catastrophe on growth LICs and small economies. HICs have a higher literacy rate, excellent institutions, higher per capita income, greater trade openness, and higher levels of expenditure, making them well able to minimize the effect of disasters. Moreover, he suggests financial stability play vital role to reduce impact of natural disasters. He used interaction term of natural disasters estimate and institutional and structural macroeconomic variable to measure output loss.

Tariq & Khan et al. (2022) estimated natural hazard and resilience indicators on losses from natural shocks crosswise different income categories from 1995 to 2019. The study discovered a strong association between the damage and hazard index across all income groups, showing vulnerability, by creating new catastrophe risk and resilience indices. The study emphasizes how crucial it is to increase disaster resilience by utilizing frameworks such as the Sendai Framework in order to successfully lessen the negative consequences of natural catastrophes.

Lulu Huang et al 2024) investigate the long-term economic effect of normal, minor shakings in China applying a difference-in-differences technique and prefecture-level city panel data. The study demonstrated how the degree of influence is determined by characteristics such as local govt. fiscal autonomy, socially capital intensity, and structure development. The study reveals three major factors - domestic savings rate, fixed asset investment, and innovation - that contribute to the long-run detrimental effects.

2.2 Economic Growth and Financial Development

Jonathan et al. (2009) using a sample of dataset panel of 79 states and a longer timeframe of 1980–2003. According to the study, foreign direct investment (FDI) significantly boosts economic growth in nations by enhancing institutional quality, trade openness, and education. To control the endogeneity, the study employed fixed and GMM dynamic estimation analyses. According to Kottardi (2005), the study provides empirical support for a complex web of relationships between FDI and measurable economic variables. This study examined a broad range of institutional, financial, economic, and regulatory settings where foreign direct investment (FDI) positively affects growth using an extensive set of interaction terms.

According to Dayong Zhang et al. (2020), natural calamities have a detrimental effect on economic expansion. According to the study, monetary reforms and an increase in credit have a significant impact on domestic financial development, which in turn affects economic development. He offers proof that financial development considerably lessens the direct and indirect effects of disasters. According to Kong Yusheng et al. (2020), financial development and economic growth are important.

2.3 Economic Growth and Institutional Quality

Barone and Mocetti, (2014) investigated the impact of institutional quality on post-earthquake GDP per capita growth in two Italian regions. They used a case study approach to create a "overall institutional quality index" with a principal component analysis. This index was calculated using four local variables: corruption levels, the percentage of politicians implicated in scandals, electoral turnout, and newspaper readership. The findings

of their investigation suggested that the region with a higher institutional quality index experienced faster economic growth following the earthquake. This shows that institutional quality has a substantial impact on post-disaster rehabilitation and economic development.

Kahn, (2005) examined the potential predictive value of the WGI and the Systemic Peace Polity Index for disaster death rates. With marginal significance, the author discovered that, when everything else is equal, democracies experience fewer fatalities from natural disasters. He attributed this finding to higher accountability and lower levels of corruption. The author discovered an overall positive association between lower catastrophe mortality WGIs which comprise measurements of property rights, democracy, regulatory quality, voice and accountability, the rule of law, and anti-corruption.

2.4 Economic Growth and Human Capital

Kotaridi (2005) study concluded that FDI and human capital play a significant influence in core countries. From 1980 to 2021, the study used Arellano-Bond dynamic panel data from two European countries. The study emphasizes a critical and underexplored problem in European countries concern the part of FDI in prosperity's EU nations. It would also be critical to explore the relationship between FDI and the availability of human capital, so that the combined effect of the two is considered alongside the solitary effect of FDI. He did not include human capital in specifications that include the interaction effect because of the nearly perfect correlation. In the final specification that incorporates both words, we used an alternate measure of human capital in the interaction.

Zhenyu and Pan (2023) study examined the effect of natural disasters on Human Capital and analyze. Author revealed long-term human cost of floods in Zhumadian, China, was calculated using a difference-in-difference model based on census data for multiple individuals. They employ the interaction term for the city and time variables as the explanatory variable flood to investigate how individuals were affected by the flood.

2.5 Economic Growth and Infrastructure

Johannessen et al. (2014) emphasize that infrastructure is essential for meeting immediate needs and preventing disasters. Krishnan and Twigg (2020) indicates water and sanitation infrastructure improves healthcare system efficiency, resulting in lower morbidity rates. He proposed that investment in infrastructure can improve disaster resilience and reduce losses from natural disasters.

French et al. (2019) finds basic infrastructure such as sanitation, electricity, and water are critical for improving the functionality of open spaces. Krishnan and Twigg (2020) found that

access to clean water, sanitation improvement and healthcare system resilience, provide more effective responses to catastrophes such as natural disaster shocks.

2.6 Economic Growth and Gross Fixed Capital Formation

Gulzar Ali (2015) examined the effect of gross fixed capital formation on Pakistan's economic growth. There is a favourable long-term relationship between GFCF and economic growth in Pakistan. Economic growth was emphasised through the provision of trained labour and exports. Gross fixed capital formation has a favourable impact on Pakistan's economic growth. Financial development drives a 34% boost in overall growth. The variables show stationarity at the first difference, making them acceptable for the Vector Error Correction Model (VECM) model. Skilled labour improves productivity, while exports stimulate economic growth. The paper used the following econometric models to analyse the results; Enhanced Dicky-Fuller unit root test, Johansen Cointegration, Vector Error Correction Model. Autoregressive model, lag length criteria, vector error correction model.

Table 1: Literature on relationship between Natural Disaster and Socio-economic Indicators

Authors	**Variables**	**Location**	**Method**	**Time Period**	**Results**
(Baig et al., 2018)	GDP, natural disasters	Pakistan	Auto Regressor Distributed Lag Model and bound test	1977–2015	1.Economic performance and natural disasters are negatively correlated. 2. Natural disasters and economic growth are causally related in a one-way manner.
(Benali et al., 2018)	budget deficit, public debt, GDP, natural disasters	Middle Income Countries	DH causality, FMOLS, DOLS	2000–2014	The budget deficit is causally impacted by natural disasters only in one direction. The public and the budget deficit are causally related in both directions.
(Mohan et al., 2018)	Export, investment, import, private & government	Caribbean countries	Bias-corrected least squares	1970–2011	1. The effects of natural disasters vary and affect every aspect of growth.

	consumption, hurricane index				2. Natural tragedies affect investment, trade openness, and both public and private expenditures.
(Wang et al., 2021b)	GDP, natural disasters, FDI	High income, Upper middle, Lower middle-income Low-income Countries	FEM	1980–2019	1. Natural tragedies hinder the development of low- and middle-income nations. 2. The economy in high Income countries is recovering to pre-disaster levels more quickly because of enhanced domestic economic capability
Raddatz (2007)	GDP, natural disasters	Low-income countries	Panel VAR	1960–2001	Natural disasters significantly reduce short-term economic growth in low-income countries.
Cavallo et al. (2013)	GDP, capital stock, natural disasters	Global sample	Case studies, cross-country panel	1960–2011	Disasters cause temporary GDP loss but may lead to faster reconstruction in countries with strong institutions.
Noy (2009)	Economic growth, natural disasters, human capital, institutions	109 countries	Cross-country regression	1970–2003	The impact of disasters depends on country characteristics; poorer governance worsens economic losses.
Strobl (2011)	Hurricane index, GDP per capita, infrastructure	Caribbean island nations	Panel regression with fixed effects	1970–2002	One major hurricane reduces GDP per capita growth by about 0.45 percentage points.

Kahn (2005)	Disaster deaths, GDP, government effectiveness	Global	Cross-country regression	1980–2002	Countries with stronger institutions experience fewer deaths and smaller economic losses from disasters.

3. Data and Methodology

To understand how natural disasters affect different industries, the paper argues for a disaggregated approach, analyzing each sector individually rather than the entire economy. The Solow-Swan growth model, chosen for its clarity in explaining medium-term economic stability, provides the framework. This model assumes a specific production function with decreasing marginal returns (less output gain from additional units of a factor), constant returns to scale (proportional increase in output with proportional increase in all factors), and three factors like labor, capital, and technology. A general productivity parameter captures additional factors influencing efficiency, while the specific function used is the common Cobb-Douglas form. Understanding these points lays the groundwork for analyzing how the paper will explore the sectoral impacts of natural disasters.

$$Y = AK^{\propto}L^{\beta}M^{1-\alpha-\beta} \qquad (01)$$

In the Solow model, output (Y) is determined by general productivity (A), capital (K), labor (L), and materials/intermediate inputs (M), with factor shares represented by a, b, and 1-a-b respectively. Each factor's marginal product is helpful but decreasing, with limits approaching infinity and zero as the aspect increases or decreases. The model's dynamics involve the accumulation of capital through savings and investment, with a constant fraction of output dedicated to this purpose. Labor grows at an exogenously determined rate, while productivity and intermediate inputs are subject to arbitrary changes. Thus, the Solow model describes how output is influenced by the accumulation of capital, exogenously determined labor growth, and changes in output and intermediate inputs over time.

$$\Delta K = sY - \delta K \qquad (02)$$

$$\Delta L = nL \qquad (03)$$

The neoclassical growth model captures the economy's dynamics through the neoclassical production function, as well as accumulation equations that regulate capital and output

growth. Key factors include the saving rate (s), capital devaluation rate (δ), and population growth rate (n). The goal is to comprehend capital and production growth rates as the economy approaches its "steady state," or long-term equilibrium in which growth rates stabilize. In this condition, both capital and productivity per worker are persistent, suggesting that capital (K) and production (Y) increase at the same pace as the population (n). To examine this, it's useful to describe all variables in per-worker terms (represented with lowercase letters), which allows for the evaluation of how capital and output change relative to per worker.

$$Gr\ (k) = \frac{\Delta\,(k)}{k} = s\frac{y}{k} - (\delta + n) \qquad (04)$$

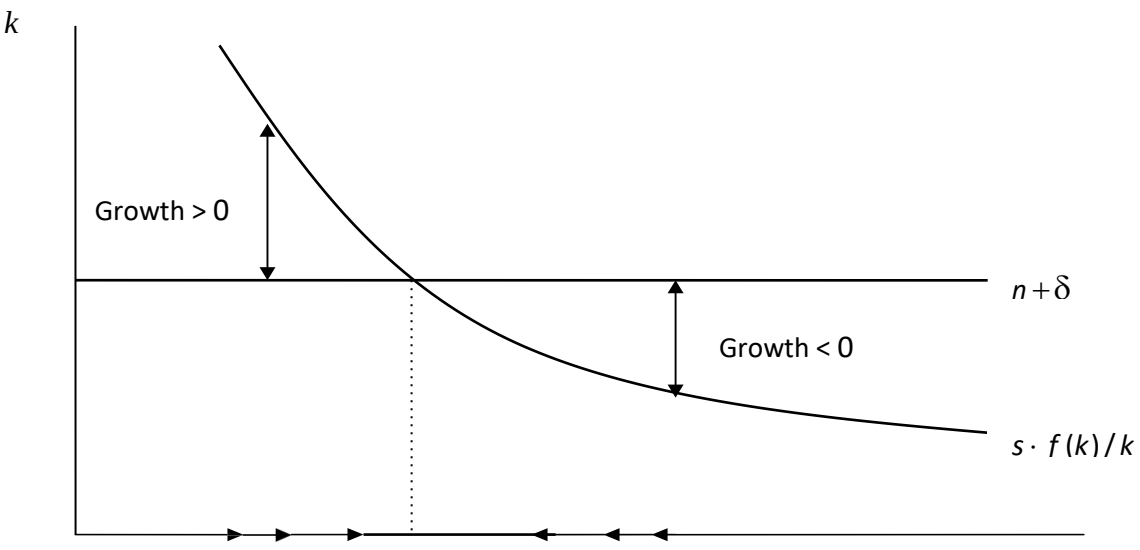
$$Gr(y) = \frac{\Delta\,(y)}{y} = \propto Gr\ (k) \qquad (05)$$

The production growth rate is intimately linked to the capital growth rate. Both rely deeply on the normal product of capital (y/k), a falling role of capital per worker (k):

$$\frac{y}{k} = Am^{1-\propto-\beta}k^{\propto-1} \qquad (06)$$

Figure 2 shows the variance amid two terms: s(y/k) and (δ+n), which represents the capital rate of growth of per worker. These two lines intersect at the level of steady-state volume of per worker capital (k*). When per worker capital is less than k*, showing relative scarcity, capital is more productive, resulting in capital growth and productivity growth per worker, although at a slower the rate till attainment the steady state. When capital per worker exceeds k*, indicating relative abundance, capital becomes less productive, resulting in a contraction of both capital and output per worker that continues at decreasing rates until equilibrium is achieved. This analysis demonstrates how the economy transitions to a steady state when capital per worker adapts, altering productivity and growth rates.

Figure 1: Economic Progress in the Change to the Steady-State



$$k^*$$

So, the three main reasons that natural disasters might impact (transitional) growth

(i) the overall factor output (a);

(ii) the material and intermediate input supply (m); and

(iii) the labor -to-capital ratio.

Growth is expected to stall if a natural disaster lowers overall output (decreasing a), shifts the downward sloping curve to the left at all levels of capital per worker, and drops the average product of capital. The same holds true if a natural disaster reduces the availability of intermediate inputs. On the other hand, growth is probable to rise (in contrary to normal, steady-state conditions) if a natural disaster abolishes more capital as compare to labor, lowering k.

Building on these elementary ideas, natural catastrophes are expected to have an adverse effect on human casualties and economy output that is why they significantly reduce the availability of water, which is a vital component of healthcare, livelihood, agriculture industrial and electricity etc. and output. It is predictable that these unfavorable effects will spread to overall economy growth. Moreover, disaster shocks may push "k" above its steady-state level and have a more negative effect on laborers and people than they do on physical capital.

In this chapter discussed the variables used and data sources. Moreover, it develops the link with macroeconomics theories and technical definition of these variable econometrics' techniques used in this research. The hypothesis of this study as:

- To examine the impact of natural disaster on economic growth.
- The role and significance of financial development (FD) institutional quality (Role of Law) School Enrollment (HC), Infrastructure and Domestic investment (GFCF) to mitigating the adverse effect of natural disasters on economic growth.

As a result, we have to establish an econometric method to estimate the econometric models and base the empirical models for both hypotheses on a theoretical framework. The same goal is achieved in this chapter. There will be two primary sections for the remainder of the chapter. The hypothetical and practical foundation for the connection between natural catastrophes and economic growth will be covered in the first section, along with the critical role those other explanatory variables show in lessening the impacts of natural tragedies. The econometric methods for estimating the regressions will be covered in the second section.

3.1 Data and Variable Construction

The region analysis, analysis time, data source, variable description, and variable generating formulas are all covered in this section. The key topic that this chapter aims to discuss is the theoretical justification for selecting certain factors for analyzing the relationship between natural disasters and economic growth and for employing interaction terms between explanatory variables with natural disasters and economic growth. The study uses panel approach to counter the endogeneity problem in the dataset and a dynamic panel estimator technique. The main specification of the model is as follows:

LGDPPC=f (LND, FD, IQ, INF, HC, GFCF) ----------1
LGDPPC=f (LND, FD, INF, HC, GFCF, LND*IQ) ----------2
LGDPPC=f (LND, IQ+, INF, HC, GFCF, LND*FD) ----------3
LGDPPC=f (LND, FD, IQ, INF, GFCF, LND*HC) ----------4
LGDPPC=f (LND, FD, IQ, HC, GFCF, LND*INF) ----------5
LGDPPC=f (LND, FD, IQ, INF, HC, LND*GFCF) ----------6
LGDPPC = Log of GDP per capita
LND = Log of Natural Disaster
FD = Financial Development
IQ = Institutional Quality
INF = Infrastructure
HC = Human Capital
GFCF = Gross Fixed Capital Formation
Econometrics Model for the functional forms as below:

$$Y_{it} = \delta_o + \delta_1 LND_{it} + \delta_2 FD_{it} + \delta_3 IQ_{it} + \delta_4 HC_{it} + \delta_5 INF_{it} + \delta_6 GFCF_{it} + \delta_7 (ND * Z)_{it} + \varepsilon_{it} \quad \text{(Eq.7)}$$

Y_{it} represents real GDP growth rate,

"Z_{it}" is part of variables which interact with natural disasters (ND) it includes five variables (FD, IQ, HC, INF and GFCF). The positive coefficient indicates that "Z_{it}" mitigates opposing impact of natural hazards on economy action. ND (as proxy overall deaths) represents Natural disasters, FD index represents financial development, IQ Index developed by WDI represents institutional quality, INF index developed by (as proxies' electricity, clean water, sanitation and clean fuel and technology) as an infrastructure, HC represents human capital

(as proxy school enrollment) and GFCF gross fixed capital formation, are involved their separate interactions with the natural disaster. Furthermore, the log of real GDP growth rate is incorporated to catch up the convergence effects between economies.

3.2 Data and Variables

Our sample covers the period from 2002 to 2021. Table 02 contains the main variables used in this study along with their definitions and sources.

Table 2: Description of the Data

Variable	Definition	Data source
Y	Real GDP growth rate	World Development Indicators (WDI)
ND	Natural disasters measured as the number of people died due to disaster	Emergency Event Database (EM-DAT)
FD	Financial Development Index	International Monetary Fund (IMF)
IQ	Institutional Quality Index	World Governance Indicators (WGI)
HC	Human Capital	Human Development Index
INF	Infrastructure	World Development Indicators (WDI)
GFCF	Gross fixed capital formation	World Development Indicators (WDI)

Instead of measuring the explanatory in as single variable, FD index developed by IMF is used, IQ (Rule of Law) index developed by WGI examines the effect of Institutional quality, we use index of following five variables 1) Voice and Accountability, 2) Political stability, 3) Rule of Law, 4) Control of Corruption, 5) Government effectiveness, and 6) Regulatory Quality. Infrastructure Index developed by WDI as proxies of basic cleaning water, basic sanitation, electricity and clean fuel and technology. Human Capital Index developed by HDI and Gross Fixed Capital Formation data taken from world bank indicators.

3.3 Model Estimation

Models have to be estimated with methods that take into account the challenges they encounter. An estimation of a constant coefficients model with residual homogeneity and normality is done using ordinary least squares (OLS). OLS can also be used to estimate fixed effects models, provided that the dependent variable is not subjected to groupwise or other heteroskedastic effects. The errors need to be homoscedastic and independent in order for OLS to function properly. Because these scenarios are so rare, it is often not practicable to expect OLS to be adequate for these kinds of models (Davidson and MacKinnon, 1993).

When the time series exceeds the cross-sectional units, FEM performs better. The conventional technique for deciding whether to use the fixed or random effects model is the Hausman specification test. The question being investigated is whether regressors and unobserved cross-sectional RE model have a significant relationship. The FE model is the recommended model if here is a correlation of this kind, as the random effects model will not compute consistently. By contrasting the regressors' covariance matrices from the REM and the LSDV model, this correlation is examined. According to the null hypothesis, there isn't any correlation.

Two important methods for estimating panel data are the FEM and the REM. In what way does the investigator decide which model is more appropriate for the estimation? A reliable statistical test that can be used to decide between the EFM and the REM is the Hausman test. Hausman made this claim back in 1978. The best method for choosing between REM and FEM is the Hausman test.

$$W = \left(\hat{\beta}_{FEM} - \hat{\beta}_{REM}\right)' [v(\hat{\beta}_{FEM} - v(\hat{\beta}_{REM})]^{-1} \left(\hat{\beta}_{FEM} - \hat{\beta}_{REM}\right) \sim x^2 \qquad \text{(Eq.8)}$$

The $\chi^{\wedge 2}$ Chi-square is tended to by the Hausman test statistics in the previous equation. In order to perform the Hausman test, we estimate both equations, assess the appropriate models, and use the $\chi^{\wedge 2}$ Chi-square to compare their statistics. Selecting between the Random Effect Model and the Fixed Effect Model is aided by this important test.

3.4 Driscoll and Karaay Standard Error

The study analysis is using fixed effect estimator for overall countries and high-income countries and random effect estimator for low-income countries for the period of 2002 to 2021. To remove the serial correlation heteroscedasticity and cross-sectional dependency, study used Driscoll and Karaay standard error (*Driscoll and Karray, 1998*). Madeline Messick, et al. (2016) explained the advantage of Driscoll and Karaay standard errors and stated that cross sectional dependence and heteroscedasticity are automatically controlled.

Driscoll and Karaay's standard errors of parameter calculations are calculated using the square roots of the diagonal elements of the asymptotic covariance matrix.

$$Var\left(\hat{\beta}\right) = (X'X)^{-1} S\wedge T\ (X'X)^{-1}$$

$$S\wedge T = \widehat{\Omega} + (\sum_{j=1=1} m(T)\ W\ (j,m)[\widehat{\Omega j} + \widehat{\Omega}')$$

$$\widehat{\Omega} + j \sum T_{t=j+1}\ \text{ht}(\left(\hat{\beta}\right)h_t + (\hat{\beta})'$$

3.5 Regression Analysis with Interaction Effects

To assess their impact on mitigation, we employed the interaction term "natural disasters" with the explanatory variable. These three authors like Noy, Ilan (2007), and Zhenyu Zhang and Pan Zhang (2023) — used the interaction term technique. For interaction impacts between two explanatory variables, X1 and X2, applied econometricians typically estimate a multiple regression model with the following structure:

$$y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 \beta_2 + \epsilon$$

Table 3: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDPPC	2720	13567.866	18757.545	255.1	112417.88
DEATHS	2740	484.407	6632.755	0	229566
FD	2740	0.337	0.234	0.03	1
IQ	2740	-0.028	0.959	-2.333	2.125
HC	2740	8.497	3.23	0.559	14.132
INF	2740	0	1	-2.911	0.632
GFCF	2601	22.681	6.729	1.402	59.723

Table 03 reports overall countries' descriptive statistics, including mean, maximum and minimum values along with standard deviation.

Table 4: VIF Test for Multicollinearity

Overall Results of All countries		
Variable	**VIF**	**1/VIF**
LND	1.35	0.739699
FD	3.62	0.276212
IQ	3.71	0.269591
HC	2.02	0.495787
INF	1.05	0.950057
GFCF	1.04	0.959354
Mean VIF	2.13	

Table 04 Shows the results of multicollinearity test by using variance inflation factor (VIF). The table presents the VIF estimates for each explanatory variable for sample of overall panel

countries. Every variable in the panel has a VIF of less than 5, which indicates that multicollinearity is not possible. Thus, there are no issues with the variables in the panel as a whole.

4. Results and Discussion

Table 5 shows the results of equation 1 for 132 countries over the period of 2002 to 2021. Column 1 to column 3 describes the results of Pooled OLS, fixed effects and random effects respectively. Hausman test has been used to choose between fixed effects and random effect models. The p- value of the Hausman test presented in figure 04 shows that the null hypothesis is rejected. The null hypothesis states that the random effect model is consistent with the explanatory variables. Therefore, we shall prefer the results of fixed effects model in the sample of overall countries case. After selection of the preferred model for interpretation of the results, the study applied the Woolridge test for auto-correlation and MWT for heteroscedasticity. The results of these post estimation tests are presented in figure-05 and figure-06. The results of these diagnostics tests indicate the presence of autocorrelation in the model. Therefore, to overcome the problems of autocorrelation and heteroscedasticity, the study applied the Driscoll Kraay model which corrects the abominations problems by using the robust standard errors (Drisc and Kraay, 1998). Column 4 of table 5 shows the outcomes of Drisc/Kraay model.

Table 5: Impact of Natural Disaster on Economic Growth Overall Countries in Panel 2002 to 2021

Dependent Variable GDP per capita					
VARIABLES	(1)	(2)	(3)	(4)	(5)
	Pooled OLS	Fixed Effects	Random Effects	Drisc/Kraay	Newey
LND	-0.0561***	-0.00390**	-0.00406**	-0.00390*	-0.0561***
	(0.00530)	(0.00156)	(0.00160)	(0.00212)	(0.00914)
FD	2.823***	0.941***	1.071***	0.941***	2.823***
	(0.100)	(0.0697)	(0.0694)	(0.175)	(0.162)
ROL	0.299***	0.257***	0.283***	0.257***	0.299***
	(0.0251)	(0.0141)	(0.0141)	(0.0189)	(0.0421)
EDU	0.125***	0.0896***	0.0945***	0.0896***	0.125***
	(0.00541)	(0.00439)	(0.00439)	(0.0136)	(0.0107)
INF	-0.0496***	0.0958***	0.0813***	0.0958***	-0.0496**

	(0.0127)	(0.0119)	(0.0118)	(0.0148)	(0.0236)
GFCF	0.00763***	-0.000451	-0.000451	-0.000451	0.00763**
	(0.00187)	(0.000595)	(0.000608)	(0.000713)	(0.00306)
Constant	6.618***	7.580***	7.498***	7.580***	6.618***
	(0.0690)	(0.0402)	(0.0672)	(0.163)	(0.126)
No. of Observations	2,589	2,589	2,589	2,589	2,589
R^2	0.800	0.436	---	---	---
Number of groups		132	132	132	
Hausman Test		121.37	121.37		
Prob>chi^2		0.0000	0.0000		
Wooldridge Test		25.240			
Probability>F		0.000			

*Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

The main objective of estimation of equation 1 is to examine the impact of natural disasters on economy growth. The study used GDP per capita as a proxy to estimate of economy growth. Drisc/Kraay aim to Robust Standard Errors Model was to remove the heteroscedasticity and autocorrelation from the data. Whereas, for interpretation, the results of Fixed Effect Model are used, because after application of Drisc/Kraay model, no difference in results as far as overall countries results are concerned.

The impact of natural hazards on economic output for our sample of 132 countries is negative but statistically significant. Column 2 of table 05 indicates that one percent increase in natural disasters lead to 0.39 percent decrease in economic output on average. This negative impact of natural disasters is consistent in other three specifications of the table as well. The results are aligned with Benson et al, (2004), Arouri et al, (2015) and Karim (2018) i.e., natural disasters effect the local economies by damaging capital, market infrastructure, and physical human losses and injuring a population. These impacts decrease the local output level and create instability in the country.

Table 06 indicates the results of overall 132 countries for the mitigation effect of variables. Column 1 of the table shows the interaction of financial development with natural disasters. The sign of interaction coefficient is positive and statistically significant implying that financial development helps to alleviate the negative impact of ND on economic growth. FD index study used as measured by the Financial Development Index (FDI) established by the

International Monetary Fund (IMF), plays a crucial role in mitigating the influence of natural disasters. Beck et al. (2000) suggested that countries with more advanced economic systems are better equipped to cope with adverse events, such as natural disasters, due to their ability to mobilize resources efficiently and allocate them to productive uses. Loayza et al. (2000) found that financial deepening, characterized by increased access to financial services and products, contributed towards faster recovery and reconstruction efforts following natural disasters.

Table 6: Interaction Impact of Explanatory Variables to Mitigate to Natural Disaster on Economic Growth (Overall Countries)

Dependent Variable GDPPC					
VARIABLES	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
LND	-0.0139***	-0.00210	-0.0315***	-0.00413***	0.000529
	(0.00251)	(0.00165)	(0.00387)	(0.00158)	(0.00347)
FD	---	1.038***	1.370***	0.945***	0.943***
	---	(0.0732)	(0.0707)	(0.0705)	(0.0696)
ROL	0.275***	---	0.274***	0.254***	0.256***
	(0.0145)	---	(0.0151)	(0.0143)	(0.0141)
HC	0.109***	0.0949***	---	0.102***	0.0896***
	(0.00424)	(0.00462)	---	(0.00416)	(0.00438)
INF	0.0951***	0.0875***	0.178***	---	0.0954***
	(0.0123)	(0.0125)	(0.0119)	---	(0.0118)
GFCF	1.87e-05	6.14e-05	-0.00114*	-0.000102	---
	(0.000613)	(0.000627)	(0.000637)	(0.000602)	---
LND*FD	0.0311***	---	---	---	---
	(0.00601)	---	---	---	---
LND*IQ	---	0.0114***	---	---	---
	---	(0.00154)	---	---	---
LND*HC	---	---	0.00300***	---	---
	---	---	(0.000443)	---	---
LND*INF	---	---	---	0.00217	---
	---	---	---	(0.00137)	---
LND*GFCF	---	---	---		-0.000198
	---	---	---		(0.000138)
Constant	7.723***	7.492***	8.228***	7.467***	7.569***
	(0.0403)	(0.0421)	(0.0284)	(0.0381)	(0.0375)
Observations	2,589	2,589	2,589	2,589	2,589
R-squared	0.401	0.373	0.352	0.422	0.436
Number of country1	132	132	132	132	132

*Note: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1*

Cavallo et al. (2013) suggested that countries with more developed financial systems experienced lower output losses and recover more quickly from natural disasters. Moreover, financial development enables smoother consumption patterns for affected households and firms through access to credit and insurance, as demonstrated by studies such as Mody and Murshid (2011). Clarke (1999), which emphasize the role of financial development in mitigating the adverse effects of natural disasters on economic outcomes and fostering long-term resilience. The mitigation effect of financial development for high-income countries and low-income countries are same as overall countries, and are mentioned in column-1 of table-10 and column-1 of table-14 respectively.

Table-2, Column: 2 displays the interaction amid natural disasters and institutional quality. The interaction coefficient is statistically significant and has a positive sign at the 1% level of significance. The results show that institutional quality mitigates the negative impact of natural disasters on economic growth. According to P. A. Reschke (2008), an important socioeconomic factor that influences a state's vulnerability to natural calamities is its institutional architecture. the high level of political stability, combined with a decline in the likelihood of fatalities and overall economic losses from natural disasters. He estimates indicate that higher-income countries have fewer fatalities from natural disasters. Research by Karim (2018) and Arouri, Nguyen, and Youssef (2015) showed the negative impacts that storms, floods, and droughts have on household income and consumption. The mitigation effect of IQ (rule of law) for HICs and LICs are same as overall countries, and are presented in column-2 of table:10 and table:14 respectively.

The 3-column illustrates how human capital and natural disasters interact. At the 1% level of significance, the interaction coefficient has a positive sign and is statistically significant. Hallegatte et al. (2018), emphasizing the part human capital plays in promoting long-run economy resilience then reducing negative effects of natural calamities. According to Becker (1964), the development of human capital increases economic growth and adaptive capacity, which helps people deal with and recover from unfavorable situations. According to Tariq Iqbal Khan et al. (2023), increased labor productivity is one way that human capital considerably boosts economic growth. It plays a major part in each of the three phases of a disaster (before, during, and after). He says that investing in HC can boost economy expansion then lessen the damaging effects of natural catastrophes. For all countries, the individual impact of infrastructure is statistically significant and beneficial at the 1% significance level. The mitigation effect of human capital for high-income countries and

low-income countries are same as overall countries, and are presented in column:3 of table-10 and table-14 respectively.

Table-06 column 4 & 5 show infrastructure and gross fixed capital formation is no effect in overall countries. But in table-10 column 4 for high income countries represents that infrastructure has positive impact and significant, these findings are aligned with studies conducted by French et al. (2019) and Krishnan and Twigg (2020), and others that show how essential infrastructure—such as water, power, and sanitation—improves the usability of public areas. Having access to sanitary facilities and clean water increases the resilience of the healthcare system, making it easier to respond quickly to crises like epidemics and natural disasters. In case of low-income countries infrastructure result is insignificant present in the table-14 column 4 respectively.

The interaction between gross fixed capital formation (GFCF) and natural disasters is shown in Table-06 and table-10 for high income countries column 5 show that GFCF is insignificant but in table-14 column 5 for low-income countries presents that GFCF has negative but significant.

After discussion the overall countries, in this section we will comparatively analysis with HICs and LICs by using same econometrics techniques. First of all, we use the descriptive analysis, VIF for multicollinearity test, model estimation i.e Pooled OLS, Fixed Effect, Random Effect, Hausman choice test, Wooldridge Test and Wald Test for detecting the Heteroscedasticity and Autocorrelation problem and Driscoll and Karaay Standard Error for Diagnose the problems.

To sum up the main findings, natural disasters were found to negatively affect economic growth in the countries studied, and this impact was statistically significant. Financial development stood out as a strong factor in softening these negative effects, with similar benefits seen in both high- and low-income countries. Institutional quality and human capital also played a helpful role in reducing the damage caused by disasters. On the other hand, infrastructure and gross fixed capital formation didn’t show much impact overall. However, when looking at income groups separately, infrastructure had a positive effect in high-income countries but not in low-income ones. Interestingly, gross fixed capital formation had no significant effect in wealthier countries but showed a negative impact in lower-income countries.

5. Conclusion and Recommendations

The current study was quantitative in nature and in order to understand how natural disasters affected economic growth, to examine the interaction between explanatory variables with natural disasters and economic growth – panel approach was used – a feasible tool to counter the endogeneity problem in the dataset and a dynamic panel estimator technique. The primary variables used in the study were; real GDP growth rate, natural disasters (measured as the number of people died in result of disaster), financial development index (FDI), institutional quality index, human capital, infrastructure and gross fixed capital formation (GFCF).

The data obtained for the mentioned variables were sourced from different platforms. The sample time period of the datasets covered the period from 2002 to 2021. Moreover, in order to assess the impact of selected variables towards mitigation of impacts of natural disaster on economic growth, interaction term "natural disasters" with the explanatory variable was employed.

The estimations showed results for 132 countries over the period of 2002 to 2021. The impact of natural disasters on economic growth sample countries was negative but statistically significant. These impacts decreased the local output level and created instability in the country. Moreover, it is implied that financial development helped to alleviate the negative impact of natural disasters on economic growth. Hence it was suggested in literature that countries with more developed financial systems experienced lower output losses and recovered more quickly from natural disasters. The results showed that mitigation effects of financial development for high-income countries and low-income countries were same as of overall countries.

Moreover, institutional quality, human capital posed positive impact on mitigation of effects of natural disasters. However, infrastructure and gross fixed capital formation showed no impact on mitigation of negative impacts of natural disasters when taking into consideration the dataset of overall countries, however, posed positive impact in case of high-income countries and whereas, insignificant in view of low-income countries dataset. The impact of gross fixed capital formation (GFCF) was insignificant in case of high-income countries but negative and significant in case of low-income countries.

The study and its results hold a significance for countries like Pakistan and China in specific since recently it is hit with various natural disasters and specifically with flood. Therefore, the study provides results and recommendations may be generalized for these countries as well. As far as the negative impacts of natural disasters are concerned, the current research study

and its results are valuable when devising national level policy measures for mitigation of negative impacts of floods for any country taken in the sample of the study. Few takeaways in this regard include; Countries should develop a sustainable and robust financial system along with significant investment towards enhancement of institutional quality and development of human capital. Moreover, they have to work on measures that help in enhancing their exports through trade openness strategies, since all these measures enhance the resilience of a country towards mitigation of negative impacts of natural disasters.

References:

Baig, N., Khan, S., Gilal, N. G., & Qayyum, A. (2018). Do natural disasters cause economic growth? An ARDL bound testing approach. Studies in Business and Economics, 13(1), 5–20. https://doi.org/10.2478/SBE-2018-0001

Balli, H. O., & Sørensen, B. E. (2013). Interaction effects in econometrics. Empirical Economics, 45(1), 583–603. https://doi.org/10.1007/s00181-012-0604-2

Barone, G., & Mocetti, S. (2014). Natural disasters, growth and institutions: A tale of two earthquakes. Journal of Urban Economics, 84, 52–66. https://doi.org/10.1016/j.jue.2014.09.002

Benali, N., Abdelkafi, I., & Feki, R. (2018). Natural-disaster shocks and government's behavior: Evidence from middle-income countries. International Journal of Disaster Risk Reduction, 27, 1–6. https://doi.org/10.1016/j.ijdrr.2016.12.014

Bölük, G., & Mert, M. (2014). Fossil and renewable energy consumption, GHGs (greenhouse gases), and economic growth: Evidence from a panel of EU countries. Energy, 74, 439–446. https://doi.org/10.1016/j.energy.2014.07.008

Cavallo, E., Galiani, S., Noy, I., & Pantano, J. (2013). Catastrophic natural disasters and economic growth. The Review of Economics and Statistics, 95(5), 1549–1561. https://doi.org/10.1162/REST_a_00413

Clarke, G. R. G. (1999). Financial development, financial openness, and economic growth. In B. Pleskovic & J. E. Stiglitz (Eds.), Proceedings of the World Bank Conference on Development Economics 1999 (pp. 203–230). World Bank.

Costantini, V., & Monni, S. (2008). Environment, human development, and economic growth. Ecological Economics, 64(4), 867–880. https://doi.org/10.1016/j.ecolecon.2007.05.011

Dayong, Z., & Managi, S. (2020). Financial development, natural disasters, and the economies of the Pacific small island states. Economic Analysis and Policy, 66, 168–181. https://doi.org/10.1016/j.eap.2020.04.003

Ebeke, C., & Combes, J. L. (2013). Do remittances dampen the effect of natural disasters on output growth volatility in developing countries? Applied Economics, 45(16), 2241–2254. https://doi.org/10.1080/00036846.2012.659347

Felbermayr, G., & Gröschl, J. (2014). Naturally negative: The growth effects of natural disasters. Journal of Development Economics, 111, 92–106. https://doi.org/10.1016/j.jdeveco.2014.07.004

Garmann, S. (2014). Do government ideology and fragmentation matter for reducing CO_2 emissions? Empirical evidence from OECD countries. Ecological Economics, 105, 1–10. https://doi.org/10.1016/j.ecolecon.2014.05.011

Gujarati, D. N., & Porter, D. C. (2009). Basic econometrics (5th ed.). McGraw-Hill.

Gulzar, A. (2015). Effect of gross fixed capital formation on economic growth: A case study of Pakistan. Impact: International Journal of Research in Humanities, Arts and Literature, 3(8), 1–8.

Hallegatte, S., Fay, M., Knapen, L., & Rozenberg, J. (2018). From the bottom up: How to address the infrastructure and services deficit to enhance economic resilience. World Bank.

Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. Stata Journal, 7(3), 281–306. https://doi.org/10.1177/1536867X0700700301

Huang, F., Zhang, L., Zhou, Z., He, Y., Wang, Y., & Zhang, H. (2024). Research on hotspots and frontier evolution of earthquake disasters in China based on CiteSpace. Progress in Earthquake Sciences, (4), 249–257. https://doi.org/10.19987/j.dzkxjz.2023-065

Ilan, N. (2007). The macroeconomic consequences of disasters. Journal of Development Economics, 88(2), 221–231. https://doi.org/10.1016/j.jdeveco.2008.02.005

ılmaz, A. (2022). The Relationship Between Foreign Aid and Economic Growth. Maliye Araştırmaları Dergisi ,8 (1), 21-36.

Kahn, M. E. (2005). The death toll from natural disasters: The role of income, geography, and institutions. The Review of Economics and Statistics, 87(2), 271–284. https://doi.org/10.1162/0034653053970339

Kanu, S. I., Ozurumba, B. A., & Anayochukwu, B. (2014). Capital Formation and Economic Growth in Nigeria: An Econometric Analysis. Global Journal of Human-Social Science, 14(4), 1-11.

Kong, Y., & Bawuah, J. (2020). Financial development and economic growth: Empirical evidence from Sub-Saharan Africa First published: 02 September 2020 https://doi.org/10.1002/ijfe.1967

Kottaridi, C. (2005). FDI, growth, and the role of governance: Changing the rules of the game. Contributions to Political Economy, 24(1), 79–98. https://doi.org/10.1093/cpe/bzi004

Krishnan, N., & Twigg, J. (2020). Menstrual hygiene: a 'silent' need during disaster recovery. Waterlines, 35(3), 265-276. DOI: 10.3362/1756-3488.2016.020.

McDermott, T. K. J., Barry, F., & Tol, R. S. J. (2014). Disasters and development: Natural disasters, credit constraints, and economic growth. Oxford Economic Papers, 66(3), 750–773. https://doi.org/10.1093/oep/gpt034

Messick, M. (2016). Natural Disasters in Latin America: Disaster Type and the Urban-Rural Income Gap. Volume 7 Table of Contents 2016, 35.

Mody, A., & Murshid, A. P. (2011). Growth from international capital flows: The role of volatility regimes (IMF Working Paper No. 11/90). International Monetary Fund.

https://www.imf.org/en/Publications/WP/Issues/2016/12/31/Growth-from-International-Capital-Flows-The-Role-of-Volatility-Regimes-25151

Mohan, P. S., Ouattara, B., & Strobl, E. (2018). Decomposing the Macroeconomic Effects of Natural Disasters: A National Income Accounting Perspective. Ecological Economics, 146, 1–9. https://doi.org/10.1016/J.ECOLECON.2017.09.011

Owusu-Sekyere, E., Lunga, W., & Karuaihe, S. T. (2021). The impact of disasters on economic growth in selected Southern Africa Development Community countries. Jàmbá: Journal of Disaster Risk Studies, 13(1). https://doi.org/10.4102/jamba.v13i1.1081

Özyılmaz, A. (2022). The relationship between foreign aid and economic growth. Maliye Araştırmaları Dergisi, 8(1), 21–36.

Padli, J., Habibullah, M. S., & Baharom, A. H. (2018). The impact of human development on natural disaster fatalities and damage: Panel data evidence. Economic Research-Ekonomska Istraživanja. https://doi.org/10.1080/1331677X.2018.1504689

Parida, Y., & Prasad Dash, D. (2020). Rethinking the effect of floods and financial development on economic growth: Evidence from the Indian states. Indian Growth and Development Review, 13(3), 485-503.

Rahman, M., & Alam, K. (2021). Exploring the driving factors of economic growth in the world's largest economies. Heliyon, 7(9), 1-9.

Raschky, P. A. (2008). Institutions and the losses from natural disasters. Natural Hazards and Earth System Sciences, 8(4), 627–634. https://doi.org/10.5194/nhess-8-627-2008

Shabnam, N. (2014). Natural disasters and economic growth: A review. International Journal of Disaster Risk Science, 5(2), 157–163. https://doi.org/10.1007/s13753-014-0022-5

Songwathana, K. (2017). The relationship between natural disaster and economic development: A panel data analysis. In 7th International Conference on Building Resilience: Using scientific knowledge to inform policy and practice in disaster risk reduction (ICBR2017, November 27–29, 2017, Bangkok, Thailand).

Tariq, M., Khan, I., Anwar, S., Sarkodie, S. A., Yaseen, M. R., & Nadeem, A. M. (2023). *Do natural disasters affect economic growth? The role of human capital, foreign direct investment, and infrastructure dynamics*. *Heliyon*, *9*, e12911. https://doi.org/10.1016/j.heliyon.2023.e12911

Teixeira, A. A., & Queirós, A. S. (2016). Economic growth, human capital and structural change: A dynamic panel data analysis. *Research policy*, 45(8), 1636-1648.

Toya, H., & Skidmore, M. (2007). Economic development and the impacts of natural disasters. Economics Letters, 94(1), 20–25. https://doi.org/10.1016/j.econlet.2006.06.020

Wang, P., Zhang, H., & Wood, J. (2021). Foreign direct investment, natural disasters, and economic growth of host countries. In Economic effects of natural disasters: Theoretical foundations, methods, and tools, 97–117. https://doi.org/10.1016/B978-0-12-817465-4.00007-8

Zhang, D., & Managi, S. (2020). Financial development, natural disasters, and the economies of the Pacific small island states. *Economic Analysis and Policy*, 66, 168–181. https://doi.org/10.1016/j.eap.2020.04.003