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The Effects of Climate Change on Kenya's Economic Growth

Dr. Matundura Erickson
University of Eldoret

Abstract:- Changes in the climate and natural disasters have hampered Kenya's growth in economy, as seen by periodic droughts, floods, and shifts in rainfall and temperature patterns. The research investigated the effects of climatic change on Kenya's GDP growth. Modeling was done using Autoregressive Distributed Lag (ARDL) model estimation technique while analyzing data from 1990 to 2023. Climate change was represented by annual rainfall fluctuations, carbon emissions, and forest depletion, with inflation, exchange rates, and government spending serving as the controlling factors. The regression results indicated that at 5% level of significance short run carbon emissions affect growth negatively but the long run results indicated a positive effect. Forest depletion positively impacts growth in the long run period. Government expenditure, changes in the exchange rate and economic growth had an inverse relationship. Inflation did not have potential long term impact on GDP. This study recommended that the government to balance economic growth with environmental sustainability by promoting cleaner technologies and renewable energy projects. Investments advanced irrigation and drought resistant crops are crucial. Sustainable forest management should involve controlled logging and reforestation to ensure long term health. Reducing exchange rate volatility through foreign reserves and diversified exports will stabilize the economy. Enhancing government expenditure efficiency by focusing on high return investments and minimizing waste will boost GDP stability.

I. INTRODUCTION

The effects of climate change have had significant effects in recent years, particularly on the socioeconomic development of countries like Kenya. Severe weather phenomena like El Niño and La Niña, as well as drought and flood cycles are becoming more common. The rainfall pattern has been significantly influenced by late onset and early or late cessation, and its distribution has been reported to be poor both temporally and geographically (Mwambire, 2020).

According to Ogbuabor and Egwuchukwu (2017), Change in the climate is characterized by long-term statistical variation, usually a decade or more. This includes a steady increase in the mean temperature of the surface of the planet as well as variations in the intensity and frequency of occasional weather-related incidents. The German advisory group on Climate Change claims that climate change is already having a considerable influence on people and natural ecosystems in both industrialized and developing countries, albeit to differing degrees. In developed countries, advanced technology, wealth, and efficient adaptation methods have reduced the adverse effects of climate change. However, emerging nations like Kenya face more pronounced impacts due to extreme temperatures, limited adaptation capacity, and inadequate early warning systems.

A change in climate has got a huge bearing on natural resource-based areas such as farming. According to some research, climate change could significantly reduce agricultural productivity in poor countries. Climate change affects the distribution of rainfall and temperature throughout the year, which is critical for crop yields, particularly those grown in rain-fed settings. Excessive rainfall can destroy arable land, impair cultivated crops, increase weed growth, and cause greater post-harvest loss, while a significant reduction in rainfall can result in drier land, reduced water levels in streams and rivers, and increased labor in search of irrigation water, consequently reducing crop. Climate change affects livestock production by reducing available pasture land, surface water resources, and increasing water salinity due to higher temperatures and evaporation rates amidst reduced rainfall. There is less protein from animals available, including meat, eggs, milk, and other animal products like hides and skins, as a result of this drop in livestock productivity. (Ogbuabor & Egwuchukwu, 2017).

According to Detelinova et al. (2023), Kenya is extremely susceptible to extreme weather events, particularly droughts and floods. From the year 2000 the country has experienced an average of 2.8 meteorological, hydrological, and climatological disasters per year, a significant increase from the 0.5 average per year recorded between 1964 and 1999 (World Bank Group, 2021). Severe droughts usually occur after every ten years, whereas moderate floods or droughts happen averagely after every three years. Between 2008 and 2011, there was an average 2.8 percent decline in GDP growth due to the drought. Over 300,000 people were displaced by the drought in 2017 and the subsequent flood in 2018. Over 800,000 people in Kenya were affected by floods caused by the prolonged rainy season in 2020, which also resulted in some deaths and population displacement. The disaster was caused by severe rainfall. The significant outbreaks of desert locusts brought on by the torrential rains in 2019 and 2020 significantly harmed agricultural output, negatively affected public health, and sparked hostilities between impacted populations.

In the early 2020s, the Northeastern Africa faced its worst drought in four decades, affecting millions of Kenyans in desert and semi-arid areas. While these regions are

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drought-prone, floods typically occur in western and southeastern Kenya near major rivers. However, in 2023, unexpected floods severely impacted historically non-flood-prone northern counties like Isiolo, Mandera, Marsabit and Wajir (Detelinova et al., 2023).

As a response, there was an initiation of Kenya National Climate Change Action Plan 2012 to lessen susceptibility to climate change as well as increase its capacity to take advantage of the opportunities that it offers. All living things on Earth depend on effective mitigation and adaptation methods to ensure their survival and sustainability.

Kenya's socio economic development, driven by 2030 Vision seeks to transform the nation into a middle income, industrialized economy with a secure and sustainable environment. To achieve this, addressing sustainable development with a focus on climate change is crucial. Since Kenya heavily depends on rain fed agriculture, any major changes in weather patterns could lead to significant costs impacting the country's socio economic progress.

Kenya’s economy faces significant risks from climate change due to its dependence on natural resources and climate-sensitive industries like agriculture and tourism. Agriculture, which makes up 22% of GDP and employs over 40% of the workforce, contributes more than 65% of the country’s exports. After recovering from COVID-19, tourism accounted for 10.4% of GDP in 2022. The energy sector, which drew 40% of its power from hydropower in 2020, is also at risk. Between 2010 and 2020, extreme weather caused annual economic losses of 3–5% of GDP. Floods and droughts impose long-term fiscal burdens of 2.0–2.8% of GDP, with damage costs rising six-fold since 2000.

II. STATEMENT PROBLEM

Though global warming is a global concern, its impacts are unevenly distributed across nations and regions. Studies consistently show that poorer countries, especially in sub-Saharan Africa (SSA) face the greatest risks from climate change. This heightened vulnerability is due to their reliance on agriculture and other climate sensitive industries as well as limited resources to cope with climate related shocks. Consequently, African countries, including Kenya, are particularly prone to extreme weather conditions that can negatively affect their economic growth. (Alagidede et al., 2014).

III. LITERATURE REVIEW

The economic theory of externalities explains how costs or benefits from an activity affect third parties who are not directly involved, leading to market failures when these impacts are not accounted for in market prices. Climate change is a clear example of a negative externality, as greenhouse gas emissions from industries, transportation, and deforestation cause widespread societal harm. This includes more frequent extreme weather events, increasing sea levels, health risks, and lower agricultural productivity. These effects strain infrastructure, raise healthcare expenses, reduce crop yields, and increase investment uncertainty, all of which impede economic growth. Policies like carbon pricing, emission limits, and support for clean technologies can help internalize these externalities, ensuring market prices better reflect societal costs and fostering sustainable growth (Lewis & Tietenberg, 2019).

Adamu and Negeso (2020) investigated the relationship between climate change and agricultural output in Ethiopia. Their long-run model revealed that climate change has a significant impact on agricultural output, which is a key component of the nation's GDP. The coefficient of the error correction term was -0.738, indicating that the system adjusts towards long-run equilibrium at an annual rate of approximately 73.8%. In the short term, the mean annual rainfall had a significant effect on agricultural output, whereas average temperature does not. Over the long term, both variables significantly influence agricultural output, with mean annual rainfall having a positive impact and average temperature a negative one. To address the impacts of climate change, this study advises the government and relevant stakeholders to formulate targeted policies that prioritize technological innovations aimed at reducing rising temperatures and boosting productivity at both macro and micro levels.

Odusola and Abidoye (2015)’s paper investigated the impact of temperature and rainfall volatility on economic growth in 46 African countries using Bayesian hierarchical modeling. It finds that a 1°C increase in temperature decreases economic growth by 1.58 percentage points, while a temperature shock reduces it by 3.22 points. A 1 percent change in rainfall leads to a 6.7 percent change in economic growth. The impact of temperature changes on GDP varies across countries, ranging from -1.24 percent to -1.82 percent. The paper recommends combined national, cross-country, and continental approaches to climate change adaptation in Africa to maximize economies of scale.

Odusola and Abidoye (2015) explored how fluctuations in temperature and rainfall affect economic growth across 46 African nations, employing Bayesian hierarchical modeling. The findings reveal that a 1°C rise in temperature lowers economic growth by 1.58%, while a temperature shock results in a 3.22% decline. Additionally, a 1% variation in rainfall corresponds to a 6.7% shift in economic growth. The effect of temperature changes on GDP differs between countries, ranging from -1.24 percent to -1.82 percent. The study suggests implementing a mix of national, regional, and continental climate adaptation strategies to optimize economies of scale in Africa.

IV. METHODOLOGY

A. Data Sources

Yearly secondary data between 1990 through 2023 were used in the study to analyze annual variations in rainfall, carbon emissions, forest depletion, inflation, exchange rate, and government expenditure in Kenya. Data was sourced from World Bank data base.

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The research employed a multivariate model regression. The relationships among these variables were expressed in the following function;

$$GDP_t = A_0 + A_1 CO2_t + A_2 AVF_t + A_3 FDL_t + A_4 INF_t + A_5 EXR_t + A_6 GOVE_t + \varepsilon_1 \ldots\ldots..$$

Where:

GDP_t = Economic Growth, A_0= Constant $A_{1,} A_{2\ldots} A_6$= variable parameters $CO2_t$ = Carbon Emissions, AVF_t= Average Rainfall,

FDL_t= Forest Depletion, INF_t= Inflation EXR_t= Exchange rate and $GOVE_{t_t}$= Government Expenditure and ε_1=error term.

Modeling was carried out using the ARDL Model, which has the following advantages over other models: the ARDL mode accommodates multiple orders of co-integration I(0) and I(1) in this space while remaining consistent and efficient. When we have a limited number of observations, the model works well (Matundura, 2021). The aforementioned equation has the following generic form:

$$Gdp = f(\Delta CO2_{t,} \Delta AVF_t, \Delta FDL_{t,} \Delta INF_t \; \Delta EXR_t \Delta GOVE_t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots$$

The ARDL model for analysis takes the following form;

$$\Delta \; y_t = v + \text{Ɣ}\beta' \; y_{t-1} + \sum_{i=1}^{n-1} \Gamma_i \; \Delta x_{t-i} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Whereby;
v = parameter representing constants
Ɣ = represents the error correction term
β = coefficient for long run
Γ_i = short run coefficients.
n =Number for the lags
ε_t = Random error term

B. *Ethical Considerations*

The study acquired a letter of authorization and a work permit from the National Commission for Science, Technology, and Innovation to present during data collection. The researcher complied with intellectual property standards by accurately acknowledging all information sources.

V. RESULTS AND DISCUSSION

A. *Descriptive Statistics*

Prior to estimating the model, the study examined the data characteristics by assessing measures of central tendency.

Table 1: Descriptive Measures

Factor	**Obs.**	**Average**	**Std. dev**	**Min**	**Max**
GDP	34	3.709132	2.298588	-.799494	8.058474
CO2	34	.298368	.0637199	.2024751	.4105815
AVF	34	631.8235	10.63291	630	692
FDL	34	6.569156	.2798144	6.1516	6.959957
INF	34	11.20505	9.117695	1.554328	45.97888
EXR	34	77.98715	25.20336	22.91477	139.8464
GOVEXP	34	5.413058	5.935705	-2.405063	29.39412

Whereby;

GDP= Economic growth rate
CO2=Carbon Emissions
AVF= Average precipitation
FDL= Forest Depletion
INF= Inflation rate
EXR=Currency exchange rate
GOVEXP = Government Expenditure (Million Ksh.)

The dataset had the following characteristics; the average annual economic growth rate change (GDP) was 3.71%, ranging -0.80% to 8.06% and 2.30% standard deviation. Carbon emissions (CO2) average 0.2984 units, with a range of 0.2025 to 0.4106 units and a standard deviation of 0.0637 units. Average annual precipitation (AVF) stood at 631.82 units, varying from 630 to 692 units, with a standard deviation of 10.63 units. Forest depletion (FDL) averages 6.5692 units, ranging from 6.1516 to 6.9599 units, with a standard deviation of 0.2798 units. The inflation rate (INF) averages 11.21%, ranging from 1.55% to 45.98% and standard variation of 9.12%. The annual exchange rate (EXR) averages 77.99 units, with a range of 22.91 to 139.85 units and a standard deviation of 25.20 units. General government consumption expenditure (GOVEXP) averages 5.41 and ranges from -2.4051 to 29.3941 and a standard deviation of 5.94 units.

B. *Augmented Dickey Fuller Unit Root Tests at Level*

In Cointegration analysis, determining the stationarity of variables gives insight into determining the integration characteristics of variables. It is important to determine the stationarity since it influences the kind of modeling. Augmented Dickey Fuller (ADF) is used to check for unit roots in variables. (Shrestha & Bhatta, 2018).

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Table 2: Augmented Dickey Fuller Tests at Level

			Level Test			
Variables	p-values	ADF Test Statistic	1%	5%	10%	**Remark**
GDP	0.0014	-4.406644	-3.646342	-2.954021	-2.615817	Stationary
CO2	0.9101	-0.327795	-3.646342	-2.954021	-2.615817	Unit root
AVF	0.0000	-5.744563	-3.646342	-2.954021	-2.615817	Stationary
FDL	0.8869	-0.457717	-3.653730	-2.957110	-2.617434	Unit root
INF	0.0431	-3.022235	-3.646342	-2.954021	-2.615817	Stationary
EXR	0.9050	-0.358331	-3.646342	-2.954021	-2.615817	Unit root
GOVEXP	0.0014	-4.407011	-3.646342	-2.954021	-2.615817	Unit root
First Difference Test						
GDP	0.0000	-7.176086	-3.661661	-2.960411	-2.619160	Stationary
CO2	0.0007	-4.673152	-3.653730	-2.957110	-2.617434	Stationary
AVF	0.0000	-9.486833	-3.653730	-2.957110	-2.617434	Stationary
FDL	0.0370	-3.095277	-3.653730	-2.957110	-2.617434	Stationary
INF	0.0000	-6.563865	-3.661661	-2.960411	-2.619160	Stationary
EXR	0.0021	-4.263915	-3.653730	-2.957110	-2.617434	Stationary
GOVEXP	0.0000	-5.966362	-3.661661	-2.960411	-2.619160	Stationary

Authors' Compilation, 2024

Before running an ARDL model, the variables should be checked for stationarity. The test indicated that GDP (Economic growth rate), AVF (Average precipitation), FDL (Forest Depletion), and INF (Inflation) were stationary at level. CO2 (Carbon Emissions), EXR (Exchange rate), and GOVEXP (Government Expenditure) were non-stationary but became stationary after first differencing at the 5% level, as indicated in Table 2.

This led the study to test for long-run co-integration using the bounds test. According to the results in Table 1.3, the F-statistic (F = 102.127) is greater than the upper bound l values at the 10%, 5%, 2.5%, and 1% levels. As a result, the null hypothesis was rejected hence co-integration exists.

This prompted the study to assess long-term co-integration through the bounds test. The findings in Table 1.3 indicate that the F-statistic (F = 102.127) exceeds the upper bound values at the 10%, 5%, 2.5%, and 1% levels. Consequently, the null hypothesis was rejected, confirming the presence of co-integration.

Table 3: Bounds Test

				F = 102.127 **t = -14.686**
	[I 0] [I 1] L_1 L_1	[I 0] [I 1] L_05 L_05	[I 0] [I 1] L_025 L_025	[I_0] [I_1] L_01 L_01
	2.26 3.35	2.62 3.79	2.96 4.18	3.41 4.68

Authors' Compilation, 2024

Table 4: Results ARDL Model in the Short Run and Long Run

Sample 1994 – 2023 Log likelihood = 51.458483				observations = 30 R^2 =0.9998 R-squared Adj = 0.9935	
	D.gdp	Coef.	Std. Error	T	P Value
ADJ	gdp				
	L1	-14.75833	1.004922	-14.69	0.043
LR	CO2	36.58	2.072432	17.65	0.036
	AVF	-.1059502	.0021571	-49.12	0.013
	FDL	1.820359	.2739649	6.64	0.095
	EXR	-.0528207	.0032361	-16.32	0.039
	GOVTEXP	-.1189649	.0050859	-23.39	0.027
SR					
	CO2				
	D1.	-79.45948	13.28913	-5.98	0.105
	LD.	-509.7819	52.64989	-9.68	0.066
	L2D.	-14.96046	11.61586	-1.29	0.420
	L3D.	289.0922	25.24818	11.45	0.055
	AVF				

	D1.	1.547127	.1043704	14.82	0.043
	LD.	1.505379	.1058161	14.23	0.045
	L2D.	.9206735	.0658551	13.98	0.045
	L3D.	.447783	.0344635	12.99	0.049
	FDL				
	D1.	-29.2326	5.656224	-5.17	0.122
	LD.	-284.225	25.22637	-11.27	0.056
	L2D.	-125.6334	14.83409	-8.47	0.075
	EXR				
	D1.	-.3507525	.0231191	-15.17	0.042
	LD.	-.6433857	.0387789	-16.59	0.038
	L2D.	-.7146149	.0625723	-11.42	0.056
	L3D.	.383677	.0412902	9.29	0.068
	GOVEXP				
	D1.	1.697167	.1603168	10.59	0.060

Notes: ADJ implies adjusted, LR-long run and SR is the short run
Source: Authors' Compilation from STATA Output, 2024

The adjusted R^2 of 0.9935 indicates that the regressors have adequately accounted for the variations of the explained factor. The rate of return to the long-run equilibrium which is negative at -14.75833 was significant at the 5% level indicating any imbalance resulting from changes in the explanatory variables is adjusted each year.

The coefficient for CO2 was 36.58, with a standard error of 2.072432, indicating that a rise in carbon emissions is linked to an increase in GDP. The positive correlation between GDP and CO2 emissions can be explained by the fact that economic growth often involves increased industrial activity, energy production, and transportation—all of which typically lead to higher carbon emissions. As economies expand, especially in developing countries, there is greater demand for energy to power factories, fuel transportation, and support urbanization. This increased energy consumption is often met by burning fossil fuels, which releases CO2 into the atmosphere. Therefore, the initial stages of economic development are frequently accompanied by a rise in carbon emissions as countries prioritize economic growth over environmental concerns. This phenomenon reflects the industrialization process, where economic output is directly tied to energy use and carbon emissions.

The study support Al-Mulali and Ozturk (2016)'s study that found carbon emissions and GDP growth are positively correlated in the short term, especially in developing countries due to industrialization and increased energy consumption. However, this contradicts with the study of Green and Stern (2017) which states that while there may be a positive correlation in the short term, long-term environmental degradation from high emissions can negatively impact economic growth through health costs and environmental damage.

The coefficient for AVF (Average Precipitation) was -0.1059502 and had a standard error of 0.0021571 this indicated higher average precipitation is in line with a decrease in GDP. The study supports Burgess et al. (2017) study that found extreme weather conditions, including excessive precipitation negatively impact agricultural productivity and overall economic performance. However, the findings contradicts Kumar et al. (2019) Kumar et al. (2019) which suggest that in some regions, particularly those prone to drought, higher average precipitation might actually benefit GDP by improving agricultural output and water availability.

The coefficient for FDL (Forest Depletion) is 1.820359, with a standard error of 0.2739649, suggesting that higher levels of forest depletion are associated with an increase in GDP. This findings are in agreement with Rodríguez-Veiga et al. (2020). The study discovered that in many African countries including Kenya forest resources are exploited for economic gain contributing to short-term GDP growth. However, contradicting studies like Morley et al. (2022) highlight the long-term negative impacts of deforestation in these regions, such as loss of biodiversity and ecosystem services, which can eventually hinder sustainable economic development.

The coefficient for the exchange rate (EXR) was -0.0528207 a standard error of 0.0032361, suggesting that a rise in the exchange rate (currency depreciation) is linked to a reduction in GDP. This aligns with Igunza's (2017) findings, which demonstrated that fluctuations of exchange rate in Kenya can hinder economic growth by raising uncertainty and transaction costs.

The coefficient for GOVTEXP (Government Expenditure) was -0.1189649 a standard deviation of 0.0050859 indicating that higher government expenditure was associated with a decrease in GDP. This is similar with Matundura (2014) found that excessive government spending in Kenya, particularly on inefficient Agricultural projects can crowd out private investment and reduce economic growth. However, the study differs with Keynesian economic theory whih explains that increased government expenditure, especially during economic downturns, can stimulate demand and boost GDP.

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VI. CONCLUSION AND POLICY IMPLICATIONS

The study highlights several significant relationships between Economic growth rate Carbon Emissions, average precipitation, forest depletion, Inflation, exchange rate, government expenditure and economic growth.

The study found out that at 5% level of significance; increased carbon emissions were associated with higher economic growth while increasing average precipitation was linked with decrease in Kenya's economic growth.

Greater forest depletion was linked to higher economic growth, though the relationship was not statistically significant at the 5% level. A higher exchange rate, on the other hand, corresponded with reduced economic growth. Similarly, increased government spending was found to negatively affect economic growth. The inflation rate did not show a significant impact over the long term.

➢ *Policy Recommendations*

Balancing Economic Growth with Environmental Sustainability; the government should implement policies that promote cleaner technologies and reduce carbon emissions without hindering economic growth. Support initiatives such as renewable energy projects and energy-efficient technologies.

Climate Adaptation Strategies, Government and non - governmental institutions should invest in infrastructure and agricultural practices that enhance resilience to extreme weather conditions. This includes developing advanced irrigation systems, promoting drought resistant crops, and constructing flood defenses.

Sustainable Forest Management; institutions should policies that balance the economic benefits of forest resource exploitation with conservation efforts. Promote sustainable forestry practices, like regulated timber harvesting, reforestation efforts, and community-led forest management are essential for maintaining long-term environmental sustainability and economic well-being.

Exchange Rate Stabilization; the government should implement measures to reduce exchange rate volatility, such as maintaining healthy foreign reserves and fostering a diversified export sector. Encourage the growth of non-traditional exports and value added products to reduce dependency on a few commodities

Enhance the efficiency of government expenditure by focusing on high-return investments and reducing waste.

➢ *Study Limitations*

This research's time span was confined from 1990 to 2023 subject to data availability for annual time series utilizing major macroeconomic variables i.e. changes in rainfall annually, carbon emissions, forest depletion, inflation, exchange rate, and government expenditure in Kenya as a result policy recommendations given hereby will not be applicable to other countries with different economic status and framework.

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