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ABSTRACT

Natural disasters occur due to global environmental changes caused by industrial and land-use emissions of greenhouse gases. The natural disasters event including floods, earthquakes, hurricanes, and droughts, lead to enormous damage and loss of the quality of the natural environment. The present study main focus is to explain the systematic relationship between natural disasters and environmental quality in developing countries. The researchers gathered data on 129 developing countries from the years 2000 to 2024. The methodology of this study is based on advanced econometric techniques such as Method of Moments quantile regression (MMQR) and Bootstrap Quantile Regression (BSQR), to analyze the influence of natural disasters on the ecosystem and environmental quality. Based on the findings of this study, the estimation indicated that the natural disaster damages destroy natural capital and environmental resources, which tends to reduce environmental quality. Furthermore, the pollution and land degradation occurs aftermath of disaster events and destroy the ecological balance. These disruptions can weaken environmental management practices and reduce the ability of the ecosystem to recover quickly, leading to worse environmental quality standards. The study suggested that the government should ensure enforcement policies and regulatory measures to eliminate the consequences of natural disasters in developing countries. In-depth investigations are more important to detect the impact of severe weather outcomes. The strategic governance plans and mitigation measures also help in reducing environmental losses.



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Introduction

Over the decades, less developed countries and small island developing states have faced many challenges due to weather-related disaster events, especially earthquakes, floods and tsunamis. The intensity and frequency of climate-related severe events cause environmental degradation and often lead to increased vulnerability according to the report of disaster risk and resilience (UNISDR, 2015). Natural disasters cause enormous damage and loss of human lives, infrastructure and also severely affect the psychological well-being. The disasters not only influence the living standard of people but also have a severe effect on environmental quality. Natural hazards have badly affected societies and their populations. The affected population is directly and indirectly influenced by natural disasters when repeatedly exposed to hazards. In particular, natural hazards like drought lead to disruptions of health and persistent mental stress in the population (Aguzarova et al., 2024).

Environmental quality is hurt by both direct and indirect environmental damage and losses. The direct damages include farmers' land, crops, businesses, and public infrastructure or indirect damages such as loss of private services (transportation, health education, and tourism) and business disruption (Sangha et al. 2020). The set of 302 hazards into eight groups including geological, meteorological, extraterrestrial, chemical, technological, hydrological, environmental, and societal hazards, all of which pose a potential threat to the environmental quality of developing nation economies (FAO, 2023c). In Africa, most people rely on the agriculture sector, due to severe global climate-induced fluctuations that distort the farmlands and rangelands. These climate change problems such as the disproportion of rainfall and temperature, have destroyed agricultural yields and major crops due to severe environmental damage (ADB, 2024). Many forms of ecological and environmental damage such as loss of biodiversity, soil erosion, degradation of pastures, and sedimentation, reduce environmental quality.

The main aim of environmental stability is to adopt efficient policies for sustainable use of natural resources, disaster-related mitigation policies, redistribution of resources, and maintenance of ecological balance to maintain the environmental standards at both local and national level (Suda, 2000). Over the last three decades, environmental problems that are linked with air quality, global warming, extreme weather, water quality, genetically modified food, and the treatment of waste have all been major causes of environmental degradation (Baccini and Leemann, 2021). Individuals are the main factor that shapes the environment-related problem and understand the large-scale natural disasters causing changes in the global climate. The damages from disaster-related events can reduced through more spending on improving the policies and practices of environmental management (Soni and Mistur, 2022). Investment in social protection programs addresses violence, food insecurity, and climate change-related problems and designs policies on how to protect and improve the quality of the environment (WFP, 2022a). Small cities, towns, and their peri-urban and rural surroundings are more affected areas that face many environmental challenges and need to transform agricultural food systems with implications for access to affordable healthy diets, particularly fruits and vegetables (FAO, IFAD, UNICEF, WFP & WHO, 2023). In Europe, the anticipated rise in the frequency and intensity of

heat waves and record-breaking temperatures is linked with global climate change, which has ruined the environmental quality and also caused an increase in the mortality rate in the summer (Wallemacq & House, 2018).

The study focuses on the natural disasters in developing countries and their implications for environmental quality. The number of related factors of natural disasters cyclones, floods, and bushfires, storms and natural hazards caused loss of biodiversity, destruction of ecosystems, and environmental pollution in developing countries. Many previous studies have mainly depended on ARDL, OLS, and GMM, which demonstrate first-generation econometric techniques. These methods fail to provide flexible and robust estimates of the conditional quantile function and also affect the efficiency of the results. Our proposed research methodological framework measures the unprecedented wildfires, environmental degradation, ruined ecosystems, destroyed habitats and environmental losses. The study is unique because researchers employed comprehensive methods and techniques including Method of Moments quantile regression (MMQR) and Bootstrap Quantile Regression (BSQR) to help evaluate disaster-related environmental losses. To evaluate the possible effects of disasters related losses, there is a need to enhance pre-disaster management and mitigation policies, which play a critical role in environmental monitoring and modeling.

The research is organized in given sections: Section 2 deals with a review of the literature of existing and former studies resting on natural disasters and their impact on environmental quality in developing countries. Section 3 shows model specification, data sources and methodology of the research. Section 4 explains the results and discussion based on the empirical findings of natural disasters and environmental quality by using MMQR and BSQR. Section 5 presents the conclusion and offers policy implications as well as recommendations for future research.

Literature Review

A wide range of studies that explored the relationship between natural disasters and environmental quality globally. This section covers the literature review of former studies done in the past, which is an indispensable part of the research activity. A number of varied studies critically analyzed the association between the two variables. The goal of this study is to analyze the relationship between natural disasters and their related events and how much affected on the quality of the environment.

This section shows the authors reviewed of previous studies that concentrate to find the effect of natural disasters on environmental quality. Aljawhari et al. (2024) asserted the impact of earthquake-induced events on environmental quality. The study revealed that all case studies covered environmental loss due to the disaster-related event earthquake. Moreover, the repairing structural components of disaster affects buildings and producing the embodied carbon that leads to seismic damage and also produces environmental quality loss. Bilgili and Çetinkaya (2024) estimated the impact of earthquake-induced construction and demolition waste on environmental quality. The study asserted that urbanization is the main cause of developing

construction and demolition waste (CDW) and also the main cause of developing environmental challenges that destroy the quality and life of the environment. The empirical estimation showed that CDW is the main cause of negative environmental impacts which mostly occur after the earthquake. Furthermore, the Turkey faced earthquakes on February 6, 2023, that destroyed the buildings and damaged a large area, the tons of debris generated to temporarily dispose of landfill method which caused global warming and environmental loss. Jiazhao et al. (2024) analyzed the association between earthquake disasters and environmental assessment in China. The authors revealed the negative impact of natural disasters on resource and environmental assessment capacity, which is generally more affected areas of southeastern Ganzi Prefecture than the northwest.

To analyzing the influence of natural disasters events on environmental quality, Safari et al. (2024) recognized the between meteorological patterns and surface water quality on the environmental health of China Nairobi River. The study determined that meteorological events consist of rainfall and temperature and water quality parameters exhibit many parameters as biochemical oxygen demand, chloride, and pH. The statistical estimation of this study indicated that all parameters of water quality are the main contributors to water pollution and potential sources of sediment pollution in the Nairobi River. Furthermore, the meteorological events as rainfall produced untreated sewage discharge led to direct contamination of the Nairobi River which destroyed the health of the ecosystem and the quality of the environment. Zanoletti and Bontempi (2024) examined the impact of earthquakes on air quality. The findings of this study indicated that there is no information found about generating air pollution due to the occurrence of natural disaster events earthquakes. However, the aftermath effect of the earthquake was around 300000 buildings and infrastructure collapsed. Moreover, the heavy machinery and equipment used in the regeneration and construction process for building, debris, and dust caused air pollution and respiratory problems in human beings. Soni and Mistur (2022) determined the Impact of natural disasters on environmental spending. The result of this study revealed that public opinion changes over time about environmental spending by the government. Furthermore, different disaster event occurs each year that require support for government spending to mitigate the effects of disasters and improve the quality of the environment. Also, many natural disasters events caused environmental shocks and have heterogeneous impacts on wildfires, agriculture, and forestry. Shith et al. (2021) stated the effect of environmental impact assessment on controlling natural disasters. The study results indicated that flood sheds and landslides are the main problems of disaster-related events that cause environmental degradation. Furthermore, EIA plays an important in the development of projects in Malaysia, also addressing the disaster risks and producing policies that reduce the adverse effects on the environment.

Baccini and Leemann (2021) discussed how natural disasters impact on voter behaviour when they face extreme weather conditions in Switzerland. The result of this study explained that natural disaster event occurs randomly in all municipalities and affect the response of voter behaviour. Furthermore, voters responses change and are more positive for voting, when they face

challenges due to damages of natural disaster and climate change issues. Aldardasawi and Eren (2021) examined the impact of natural disasters event flood on the environment. The empirical estimations revealed that natural disaster flood event caused both positive and negative influence on the environment quality. Moreover, floods caused the negative effect on environment as contamination of groundwater, decline the agriculture fertile land, disturbed the aquatic ecosystem and macroinvertebrates also leads to deforestation and environmental degradation. Also, the positive aftermath floods impact on the nutrient deposition and also favorable for habitat of the macroinvertebrates such as insects and others. Ali et al. (2020) conducted the association between natural disasters events, environmental quality, and human health. The study revealed that severe extreme events disturb human life and the quality of the environment. Furthermore, safety measures are necessary to reduce financial losses.

By tracing the severe impact of natural disaster, finding suggests the loss of environmental quality, Sangha et al. (2020) considered quality of environment of Australia. The study recognized that natural disasters cause to producing both marketable and non-marketable losses which directly have a severe impact on human life and environmental quality. The findings of this paper indicated that disaster-related events severe impact on wildfires and people well-being of Australians who reside in the Northern Territory (NT). Also, the environmental loss produces a severe impact on human life where people livelihoods greatly depend on natural systems. Wang et al. (2015) checked the impact of deteriorations in living environments on the health of disaster that caused due to natural disaster event earthquake. The study revealed that the natural disaster event earthquake caused the disaster victims in relief housings which led to deteriorate the environmental quality. Furthermore, the results of field test showed that thermal environment in relief housings was very low especially in summer season outdoor air temperature more decline than the indoor temperature and caused the disaster victims that put the negative impact on the living environment. Rahman (2014) determined the effect of various environmental disasters on environmental quality. The results of this study showed that floods and landslide both are the common form of environmental disaster in Malaysia that caused the disruption of economic systems, property damage, injuries and death of the people. Also, these severe natural disaster events created the environmental problems. Moreover, the natural disaster events destroyed the environmental quality and leads to deplete natural resources, caused deforestation and destroyed agricultural crops. Mata-Lima (2013) show association between disasters events, environmental quality and socioeconomic progress. The findings of this study showed that natural disaster events caused the significant negative impact on environment quality specially in urban areas of the country. Furthermore, the badly disturbance observed in both socioeconomic and environmental quality due to occurrence of different type of disaster in these regions. Suda (2000) presented preparedness, environmental degradation and sustainable development of Kenya. The empirical estimation stated as natural disaster event floods and drought mainly caused the negative impact on environment quality which also leads to environment degradation and stress. Furthermore, the sustainable development measure helps to decreases losses of the disaster events and protect the environment from natural calamities and environmental stress.

Model, Data and Methodology

This section shows the model specification, data and methodology. The functional and econometric form of model explain the relationship between natural disasters and environmental quality.

Natural Disasters and Environmental Quality

The functional form of natural disasters and environmental quality model is given as

$$EPI = f(GDP, GDP^2, ND, FDI, UR, HE, EI, IG, HCI)$$

The econometric form of the model is given as

$$EPI_{it} = a_1 + a_2GDP_{it} + a_3GDP_{it}^2 + a_4ND_{it} + a_5FDI_{it} + a_6UR_{it} + a_7HE_{it} + a_8EI_{it} + a_9IG_{it} + a_{10}HCI_{it})$$

Data: Description and Measurement

Table 1 shows a description of all relevant variables, measurement units of the variables and corresponding sources of variables from which the data collected.

Table 1: Variables, Description, Unit of Measurement and Sources

Variables	Description	Unit of Measurement	Sources
HCI	Human capital index	Index constructed through PCA	WDI
GDPPC	GDP Per Capita Growth	(Annual % growth)	
UR	Urban population	(% of total population)	
HE	Health Expenditure (out-of-pocket expenditure)	(% of current health expenditure)	
EI	Energy Intensity	(As GDP per unit of energy use (PPP\$ per kg of oil equivalent)	
IG	Industry Growth (including construction), value added	(% of GDP)	
FDI	Foreign Direct Investment, Net Inflows	(% of GDP)	
ND	Natural Disasters	Total affected Population in Natural Disasters (persons)	EM-DAT from the Centre for Research

EPI	Environmental Performance Index	https://epi.yale.edu/
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Data and Methodology

This study gathered data on variables from various sources to determine the relationship between variables. The data on environmental and other variables collected from World Bank Indicators. The natural disasters gathered from by EM-DAT from the Centre for Research on the Epidemiology of Disasters (CRED). The environmental performance index (EPI) was proposed by Yale University to determine the actual environmental and its related indicators as environmental volatility, climate change issues, environmental and ecosystem health. The EPI captures the 58 indicators that access the main three policy variables,11 issues and rank the 180 countries through analyzing, determining and comparing the environmental performance of the country (Yale, 2024). We are collecting data of concerned variables from the period 2002 to 2024. Moreover, this study collected data from 129 developing countries: these countries are classified according to the World Bank’s country classification. These countries are segregated on the basis of income such as 25 low-income countries, 50 lower-middle-income countries and the remaining 54 are upper-middle-income countries.

Moreover, the study aim is to provide more clarification of relevant methodological approaches and focus on explaining the functional form of the models. This research employed Method of Moments Quantile Regression (MM-QR) and Bootstrap Quantile Regression (BSQR) for analyzing the impact of natural disasters on environmental quality.

Results and Discussion

Summary Statistics and Correlation Analysis

Table 2 provides summary statistics for key variables from the years 2000 to 2024. The highest mean value of GDPPC² is 6399.10% and Energy intensity (EI) is 101.46% predicts the central tendency of the data. The environmental performance index (EPI) and HCI have a lowest mean value of 0.47% and 0.77, respectively. The standard deviation presents the variability from the mean value, where the findings show GDPPC² exhibits the largest standard deviation value as 316903%, reflecting a significantly large variation form the central tendency. The EPI has the lowest standard deviation value is 0.20%, indicating low variability in environmental performance among countries. In descriptive statistics, the highest skewness value of GDPPC² and GDPPC indicates that a distribution is highly rightward, positively skewed and a significant departure from the normal distribution. The EI and IG shows the moderately highly right-skewed and the TD and TAP value represent the negative skewness value and suggesting a left tail distribution. Some variable values as TAP, HE, EPI and UR are close to zero, representing approximately a symmetric distribution. The highest kurtosis value of GDPPC², GDPPC, EI, IG and HCI, suggesting a an extremely leptokurtic distribution. Whereas, EPI, HE and UR values indicate platykurtic distribution. Also, only one variable TAP value is close to zero and suggesting

a mesokurtic distribution. All variables value indicates non normal distribution where reject null hypothesis except TAP.

Table 2: Summary Statistics of Key Variables

	Mean	Media n	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque- Bera	Prob.
EPI	0.47	0.46	100	0.00	0.20	0.11	2.69	19.60	0.00
GDPPC	5.97	4.318	423172	-50.33	80.09	48.10	2446.8 5	810000000	0.00
GDPPC 2	6399.1 0	21.61	1790748 0	0.00	316902	55.28	3112.80 0	132000000	0.00
TAP	10.80	10.71	19.65	0.00	2.75	-0.05	3.07	2.22	0.32
TD	11.52	11.71	18.52	0.69	2.44	-0.50	3.41	99.38	0.00
HCI	0.77	0.47	55.50	0.05	3.70	12.76	165.96	3116705.00	0.00
UR	48.05	47.31	9258	8.24	19.79	0.12	2.08	120.74	0.00
HE	38.67	38.12	86.49	0.05	20.33	0.06	2.23	80.91	0.00
EI	101.46	83.76	693.05	0.14	71.00	2.73	14.94	19961.30	0.00
IG	26.41	24.66	95.76	0.73	12.60	1.35	6.41	2547.73	0.00

This section explains the correlation analysis among variables from 2000 to 2024. Table 3 represents the correlation analysis among variables, which shows the strength of the relationship between variables. There is a positive, weaker correlation between EPI with GDPPC², HCI, and EI. Also, the weaker negative correlation among EPI, GDDPC, TAP, TD, UR, EI and IG. The GDPPC and GPPCC² have a weaker negative correlation among TD, TAP and UR. The natural disaster variables TD and TAP both negatively correlated with HCI and UR. There is a positive moderate correlation between UR and IG. The weaker negative correlation between HE and EI.

Table 3: Correlation Analysis

	EPI	GDPPC	GDPPC2	TAP	TD	HCI	UR	HE	EI	IG
EPI	1.00									
GDPPC	-0.08	1.00								
GDPPC2	0.01	0.39	1.00							
TAP	-0.11	0.06	0.00	1.00						
TD	-0.05	-0.08	-0.03	0.17	1.00					
HCI	0.01	-0.01	-0.02	-0.01	-0.19	1.00				
UR	-0.05	-0.14	-0.04	-0.13	0.22	0.06	1.00			
HE	-0.36	0.09	0.01	0.13	-0.03	-0.01	-0.12	1.00		
EI	0.12	0.07	0.00	0.06	-0.20	-0.03	-0.22	-0.02	1.00	
IG	-0.35	0.09	0.09	0.01	0.03	-0.05	0.38	0.15	-0.03	1.00

Table 4 shows the findings of the cross-sectional dependence test. This study using the second-generation cross-sectional dependence test, also known as the Pesaran Cross-Sectional Dependence (CD) Test. The result of Pesaran CD test indicates that the test statistics of all variables are statistically significant, which shows the strong cross-sectional dependence across countries and units. Also, GDPPC and UR exhibit the highest CD test value, revealing highest cross-country dependence. The results also indicate that strong country interconnectedness occurs due to global shocks, climatic conditions, market structure and other spillover effects.

Table 4: Cross-Sectional Dependence Test

Variables	CD-Test	P-value
EPI	12.97	0.00
GDPPC	102.88	0.00
GDPPC ²	21.13	0.00
TAP	11.89	0.00
TD	21.37	0.00
HCI	27.38	0.00
UR	337.66	0.00
HE	55.67	0.00
EI	88.29	0.00
IG	19.14	0.00

To examine whether the slope homogeneity exists or not across cross-sectional units, we apply the two tests that are very commonly used for determine the slope coefficients same in the model or not such as the Delta test, which was apply by Pesaran and Yamagata, (2008) and the HAC Robust Delta test (Delta Adjusted) by Blomquist & Westerlund, (2013). The empirical estimation of environmental quality model based on both test results. The findings of the Delta test represent that the results are significant and reject the null hypothesis. Moreover, the results of the HAC Robust Delta test (Delta Adjusted) suggested not accepted alternate hypothesis and confirm the slope heterogeneity. Collectively, the estimation of both tests confirms that there is no slope homogeneity in this model.

Table 5: Slope Homogeneity Tests

(Pesaran and Yamagata, 2008)				(Blomquist and Westerlund, 2013)			
Delta Test				HAC Robust Adjusted Delta Test			
Adjusted	p-value	Unadjusted	p-value	Adjusted	p-value	Unadjusted	p-value
24.84	0.00	17.87	0.00	-18.86	0.00	-13.57	0.00

Table 6 presents the results of the second-generation panel unit root tests: the Maddala and Wu panel-unit root test and the Im-Pesaran-Shin (CSDIPS) panel unit root test. Without a trend, the results of the Maddala and Wu panel-unit root tests show that all variables are stationary because the test statistics are highly significant except for HCI. With the trend, all variables also exhibit significant results except EPI. The findings of the second-generation unit root test of Im-Pesaran-Shin (CSDIPS) panel unit root test indicate that HCI and IG is non-stationary because the test statistics are not significant without a trend. The findings of this test at with trend show that some variables are stationary such as GDPPC, GDPPC² TAP and TD but some are non-stationary including EPI, HCI, UR, HE and IG.

Table 6: Results of Second-Generation Panel Unit Root

Second-Generation Panel Unit Root Tests												
Maddala and Wu (1999) Panel Unit Root test (MW)							Pesaran (2007) Panel Unit Root test (CIPS)					
Variables	Without Trend			With Trend			Without Trend			With Trend		
	Lags	Zt Statistics	P-value	Lags	Zt Statistics	P-value	Lags	Zt Statistics	P-value	Lags	Zt Statistics	P-value
EPI	1	290.39	0.00	1	220.01	0.56	1	-1.60	0.05	1	-0.69	0.24
GDPPC	0	1725.51	0.00	0	1529.22	0.00	0	-27.52	0.00	0	-25.03	0.00
GDPPC ²	0	1476.81	0.00	0	1365.15	0.00	0	-22.09	0.00	0	-20.06	0.00
TAP	0	1058.01	0.00	0	1040.02	0.00	0	-17.89	0.00	0	-18.57	0.00
TD	0	756.43	0.00	0	695.56	0.00	0	-15.85	0.00	0	-14.11	0.00
HCI	0	138.48	0.29	0	182.79	0.00	0	4.07	1.00	0	2.59	0.99
UR	0	637.29	0.00	0	881.60	0.00	1	-2.48	0.01	1	-0.72	0.23
HE	0	220.36	0.00	0	247.32	0.00	0	-2.88	0.00	0	-0.51	0.50
EI	0	449.67	0.00	0	811.46	0.00	0	-3.41	0.00	0	-10.15	0.00
IG	0	243.73	0.08	0	307.56	0.00	0	-0.43	0.33	0	-0.55	0.29

Table 7 posit the empirical estimation of long run relationship among variables that confirm the panel cointegration. This research used three panel cointegration tests such as Westerlund test, Kao test, Pedroni test. The study employed four Westerlund tests statistics such as Gt, Ga Pt, Pa, and five test statistics of Kao test including Modified Dickey-Fuller, Dickey-Fuller, Augmented Dickey-Fuller, Unadjusted Modified Dickey, and Unadjusted Dickey-Fuller. Moreover, three test statics of Pedroni test are used in this study named as: Modified Phillips-Perron test, the Phillips-Perron test and the Augmented Dickey-Fuller test. The whole test statistics findings of Westerlund test show that the existence of cointegration across country units except Ga. The Kao test findings indicate that three tests statistics including Modified Dickey-Fuller and Dickey-Fuller Augmented Dickey-Fuller results are not significant. Only two Kao test statistics such as Unadjusted Modified Dickey, and Unadjusted Dickey-Fuller, results show long run relationship among variables. In Pedroni test, the results of all three test statistics are significant reject null hypothesis and shows there is long run cointegration in all models.

Table 7: Panel Cointegration Tests

Westerlund Test	Gt	Ga	Pt	Pa
	-2.487 (0.000)	-1.050 (0.295)	-10.720 (0.000)	-5.489 (0.000)
Kao Test	Modified Dickey-Fuller	Dickey- Fuller	Augmented Dickey- Fuller	Unadjusted Dickey-Fuller
	1.150 (0.125)	-0.305 (0.380)	2.010 (0.022)	-3.085 (0.002)
Pedroni Test	Modified Perron	Phillips- Phillips-Perron	Augmented Dickey-Fuller	
	5.340 (0.000)	-5.920 (0.000)	-5.610 (0.000)	

MMQR and BSQR Results of Environmental Quality

In this section, the MMQR findings indicate the relationship between natural disasters and environmental quality in developing countries. The study found how natural disasters such as earthquakes, floods, drought, storms etc. put severe pressure on environmental quality. Moreover, how to reduce the impacts of these events on environmental quality and sustainability especially in lower-middle-income economies. Moreover, this research highlights the results of BSQR for ensuring the reliability of the MMQR results.

Table 6.1 demonstrates the results of the method of moments of quantile regression (MMQR) by determining the impact of GDP per capita on environmental quality. The estimation shows the positive and significant association across all quantiles. The findings can be explained according to economic theory. The improvement in economic growth supports better environmental quality. The Environmental Kuznets Curve (EKC) is closely linked with our estimations, which show that when income rises, initially environmental quality declines and then the economy reaches a maximum level after getting a certain amount of income, environmental quality improves. Because countries invest more in environmental protection programs, cleaner infrastructure and renewable energy systems (Grossman & Krueger, 1995). The results are in line with prior studies (Awad, 2021; Bello & Abimbola, 2010; Diao et al., 2009; Kouton et al., 2024; Yassin & Aralas, 2017). Our results regarding the effect of GDPPC² on environmental quality in developing countries are negative and insignificant across all quantiles. The economic reason for this relationship stated as higher level of economic growth does not necessarily lead to an increase in environmental standards in some developing economies. EKC suggests that in the early stages of development, as income increases, the use of non-renewable energy sources, natural resources, and industrial production increases (Grossman & Krueger, 1995). This implies that it strongly degrades environmental quality rather than improving it. Moreover, limited institutional quality, bad governance and weak enforcement mechanisms cause environmental degradation. Weak governance may offset the environmental potential benefits as income level rises (Tan, 2006). The

findings of economic growth and environmental quality seconds the results of these studies (Dincă et al. 2022; Donkor et al. 2022; Indriana et al. 2021).

Our findings reveal a negative and statistically significant relationship between total damages (TD) from natural disasters and environmental quality. natural disaster-related events such as floods, storms and earthquakes cause greater economic and physical damages including agricultural arable land, water systems. The natural disaster damages destroy natural capital and environmental resources, which tends to reduce environmental quality (Mata-Lima, et al. 2013). Studies by Debortoli et al. (2017) and Ali et al. (2020) also highlight that climate vulnerability and extreme events increase environmental stress and disturb the ecological system, particularly in developing countries. The impact of total affected people (TAP) by natural disaster events on environmental quality. the higher number of people affected by natural disaster events shows that people are migrating from rural areas to urban. The urban expansion causes pressure on the environmental system including a lack of environmental infrastructure for households and they face water, sanitation and waste management problems, which lead to a decline in environmental quality in the developing countries (Neil Adger et al. 2005). Our findings were also confirmed by Crighton et al. (2003) and Anttila-Hughes & Hsiang (2013).

The coefficient of foreign direct investment has a positive influence on environmental quality in developing countries. The results imply that a greater inflow of foreign direct investment improves environmental standards. The first economic reason indicates that multinational companies bring advanced environmentally friendly technologies that can help reduce environmental pollution and contribute positively to environmental quality (Keller, 2004). Our estimation agrees with previous literature findings by Wu et al. (2021) and Hao et al. (2020) shows increased FDI, reduced environmental pollution and greater technology transfer, industrial modernization and the development of the green sector raise environmental quality. The urbanization indicator shows a positive but insignificant impact on environmental quality in developing countries. The economic explanation of the findings is elaborated in several ways. First, people in urban areas are more educated and their knowledge accumulation helps in using resources efficiently. Also, people have more awareness about environmental standards. The government also applies strict environmental regulations and ensures healthy environmental protection policies (Liang et al. 2019). Second, in urban areas, government and private institutions invest more in centralized waste management systems, pollution control technologies, sewage treatment, clean water systems and filtration plants. These infrastructure developments lead to a positive impact on environmental quality (Dasgupta et al. 2002). Due to unplanned urban growth and congestion offset the positive effect on environmental quality (Wei & Zhang, 2017). Our findings are consistent with these studies (Li & Ma, 2014; Martinez-Zarzoso, 2008; Wang et al. 2019).

Our findings regarding the effect of health expenditure on environmental quality indicate a negative and statistically significant effect. The health expenditure significantly impacts the carbon emissions because the health sector itself pollutes the environmental quality through generating chemical emission sand medical waste (Eckelman & Sherman, 2016). Our findings

have also been confirmed by Chartier et al. (2014) and McMichael (2013). The findings illustrate the relationship between energy intensity and environmental quality. The empirical estimation shows mixed results and indicates a positive and significant relationship at higher quantiles. Conversely, there is a negative and insignificant association at the lower quantiles (10th and 25th). Possible reasons for this association are that energy intensity indicates that economies have adopted advanced efficiency measures and cleaner technologies, which lead to a reduction in emissions per unit of energy consumed and are associated with better environmental quality (Xu & Lieuea, 2025). The pieces of evidence are in line with these empirical findings of (Degirmenci et al. 2025; El Anshasy & Katsaiti, 2014; Shokoohi et al. 2022). The findings reveal the negative impact of industrial growth on environmental quality.

The study results also demonstrate that the variables are statistically significant throughout the quantiles. The economic explanation is that industrial growth in emerging economies generates chemicals, solid wastes and toxic substances that contaminate air, water and soil. If these wastes are not properly managed, they significantly harm the environmental quality of developing economies (Ahuti, 2015). Our findings are compatible with Khan et al. (2021) and Shafik (1994). The human capital index (HCI) has a nonlinear effect on environmental quality. The empirical estimates indicate a positive and significant relationship between variables at lower quantiles and a negative association with higher quantiles. The possible reason is that human capital (education and skills) improves environmental awareness in individuals by promoting industrial technological modernization, pollution control mechanisms and renewable energy sources, which reduce environmental pressure and improve environmental quality in developing countries (Goetz et al., 1998). According to empirical findings, our results have some affinity with Jun et al. (2011), Graff Zivin & Neidell (2013) and Guo & Xu (2024).

Table 8: MM-QR Estimates of Natural Disasters and Environmental Quality

Variables	Location	Scale	(Q 0.10)	(Q 0.25)	(Q 0.50)	(Q 0.75)	(Q 0.90)
GDPPC	-0.0000002.07 (0.000133)	0.000000334 (0.000000796)	0.00000033*** (0.000180)	0.000000769* (0.000145)	0.000000201** (0.000133)	0.000000050 1*** (0.000154)	0.000000730* ** (0.000188)
GDPPC2	-8.92e-09 (3.14e-08)	-5.85e-09 (1.88e-08)	6.05e-10 (4.24e-08)	-3.97e-09 (3.43e-08)	-8.82e-09 (3.14e-08)	-1.40e-08 (3.65e-08)	-1.80e-08 (4.45e-08)
TD	-0.00647*** (0.00189)	-0.00266** (0.00113)	-0.00212** (0.00256)	-0.00421*** (0.00206)	-0.00642*** (0.00189)	-0.00880*** (0.00220)	-0.0106*** (0.00268)
TAP	-0.00608*** (0.00156)	-0.00223** (0.000935)	-0.00244*** (0.00211)	-0.00419*** (0.00170)	-0.00604*** (0.00156)	-0.00804*** (0.00181)	-0.00957*** (0.00221)
FDI	0.00391*** (0.00104)	0.00117* (0.000621)	0.00199** (0.00140)	0.00291** (0.00113)	0.00388*** (0.00104)	0.00493*** (0.00120)	0.00574*** (0.00147)
UR	0.000253 (0.000238)	3.47e-05 (0.000143)	0.000197 (0.000322)	0.000224 (0.000260)	0.000253 (0.000238)	0.000284 (0.000277)	0.000307 (0.000337)
HE	-0.00315*** (0.000228)	-0.000287** (0.000136)	-0.00268*** (0.000308)	-0.00291*** (0.000249)	-0.00315*** (0.000228)	-0.00340*** (0.000264)	-0.00360*** (0.000323)
EI	0.000126 (9.01e-05)	0.000249*** (5.40e-05)	-0.000280** (0.000122)	-8.49e-05*** (9.88e-05)	0.000122*** (9.03e-05)	0.000345*** (0.000105)	0.000515*** (0.000128)

IG	-0.00635*** (0.000482)	0.000583** (0.000289)	-0.00731*** (0.000652)	-0.00685*** (0.000527)	-0.00637*** (0.000482)	-0.00584*** (0.000560)	-0.00544*** (0.000684)
HCI	-0.000912*** (0.000349)	-0.00220*** (0.000209)	0.00269*** (0.000477)	0.000962** (0.000389)	-0.000872** (0.000354)	-0.00285*** (0.000409)	-0.00436*** (0.000504)
Constant	0.815*** (0.0293)	0.155*** (0.0176)	0.560*** (0.0399)	0.682*** (0.0324)	0.812*** (0.0296)	0.951*** (0.0343)	1.058*** (0.0421)
Observations	1,716	1,716	1,716	1,716	1,716	1,716	1,716

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

Table 9 displays BSQR estimation for examining the impact of natural disasters on environmental quality in developing countries. The strong interconnection between natural disasters and environmental quality MMQR may lead to biased estimates. To overcome this problem, BSQR results are implemented to check robustness and ensure the reliability of the results. The empirical results present that BSQR findings closely resemble the findings of MMQR estimates shown in Table 8.

Table 9: BS-QR Estimates of Natural Disaster and Environmental Quality

Variables	Location	Scale	(Q 0.10)	(Q 0.25)	(Q 0.50)
GDPPC	0.000244*** (0.00211)	0.000186*** (0.00262)	0.000126** (0.00149)	3.09e-05*** (0.000818)	0.000104*** (0.000953)
GDPPC ²	-5.64e-08 (3.05e-05)	-4.74e-08 (2.88e-05)	-3.91e-08 (1.52e-05)	-2.30e-08 (9.38e-06)	-1.50e-09 (3.05e-05)
TD	-0.00418*** (0.00420)	-0.00583*** (0.00235)	-0.00501*** (0.00208)	-0.00995*** (0.00282)	-0.00829*** (0.00299)
TAP	-0.00392*** (0.00285)	-0.00250*** (0.00217)	-0.00302** (0.00174)	-0.00594*** (0.00166)	-0.0109*** (0.00269)
FDI	-0.00303*** (0.00203)	0.00476*** (0.00184)	0.00715*** (0.000774)	0.00482** (0.00202)	0.00358** (0.00156)
UR	-0.000271 (0.000597)	0.000614 (0.000455)	0.000267 (0.000285)	0.000206 (0.000252)	0.000679 (0.000413)
HE	-0.00207*** (0.000506)	-0.00252*** (0.000383)	-0.00352*** (0.000244)	-0.00405*** (0.000253)	-0.00380*** (0.000285)
EI	3.73e-05*** (0.000150)	-0.000161** (7.41e-05)	-0.000282*** (0.000109)	9.97e-05*** (0.000176)	0.000576*** (0.000186)
IG	-0.00644*** (0.000940)	-0.00684*** (0.000897)	-0.00782*** (0.000356)	-0.00681*** (0.000654)	-0.00468*** (0.00119)
HCI	0.00304*** (0.000509)	0.000868* (0.000510)	-0.000941*** (0.000299)	-0.00253*** (0.000570)	-0.00369*** (0.000478)
Constant	0.559 (0.0906)	0.652 (0.0502)	0.845 (0.0247)	1.015 (0.0410)	1.022 (0.0304)
Observations	1,716	1,716	1,716	1,716	1,716

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

Conclusions and Policy Recommendations

This study provides the valuable insight on the relationship between natural disasters and environmental quality in developing countries. The study employed secondary data method over the period of 2000 to 2024. Our study employs the environmental performance index using 58 indicators. The study incorporated the Method of Moments-Quantile Regression (MMQR) and Bootstrap Quantile Regression (BSQR) for finding the heterogenous impact of economic and ecological indicator on the developing countries economy. The empirical findings of this study indicate the GDP per capita (GDPPC), foreign direct investment (FDI), Urbanization positively related with environmental quality. The government and institutions are increasing investment in environmental protection measures, pollution control technological instruments cleaner infrastructure, planned urban growth control measures and more focus on renewable energy sources which plays a vital role in improving environmental quality of the developing economies. The energy intensity (EI) and human capital index (HCI) shows the mixed result at different quantiles. The GDP per capita (GDPPC²), total damages (TD), total affected people (TAP), health expenditure (HE) and industrial growth lead to negative influence on environmental quality. The natural disasters and industrial expansion cause increasing energy usage, higher carbon emissions, solid wastes and toxic substances leading to resource depletion and ecosystem degradation and declining the environmental quality. Moreover, after examining the crucial and dynamic relationship between variables, we determine that rational decision-making in disaster preparedness and strong policy implications contribute to reducing the impact of these severe natural disasters in developing countries. To achieve these goals, the study develops a distinct relationship of natural disasters and environmental quality to determine the interconnectedness and significance of the variables in terms of developing economies. The government officials and agencies are responsible for preparing the report on environmental hazards. Also, the officials must design land-clearing policies and frameworks and regularly monitor for any sign of erosion faced by the environment.

Based on empirical findings, this study suggested some policy implications for policymakers.

- The study findings indicate that natural disasters often cause environmental degradation, which reduces environmental quality. Policymakers must adopt sustainable land management practices and strong regulatory frameworks to control air, water, and soil pollution.
- The analysis shows that urbanization has a positive influence on environmental quality. It is recommended that the government develop policies for sustainable urban planning to reduce environmental stress and disaster vulnerability.
- The government should promote advanced, environmentally friendly technologies and climate-smart agricultural equipment that reduce chemical usage and protect environmental quality.
- The energy intensity (EI) indicates a mix but generally has a positive impact on environmental quality in upper-middle-income countries. Government policies should

encourage the transition to renewable energy, which provides clean energy and enhances environmental quality.

- The findings reveal that industrial growth (IG) is negatively associated with environmental quality. Planners and government officials should work on industrial waste management and recycling systems to control pollution and emissions in developing countries.

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