Does Institutional Quality Strengthen the Energy-Mix-Climate Change Relation? A Case of Highly Vulnerable Countries

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https://doi.org/10.62345/jads.2024.13.1.501

Abstract

The world's most vulnerable countries are at a high risk of the inverse impact of climate change, and at the same time, these countries have limited resources and strategies to cope with the effects of climate change. Developing countries are the consumers of climate change and more vulnerable to climate change. The current study will highlight the importance of institutions in reducing the impact of natural disasters. A sample of 40 highly vulnerable countries is used as a study sample based on the ND-GAINS ranking for 1995-2020. This sample is comprised of low-income and developing countries. Panel Quantile Regression is used as an econometric technique to find the results of this study. Results indicate that the high quality of institutions and the use of renewable energy resources in a mixture of energies have the potential to reduce the risk associated with climate change. Moreover, natural disasters and weak institutions in developing countries can potentially worsen the inverse impact of climate change and trap these countries in a vicious cycle. Policymakers and governments in these countries should focus on institutional reforms of institutions directly responsible for mitigating climate change. This is the only way these countries can break the vicious cycle and decrease their vulnerability to climate change.

Keywords: Institutional Quality, Energy Mix, Climate Change, Vulnerable Countries.

Introduction

Climate changes adversely impact human and natural systems due to human interference in climate systems within past decades (IPCC, 2014). An increase in the incidence of drought, wildfires, floods, cyclones, and heat waves is causing damage to infrastructure, loss of production, damage to the settlements, and disruption of water and food supply (Field, 2014). Climate change is inversely impacting the economies of the world. The intensity and frequency of droughts, floods, cyclones, rising temperatures, sea levels, earthquakes, and precipitation have been increased over the last few years and expected to rise more in the future (IPCC, 2018). These hazardous events occur and impact the economies due to a lack of economic, social, and governance readiness to deal with climate-related events (IPCC, 2014). Economies are experiencing enormous costs due to a dramatic increase in climate-related events. Both natural disasters and a gradual increase in global warming negatively impact the long-term economic growth of economies (Botzen et al.,

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Compliance with ethical standards: There are no conflicts of interest (financial or non-financial). This study did not receive any funding.

2019; Alano & Lee, 2016). Although the impact of climate change varies across different countries, developing countries face a more significant impact. According to empirical evidence by Kling et al. (2018), climate susceptibility increases economic costs by increasing the cost of sovereign borrowing. This cost affects the public budget and constrains investment in areas such as education, infrastructure, and health. It also affects the ability of government to invest in climate adaptation and mitigation.

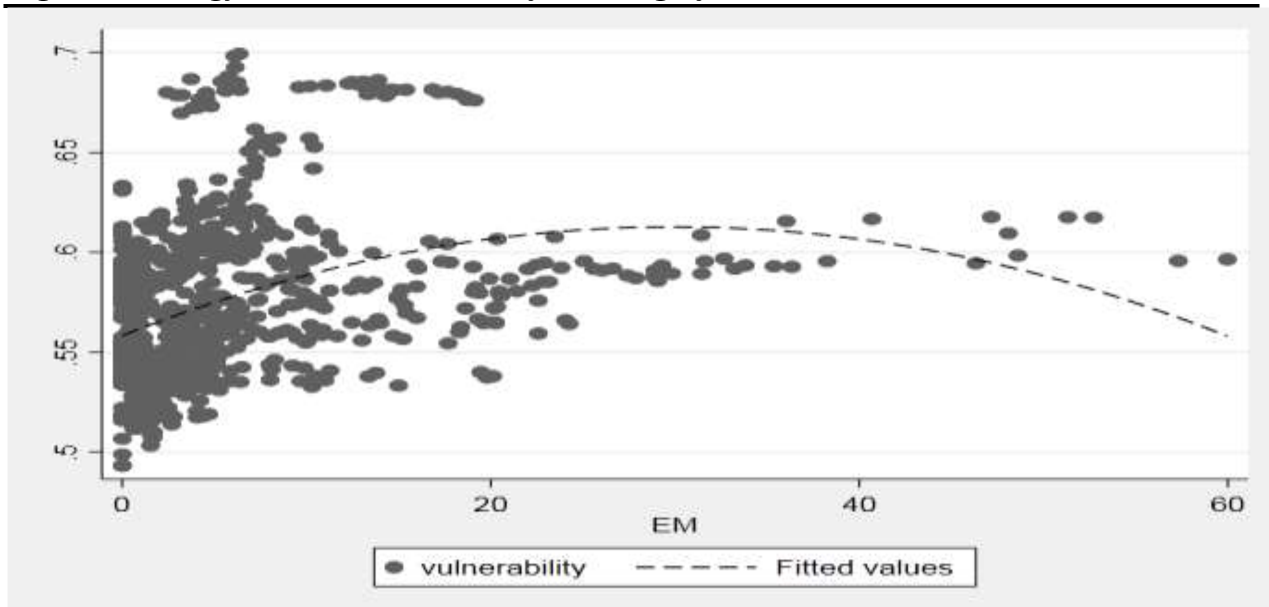
Climate changes pose more severe threats to mental and physical health, economic growth, food security, and the environment of the population, which is already experiencing inequalities, multidimensional poverty, and social and political disparity. The excessive emissions of greenhouse gases are rapidly increasing the global temperature. Global rise in temperature impacts human life in numerous ways and disproportionally affects the lives of those living in poverty. According to the World Bank (2020), approximately 79 percent of poor people in the world live in rural areas and mainly rely on environmental assets like forests, oceans, and lakes for livelihood. Abrupt climate changes impact approximately 80 % of landmasses in which 85% of people live. Low-income countries face more adverse climate change impacts than high-income countries.

With the endorsement of the Paris Agreement, different countries set their targets to reduce greenhouse gases. Many countries have devised their policies and strategies to mitigate climate change's impact and improve socioeconomic and health outcomes. However, the whole world is experiencing severe and more frequent effects of climate change because many countries still need to implement their policies properly and the inability of the Paris Agreement to make targets mandatory. Many countries still need to consider the interconnectedness of different dimensions that affect social determinants of health outcomes (Wei et al., 2021). Historical events prove that many countries have adopted different strategies and adaptation measures in their development plans. In South, North, and Central America, the government is implementing eco-system adaptation measures (Vignola et al., 2013), adaptation planning and assessment, long-term public infrastructural and energy investment (Easterly & Serven, 2003), climate forecast, resilient crops and water resource management in the Agricultural sector (Lin, 2001). In Europe, planning is incorporated into coastal management, land planning, water resource management (Bielza et al., 2007), and risk management (Fekete et al., 2014) in agriculture, and adaptation policies are being developed. Poor and underdeveloped countries are severely affected by the abrupt and frequent changes in climate change that trigger environmental-related health issues, destroy livelihood and resources, and cause a loss in agricultural production, jeopardizing the long-term goal of poverty elimination (Masson-Delmotte et al., 2021). Climate change risk is expected to be higher in already hot countries and those with limited institutional and socio-economic resources for adaptation (Godde et al., 2021).

According to the UN Population Division (2018), the urban population comprises approximately 4.4 billion people, and approximately 3.4 billion live in urban centers in "less-developed regions." According to the UN projection, the population growth in less developed countries will increase by 2 billion people in 2050. About 90 percent of the increase will be in Africa and Asia, requiring more basic services, housing, and resilience to the impact of climate change. Approximately 1 billion people live in informal settlements where the government is unwilling to extend its services like risk-reducing infrastructure and health and emergency assistance. The informal settlements fall outside any laws and regulations of land use, land ownership, and buildings. These settlements are at a high risk of climate-related natural hazards.

Developed countries mainly contribute to climate change, but developing countries face different challenges. Climate change causes a serious threat to the poor sector of the economy and makes it difficult for them to escape from extreme poverty. It poses a serious threat with the chances of pushing approximately 100 million people back into poverty in the next 15 years (Masson et al., 2021). Rising carbon emissions in the atmosphere are the main contributors to climate change, i.e., rising temperature, droughts, rising sea levels, and increased wildfire incidence. Fossil fuel is the primary cause of this emission. GHGs are increasing at 0.9% per annum since 2010 (Secretariat, 2019). Figure 1 below represents the mixture of energies and vulnerability of 40 highly vulnerable countries of the world.

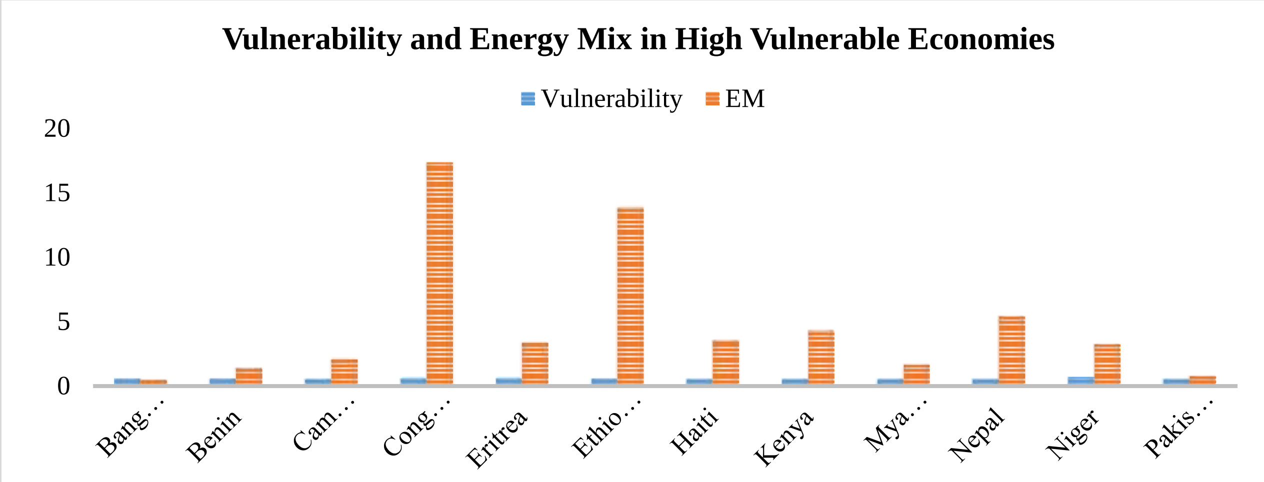
Figure 1: Energy mix and vulnerability of 40 highly vulnerable countries of the world



The most vulnerable countries not only face adverse impact of climate change but these countries also face difficulty in coping with climate change due to shortage of resources and limited strategies. Due to limited capacities and limited resources these countries experience worst impact of climate change. The obligation of developed countries is to financially support the vulnerable countries of the world (Persson et al., 2009).

Figure 2 below shows that there is a need to focus on the quality of institutions in highly vulnerable economies. This figure shows variability in the use of energy mix and susceptibility to climate change among different countries. Some countries have low mixture of energies and low susceptibility while some countries are experiencing high sensitivity despite the high use of renewable energy. This variation in the results indicate that there are some countries which are not able to maximize the reward of using renewable energy. There is a major role of public institutions in mitigating the impact of climate change. Institutions that are directly responsible for tackling the natural disasters have to perform multiple duties i.e. permit the construction of seismically sound building, ensure compliance with these type of regulations and permitting the public to locate safer places etc. If institutions failed to perform their duties then death toll can be increased (Mahadevia Ghimire, 2021). Weak institutions and poor performance of government institutes in developing countries worsen the impact of disasters in these countries and trap them in vicious cycle (Mahadevia Ghimire, 2021).

Figure 2: Energy mix and vulnerability to climate change in highly vulnerable countries



Due to climate change, six significant sectors of the economy, i.e., food, ecosystem, health, water, human habitat, and infrastructure, are the most vulnerable sectors of the economy (Sarkodie & Strezov, 2019). According to FAO 2018, climate change impacts food production and accessibility. Abrupt changes in climate impact the cereal yields, i.e., maize, wheat, and rice, which contribute two-thirds of the total food consumption of the world. These changes increase dependency on food imports due to a shortage of production and rising demand for food items by a growing population. Climate changes also impact freshwater availability, annual rainfall, and accessibility to drinking water. Moreover, these changes exacerbate health issues, water-borne, air-borne, and food-borne diseases. These changes lead to high mortality rates in developing countries with poor resources and low-income levels (Field et al., 2014).

Natural disasters are associated with climate change. These disasters are connected with economic losses and a high death rate. According to UNDRR, approximately 1.6 million people lost their lives between 1990 and 2015 to these disasters (Dilley, 2005). Due to natural disasters, approximately 77,000 average deaths per annum were reported between 2000 and 2017 (United et al., 2018). These calamities have affected a large number of people; approximately 4.4 billion people were homeless, needed emergency assistance, and were injured between 1998 and 2017. In 2017, approximately 18 million people were displaced in 135 countries by natural calamities (Fowler, 2017). Natural disasters such as tsunamis, earthquakes, floods, etc., are associated with economic loss, harming citizens and undermining long-term development goals. Although these disasters cause losses in developed and developing countries, their impacts are worse in developing countries (Mahadevia Ghimire, 2021). Developing countries suffer predominantly from weak and poor-performing public institutes (Benali & Saidi, 2017). When natural disasters strike, developing countries experience a worse impact of these disasters than developed countries (Brinkman & Hendrix, 2011). Developed countries have incorporated adaptation policies and plans into their development agendas to safeguard their populations from the damage caused by climate change (Sarkodie & Strezov, 2019). This study aims to empirically analyze the role of a mixture of energies in decreasing climate change sensitivity in highly vulnerable economies of the world. How does the inclusion of IQ strengthen the role of a mixture of energies in controlling aggregated and disaggregated climate change sensitivity in less and highly vulnerable economies of the world?

This study focuses on the susceptibility of the world's most vulnerable economies and provides solutions to combat hazardous events due to climate change. Researchers have conducted their research in different countries to investigate climate change susceptibility. The major contribution of the current study is that this study will investigate EKC in highly vulnerable economies while including Institutional quality as a necessary condition in mitigating climate change susceptibility. Data indicate the variation of results of using renewable energy resources and vulnerability to climate change. This study will find out the possible reasons for variation in results. Previously, studies have yet to investigate the impact of Institutional Quality on the role of a Mixture of energies in reducing the vulnerability of highly vulnerable economies of the World. This study will use the panel Quantile regression method, accounting for unconditional distribution and heterogeneity across quantiles.

The rest of the paper is organized as follows: literature is discussed in section 2, section 3 is comprised of a theoretical framework, a sample of study and estimation techniques are discussed in section 4, section 5 is comprised of a discussion of results, and the conclusion is discussed in section 6.

Literature Review

Sarkodie and Strezov (2019) investigated the susceptibility of 192 countries from 1995-2016. This study employed Panel Quantile Regression to control cross-sectional dependence, unconditional distribution, and heterogeneity across quantiles. This study's results revealed that the world's most vulnerable continent is Africa, with adaptive capacity, high exposure, and sensitivity. At the same time, developed nations like Germany, Switzerland, Norway, France, Finland, Sweden, Canada, Spain, and the United Kingdom are less vulnerable due to solid governance and social and economic adaptation.

Hanif (2018) studied the impact of economic growth, urbanization and energy consumption on the carbon emissions of East Asia and Pacific developing Countries. GMM approach is used to get the empirical results, which indicate that fossil-fuel energy consumption, growth, and urbanization significantly contribute to carbon emissions, which are responsible for severe challenges in these regions. Further, this study confirmed the inverted-U shape EKC between economic growth per capita and carbon emissions in these regions. Acheampong et al. (2019) studied 46 African countries to investigate the effect of renewable energy and globalization on carbon emissions using Fixed and Random Effects techniques. FDI and renewable energy reduced carbon emissions in the sample countries, while financial development and population growth contributed to increased carbon emissions in the atmosphere. Institutional quality based on regulations has a lesser effect on carbon reduction, but these regulations moderate FDI and economic growth to decrease carbon emissions.

Khan et al. (2021) researched to map farmer's weaknesses to changes in climate in the rice growing zone of Punjab, Pakistan. In developing countries like Pakistan, the agriculture sector constitutes a significant source to support most of its population. Despite its central role, this sector faces significant challenges like droughts, rising temperatures, yield loss, and floods. Results of this study indicate that the farmers in the study area are most vulnerable to change in climate. They have a high level of sensitivity and exposure to uncertainties in climate change with the least adaptive capacity.

Furthermore, farmers in low-yield areas are more vulnerable than farmers in high-yield areas. To reduce losses in farm production, regional priority must be given regardless of differences in performance. Two types of relationships exist between institutions and natural disasters. First, poor performance and weak institutions in developing countries are responsible for worsening the impact of climate change, and second, the relationship between natural disasters and institutions in developing countries is that natural disasters are responsible for the poor performance of these institutions by overwhelming these institutions. This two-way relationship can potentially trap developing countries in a vicious cycle. Weak public institutions fail to mitigate the disasters, which worsens the situation by weakening the performance of public institutions and overwhelming these institutions. Developing countries should focus on institutional reforms to break this vicious cycle (Mahadevia, 2021). Tang et al. (2021) investigated the impact of institutional quality in reducing environmental degradation for the sample of unbalanced data from 114 countries. The dynamic GMM approach was used to compute this analysis's results. The results of this study supported the existence of EKC.

Institutional quality and education facilitate FDI and renewable energy resources to reduce environmental degradation. Dai et al. (2022) used the panel ARDL approach to investigate the impact of a mixture of energies in reducing the weakness of G7 countries. The findings of this study indicate the quadratic impact of a mixture of energies on climate change weakness. Moreover, the lowest threshold of renewable energy is required to reduce health, infrastructure, and food vulnerability. Pomoim et al. (2022) conducted their study to investigate the impact of climate change on the susceptibility of species in the protected areas of Thailand. Results indicate that most birds, plants, and mammals are projected to drop by 2070, and most reptiles and amphibians are projected to increase. This projection requires long-term and regular monitoring of communities and species to detect early signals of climate change impact.

Khine and Langkulsen (2023) conducted their study to investigate the role of climate change in increasing inequalities amongst vulnerable populations and identify the limitations of adaptation strategies in South Africa. A systematic review of the literature was conducted from 2014-2022. The results of this review indicate that climate change in South Africa intensified the multidimensional inequalities amongst the vulnerable populations. Although National Climate Change Adaptation pays attention to the population's health issues, less attention is paid to occupational and mental health. Community-based social and health services should be increased amongst vulnerable populations to reduce these inequalities. Saraiva and Monteiro (2023) researched the risk of climate change on the food security of vulnerable African countries. In order to check the impact of climate change on the security of food and its stability, a systematic literature review is conducted. This study indicates water scarcity, humanitarian crises, and food security related to agriculture result from institutions' ineffectiveness in climate change response. These results require urgent actions by institutions in response to frequent changes in climate. The negative impact of changes in climate falls disproportionately on the poor economies, and these economies will experience a worse impact in the future if nothing is done to mitigate the negative impact of climate change (Toulmin, 2009). This is due to the high dependency of most economies on the agriculture sector and limited adaptive capacity (Collier et al., 2008; Shackleton et al., 2015). Literature suggests that policies to foster the use of renewable energy resources to control carbon emissions are the primary reason for environmental degradation, and support the increase in the demand for energy due to urbanization in developing countries. A sizeable literature has determined the inverse impact of the consumption of fossil fuel or non-renewable energy sources on environmental degradation, especially in developing nations where institutions are weak (Hanif, 2018; Mahadevia Ghimire, 2021). Studies have determined the inverse impact of renewable energy on environmental degradation (Acheampong et al., 2019; Tang et al., 2021).

Dai et al. (2022) have determined the increased proportion of renewable energy in combination with energies can decrease climate change vulnerability in G7 countries. This study is limited to G7 countries and ignores the facilitating role of institutions. Combining energies alone does not solve the problem for all economies. Many countries are experiencing high susceptibility despite the increased use of a combination of energies, while many countries have a low combination of energy values and face low susceptibility. So, there is a need to focus on the quality of institutions. This study attempts to draw together the analysis of the impact of the combination of energies on climate change sensitivity and, at the same time, use institutional quality as a facilitator that promotes the use of renewable energy in the combination of energies. This study provides a solution to mitigate the negative impact of climate change by increasing the proportion of renewable sources in the energy mix and by strengthening the quality of institutions.

Theoretical Framework

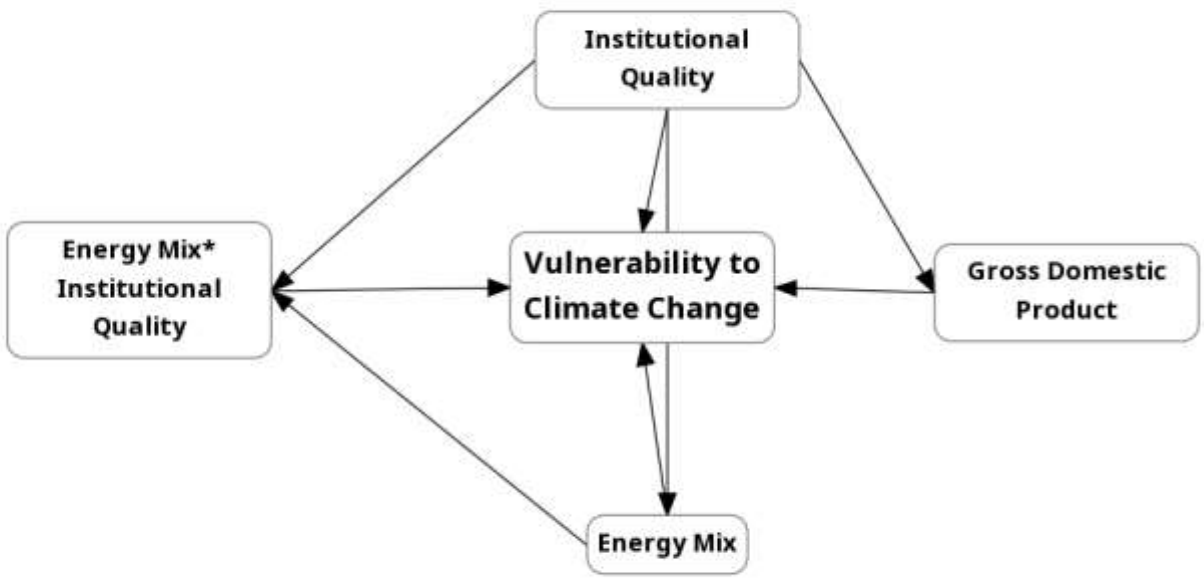
Climate change is the most substantial environmental challenge associated with anthropogenic activities. These activities increase carbon emissions in the atmosphere, contributing to global warming (Franchini & Mannucci, 2015). Increased frequency of extreme events, i.e., heat waves, droughts, cyclones, and floods, is the consequence of climate change. These events would have higher intensity, leading to extensive effects on human and environmental systems (IPCC, 2014; Gupta et al., 2019).

Vulnerability mediates hazard and its impacts. Vulnerability is the function of exposure, sensitivity, and adaptive capacity (Kallis, 2008; Ebi & Bowen, 2016). Policies, social behavior, and technologies can also determine sensitivity. Different studies indicate that the adverse impact of droughts is associated with the level of development, the capacity of the government to respond, socioeconomic factors, and the country's preparedness to tackle this problem (IPCC, 2014). Developed countries mainly contribute to climate change, but developing countries face different challenges. Climate change causes a serious threat to the poor sector of the economy and makes it difficult for them to escape from extreme poverty (Masson-Delmotte et al., 2021). Poor performance of public institutions in developing countries has worsened the impact of climate change. Their inefficient performance in mitigating the impact of natural disasters and disasters further worsens the performance of these institutions. Weak institutions in these countries can potentially trap developing countries in a vicious cycle. These countries should focus on institutional reforms of those institutions that are directly involved in mitigating the impact of climate change (Mahadevia, 2021).

The performance of public institutions plays a critical role in determining whether the devastation is exacerbated or mitigated. The weak performance of these institutions increases the disaster risk. In developing countries, poor performance by public institutions before the disaster and immediately after the natural hazard strikes makes these countries more vulnerable (Mahadevia, 2021). Developing countries are less able to deal with disasters due to less functional public institutes than developed countries. These natural disasters make it harder to achieve long-run developmental goals in developing countries and make it challenging to enhance the lives of citizens. Natural disasters increase the loss of infrastructure or assets in developing countries, overburden the less functional institutions, and hinder their performance. Traditionally, there was believed to be a positive association between growth and environmental degradation. According to EKC, initially, environmental degradation increases with the increase in growth. However, after reaching a certain level of growth, environmental degradation decreases due to the use of environmentally friendly technologies and people's awareness of the environment's quality

(Aslanidis, 2009). An increase in the use of renewable energy resources has the potential to decrease the sensitivity of climate change, but renewable energy alone cannot solve this problem. Institutions ensure sustainability and play a vital role in the country's development. Strong institutions and high use of renewable energy can decrease sensitivity to climate change.
Figure 3 shows that institutional quality and a combination of energies can decrease the susceptibility to climate change. Growth and production demand technologies that can decrease climate change susceptibility.

Figure 3: Institutional quality, energy mix and vulnerability to climate change



Methodology

Data Sources

The data on climate change susceptibility is obtained from ND-GAINS, it combines exposure, sensitivity and capacity to adapt. The latter is affected by country's political, social and economic settings (Kling et al., 2021). The data on Institutional Quality is obtained from WGI while data on Renewable energy, non-renewable energy and GDP is obtained from WDI.
Table 1 represents the details of variables and their composition.

Table 1: Variable representation and their composition

Variables	Vulnerability	Institutional Quality	Iix	
Representation	V_{it}	IQ_{it}	EM_{it}	GDP_{it}
	Index	Index	Ratio of Renewable Energy to Non-renewable energy	ln (Gross Domestic Product Constant USD)
Source of Data		ND-GAIN, WDI, WGI		
Data Range		1995-2020		

Where t is for time and i is for country.

Sample Countries

The sample of study is comprised of 40 highly vulnerable economies of world. ND-GAINS rank the countries according to their susceptibility (ND-GAINS, 2023). So 40 highly vulnerable countries are taken as a sample of highly vulnerable economies based on the ranking of ND-GAINS. Countries included in this sample are mostly low income countries.

Model Specification

This study constructs an econometric model which is based on relationship between climate change vulnerability, energy mix, Institutional quality and GDP.

Vulnerability = *f* (Energy Mix, Institutional Quality, Gross Domestic Product)

Energy mix is used as an independent variable in the model, constructed by dividing renewable energy on non-renewable energy (Dai et al., 2022).

Where,

$EM = \frac{Renewable\ Energy}{Non-Renewable\ Energy}$

Institutional quality "captures perception of the ability of government to formulate and implement sounds policies and regulations that permit and promote private sector development.

This study examines the impact of Institutional Quality on the role of energy mix in reducing susceptibility of highly vulnerable countries of the world.

The hypothesis of the study is:

H_1 = Inclusion of Institutional Quality strengthen the role of energy mix in controlling climate change susceptibility in highly vulnerable economies of world.

The econometric equation of the current study is as follows:

$$V_{it} = \alpha_{\circ} + \beta_1 EM_{it} + \beta_2 EM^2_{it} + \beta_3 EM_{it} *IQ + \beta_4 EM^2_{it} *IQ + \beta_5 \ln GDP_{it} + \mu_{it} \quad (1)$$

EM and EM^2 will prove the existence of U-shaped or inverted U-shaped curve. Institutional quality is multiplied by EM and EM^2, where the former cross-product will describe the way institutional quality changes the linear effect of energy-mix on sensitivity, and the latter cross-product will describe the way institutional quality changes the curvilinear effect of EM on sensitivity.

Econometric Techniques

In general, panel data unit roots depend on the following univariate regression:

$$\Delta y_{it} = \rho_i y_{it-1} + z'_{it} \gamma + u_{it} \quad (2)$$

Where, i = 2,1 ,..., N cross-sectional observations and t = 2,1 ,...,T time-series observations, z is deterministic component while u is a stationary process. The deterministic component, z could be 0 (zero), 1 (one), the μi (fixed effects) or fixed effects as well as the time trend 't'.

Fisher's Dickey Fuller and Im Pesaran-Shin (IPS) unit root tests for panel data are used in the analysis to test the stationarity of data. IPS unit root test considers the likelihood ratio and provide flexible and simple test for testing for unit root in panel data. Allow for stationary and non-stationary series simultaneously (Barbieri, 2009). IPS consider the mean of ADF test statistics that is computed for every cross-sectional unit when u_{it} is serially correlated in panel data but with different pattern of serial correlation across cross-sections when number of cross-sections and time period is sufficiently large (Im et al., 2003),

$$u_{it} = \sum_{j=1}^{pi} \varphi_{ij}\, u_{it-j} + \varepsilon_{it} \quad (3)$$

By substituting equation (3) in equation (2) and consider linear trend in cross-sections, we get

$$\Delta y_{it} = \alpha o_{it} + \rho i y_{it-1} + \sum_{j=1}^{pi} \varphi_{ij}\, u_{it-j} + \varepsilon_{it} \quad (4)$$

Hypothesis for unit root test are as follows:

Ho ρi = 0 against Ha: ρi < 0 for i = 1,2..., N .
IPS unit root estimate separate unit root tests for N cross-sectional units and statistics t-bar is simply average of individual statistics of ADF,t_{iT} null hypothesis:

$$\bar{t}\ \frac{1}{N}\sum_{i=1}^{N} t_{iT} \quad (5)$$

Im Pesaran-Shin unit root test considers only balanced panel data (Barbieri, 2009). Reject Ho if probability value is significant and conclude that the variable is stationary at level and vice versa. After testing for stationarity of data the next step is to test for long-run relationship. Kao, Pedroni and Westerlund Cointegration tests for panel data are used to confirm the existence of long-run relationship between dependent and independent variables. Pedroni's test for cointegration allows for interdependence between different cross-sections. Panel cointegration test proposed by Pedroni (1999, 2004) use four statistics such as panel ρ, panel v, panel ADF, and panel PP. "These statistics pool the autoregressive coefficients across different countries for the unit root tests on the estimated residuals. These statistics take into account common time factors and heterogeneity across countries. The group tests are based on the between dimension approach which includes three statistics: group r, group PP, and group ADF-statistics. These statistics are based on averages of the individual autoregressive coefficients associated with the unit root tests of the residuals for each country in the panel" There hypothesis are as follows:
Ho: No Cointegration
Ha: All panels are cointegrated
Reject Ho if probability value is significant and conclude that there is long run relationship between dependent and independent variables and vice versa. To get the final results of the study, current study uses Panel Quantile Regression. Quantile regression allows the researchers to account heterogeneous covariates effect and unobserved heterogeneity (Canay, 2011). Panel Quantile Regression is used to control cross-sectional dependence, unconditional distribution and heterogeneity across quantiles (Sarkodie & Strezov, 2019).

Results and Discussions

Summary statistics is the starting point of any analysis. This provides basic information about the nature of data i.e. mean, median, standard deviation, skewness and kurtosis. Table 2 represents summary statistics of data. Energy mix and Institutional Quality are under dispersed because their mean value is less than their standard deviation while vulnerability and GDP are over dispersed.

Table 2: Summary statistics

Variables	**Mean**	**Standard Deviation**	**Skewness**	**Kurtosis**
Vulnerability	0.5733119	0.0398447	1.010027	3.999339
EM	5.550944	7.697701	3.060058	15.34891
IQ	-0.908058	0.5707262	-0.23179	3.591987
lnGDP	22.566	1.634992	0.024681	2.510526

Author's own estimation

Furthermore, Variance Inflating Factor is estimated to confirm the existence of multicollinearity. Table 3 presents VIF which indicates that data is not suffering from the problem of multicollinearity.

Table 3: Variance inflating factor				
	Vulnerability	**EM**	**IQ**	**lnGDP**
Vulnerability	-			
EM	1.090446	-		
IQ	1.012818	1.078381	-	
lnGDP	1.008762	1.001192	1.002195	-

Author's own Estimation

Next step is to estimate the stationarity of panel data. For this purpose Fisher's Dickey Fuller and Im Pesaran-Shin unit root test for panel data are used to measure the stationarity of data (Table 4). These tests indicate mix order of integration in the data (Table 5).

Table 4: Unit root for panel data								
Fisher's Dickey Fuller Unit Root Test					**Im-Pesaran-Shin Unit Root test**			
	At Level		**At First Difference**		**At Level**		**At First Difference**	
Variables	**Statistics**	**P-Value**	**Statistics**	**P-Value**	**Statistics**	**P-Value**	**Statistics**	**P-Value**
Vulnerability	85.42	0.31	131.7	0.0002	-2.0548	0.0199		
EM	148.7	0.000			-3.1403	0.0008		
IQ	82.66	0.39	100.73	0.05	-0.03758	0.3535	-1.2939	0.0978
lnGDP	51.69	0.99	97.73	0.08	2.4131	0.9921	-13.5101	0.000

Author's own Estimation

Table 5: Order of integration		
Variables	**Order of Integration**	
	Fisher's Dickey Fuller Unit Root Test	**Im Pesaran Shin Unit Root test**
Vulnerability	I(1)	I(0)
EM	I(0)	I(0)
IQ	I(1)	I(1)
lnGDP	I(1)	I(1)

Author's own Estimation

In order to confirm the existence of long-run relationship between dependent and independent variables Kao, Pedroni and Westerlund Cointegration tests for panel data are used. There results confirmed the existence of long-run relationship between variables.

Table 6: Co-integration for panel data		
Kao Test For co-integration		
Tests	**Statistics**	**P-Value**
Augmented Dickey–Fuller t	1.4264	0.0769
Unadjusted modified Dickey–Fuller t	-3.2276	0.0006
Unadjusted Dickey–Fuller t	-3.3136	0.0005
Pedroni Test for co-integration		
Tests	**Statistics**	**P-Value**
Phillips–Perron t	-9.2119	0.000

Augmented Dickey–Fuller t	-9.0003	0.000
Westerlund Test for co-integration		
Test	**Statistics**	**P-Value**
Variance ratio	-3.9959	0.000

Author's own Estimation

In the final step, panel Quantile Regression is used to estimate the results of model (Sarkodie & Strezov, 2019). Table 6 presents results of estimated model.

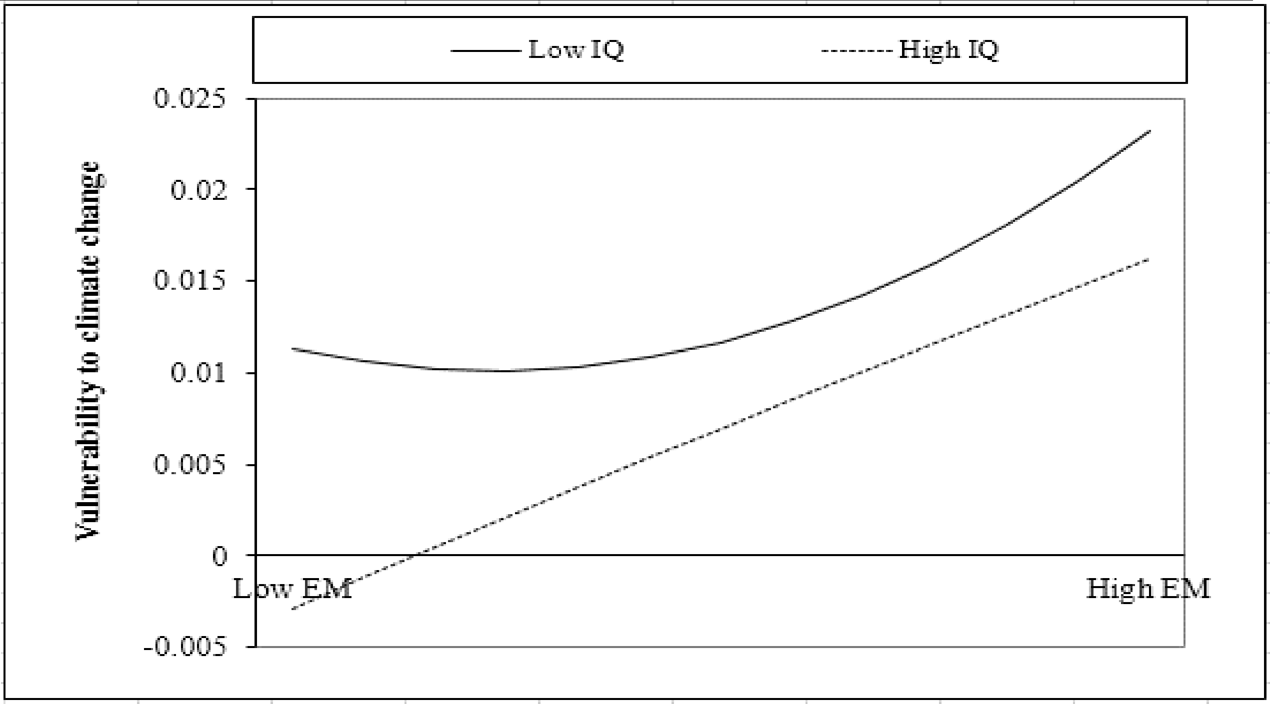
Table 7: Panel quantile regression

Vulnerability	Coefficient	Std. Error	z-value	P-Value
IQ	-0.0068	-0.0025	-2.9	0.004
EM	0.00108	-0.0001	10.66	0.000
EM2	-1.50E-05	-9.28E-06	-1.66	0.096
EM*IQ	0.0007	-6.62E-05	10.62	0.000
EM2*IQ	-0.000039	-6.46E-06	-5.99	0.000
lnGDP	-0.01421	-0.00068	-20.94	0.000
Ecmt-1	-0.0113	0.00004	-308.86	0.000

Author's own calculations

These results indicate that increase in IQ and GDP will decrease the climate change vulnerability. The results are supported by Tang et al. (2021) who also found the inverse relationship between IQ and environment degradation. There is positive relationship between mixed energy and vulnerability while there is negative relationship between mixed energy square and vulnerability. These results are supporting the existence of inverted u-shaped curve (Dai et al., 2022). This relationship indicates that at initial level vulnerability increases with the increase in mixture of energies but after reaching a certain level vulnerability decreases due to high use of renewable energy sources. This is due to the fact that at initial level cost of installation of renewable energy plants is high so that benefits are low while gradually their benefit increases (Dai et al., 2022). Institutional Quality is used as a facilitator that increases the benefit of renewable energy sources in mixture of energies and reduces the climate change vulnerability (Tang et al., 2021). Interaction of IQ with energy mix and energy mix square is used. Mixture of energies along with IQ has positive relationship with climate change vulnerability. While mixture of energies square along with IQ has negative relationship with climate change vulnerability. These results indicate that Institutional Quality with high combination of energies reduces the vulnerability to climate change. The value of ECM_{t-1} is negative and significant. The negative sign indicates that convergence hypothesis holds which means that whenever any macroeconomic shock occurs in the economy, this model has the tendency to converge back to equilibrium. Figure 4 is drawn by using the methodology of (Dawson, 2014). This figure shows that Institutional Quality has the potential to decrease the vulnerability to climate change.

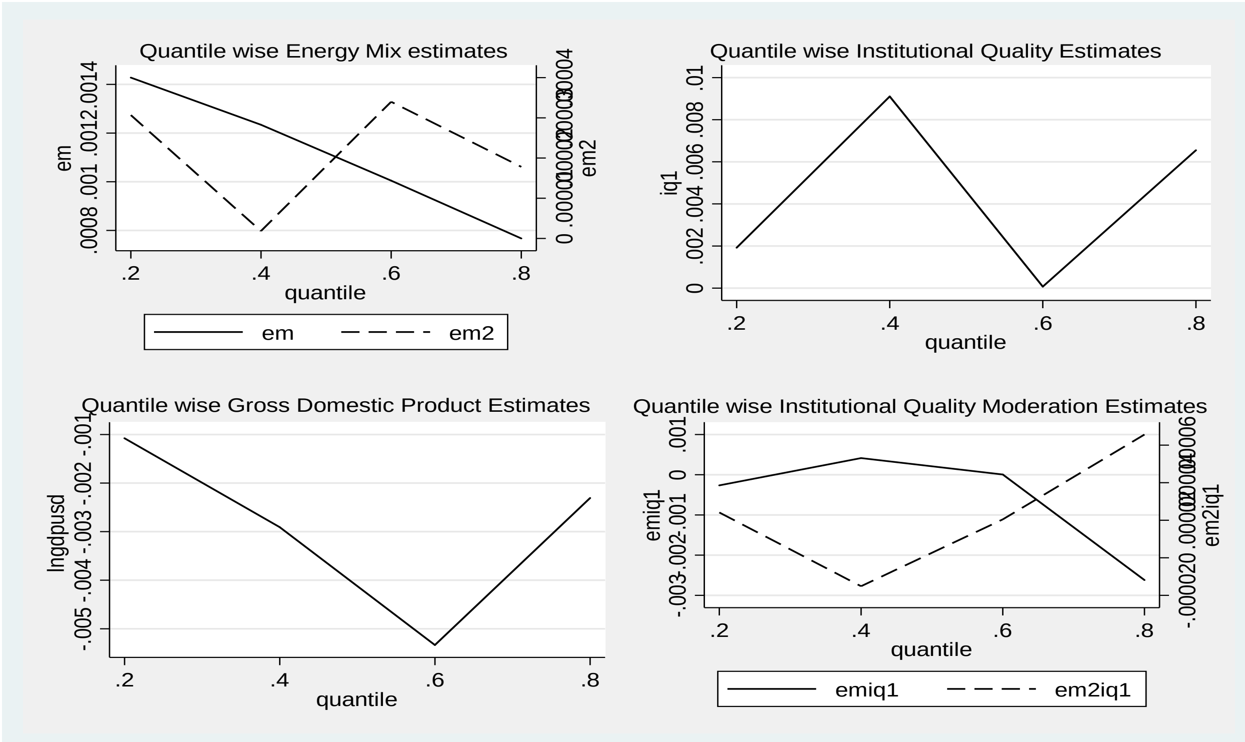
Figure 4: Impact of institutional quality on the role of energy mix in decreasing vulnerability of highly vulnerable countries



Author's own estimation

Quantile-wise graphs are measuring the impact of independent variables with the change in distribution of dependent variable that is climate change vulnerability. Quantile wise plots are presented in figure 5. In these graphs x-axis is showing the change in the size of dependent variable while y-axis is presenting the change in impact of independent variable with the change in the size of dependent variable. These graphs explain that with the increase in quantile of climate change vulnerability size of EM decreases while the size of EM2 increases which is indicating U-shaped EM. Combination of energies will be of U-shaped where vulnerability is high as compared to countries where climate change vulnerability is low. Second panel is showing quantile wise IQ estimates. The impact of institutional quality increases then deceases and again increases with the increase in quantile or distribution of climate change vulnerability which graph is showing N-shaped relationship between these variables. Third panel is measuring quantile wise GDP estimates which indicates that GDP first decreases with the increase in distribution of climate change vulnerability then increases in with the increase in quantile of climate change vulnerability. Forth panel is showing quantile wise Institutional quality moderation estimates. This graph shows that with the increase in quantile of vulnerability interaction of combination of energies and IQ decreases while the square of EM and IQ increases.

Figure 5 Quantile-wise plots



Author's own estimation

Conclusion

Abrupt changes in climate cause loss of food production, infrastructure, and mental and physical health of well-being. Carbon emissions in the atmosphere are polluting the air. Fossil fuel is the primary cause of this emission. Renewable energy resources, combined with energy, can mitigate this problem.

This study investigated the problem of vulnerability to climate change in highly vulnerable economies and provided a solution to it. Panel Quantile regression is used to get the final results of the study. The study sample comprised 40 highly vulnerable countries from 1995-2020. These highly vulnerable economies were selected based on the ranking of ND-GAINS (ND-GAINS, 2023). The sample was comprised of less developed and developing countries. These countries are more vulnerable due to limited resources and weak government institutions. Developed countries are major contributors of environmental change due to high carbon emission in the atmosphere and less vulnerable to climate change.

In contrast, developing countries are consumers of climate change and highly vulnerable to climate change. The rapid increase in population in lower and middle-income countries is accompanied by the rapid increase in vulnerable populations by forcing people to live in urban informal settlements. There is an urgent need to build resilience to change in climate in these informal settlements.

Results of this study indicate a positive relationship between mixed energies and vulnerability and a negative relationship between mixed energies square and vulnerability. These results support the inverted U-shaped curve (Dai et al., 2022). Institutional Quality is a facilitator that increases the benefit of renewable energy sources in mixed energies and reduces the vulnerability to climate change (Tang et al., 2021). Mixed energies and IQ have a positive relationship with climate change vulnerability. At the same time, mixed energies square along with IQ has a negative relationship with climate change vulnerability. These results indicate that Institutional Quality with high mixed energies reduces the vulnerability to climate change. Good governance is necessary to mitigate this problem.

Furthermore, developing countries should focus on and formulate institutional reforms. In this way, the efficiency of government institutions can be increased. Government must identify the institutions that are directly responsible for mitigating natural calamities. Public institutions in developing countries can bring optimal reforms to enhance their performance and overcome institutional failures. International commitment from developed nations to developing countries is necessary to strengthen economic readiness, resilience to climate change, and adaptive capacity to climate-related events/disasters. This study is limited to 40 highly vulnerable countries. The results of this study may support government agencies, researchers, and environmental activists in developing resilient and inclusive climate change strategies that will increase the social well-being and health of the more vulnerable populations of the world. By strengthening the quality of institutions, the government should promote the use of renewable energy and reduce the use of fossil fuels, the main contributor to environmental pollution. This study provides

- The primary input for the decision-making of government and policymakers in planning and designing.
- Managing, monitoring, and implementing the resistant climate change susceptibility-centered development actions.

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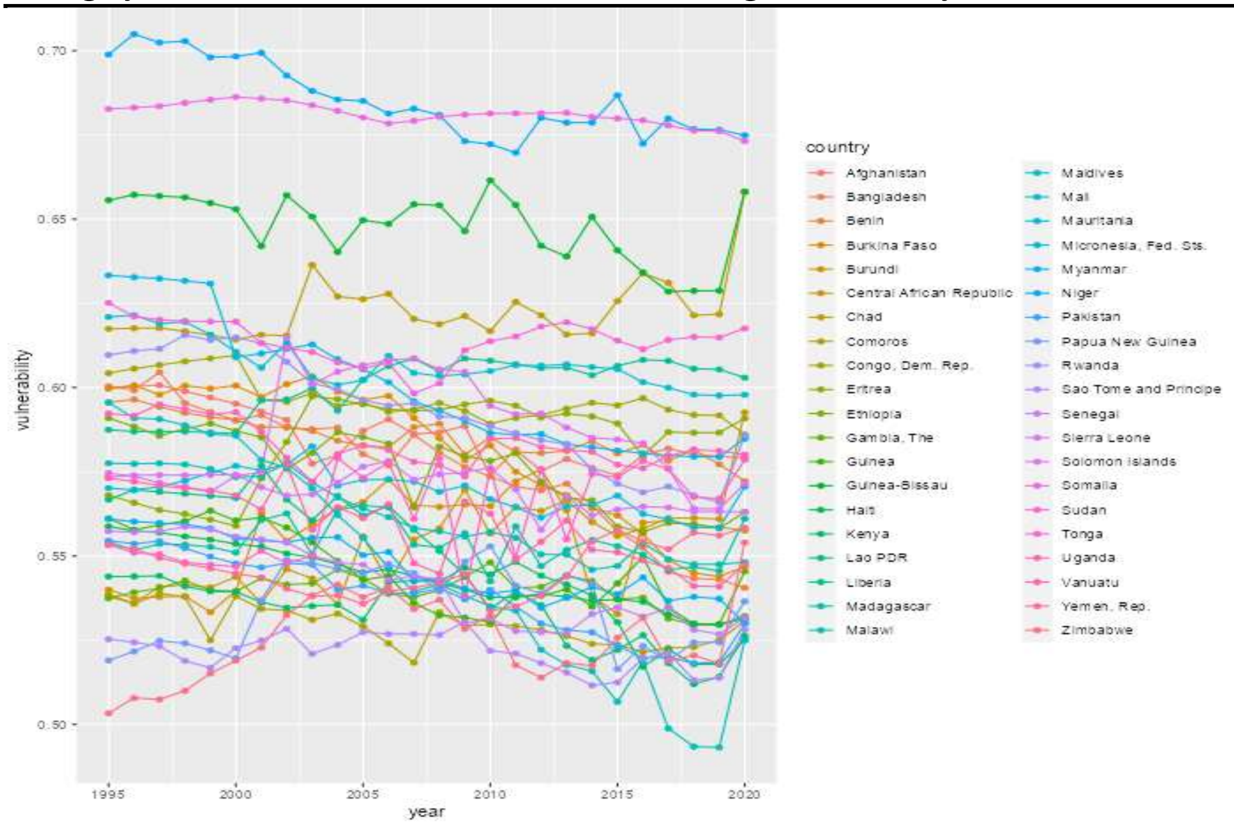
Appendix

List of high vulnerable countries

Highly vulnerable countries

Rank	**Country**	**Income Group**	**Vulnerability**	**Rank**	**Country**	**Income Group**	**Vulnerability**
143	Kenya	Low	0.525	163	Ethiopia	Low	0.563
143	Maldives	Upper middle	0.525	163	Sierra Leone	Low	0.563
145	Laos	Lower middle	0.526	165	Mauritania	Lower middle	0.571
146	Sao Tome & Principe	Low	0.528	165	Solomon Islands	Low	0.571
147	Myanmar	Lower middle	0.53	167	Benin	Low	0.572
147	Pakistan	Lower middle	0.53	168	Afghanistan	Low	0.579
149	Comoros	Low	0.531	168	Tonga	Lower middle	0.579
149	Haiti	Low	0.531	170	Uganda	Low	0.58
151	Guinea	Low	0.532	171	Micronesia	Low	0.585
151	Senegal	Low	0.532	172	Dem. Rep. of the Congo	Low	0.586
153	Papua New Guinea	Low	0.536	172	Rwanda	Low	0.586
154	Bangladesh	Lower middle	0.541	174	Eritrea	Low	0.591
155	Gambia	Low	0.545	175	Central African Rep.	Low	0.593
156	Burkina Faso	Low	0.547	176	Mali	Low	0.598
157	Malawi	Low	0.548	177	Liberia	Low	0.603
157	Vanuatu	Low	0.548	178	Sudan	Low	0.618
159	Zimbabwe	Low	0.554	179	Guinea-Bissau	Low	0.658
160	Burundi	NA	0.558	179	Chad	Low	0.658
160	Yemen	Low	0.558	181	Somalia	Low	0.673
162	Madagascar	Low	0.561	182	Niger	Low	0.675

40 Highly vulnerable countries and their climate change vulnerability



Source: ND-GAINS