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The Role of Human Capital in Strengthening Energy Mix-Climate Change Relation: A Study of Selected Low and High Vulnerable Economies

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Abstract
Adaptive capacity of human is influenced by socio-economic factors such as skills, resources, technology and governance. Human-induced climate change is affecting all the nations of world. Adaptation measures are required to mitigate its effects. The aims of current research are: a) to identify the factors that can reduce vulnerability in low and high vulnerable countries, b) to find the factors that can moderate the effect of climate change in these countries, c) to compare the effect of these factors in high and low vulnerable economies. Panel Quantile Regression is used as an econometric technique to get the final results of the study. Sample is comprised of 40 low and high vulnerable countries, and data range from 1995-2020. Division of sample countries is based on the ranking of ND-GAINS. Data for present study is collected from ND-GAINS, WDI and PWT. Results exposed negative relationship between Human Capital and climate change vulnerability. Moreover, human capital along with energy-mix reduces climate change vulnerability in case of low and high vulnerable countries. Communication and education increase capacity-building skills and knowledge which help to reduce the risk associated with hazard and prepare us to deal with that hazard. Present study is conducted to highlight the importance of Socio-Economic factors in strengthening energy-mix climate change relation. This study will help the Policy makers and governments to cope with the adverse impact of climate change.
Keywords: Human Capital, Vulnerability, Energy Mix, renewable energy

1. Introduction

The excessive use of energy brings different challenges to the environment in the form of carbon emission that is a main cause of climate change. Due to health issues linked with carbon emissions, clean energy such as renewable energy is an effective alternative to fossil-fuel (Wang et al., 2018). Renewable energy can tackle climate change by reducing CO2 emission in the atmosphere. In the energy mix inclusion of renewable energy has become an important part in the energy policies of world (Dong et al., 2018). Human-induced climate change is affecting all the nations of world. Adaptation measures are required to mitigate its effects (Abbass et al., 2022). Due to global warming, consequences in the form of shortage of food, failure of crops, disruption of water system, and destruction to infrastructure and settlements, harm to human health further increases (Field & Barro, 2014).
Over past two decades, in the world approximately 11,000 weather related extreme events reported which affected almost 94.9 million people, approximately 475,000 died from these events and these disasters incurred the loss of 2.56 trillion USD (Eckstein et al., 2021). Climate change is causing more vulnerable impact on poor economies as compared to developed economies (Amegavi et al., 2021). Unfortunately developing nations are suffering a lot due to extreme weather events because of weak socio-economic status, poverty and poor environment (Hamidi et al., 2020). Developing countries are not able counter climate-related risks because these countries lack suitable infrastructure, technology, adaptive capacity and more importantly human and physical capital as compared to developed countries (Millner & Dietz, 20151). Climate-related hazards are responsible for significant consequences due to lack of adaptation and readiness to combat these events (Sarkodie & Strezov, 2019). Energy is the need of an economy without which development is not possible. Greenhouse gases are increasing rapidly and fossil-fuel is the primary cause of it. To address this issue, countries are focusing on the use of renewable energy to cut these emissions (Sarkodie et al., 2020; Wang et al., 2018). The transition of moving from traditional sources to renewable energy sources i.e. solar, wind, hydro, tidal etc. is increasing adaptive capacity (Ellabban et al., 2014), reducing GHGs and improving living standard (Zahid et al., 2021).
Climate change is main economic, environmental, social and political problem in many countries of world. Many recent studies have confirmed the variability of impact of changes in climate on human population and their environment. Many countries have accepted this fact and implemented different measures to reduce the impact of human activities on environment. Human activities include the uses of land for urbanization and misuse of fossil fuel for energy, agriculture and industry etc. increases carbon emission in the atmosphere (Cao et al., 2017; Ali & Audi, 2016). Due to increase in carbon emission in the circulation average temperature increases, sea-level rises and number of incidence of natural disaster increases. These disasters increase famine, financial loss, death toll increases, decreases biodiversity and spread different diseases (Rekacewicz & Bournay, 2005). Figure 1 below represents the process of climate change, its characteristics and threats that are related to climate change.
Many developed countries are reducing the consumption of fossil fuel which is the major source of climate change and promoting the use of renewable energy sources (RES) aims to provide energy to the society from environment friendly sources (McInerney & Bunn, 2019). Use of RES reduces greenhouse gas emission (Gielen et al., 2019). Renewable energy is specified as climate mitigation strategy by different studies (Chen et al., 2011; Searle and Malins, 2015; Ziska et al., 2009). These resources provide many advantages to the population and it reduces GHGs emission that help to improve the health of people and protect them from different respiratory diseases (Sahoo, 2016; Baqir et al., 2019; Dong et al., 2019). In European Union many western countries have changed their policies with their main focus is on mitigation of climate change and energy emission (Kedward & Ryan-Collins,

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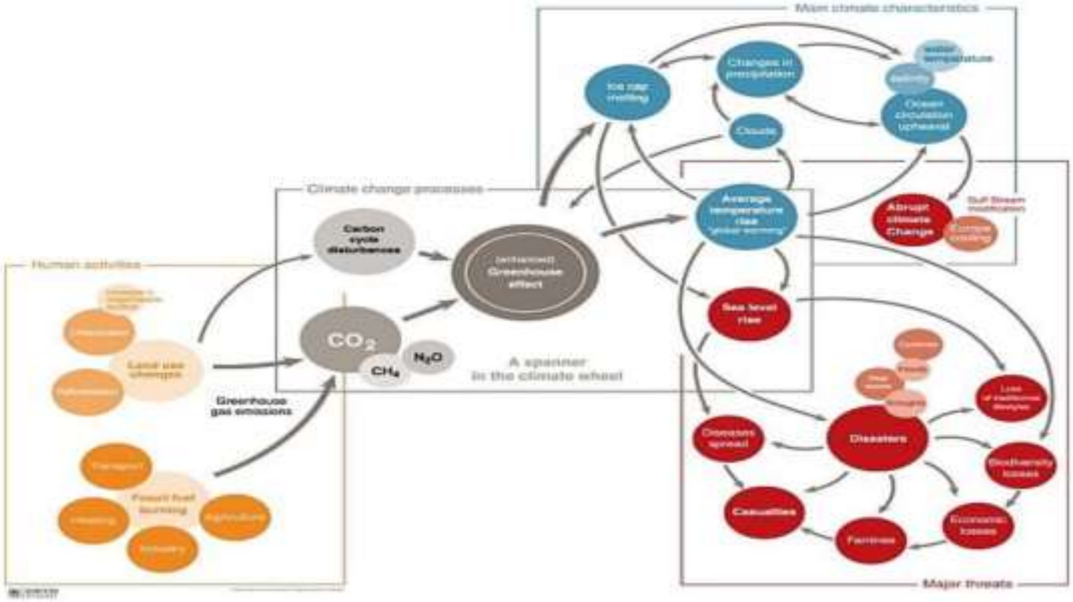
2022). For sustainable economic recoveries fostering energy policies include: curb fossil consumption, accelerate efficient energy, investment in renewable energy, energy security, resource management and climate mitigation (Hainsch et al., 2020; Christou, 2021; Schoenefeld, 2021; ; Ali et al., 202). The relationship between human capital and climate change vulnerability of low and high vulnerable economies is represented in graph 1. These graph indicate that vulnerability is high when human capital is low and vice versa.

Figure 1: Climate change: process, characteristic, and threats

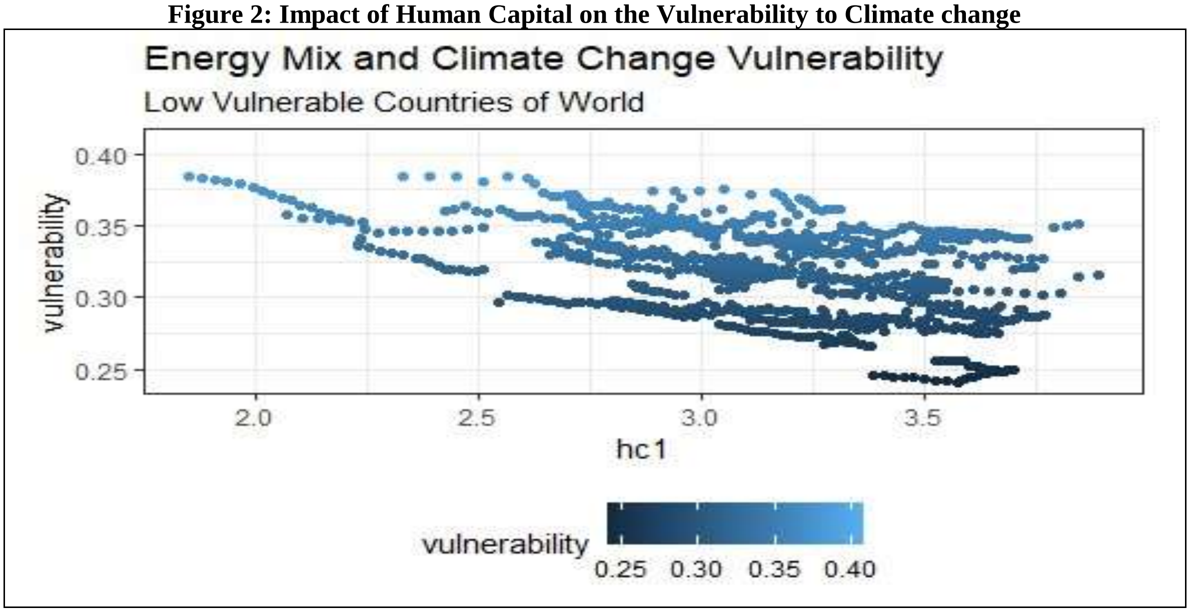


Source: Rekacewicz and Bournay (2005)

Figure 3 indicates that use of renewable energy alone does not reduce vulnerability of high vulnerable countries. There is a need to incorporate moderator or facilitator that have the ability to maximize the reward of using renewable energy. We can maximize the benefits of renewable energy through Education by encouraging people to install panels at micro-level (homes).

This study will investigate the preconditions for the effective consumption of energy-mix which will decrease the climate change vulnerability. In this vein HC is used as moderating (facilitating) factors on the relationship between consumption of energy mix and climate change vulnerability (Tang et al., 2021; Audi & Ali, 2023). This study will investigate the role of energy mix in decreasing climate change vulnerability and include HC as a necessary condition in mitigating climate change vulnerability. The objectives of conducting this research are: a) to identify the factors that can reduce vulnerability in low and high vulnerable countries, b) to find the factors that can moderate the effect of climate change in these countries, c) to compare the effect of these factors in high and low vulnerable economies. The result of current study will provide the guidance to improve the adaptive capacity of high vulnerable economies.

Figure 2: Impact of Human Capital on the Vulnerability to Climate change



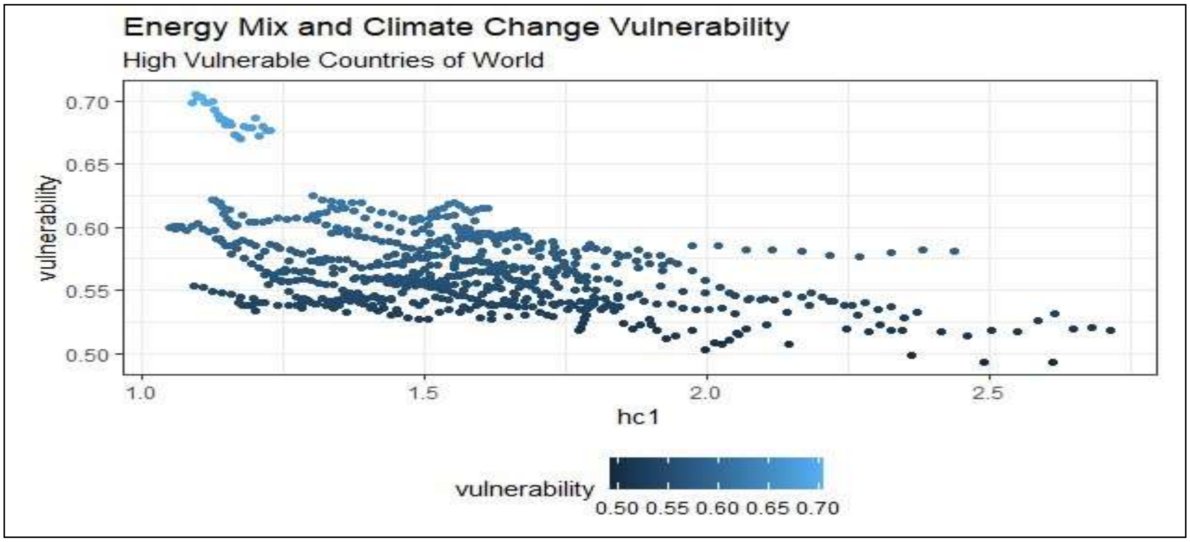
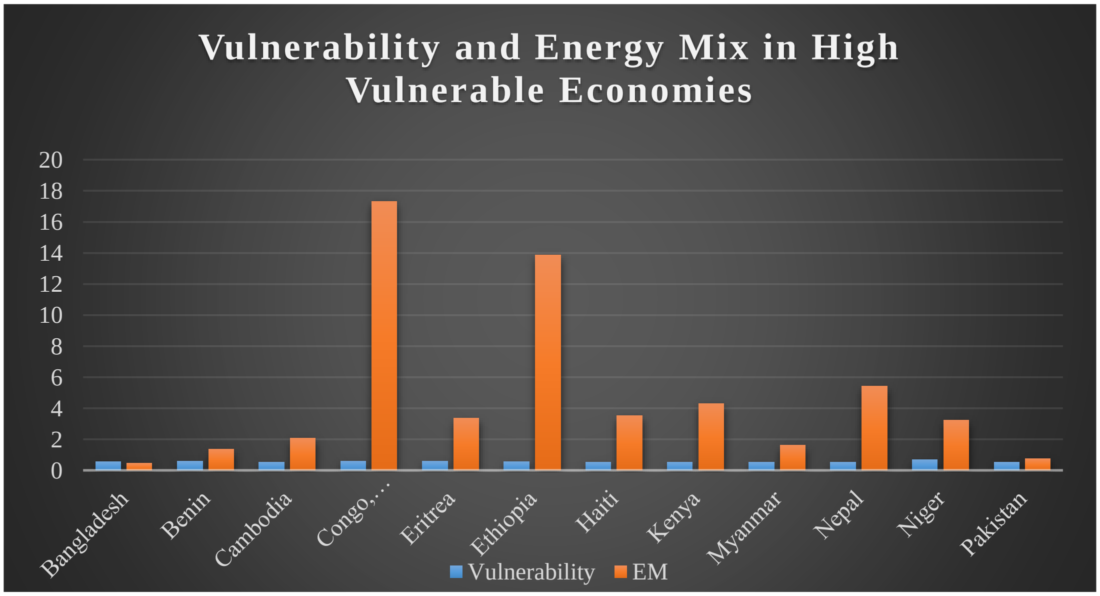


Figure 3: represents vulnerability and energy mix in high vulnerable economies.

Figure 4: Energy Mix and Vulnerability to climate change in High Vulnerable Countries



Data Source: WDI, ND-GAINS

Organization of this study is as follows: Literature review is discussed in section 2, section 3 is comprised of theoretical framework, section 4 includes methodology, and results are discussed in section 5 and section 6 is comprised of conclusion.

2. Literature Review

Many researchers have discussed climate change and its impact on environment in their research papers. Lemos et al. (2007) mentioned the factors that can create adaptive capacity and encourage institutions that authorize evolutionary change and raise the level of education and income. These factors are knowledge and information. Investment in knowledge and information is necessary for the creation of adaptive capacity. Mertz et al. (2009) argued that there is a need of innovative, robust, institutional, and flexible, governance, policy and inclusive structure to limit the uncertainties associated with climate change, to support the population of developing countries to better adapt to these adaptations.

Manandhar et al. (2011) in their research explored that in Nepal farmers were responding quickly to changes in climate but their responses were limited to short-term. In the long-run these responses were inadequate to cope the adverse impact of climate change. Lebel (2013) identified few evidences indicating the direct influence of local knowledge in reducing vulnerability to climate change. Out of these contributions, most of them were based upon responses to existing changes in climate opposed to long term variations in climate. Regmi and Bhandari (2013) conducted research to explore the ways to overcome the barriers in implementing the adaptations in Nepal. These barriers are institutional framework, available technology and knowledge. These barriers should be removed for the implementation of effective adaptation measures. Lucas et al. (2017) studied different challenges for the deployment of renewable energy in the small developing Pacific Island which is most vulnerable to changes in climate and identified successful examples of using RE in this region. Many barriers also exist in this region that prevent the use of

RE at larger scale. These barriers include lack of data on RE, socio-cultural impediments, scarcity of financial resources, costly infrastructure, need for regulatory framework and policies, and shortage of human resources.

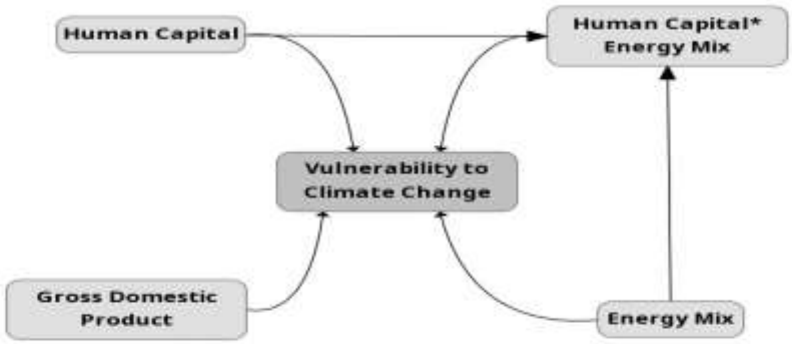
Mahmood et al. (2019) used 3SLS regression method to examine the impact of renewable energy, economic growth and human capital on carbon emission in Pakistan. Income level in Pakistan and renewable energy contribute to carbon emission while human capital mitigate the effect of CO_2 emission. Sarkodie et al (2019) studied the impact of social, economic and governance readiness measures on the climate change vulnerability of 192 countries. This study used Pooled OLS, PMG and Panel Quantile Regression. Africa is most vulnerable economy due to high exposure and sensitivity but less adaptive capacity while developed economies are less vulnerable due to high adaptive capacity. Least-developed nations with less adaptive capacity are more vulnerable to changes in climate (Edmonds et al., 2020). Amegavi et al (2021) used panel Quantile Regression to study the impact of readiness on the vulnerability of 51 African countries for the time of 1995-2018. Results indicate negative impact of adaptation readiness on the climate change vulnerability. Tessema et al. (2021) studied the Ethiopian rural community's vulnerability to climate stress i.e. droughts. Land cover is the major factor which affect the sensitivity of droughts in those areas. Major factors that affect the adaptive capacity are annual income, number of owned livestock and educational level of head household. The livelihood vulnerability is attributed to higher sensitivity and low capacity to adapt. Sensitivity of community to droughts is determined by health infrastructure, access to assets, water supply quality and bio-physical factors such as soil fertility and size of land holding while adaptive capacity determined by level of social group relation, education and factors such as holding of land and number of owned livestock (Tessema et al., 2021). Tang et al. (2021) examined the moderation effect of IQ and Education on environmental pollution. IQ and education act as a facilitator that facilitate renewable energy to reduce environmental pollution. Sarkodie et al. (2022) used 2SLS method to investigate the effect of readiness on the vulnerability of 192 countries for the period of 1995-2017. Findings indicate that less developed countries with lower adaptive capacity are more vulnerable to climate change while high income countries with adaptation and readiness are less susceptible to climate change. Joof et al. (2023) conducted their study to investigate the effect of climate change and renewable energy on biodiversity in BRICS countries. NARDL method is used to investigate this problem. Findings indicate that CO_2 emissions are harmful to environmental quality. Moreover, decrease use of renewable energy worsen the biodiversity loss while promotion of renewable energy reduces biodiversity loss. Saeed et al. (2023) conducted their study to compare climate change and adaptation in lower-middle income, upper-middle income and high-income countries by using Driscoll–Kraay standard-error method for panel data over the period of 1995-2020. Developed nations such as France, USA, Germany, Ireland, Sweden, Australia, New Zealand, Austria, Canada, Belgium, UK, Denmark and Switzerland are extremely adaptive countries due to readiness for the adaptation. While developing nations with their low level of readiness are more vulnerable to changes in climate. Developed nations are less vulnerable to climate change because of their rich capital-resources, well-established economies, good governance and timely effective strategies.

Previously, few studies have focused on the importance of education to tackle the problem associated with climate change. Current study is conducted to highlight the importance of socio-economic factors to reduce climate change vulnerability. Current study is conducted to fill the gap in the vulnerability literature. Different studies have discussed climate change vulnerability in different context while these studies have ignored the facilitating role of human capital in reducing climate change vulnerability.

3. Theoretical framework

The dilemma of climate change was first discussed in the first assessment report of IPCC in 1990. The pattern of climate change, its drivers and effect of changes in climate on ecological and socio-economic system are highlighted in this report (Intergovernmental Panel on Climate Change, 1992). The results of this discussion contributed to the organization of UNFCCC (1992/1994). After the Rio Earth Summit in 1992, UNFCCC goals to stabilize greenhouse gas emissions. In 1994 UNFCCC became active and set framework for agreements such as Koyoto protocol and Paris agreement. Paris agreement was adopted after the failure of Koyoto agreement to reduce greenhouse gas emissions and reduce global temperature (Pachauri et al., 2014; Baste and Watson, 2022). Paris Agreement in 2016 set adaptation goal "strengthening adaptive capacity, improving resilience, and lessening vulnerability to climate change to contribute to sustainable development." This agreement emphasize capacity building for under-developed economies and demand developed nations to support developing countries in their climate-related capacity building (McCarthy, 2001) (IPCC, 2018). Rapid increase in CO_2 Emission is linked with rapid development by utilizing more resources. Emerging and developed economies are at the forefront of carbon emission per capital as compared to developing economies (Froemelt et al., 2018; Audi & Ali, 2023). Adaptive capacity of human is influenced by socio-economic factors such as skills, resources, technology and governance. The enabling properties of both societal and natural assets are also involved in the adaptive capacity, including technological, financial and information context and resources including environment, social network, infrastructure, public policy, institutional governance and political influence within which assets are held (Ensor & Berger, 2009). Climate change adaptations involve complex set of institutional and socio-economic interactions (Smithers and Smit, 1997; Schipper and Burton, 2009). Adaptation history indicate that both human and natural system are adapting to ecologic and environmental stresses. According to Smith 1994 and Smithers and Smit (1997) adaptive responses are better explained by role and intent of government, timing, scale, duration, effect and form. Multiple factors influence adaptive capacity include social, economic, technological, governance and human. Social network, social capital, traditions, customs, values, cognition level and perceptions affect the capacity of community to adapt to risk associated with climate change (Adger et al., 2006). Organizations, institutions and people can use skills and resources to anticipate, cope and recover from natural hazards. Communication and education increases capacity-building skills and knowledge which help to reduce the risk associated with hazard and prepare us to deal with that hazard (Pismel et al., 2023). Figure 5 presents the role of human capital in strengthening Energy Mix-Climate Change Relation.

Figure 5: Role of Human Capital in reducing Energy Mix-Climate Change Relation



4. Methodology

4.1. Data Source

Data for this paper is collected from WDI, ND-GAINS and PWT. Below table 1 represents variables, their source and transformation.

Table 1: Variables and their Transformation

Variables	Transformation	Source
Vulnerability	V_{it} "Index"	ND-GAINS
Human Capital	HC_{it} "average years of schooling and return to education"	PWT
Energy-Mix	EM_{it} "ratio of renewable to non-renewable energy"	WDI
GDP US$	$lnGDP_{it}$ "ln(GDP US$)"	WDI

4.2. Sample Selection Criteria

Sample of 40 Low and 40 high vulnerable countries of world are selected for this analysis. Countries are selected on the basis of ranking of ND-GAINS (*ND-GAINS*, 2023). The less vulnerable countries are mostly upper income and upper middle-income countries while high vulnerable countries are mostly under developed and developing countries.

4.3. Model Specification

This study constructs on the model which exhibits on the relationship between climate change vulnerability, human capital, energy mix and GDP.

Vulnerability = *f* (Energy Mix, Human Capital, Gross Domestic Product)

Where,

Vulnerability is used as dependent variable in the model. Notre Dame University is the producer of "Global Adaptation Index". This index is worldwide accepted to assess climate changes since 1995 (Abdelzaher et al., 2020). Vulnerability is composed of three components which are weighted equally. These are exposure, sensitivity and ability to adapt.

The definitions of components of vulnerability index are:

1) Exposure: "The *exposure* of the sector to climate-related or climate-exacerbated hazards which is mostly a function of biophysical attributes"
2) Sensitivity: "the *sensitivity* of that sector to the impacts of the hazard"
3) Adaptive Capacity: "*adaptive capacity* of the sector to cope or adapt to these impacts"

Energy mix is used as explanatory variable in the analysis which is the "ratio of renewable energy to non-renewable energy" (Dai et al., 2023).

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

Human capital is used as explanatory variable as well as a facilitator in the analysis that have capability to moderate the impact of climate change. It is based on "average years of schooling and return to education"

GDP is used as a control variable in the analysis which represents the growth of economy.

The econometric equation of model is as follows:

$$V_{it} = \alpha_{\circ} + \beta_1 EM_{it} + \beta_2 EM^2_{it} + \beta_3 EM_{it} *HC + \beta_4 EM^2_{it} *HC + \beta_5 lnGDP_{it} + \mu_{it} \qquad (1)$$

This paper uses the methodology provided by Haans et al. (2016) to find mediation effect. EM and EM2 will confirm the existence of U or inverted U-shaped curve. First cross product will describe how HC changes the linear effect of EM on Climate change vulnerability while cross product with EM2 will describe how HC changes non-linear effect of EM on Vulnerability.

4.4. Econometric Technique

The first step is to estimate summary statistics which provide basic information about the variables used in analysis. After checking for multicollinearity of data panel DF unit roots test by Fisher is used to check the stationarity of data. In the next step, Westerlund, Pedroni and Kao test of co-integration are used to confirm the existence of long-run relation between variables. This study uses Quantile Regression for Panel Data to get the final results. This method allows researchers to account unobserved heterogeneity (Canay, 2011). It is used to control heterogeneity across quantiles, cross-sectional dependence and unconditional distribution (Sarkodie & Strezov, 2019).

5. Discussion of Results

Summary statistics is the initial step of analysis. It provides basic information about all the variables used in the analysis. As the mean value of vulnerability, HC and lnGDP are greater than their standard deviation, these variables are over-disbursed while the mean value of EM is less than its standard deviation, and EM is under-disbursed. Table 2 provides the summary statistics of data of less vulnerable countries.

Table 2: Summary Statistics of Low vulnerable countries

Low Vulnerable Countries							
Variables	Mean	Median	Minimum	Maximum	Standard Deviation	Skewness	Kurtosis
Vulnerability	0.320387	0.323927	0.241105	0.408288	0.03233	-0.17955	2.404515
EM	0.3421	0.138525	0	7.532877	0.752833	6.342432	51.45873
HC	3.16561	3.204533	1.854199	3.89154	0.37974	-0.71349	3.376959
lnGDP	25.976	26.19076	20.99624	30.6232	1.929748	-0.31965	2.92703

Author's own Estimation

The mean value of vulnerability, HC and lnGDP are greater than their standard deviation so these variables are over-disbursed while the mean value of EM is less than its standard deviation, and EM is under-disbursed. Table 3 provides the summary statistics of data high vulnerable countries.

Table 3: Summary Statistics of Low vulnerable countries

High Vulnerable Countries							
Variables	Mean	Median	Minimum	Maximum	Standard Deviation	Skewness	Kurtosis
Vulnerability	0.573312	0.567435	0.493146	0.704934	0.039845	1.010027	3.999339
EM	5.550944	3.192264	0.007097	59.97317	7.697701	3.060058	15.34891
HC	1.574133	1.542946	1.049339	2.713408	0.309265	0.88573	4.018675
lnGDP	22.566	22.67177	18.86742	26.50528	1.634992	0.024681	2.510526

Author's own Estimation

VIF is estimated to detect the problem of multicollinearity. Table 4 and 5 represents VIF which indicate that there is no problem of multicollinearity. Explanatory variables have no linear association with other explanatory variables.

Table 4: Variance Inflating Factor

Low Vulnerable Countries				
	Vulnerability	EM	HC	lnGDP
Vulnerability	-			
EM	1.015084	-		
HC	1.370223	1.000993	-	
lnGDP	1.09825	1.068271	1.076329	-

Author's own Estimation

Table 5: Variance Inflating Factor

High Vulnerable Countries				
	Vulnerability	EM	HC	lnGDP
Vulnerability	-			
EM	1.067409	-		
HC	1.339065	1.031593	-	
lnGDP	1.005672	1.008039	1.125733	-

Author's own Estimation

In the next step unit roots are estimated to check the order of integration. Results of Fisher's DF and IPS unit root test are presented in table 6.

Table 6: Unit Root for Panel Data

Low Vulnerable Economies								
	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	116.73	0.0046			-2.2615	0.011		
EM	52.9	0.9916	99.09	0.0727	4.3745	1	-2.1513	0.0157
HC	530.8	0			7.1211	1	-3.1741	0.0008
lnGDP	225.62	0			-3.6376	0.0001		
High Vulnerable Economies								
	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			-3.1403	0.0008		
HC	153.8	0			6.9208	1	-58.223	0
lnGDP	51.69	0.99	97.73	0.08	2.4131	0.9921	-13.5101	0

Author's own Estimation

Estimates of unit root have identified mix order of integration of variables used in the analysis. Table 7 presents order of integration.

Table 7: Order of Integration

Low Vulnerable Countries		
Variables	Fisher's Dickey Fuller Unit Root Test	Im Pesaran Shin Unit Root test
Vulnerability	I(0)	I(0)
EM	I(1)	I(1)
HC	I(0)	I(1)
lnGDP	I(0)	I(0)
High Vulnerable Countries		
Variables	Fisher's Dickey Fuller Unit Root Test	Im Pesaran Shin Unit Root test
Vulnerability	I(1)	I(0)
EM	I(0)	I(0)
HC	I(0)	I(1)
lnGDP	I(1)	I(1)

Author's own Estimation

Before moving to final step of analysis it is necessary to confirm the long-run relationship between variables used in analysis. For this purpose Kao, Westerlund and Pedroni co-integration test are used in the analysis which confirm the existence of long-run relationship between variables. Their results are presented in table 6.

Panel Quantile Regression is used to estimate the final results of this study. The same technique is used by Sarkodie and Strezov (2019). Final results of model are presented in table 9.

There is inverse relationship between human capital and climate change vulnerability. 1 unit increase in HC will reduce vulnerability by 0.03 units. Human capital through knowledge and skills reduces pollution as well as climate change vulnerability (Tang et al., 2021). Growth also reduces vulnerability. Vulnerability reduces with the increase in energy-mix while increase in EM2 increases vulnerability. The relationship of EM and EM2 with vulnerability support U-shaped curve. The cross-product of EM and HC reduces vulnerability while the cross-product of EM2 and HC also reduces vulnerability. These results of first cross-product indicate how HC changes the linear effect of EM on vulnerability. Its negative value indicate that cross-product of EM and HC reduces vulnerability. These results of second cross-product indicate how HC changes the non-linear effect of energy-mix on vulnerability. Its negative value also indicate that cross-product of EM2 and HC reduces vulnerability. HC along with energy-mix reduces the vulnerability of climate change. The negative and significant value of ECM_{t-1} indicate that convergence hypothesis hold for this analysis. This model have ability to converge back to equilibrium in respond to any shock (Narayan & Smyth, 2006). Table 10 represents the results of PQR in case of high vulnerable countries.

Table 8: Co-integration for Panel Data

Tests	Low Vulnerable Countries		High Vulnerable Countries	
	Statistics	P-Value	Statistics	P-Value
Kao test for co-integration				
Modified Dickey–Fuller t	-4.2818	0.000		
Dickey–Fuller t	-3.5304	0.0002		
Augmented Dickey–Fuller t	-2.5539	0.0053		
Unadjusted modified Dickey–Fuller t	-5.1777	0.000	-1.4615	0.0719
Unadjusted Dickey–Fuller t	-3.9103	0.000	-1.4257	0.077
Pedroni test for co-integration				
Phillips–Perron t	-5.4795	0.000	-5.6116	0.000
Augmented Dickey–Fuller t	-4.9355	0.000	-5.597	0.000
Westerlund test for co-integration				
Variance ratio	-3.6933	0.0001	-3.0667	0.001

Author's own Estimation

Table 9: Panel Quantile Regression in case of Low Vulnerable Countries

Low Vulnerable Countries				
Vulnerability	Coefficient	Std. Error	z-value	P-Value
HC	-0.03809	0.0000292	-1303.82	0.000
EM	-0.000129	0.0000319	-4.05	0.000
EM2	0.027505	0.0000892	308.33	0.000
EM*HC	-0.009975	0.0000169	-590.01	0.000
EM2*HC	-0.007479	0.0000295	-253.68	0.000
lnGDP	-0.005586	0.00000532	-1050.92	0.000
Ecmt-1	-1.15446	0.0230535	-50.08	0.000

Author's own calculations

Table 10: Panel Quantile Regression in case of high Vulnerable Countries

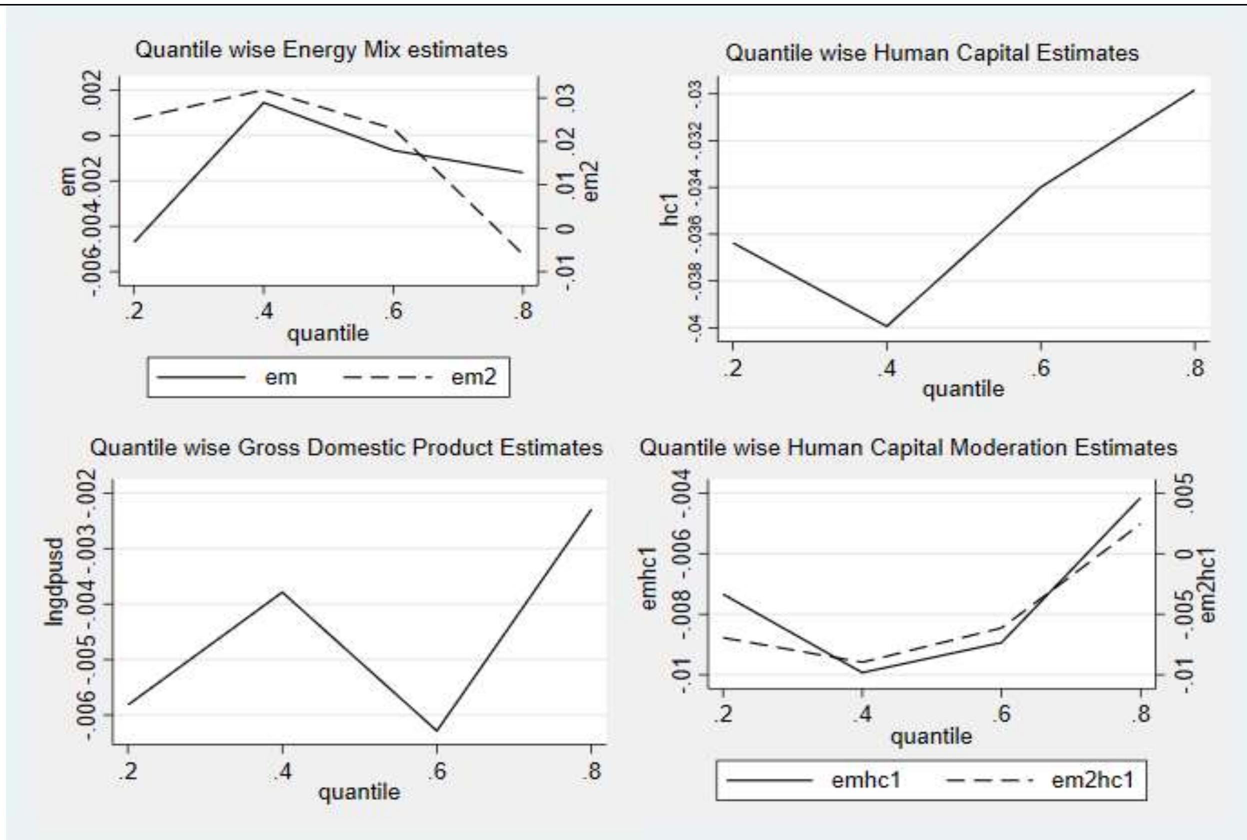
High Vulnerable Countries				
Vulnerability	Coefficient	Std. Error	z-value	P-Value
HC	-0.02551	0.0012612*	-20.23	0.000
EM	-0.00076	0.0000284	26.89	0.000
EM2	-0.000087	0.00000423	-20.57	0.000
EM*HC	-0.000058	0.0000298	-1.97	0.049
EM2*HC	0.000064	0.00000298	21.59	0.000
lnGDP	-0.00829	0.000565	-20.94	0.000
Ecmt-1	-0.02088	0.00186	-14.68	0.000

Author's own calculations

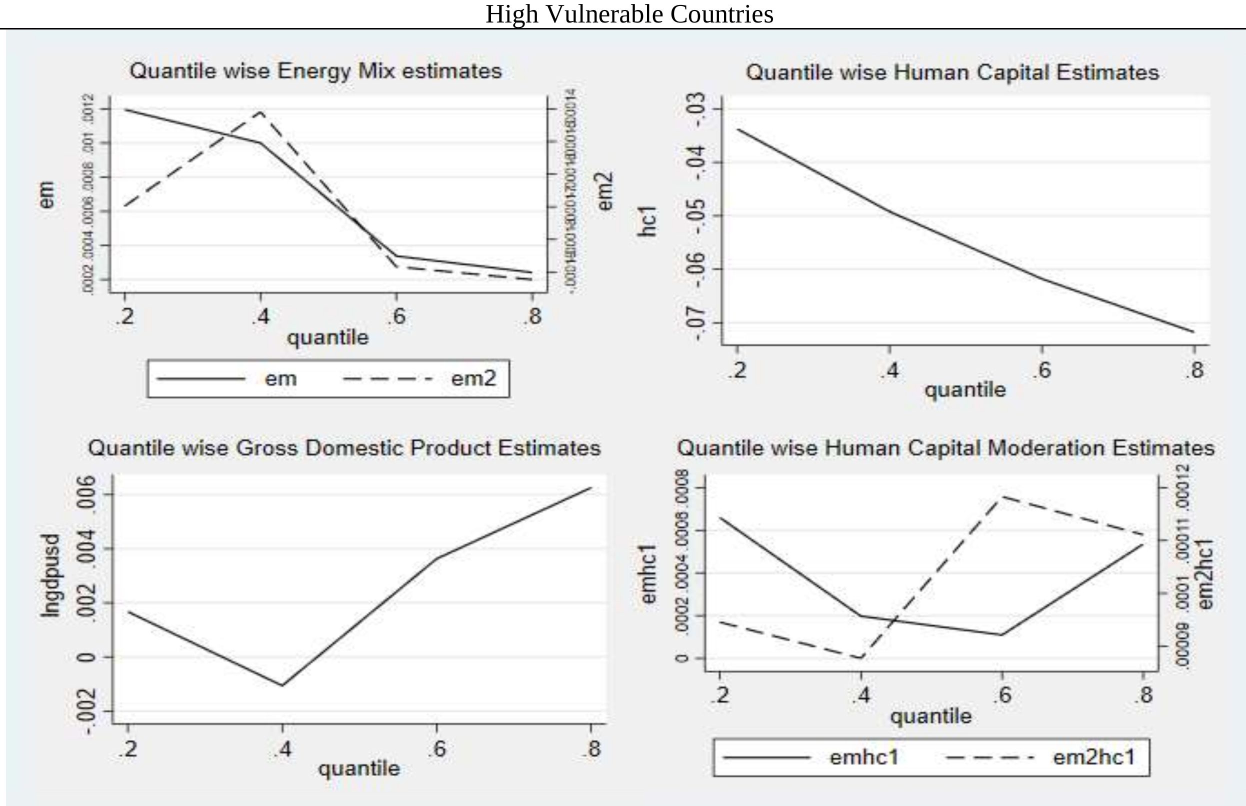
Results indicate inverse relationship between HC and Vulnerability. HC reduces Vulnerability. 1 unit increase in HC will reduce vulnerability by 0.02 units. Human capital through knowledge and skills reduces pollution as well as climate change vulnerability (Tang et al., 2021). Growth also reduces vulnerability. Both EM and EM2 are negative. Vulnerability reduces with the increase in energy-mix (Dai et al., 2023). The cross-product of EM and HC reduces vulnerability indicate that HC along with energy-mix reduces the vulnerability of climate change while the cross-product of EM2 and HC increases vulnerability in case of high vulnerable countries. The negative and significant value of ECM_{t-1} indicate that convergence hypothesis hold for this analysis. This model have ability to converge back to equilibrium in respond to any shock.
Quantile-wise graph estimates the effect of explanatory variables with the change in dependent variable (Graph 2).

Graph 2: Quantile-wise Estimates

Low Vulnerable Countries



High Vulnerable Countries

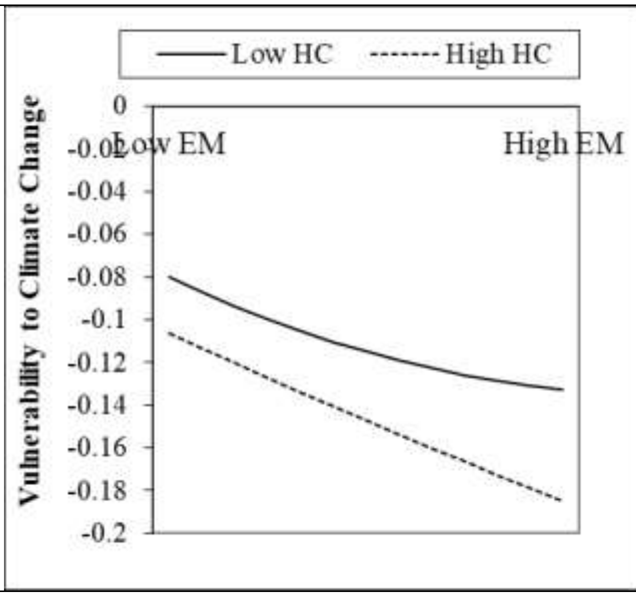
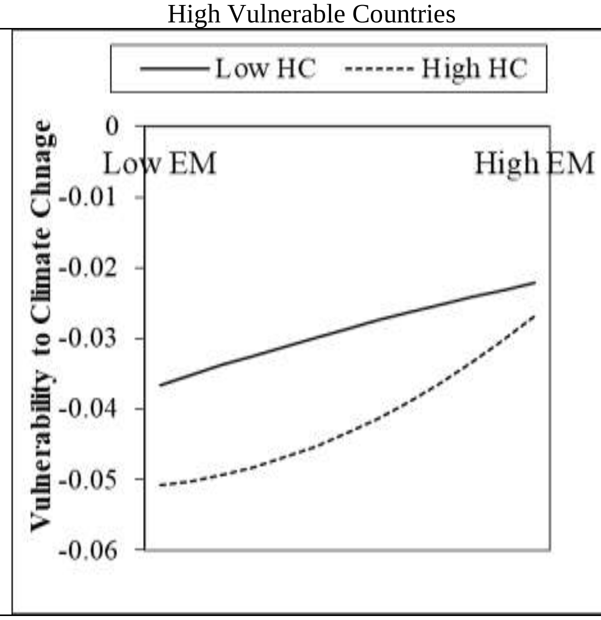


In case of less vulnerable countries, graph 2 indicate that with increase in vulnerability EM increases while EM2 decreases support inverted u-shaped relationship. EM is of inverted u-shaped where vulnerability is high as compared to low vulnerability. In the second panel, HC increases with the increase in the size of vulnerability. Third panel indicates quantile-wise estimates of GDP which shows N-shaped relationship of GDP and vulnerability. GDP first increases with the increase in vulnerability then decreases and again increases with the increase in the size of vulnerability. Panel four presents quantile-wise HC moderation estimates. Both cross-products increases with the increase in the size of vulnerability.

In case of high vulnerable countries, this graph indicate that with increase in vulnerability EM and EM2 decreases. In the second panel, HC decreases with the increase in the size of vulnerability. Third panel indicate quantile-wise estimates of GDP which indicate that GDP increases with the increase in vulnerability. GDP first decreases with the increase in vulnerability then increases with the increase in the size of vulnerability. Panel four presents quantile-wise HC moderation estimates. Both cross-products increases with the increase in the size of vulnerability.

Graph 3 is drawn by using methodology of Dawson (2014). This graph shows that climate change vulnerability is high at low HC and Low EM, while vulnerability reduces when both EM and HC are high. High EM and HC have potential to reduce climate change vulnerability. The intensity of human capital to reduce vulnerability is high in case of low vulnerable countries as compared to high vulnerable countries because sample of low vulnerable countries are high and upper middle-income countries. Developed nations such as France, USA, Germany, Ireland, Sweden, Australia, New Zealand, Austria, Canada, Belgium, UK, Denmark and Switzerland are extremely adaptive countries due to readiness for the adaptation. While developing nations with their low level of readiness are more vulnerable to changes in climate. Developed nations are less vulnerable to climate change because of their rich capital-resources, well-established economies, good governance and timely effective strategies (Saeed et al., 2023).

Graph 3: Impact of Energy Mix and Human Capital on Climate change Vulnerability

Low Vulnerable Countries	High Vulnerable Countries
	

Author's own Estimation

6. Conclusion

Adaptive capacity of human is influenced by socio-economic factors such as skills, resources, technology and governance. Current research is conducted to identify the factors that can reduce vulnerability in low and high vulnerable countries, find the factors that can moderate the effect of climate change in these countries and to compare the effect of these factors in high and low vulnerable economies. Panel Quantile Regression was used as an econometric technique to get the final results of the study. Sample was comprised of 40 low and 40 high vulnerable countries and data range from 1995-2020. Data for present study was collected from ND-GAINS, WDI and PWT.

Results revealed negative relationship between Human Capital and climate change vulnerability. Moreover, human capital along with energy-mix reduces climate change vulnerability in case of low and high vulnerable countries. Communication and education increase capacity-building skills and knowledge which help to reduce the risk associated with natural hazard and prepare us to deal with that hazard. Present study highlighted the importance of Socio-Economic factors in strengthening energy-mix climate change relation. Present study is limited to 40 low and 40 high vulnerable communities. Results of this study will help the governments, policy makers and researchers in formulating resilient climate change strategies that will improve the health of vulnerable population. Vulnerable communities should respond to changes in climate without any delay to enable them to on-going changes in climate. Scholars can conduct future research by considering more indicators to study vulnerability to climate change.

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Appendix

List of Low Vulnerable Countries

Rank	Country	Income Group	Vulnerability	Rank	Country	Income Group	Vulnerability
1	Switzerland	Upper	0.255	21	Greece	Upper middle	0.327
2	Norway	Upper	0.257	21	Poland	Upper	0.327
3	Austria	Upper	0.284	23	United States	Upper	0.329
4	Germany	Upper	0.293	24	Portugal	Upper	0.335
5	United Kingdom	Upper	0.296	25	Malta	Upper	0.338
5	Sweden	Upper	0.296	26	Belarus	Upper middle	0.345
7	Spain	Upper	0.3	27	Belgium	Upper	0.346
8	Canada	Upper	0.301	28	Kyrgyzstan	Lower middle	0.35
8	Luxembourg	Upper	0.301	28	Russian Federation	Upper	0.35
10	Czech Republic	Upper	0.303	28	Turkey	Upper middle	0.35
11	Finland	Upper	0.31	31	Netherlands	Upper	0.351
11	France	Upper	0.31	32	Denmark	Upper	0.354
11	New Zealand	Upper	0.31	33	Kazakhstan	Upper middle	0.358
14	Israel	Upper	0.316	34	Saint Lucia	Lower middle	0.359
15	Ireland	Upper	0.319	35	Estonia	Upper	0.363
16	Australia	Upper	0.32	36	Bulgaria	Upper middle	0.365
17	Iceland	Upper	0.321	36	Cyprus	Upper	0.365
18	Slovenia	Upper	0.322	38	Slovakia	Upper	0.366
19	Italy	Upper	0.323	39	Bosnia & Herzegovina	Upper middle	0.369
20	Chile	Upper middle	0.325	40	United Arab Emirates	Upper	0.37

List of high Vulnerable Countries

High Vulnerable Countries

Rank	Country	Income Group	Vulnerabilit y	Ran k	Country	Income Group	Vulnerabilit y
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