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The impact of climate change on the economies of developing countries

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Abstract

This study investigates the impact of climate change on the economies of developing countries, focusing on its effects on Gross Domestic Product (GDP) and other economic indicators. Employing a Panel Autoregressive Distributed Lag (ARDL) regression model, specifically the Pooled Mean Group (PMG) estimation, the analysis reveals both long-run and short-run relationships between climate variables and economic growth. The results indicate that rising temperatures and carbon emissions negatively influence economic growth in the long term, with temperature exhibiting a coefficient of -0.031 (p = 0.000) and carbon emissions showing a coefficient of -0.003 (p = 0.001). Conversely, energy consumption and population growth are identified as significant positive drivers of economic development, highlighting their roles in enhancing economic performance. Interestingly, the study also finds that short-term increases in temperature can temporarily boost economic activity, with a coefficient of 0.109 (p = 0.000), while rainfall has a marginally positive impact. However, these short-term benefits do not mitigate the long-term adverse effects of climate change, underscoring the vulnerability of developing economies reliant on climate-sensitive sectors. The findings emphasize the necessity for targeted policies aimed at fostering resilience to climate change, enhancing energy infrastructure, and promoting sustainable development. By addressing these challenges, developing countries can better safeguard their economic prospects amid an increasingly volatile climate.

Keywords: Climate Change; Gross Domestic Product; Developing Countries Introduction

1. Introduction

Climate change represents a persistent alteration in temperature and weather patterns over extended periods. While some of these changes can be attributed to natural phenomena such as variations in solar activity or significant volcanic eruptions, the primary driver has been anthropogenic activities. Human actions, including the burning of fossil fuels like coal, oil, and gas, coupled with deforestation and industrial emissions, have been identified as the predominant causes of this phenomenon (Kumar et al., 2021). These activities release substantial amounts of greenhouse gases (GHGs), such as carbon dioxide (CO2) and methane, into the atmosphere. These gases function as a thermal blanket, trapping heat from the sun and progressively warming the Earth's surface, a process widely referred to as global warming (Driga & Drigas, 2019). Scientific consensus underscores the undeniable role of humans in exacerbating global warming. Researchers have confirmed that human activities have been responsible for almost all the global heating observed in the last 200 years (Nordhaus, 2019). The pace of warming is unprecedented, occurring faster than at any other time in the last two millennia due to the continuous release of GHGs (Kweku et al., 2018). The Intergovernmental Panel on Climate Change (IPCC) reports that global temperatures have risen by an estimated 1.1°C above pre-industrial levels. This seemingly modest increase has already triggered significant disruptions across natural and human systems, signaling a dire need for immediate action (Adamo et al., 2021).

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The repercussions of climate change extend beyond environmental degradation, posing critical challenges to global food security, public health, and economic stability. Developing countries, often classified as low- and middle-income nations, are disproportionately affected by these changes (Dang & Pheng, 2015). These countries, characterized by lower levels of industrialization, inadequate infrastructure, and reduced income per capita, face compounded socio-economic vulnerabilities, including poverty, limited access to healthcare and education, and political instability (Ahmad & Primi, 2017). The geographic distribution of developing nations—primarily in Africa, South Asia, Southeast Asia, and Latin America—places many of them in climate-sensitive regions, further exposing them to the adverse effects of a changing climate (Das & Ansari, 2021). Agriculture, a cornerstone of economic livelihoods in many developing nations, is particularly susceptible to climate variability. For regions like Sub-Saharan Africa and Asia, where large populations rely on agriculture for subsistence and economic activity, climate-induced shocks such as droughts and floods have devastating effects. These events disrupt planting and harvesting cycles, diminish crop yields, and exacerbate food insecurity (Creti et al., 2021). Moreover, the economic costs of these disruptions are immense, with studies indicating that climate change-induced shocks could lead to severe financial instability and heightened poverty rates in affected regions (Gitz et al., 2016).

The consequences of climate change in developing countries are far from uniform, as they vary significantly based on geographical and socio-economic contexts. For example, Bangladesh, with its high population density and geographical vulnerability to flooding and cyclones, is often cited as one of the most climate-vulnerable countries in the world (Zaman, 2019). In contrast, countries located in arid and semi-arid regions, such as those in the Sahel, grapple with challenges like desertification and prolonged droughts, necessitating targeted adaptation strategies to manage water resources and sustain agricultural productivity (Tramblay et al., 2020). Climate change also undermines the infrastructure and economic stability of developing nations. Extreme weather events, including hurricanes and floods, inflict widespread damage to essential infrastructure such as roads, bridges, and energy systems, often crippling economic activities for prolonged periods (Salik et al., 2015). For nations like Somalia, where institutional frameworks are weak, the interplay between climate change and governance challenges exacerbates economic stagnation, highlighting the multifaceted nature of climate vulnerability (Warsame et al., 2023). Public health systems in developing nations are equally strained by the cascading effects of climate change. Rising temperatures and erratic weather conditions foster the spread of infectious diseases such as malaria and dengue fever, particularly in tropical regions where healthcare systems are already overburdened (Akter et al., 2017). Malnutrition, stemming from reduced agricultural productivity, further compounds health challenges, disproportionately affecting vulnerable populations like children and the elderly. The need for effective mitigation and adaptation strategies in developing countries cannot be overstated. These nations require significant financial and technical support to build climate resilience and safeguard their economies and populations against the multifaceted threats posed by climate change. Addressing these challenges demands a collaborative global approach that prioritizes the unique vulnerabilities of developing nations while leveraging innovative solutions to foster sustainable development.

2. Literature Review

This section delves into the existing body of knowledge surrounding climate change and economic growth, particularly in the context of developing countries. It explores the definitions, mechanisms, and interactions between these two phenomena, drawing on empirical evidence and theoretical models to assess the impacts of climate change on economic performance. The relationship between climate variability and growth is complex and multidimensional, with climate change affecting key economic sectors like agriculture, energy, and infrastructure, especially in vulnerable economies.

2.1. Climate Change

Climate change refers to the long-term alteration of temperature, precipitation patterns, sea levels, and weather extremes, largely driven by human activities such as fossil fuel combustion, deforestation, and industrial processes. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as a significant variation in the state of the climate that persists over extended periods, typically decades or longer. Global warming, the most prominent indicator of climate change, has resulted in rising average temperatures, increased frequency of extreme weather events, and shifts in ecosystems. These climatic disruptions pose significant risks to the natural environment and socio-economic systems, especially in developing countries where adaptive capacities are limited.

Developing countries are disproportionately affected by climate change due to their reliance on climate-sensitive sectors like agriculture, fisheries, and tourism, as well as their geographical positioning, which often makes them vulnerable to rising sea levels, droughts, and floods. According to Stern (2007), the economic costs of climate change will fall disproportionately on poorer countries, which lack the resources and technological capacity to effectively mitigate or adapt to its impacts. For instance, coastal nations in Africa and Southeast Asia face the threat of flooding due

to rising sea levels, while inland regions may experience more frequent droughts, affecting water availability and agricultural productivity.

Several studies have attempted to quantify the impact of climate change on developing economies. For example, Bezabih et al. (2011) examined the Tanzanian economy, finding that temperature variability and changing precipitation patterns have a substantial negative impact on agricultural productivity, a critical sector in most developing economies. Similarly, Bhatta (2013) found that the agro-economy of Nepal is highly susceptible to climate variability, exacerbating challenges such as food insecurity and resource scarcity. These studies highlight the broader economic repercussions of climate change, beyond just environmental degradation.

The effects of climate change are not limited to agriculture. According to Falco et al. (2019), adverse weather events can drive higher rates of emigration from developing countries, particularly those dependent on agriculture. This migration may further strain economies by reducing labor availability and increasing dependency on remittances. Kamau and Mwaura (2013) argue that the poorest populations in low-income countries are disproportionately affected by climate change, which threatens sustainable development goals and exacerbates inequality. Nema and Muthupriva (2022) elaborate on how climate change fuels food insecurity, poverty, and health crises, further hindering economic growth in already vulnerable regions.

Beyond agriculture and migration, climate change also impacts other critical sectors. The tourism industry, which is vital for many developing countries, is highly sensitive to climate variability. Pandy and Rogerson (2021) highlight that tourism-dependent communities in South Africa are particularly vulnerable to the effects of climate change, which could undermine the sector's economic contribution to national income. Similarly, extreme weather events such as hurricanes or droughts can disrupt tourism, leading to substantial economic losses.

From a macroeconomic perspective, Adeniran et al. (2023) demonstrate that climate change, particularly through temperature anomalies, exerts inflationary pressures on emerging economies. This inflation not only raises the cost of living but also reduces purchasing power and exacerbates poverty, especially among vulnerable populations. Furthermore, climate uncertainty affects financial markets, with negative consequences for stock returns and overall economic stability in developing countries. These findings underscore the far-reaching economic risks posed by climate change, particularly for countries with low adaptive capacities.

In conclusion, the existing literature establishes a clear link between climate change and its detrimental effects on economic structures, particularly in developing countries. Climate change exacerbates existing vulnerabilities, especially in sectors such as agriculture, tourism, and infrastructure, while simultaneously introducing new risks to macroeconomic stability and human well-being. As these countries face growing challenges from climate variability, the literature emphasizes the urgent need for comprehensive adaptation strategies to mitigate the economic and social impacts of climate change.

2.2. Economic Growth

Economic growth, often measured by the increase in gross domestic product (GDP), represents the expansion of a country's production capabilities and the improvement in living standards over time. It is a key indicator of national prosperity, signifying advancements in technology, capital accumulation, and labor productivity. In classical economic theory, growth is driven by factors such as labor, capital, and technological innovation, which contribute to the overall efficiency and productivity of an economy.

The study of economic growth has a rich theoretical foundation. Early models like the Solow-Swan model (Solow, 1956) attribute growth primarily to capital accumulation and technological progress, with diminishing returns to capital playing a central role in determining long-term growth rates. In contrast, endogenous growth theories, such as those proposed by Romer (1990), highlight the importance of knowledge, human capital, and innovation as internal drivers of sustained economic growth. These models suggest that economies can continue growing as long as they invest in education, research, and development, which promote technological advancements.

However, in the context of developing countries, the path to economic growth is often complicated by a variety of structural and external factors. These nations frequently face challenges such as weak institutions, political instability, limited access to capital, and infrastructure deficits, all of which hinder their ability to achieve sustainable economic growth. Moreover, developing countries are often reliant on primary sectors like agriculture and mining, which are highly vulnerable to external shocks such as climate change, commodity price volatility, and international trade fluctuations.

The relationship between climate change and economic growth has become a critical focus of research, particularly for developing countries. The adverse effects of climate variability on growth are particularly evident in countries where agriculture plays a dominant role in the economy. As climate change affects rainfall patterns, temperature stability, and the frequency of extreme weather events, agricultural output becomes increasingly unpredictable. This unpredictability undermines food security, export revenues, and rural livelihoods, ultimately slowing down overall economic growth. For instance, studies by Nelson et al. (2010) show that climate change-induced reductions in agricultural productivity could decrease GDP growth in many developing countries, particularly in sub-Saharan Africa and South Asia.

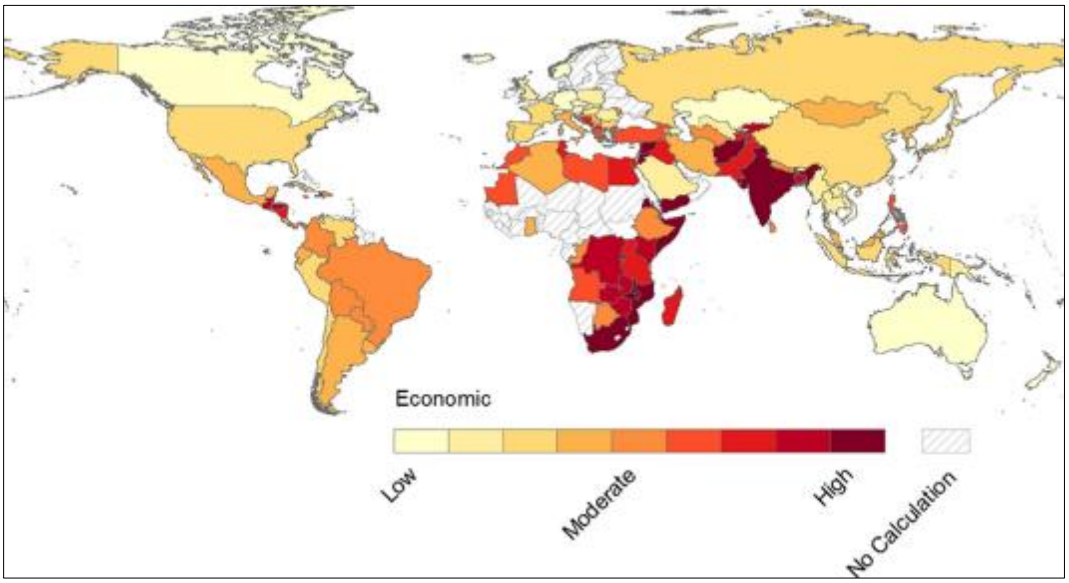
In addition to agriculture, climate change affects other key drivers of economic growth in developing countries. The availability of energy is crucial for industrialization and economic diversification, yet climate change threatens energy security in several ways. For example, rising temperatures and changing precipitation patterns can affect hydropower generation, which is a key source of renewable energy for many developing nations. This disruption in energy supply can lead to reduced industrial output and slower economic growth.

Another significant pathway through which climate change affects economic growth is through human capital. Increased frequency of extreme weather events such as floods, droughts, and heatwaves can lead to displacement, health crises, and loss of life, all of which diminish the productive capacity of the workforce. According to the World Bank (2018), climate change is expected to push an additional 100 million people into poverty by 2030, predominantly in developing countries, further reducing human capital and undermining growth prospects.

Despite these challenges, there are opportunities for growth in the context of climate change, particularly through green growth strategies. The adoption of renewable energy technologies, sustainable agricultural practices, and climate-resilient infrastructure can offer pathways for economic expansion that are both environmentally sustainable and growth-enhancing. The United Nations Environment Programme (UNEP) advocates for a green economy approach, which integrates economic growth with environmental sustainability, creating opportunities for developing countries to transition to low-carbon growth models that mitigate the impacts of climate change while promoting long-term economic resilience.

In conclusion, economic growth in developing countries is deeply intertwined with the challenges and opportunities presented by climate change. While climate change poses significant risks to key sectors such as agriculture, energy, and human capital, it also presents opportunities for growth through green economic strategies. The literature emphasizes that addressing the economic impacts of climate change requires a multifaceted approach that includes policy reforms, investments in sustainable technologies, and international cooperation. Developing countries must balance the pursuit of economic growth with the imperative to adapt to and mitigate the effects of climate change in order to ensure long-term prosperity.

2.3. Economic Vulnerability of Developing Nations



Source: Burton, M. Toquica (September 2020)

Figure 1 Economic Vulnerability in the Developing Economies

The developing nations are frequently vulnerable to climate changes due to their low adaptive capacities, reliance on the climate sensitive sectors and constrained financial resources. According to the intergovernmental panel on climate change (IPPC, 2021), lay more emphasis on the low-income countries such as in Africa, Asia, and Latin America face risks due to their dependent on agriculture and natural resources, which are more vulnerable to the climate variability. Therefore, according to Mandesohn et al. (2010), the economies lack institutional and infrastructure needed to mitigate the climate impacts and make them susceptible to the shocks in the economic. Baarsch et al. (2020) also emphasis that due to the existing economic fragility and the inequality stemming from the climate induced shock, Sahel region is more vulnerable. Cevik and Jalles, (2020) note the negative impacts of the climate change on the economic growth are well documented, still the specific outcomes and mechanism are varied significantly across different regions and countries. Warsame et al. (2023) findings support by revealing that the severity of the climate change effects is contingent upon a nation's economic level, location and institutional quality.

2.4. Theoretical Framework: Climate-Induced Structural Vulnerability Model (CISV)

The Climate-Induced Structural Vulnerability Model (CISV) explains how climate change affects economic growth in developing countries by emphasizing structural vulnerabilities that are prevalent in these economies. The CISV model focuses on how structural factors in developing nations interact with climate-induced shocks, leading to sustained economic challenges.

2.4.1. Sectoral Dependence on Climate-Sensitive Activities

One of the central aspects of the CISV model is the heavy dependence of developing countries on climate-sensitive sectors such as agriculture, natural resource extraction, and tourism. These sectors form the backbone of many developing economies, and their reliance on stable climate conditions makes them especially vulnerable to changes in temperature, rainfall patterns, and the frequency of extreme weather events. For instance, studies have shown that the agricultural sectors in many African countries suffer significantly from climate variability, leading to reduced crop yields and increased food insecurity (Bezabih et al., 2011). Similarly, tourism-dependent communities in South Africa are facing severe risks due to the effects of climate change, which threaten the sustainability of the sector (Pandy & Rogerson, 2021). This dependence on climate-sensitive sectors means that climate change-induced disruptions in these sectors can have wide-reaching impacts on economic growth. Reduced agricultural productivity or declines in tourism activity can lead to lower GDP, reduced employment, and increased poverty levels, which further undermine economic stability (Falco et al., 2019).

2.4.2. Weak Institutional Capacity and Governance Challenges

Developing countries often face challenges in governance and institutional capacity, which exacerbates their vulnerability to climate change. Weak institutions make it difficult to implement effective climate adaptation strategies or enforce environmental regulations, leaving these countries more exposed to the adverse impacts of climate change (Kamau & Mwaura, 2013). In many cases, government policies fail to adequately address climate risks due to limited financial resources, political instability, or corruption. Moreover, inadequate disaster preparedness and response mechanisms leave many developing countries unprepared to cope with the increasing frequency of climate-related disasters, such as floods, droughts, and storms. These disasters not only cause immediate economic losses but also have long-term effects on infrastructure, health, and education, further weakening the prospects for economic growth (Nema & Muthupriva, 2022).

2.4.3. Poverty and Limited Adaptive Capacity

Poverty in developing countries limits the capacity of both individuals and governments to adapt to climate change. Poor households typically have fewer resources to invest in climate-resilient technologies or practices, such as improved irrigation systems or drought-resistant crops. They are also more likely to be employed in informal sectors or subsistence farming, which are highly susceptible to climate shocks (Bhatta, 2013). This limited adaptive capacity means that even small changes in climate conditions can lead to significant economic setbacks, reinforcing cycles of poverty and vulnerability.

At the national level, many developing countries lack the financial resources to fund large-scale climate adaptation projects, such as building flood defenses or transitioning to renewable energy sources. International cooperation and financial assistance are often necessary to bridge this gap, but even then, the ability of these countries to effectively utilize such resources is hampered by governance and institutional challenges (Adeniran et al., 2023).

2.4.4. Feedback Loops and Long-Term Economic Implications

The CISV model also recognizes the existence of negative feedback loops that can arise from the interaction of structural vulnerabilities and climate change. For example, climate-induced declines in agricultural productivity can increase food insecurity and poverty, which in turn reduces the capacity of the population to invest in education, health, or technological innovation. This creates a vicious cycle in which poverty and climate vulnerability reinforce each other, making it even harder for these countries to achieve sustained economic growth (Bezabih et al., 2011).

Furthermore, climate change can have broader macroeconomic effects by contributing to inflationary pressures, as seen in many developing economies where temperature anomalies drive up food prices and energy costs. These inflationary effects reduce the purchasing power of consumers, increase the cost of living, and further strain already fragile financial systems (Adeniran et al., 2023).

2.5. Empirical Review

Various studies on shows to quantify the overall impact of climate change on economic growth. Studies by Dell and Olken (2012) reveal that increased temperature decreases the growth rates in the low-income nations, with the estimates suggesting of 1.3% decrease in GDP per capital for each 10c increase in temperature. The developing countries who reliant on Agricultural sector and tourism sector, are most vulnerable to such economic downturns. The long-term impact of climate change can also decrease investments and boost borrowing costs due to higher economic uncertainty (Burke and Miguel, 2015). Bezabih et al. (2011) also revealed that the climate change has negative effects on the factors of production in the Tanzanian economy, also made more emphasis on the need to adopt the adaptation strategies in order to mitigate these effects. In additions, the study of Bhatta's, (2013) on the Nepal shown that the Argo economy is more susceptible to climate variability, which exacerbates the challenges likes scarcity of resource and food insecurity. Falco et at., (2019) study outcomes also support by indicating that adverse weather event also can lead to the higher emigration from developing nations, especially those that focus mainly on agriculture.

The implication of the economic is beyond agriculture to the broader macroeconomics factors. The evidence provided by Adeniran et al., (2023), that climate change especially through the anomalies of the temperature, has a inflationary impact on the emerging economies, which are always categorized aby low stable financial systems. The inflationary may lead to higher costs of living and reduced the purchasing power, it brings poverty to the vulnerable populations. Adeniran et al. (2023) notes that the policy of the climate uncertainty may affect the stock returns negatively, revealing that the financial markets in developing nations are always sensitive to climate-related risks.

Kamau and Mwaura (2013) in their study revealed that the poorest populations in the low-income countries are disproportionally affected by climate change, this threatens the sustainable development. Nema and Muthupriva (2022) explained how the climate change cause food insecurity, poverty and health issues in the regions. The less infrastructure and available resources for the adaptation strategies hinder the potential ability of these countries to adapt to the climate challenges. However, the tourism sector, which is very crucial in the developing countries faces high risks from the climate change. Pandy and Rogerson (2021) in their study pointed out that tourism dependent communities in the South Africa are more vulnerable to the effects of the climate change, this may undermine the economic sustainability.

In conclusion, the empirical evidence has revealed that the climate change poses various economic risks to developing nations, affecting agricultural productivity, macroeconomic stability, and critical sectors such as tourism. The interplay of these factors showed the urgent need for comprehensive adaptation strategies that address both the immediate and long-term challenges posed by climate change.

3. Methodology

The methodology shows the processes and methods used to analyses the impact of the climate change on the economies of developing countries. The study employed quantitative approach, used secondary data from a reliable and credible source like the world bank data indicator, FAO and IPCC. The methodology entailed a detailed analysis of how climate change affects the key economic indicators.

3.1. Model Specification

The research aimed at examining the impact of climate change on economies of developing nations; in order to meet the objective of the study, the model of Raymond (2009) was adapted. From his study of the impact of climate change on Indian Agriculture, the model was specified as:

$$AGRIC = f(WTH, TEMP) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots i$$

Where;
AGRIC-= Agriculture output
WTH= Weather
TEMP= temperature

This study adapted the above model by extending the variables. Therefore, this study presented as:

$$GDP = f\ (TEMP, CO2, ENERGEY, PGROWTH, RAIN) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots ii$$

Where;
GDP represents the economic growth (GDP or GDP per capita) of the developing country.
Temp is the temperature change.
CO2 is the level of CO2 emissions.
Energy measures changes in energy consumption.
Rain measures the Rainfall Statistics
Controls represent control variables such as population growth, FDI, and industrialization levels.
μi is the error term.

The econometries form of the functions model specified as;

$$GDPi = \beta 0 + \beta 1 Tempi + \beta 3 CO2i + \beta 4 Rain + \beta 5 ENECi + \beta 6 POPGi + \mu i \ldots\ldots\ldots\ldots\ldots (2)$$

Where:
B0 = constant
B1 – β6 = Shift Parameters
i= time series

3.2. Data and Sources

The study adopted secondary data from the following sources such as data for gross domestic product, population growth, and Co2 emission were extracted from the World Bank Development Indicators. Likewise, the data on energy consumption and rainfall statistics were sourced from Carbon Dioxide Information Analysis Center. The study employed data for 20years life span which cover from year 2000 to year 2020 across the sample of the developing countries in Asia, Africa, and Latin America.

3.3. Estimation method

The study employed a variety of data analysis techniques to explore the effects of climate change on the economies of developing countries. Initially, descriptive analysis was conducted to summarize the key characteristics of the dataset, providing insights into the distribution and variability of variables such as Gross Domestic Product (GDP), temperature (TEMP), carbon emissions (C02), energy consumption (ENGC), population growth (POPG), and rainfall (RAIN).

Following this, correlation analysis was performed to examine the relationships among the economic and environmental factors. Before proceeding to regression analysis, pre-estimation tests, specifically the Fisher-Type Augmented Dickey-Fuller (Fisher-ADF) and Phillips-Perron (Fisher-PP) tests, were conducted to assess the stationarity of the data. The study ultimately employed the Panel Autoregressive Distributed Lag (ARDL) regression model, using the pooled mean group (PMG) estimation.

4. Data Analysis and Findings

This section presents the data analysis and discussion of findings pertinent to the study. The analysis of the research encompasses the summary statistics, correlation matrix analysis and the regression analysis of the study on how climate change affects the economy of the developing countries.

4.1. Descriptive Analysis

4.1.1. Summary Statistics

Table 1 Results of Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
GDP	30.13	144.98	13.60	25.49
TEMP	4.77	5.30	0.36	34.15
C02	7.66	8.16	-3.60	70.75
ENGC	5.03	7.53	30.15	149.97
POPG	14.60	146.19	9.62	4145.11
RAIN	6.55	31.10	0.00	513.91

Source: Author's Computation, 2024

Key: GDP stands for economic growth in developing countries, TEMP represents temperature, C02 stands for Carbon Emissions, ENGC represents Energy Consumption, POPG stands for Population Growth and RAIN represents Rainfall

The summary statistics for the study variables present several insights into the dataset's characteristics. The average economic growth (GDP) for the developing countries under consideration is 30.13, with a substantial standard deviation of 144.98, indicating a wide variation across the sample. The minimum GDP value is 13.60, while the maximum is 25.49. For temperature (TEMP), the mean is 4.77, with a standard deviation of 5.30. The temperatures range from a low of 0.36 to a high of 34.15. Carbon emissions (C02) have a mean value of 7.66, with significant variation (a standard deviation of 8.16), reflecting the diversity in emission levels among the countries. The minimum value is -3.60, suggesting some countries might have negative net emissions, while the maximum value reaches 70.75. Energy consumption (ENGC) averages 5.03, with a standard deviation of 7.53, and shows values ranging from 30.15 to 149.97, indicating considerable variation in energy use.

Population growth (POPG) displays a mean of 14.60, but the high standard deviation of 146.19 suggests large differences in growth rates across countries. The minimum population growth rate recorded is 9.62, while the maximum is a striking 4145.11. Finally, rainfall (RAIN) averages 6.55, with an extreme range from 0.00 to 513.91, indicating that some areas experience no rainfall while others receive substantial amounts. Overall, these statistics highlight significant variability across the key economic and environmental factors in developing countries.

4.1.2. Correlation Analysis

Table 2 Correlation Matrix of Variables

Variable	GDP	TEMP	C02	ENGC	POPG	RAIN
GDP	1					
TEMP	0.411***	1				
C02	-0.286*	-0.199	1			
ENGC	0.744***	0.455***	-0.511***	1		
POPG	0.656***	0.427***	-0.571***	0.962***	1	
RAIN	0.800***	0.329**	-0.274*	0.778***	0.675***	1

Source: Author's Computation, 2024

The correlation analysis reveals the relationships between various economic and environmental factors in developing countries. Economic growth (GDP) has a positive and statistically significant correlation with temperature (TEMP), showing a correlation coefficient of 0.411. This suggests that higher temperatures are moderately associated with increased GDP. In contrast, GDP has a negative but weak relationship with carbon emissions (C02), as indicated by the correlation coefficient of -0.286, implying that higher carbon emissions may be slightly associated with lower economic growth.

Energy consumption (ENGC) exhibits a strong positive correlation with GDP, with a coefficient of 0.744, indicating that higher energy consumption is strongly associated with higher economic growth. Population growth (POPG) also shows a significant positive correlation with GDP (0.656), suggesting that as population grows, GDP tends to increase. Rainfall (RAIN) is even more strongly correlated with GDP, with a coefficient of 0.800, indicating that areas with higher rainfall tend to experience higher economic growth.

Temperature has a weak but positive relationship with energy consumption (0.455) and population growth (0.427), while it shows a non-significant negative correlation with carbon emissions (-0.199). Carbon emissions have a negative and significant relationship with both energy consumption (-0.511) and population growth (-0.571), suggesting that as these factors increase, carbon emissions tend to decrease.

Energy consumption and population growth are highly correlated, with a coefficient of 0.962, reflecting a very strong relationship between the two. Rainfall shows strong positive correlations with both energy consumption (0.778) and population growth (0.675), indicating that higher rainfall is associated with increased energy consumption and population growth. The overall pattern of correlations highlights strong interconnections between economic growth, environmental factors, and resource use in developing countries.

4.2. Pre-Estimation Test

Table 3 Results of Fisher-Type augmented Dickey-Fuller (Fissher-ADF) and Phillips-Perron (Fisher-PP) Panel Unit Root Tests

	Fisher-ADF				**Fisher-PP**			
	Level		**First Difference**		**Level**		**First Difference**	
Variable	**t-stat**	**p-value**	**t-stat**	**p-value**	**t-stat**	**p-value**	**t-stat**	**p-value**
TEMP	-1.679	0.953	19.82***	0.000	-1.732	0.958	47.47***	0.000
GDP	17.48***	0.000			30.35***	0.000		
C02	31.96***	0.000			49.15***	0.000		
ENGC	1.913**	0.027			0.538	0.295		
POPG	-3.148	0.999	18.91***	0.000	-3.454	0.999	19.62***	0.000
RAIN	3.481***	0.000			8.915***	0.000		

Source: Author's Computation, 2024; Note: * indicates significance at 10%; ** indicates significance at 5%; *** indicates significance at 1%.

The Fisher-type augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) panel unit root tests show mixed results for the stationarity of variables. At the level, GDP is non-stationary in both tests, but it becomes stationary after the first difference, as indicated by significant p-values (0.000). Temperature (TEMP), carbon emissions (C02), and rainfall (RAIN) are stationary at level in both tests, with significant t-statistics and p-values. Energy consumption (ENGC) is stationary at level in the ADF test but not in the PP test. Population growth (POPG) is non-stationary at level but becomes stationary after the first difference.

The implication of this outcome is that employing these variables directly in a regression model without further test of cointegration may lead to spurious regression result. Therefore, cointegration test is necessary to verify if long run cointegration exists among the variables of the models of this study. Given that there is a combination of I(0) and I(1) series, the most suitable cointegration test is the ARDL bounds test procedure to cointegration. As argued by Peseran and Shin (1999), each variable must be I(0) or I(1) in order to satisfy the bounds test assumption of the ARDL models, under no circumstances, should it be I(2). Although, De Vita et al. (2006) also noted that the dependent variable should be I(1), however, this is not widely claimed in the current literature (Menegaki, 2019), nor in the original article by Peseran and Shin (1999). Therefore, with the dependent variable of this study being I(1), the ARDL bounds test procedure can be conducted to test the long run cointegration of variables.

4.3. Regression Analysis

Table 4 Panel ARDL Regression Results – Climate Change Effect on Economics of Development Countries

Dependent Variable: Economic Growth

Variable	**Coefficient**	**Z**	**p-value**	**Coefficient**	**z**	**p-value**	**Coefficient**	**z**	**p-value**
	Pooled MG			**Mean Group**			**Dynamic Effect**		
Long-Run Estimate									
TEMP	-0.031	-4.85	0.000	-0.014	-0.51	0.607	0.0006	0.17	0.868
Co2	-0.003	3.19	0.001	-0.015	-0.82	0.411	-0.006	-4.37	0.000
GNGC	0.004	2.29	0.022	0.002	0.09	0.925	-0.004	-1.27	0.202
POPG	0.010	9.21	0.000	0.022	2.04	0.042	-0.0004	-0.91	0.362
RAIN	0.0001	0.08	0.938	-0.013	-1.1	0.272	0.0005	0.84	0.398
Short-Run Estimate									
TEMP	0.109	3.75	0.000	0.312	6.37	0.000	0.192	12.45	0.000
Co2	-0.001	-2.19	0.029	0.001	0.73	0.467	0.0001	0.09	0.928
GNGC	0.001	1.03	0.302	0.002	0.69	0.489	0.0004	13.95	0.000
POPG	-0.0001	-0.12	0.901	-0.0003	-0.18	0.854	0.0001	-0.05	0.956
RAIN	0.006	1.72	0.085	0.008	1.86	0.063	-0.0003	-0.77	0.442
Constant	-0.001	-0.09	0.925	0.011	0.16	0.873	-0.016	-1.0	0.317
Observations									
Hausman test				0.71		0.702	3.23		0.198

Source: Author's Computation, 2024

Table 4 presents the results of the effects of climate change on the economies of developing countries. The result of the Hausman test shows a statistic value of 0.71 and p-value of 0.702 for the choice between the pooled mean group and mean group variants. As can be seen, the statistics are not significant. With the Hausman test's null hypothesis being that 'the pooled mean group is preferred to its mean group counterpart' the test result indicates that this null hypothesis could not be rejected since the Hausman test's statistic is not significant. Therefore, the pooled mean group is more appropriate than the mean group estimates. The Hausman test result also shows a statistic value of 3.23 and a p-value of 0.198 for the choice between the pooled mean group and dynamic fixed effects variants. The statistics are also not significant. With the Hausman test's null hypothesis being that 'the pooled mean group is preferred to its dynamic fixed effects counterpart' the test result indicates that this null hypothesis could not be rejected since the Hausman test's statistic is not significant. Therefore, the pooled mean group is more appropriate than the dynamic fixed effects estimate. Therefore, the most appropriate result is that of the pooled mean group method.

The Pooled Mean Group (PMG) results from the panel ARDL regression show the long-run and short-run impacts of climate change variables on economic growth in developing countries.

In the long run, temperature (TEMP) has a significant negative effect on economic growth, with a coefficient of -0.031 ($p = 0.000$). This suggests that as temperatures increase, economic growth tends to decrease over time. Carbon emissions (C02) also negatively affect economic growth, with a coefficient of -0.003 ($p = 0.001$), indicating that higher levels of carbon emissions are associated with reduced economic growth in the long term. On the other hand, energy consumption (GNGC) positively influences economic growth, with a significant coefficient of 0.004 ($p = 0.022$), implying that greater energy use supports economic expansion. Population growth (POPG) also has a strong positive impact on economic growth, with a coefficient of 0.010 ($p = 0.000$), indicating that a growing population contributes to long-term economic development. Rainfall (RAIN), however, is insignificant in the long run, with a coefficient of 0.0001 ($p = 0.938$).

In the short run, temperature has a significant positive effect on economic growth, with a coefficient of 0.109 (p = 0.000). This suggests that in the short term, temperature increases can lead to a boost in economic activity. Carbon emissions have a slight but significant negative impact, with a coefficient of -0.001 (p = 0.029), showing that higher emissions may hinder short-term economic growth. Energy consumption and population growth have no significant short-run effects, with p-values of 0.302 and 0.901, respectively. Rainfall has a marginally significant positive impact on economic growth, with a coefficient of 0.006 (p = 0.085), indicating that higher rainfall may have a modest short-term benefit for economic performance. Overall, the PMG results suggest that while temperature and carbon emissions negatively affect economic growth in the long run, temperature increases, and rainfall can have short-term positive effects. Energy consumption and population growth are significant drivers of long-term growth but not short-term changes.

5. Discussion

The findings from the Pooled Mean Group (PMG) analysis provide significant insights into the long-run and short-run impacts of climate change on economic growth in developing countries. These results align with existing empirical evidence on the vulnerability of developing economies to climate variability due to their economic structures, heavy reliance on climate-sensitive sectors like agriculture, and limited adaptive capacity.

In the long run, the PMG results show that temperature has a significant negative impact on economic growth, reflecting the broader concern seen in studies such as those by Bezabih et al. (2011) and Bhatta (2013), which emphasize the detrimental effects of rising temperatures on agricultural productivity. Given that many developing economies rely heavily on agriculture, this negative relationship between temperature and economic growth reinforces the idea that climate volatility—particularly in temperature—can hamper long-term economic development. As shown in the studies, disruptions in agricultural output due to climate change increase the vulnerability of these economies, exacerbating poverty and food insecurity, as Nema and Muthupriva (2022) pointed out.

Similarly, carbon emissions also negatively affect long-term economic growth, as revealed by the PMG regression. This aligns with studies such as those by Adeniran et al. (2023), which underscore the inflationary pressures and economic instability driven by climate-related changes, including the impact of carbon emissions. Higher carbon emissions lead to broader environmental degradation, affecting not only agriculture but also industrial productivity, resource availability, and human health, all of which are critical to the economic stability of developing nations.

In contrast, energy consumption is found to have a positive and significant effect on long-run economic growth. This finding highlights the essential role that access to energy plays in the development process. Given that many developing countries are experiencing rapid population growth and industrialization, energy consumption is crucial to powering economic activities and improving living standards. This is consistent with the broader literature that emphasizes energy as a key driver of economic expansion, especially in emerging markets where infrastructure development is crucial.

Population growth also shows a strong positive long-term relationship with economic growth, which suggests that expanding populations in developing countries contribute positively to economic output over time. This could be attributed to the potential for a larger labor force and greater domestic market size, which can stimulate economic activity. However, unchecked population growth without corresponding investments in infrastructure, education, and healthcare may lead to further strain on already limited resources, as noted in the studies by Kamau and Mwaura (2013).

In the short run, the results suggest that temperature increases can lead to a boost in economic activity, likely due to short-term shifts in agricultural production or tourism-related sectors that benefit temporarily from favorable climate conditions. This finding reflects the short-term adaptation strategies that many economies may adopt, though such strategies may not be sustainable in the long term. The positive short-run impact of rainfall further supports this idea, as it can temporarily enhance agricultural yields and water availability, leading to a short-term economic benefit. However, the marginal nature of these effects highlights the temporary nature of such boosts.

Interestingly, the short-run negative impact of carbon emissions on economic growth, though slight, suggests that even in the short term, environmental degradation begins to affect economic performance, likely through health costs, resource depletion, or regulatory burdens. This reflects the findings of studies that show how emerging economies' financial systems, as observed by Adeniran et al. (2023), are highly sensitive to climate-related risks, even in the short run.

In summary, the PMG analysis highlights that the effects of climate change on developing economies are complex, with both long-term and short-term dynamics at play. The long-run negative impacts of temperature and carbon emissions on economic growth emphasize the need for robust adaptation strategies to mitigate the economic fallout from climate change, particularly in climate-sensitive sectors like agriculture. Meanwhile, the positive role of energy consumption and population growth in the long run suggests that investments in energy infrastructure and human capital can help offset some of the adverse effects of climate change. In the short term, temporary boosts from temperature and rainfall fluctuations offer some relief, but they are not sustainable solutions to the broader climate challenges facing developing nations. These findings underscore the urgency for comprehensive climate policies that address both immediate and long-term economic vulnerabilities.

6. Conclusion

The study highlights the significant impact of climate change on the economic growth of developing countries, underscoring the vulnerability of these nations due to their reliance on climate-sensitive sectors like agriculture and their limited adaptive capacity. The analysis, particularly through the Pooled Mean Group (PMG) model, reveals that rising temperatures and carbon emissions have a detrimental long-term effect on economic growth, confirming the broader literature on the economic risks posed by climate change. Conversely, energy consumption and population growth are shown to be positive drivers of long-term growth, reflecting the importance of energy infrastructure and human capital development in these economies.

In the short run, the findings indicate that while temperature increases and rainfall can temporarily boost economic activity, these effects are not sustainable and do not offset the long-term negative impacts of climate volatility. Carbon emissions even begin to show adverse effects in the short term, further emphasizing the need for mitigation efforts. The results suggest that developing countries must adopt comprehensive adaptation strategies to address both the immediate and future economic challenges posed by climate change.

Ultimately, this study underscores the critical need for targeted policies that promote resilience to climate change, enhance energy access, and foster sustainable development in order to safeguard the economic prospects of developing nations in the face of an increasingly volatile climate.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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