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Climate Change, Natural Resource Depletion and Economic Growth of Kenya

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Abstract
The adverse effects of climate change ravage more the growth trajectories of developing countries than developed countries. This is aggravated by random depletion of natural resources arising from rapid economic growth, consequences of civilization as well as existence of weak institutional infrastructure for environmental protection. The paper empirically investigates the nexus between climate change, natural resource depletion and economic growth of Kenya. The trend analysis demonstrates that depletion of forest cover as a percentage of gross national income moves in tandem with the cost of damage to the economy arising from carbon dioxide emissions. The depletion of forest cover also reduces the growth rate in gross domestic product. The empirical findings from regression analysis show that natural resource depletion increases the cost of damage arising from carbon dioxide emissions and this finding mimics the trend analysis. The increased cost of damage arising from carbon dioxide emissions in turn reduces savings, investments and ultimately reduces the growth rate in gross domestic product of Kenya. Agriculture sector in Kenya plays a pivotal role in GDP growth and is immensely affected by climate change. The paper also empirically examined the impact of the cost of carbon dioxide damage on agriculture crop production and livestock product. Results show that both livestock production and crop production reduce with increased carbon dioxide emissions. These findings point to the importance of implementation of policies or protocols for controlling carbon dioxide emissions and natural resource depletion because of their devastating effect on economic growth of Kenya.

Keywords: Agriculture Production, carbon dioxide emissions, climate change, economic growth, natural resource depletion

Introduction
The first economic debate on climate change started during the 1990s and the economic studies focussed on Brazil and India because these countries kept good records on agriculture (Mendelsohn & Dinar, 1999; Kumar & Parikh, 2001; Mendelsohn, 2008). These early studies on climate change used the Ricardian Method and findings revealed that agriculture in both countries was sensitive to modest warming. In fact, marginal increases in temperature resulted in reduction in average net revenue from agriculture.

Climate change is one of the most pressing threats confronting economies (Farajzadeh et al. (2022). Due to anthropogenic activities, the average temperature has risen by 0.9^{o}C since the 19th Century, mainly due to Green House Gas (GHG) emissions in the atmosphere. This rise is estimated to increase by 1.5^{o}C by 2050 as a result of deforestation (Arora, 2019). The unprecedented rise in temperatures has resulted in increased droughts especially in the Horn of Africa, floods in Pakistan, hurricanes in USA, irregular patterns of precipitation, and heatwaves in

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Europe and China. Emissions on their part have a direct impact on health and environmental degradation (De Angelis et al. 2019).

In the year 2018, natural disasters caused economic losses to the tune of USD 225 billion across the world (Arora, 2019). About 95 percent of these losses are attributed to weather related incidences of which cyclones, floods and droughts are the key players. During the year 2022, climate change caused heavy floods in Pakistan, heatwaves in China and Europe as well as drought in the horn of Africa. As of 8th May 2023, South East Asian countries recorded the worst heatwave ever experienced in the region that is compounded by an intense smoggy season that spiked pollution levels. In fact, Vietnam, Thailand and Laos recorded temperatures of 44.2^{o}C, 45.4^{o}C and 43.5^{o}C, respectively, and Philippines recorded temperatures of between 42^{o}C-51^{o}C. These high temperatures led to closure of schools and caused misery to many. Therefore, as is articulated by Duan et al. (2022), global warming not only affects the level of output, but also damages the ability of an economy to grow by damaging crops and increasing heat-related mortality.

Effects of climate change ravage more developing countries than developed countries. In fact, developed countries benefit from climate change because of its link to production and consumption whilst developing countries suffer the adverse effects of environmental pollution. Climate change is a civilization threatening consequence (Rezai et al., 2018) since exponential economic growth results from capital accumulation and the ever increasing use of natural resources such as energy and fossil fuels. Consumption of fossil fuels account for most emissions in the world (De Angelis et al., 2019). Emissions from climate change, especially carbon dioxide emissions, have a direct effect on environmental degradation (De Angelis et al., 2019). The study by Burke et al. (2015) indicate that climate change may cause over 77 percent of the world's economy to become poorer if no substantial control strategies are implemented to reduce emissions. The effects of climate change severely affect agriculture based productivity of poor countries while developed countries benefit because of the positive changes in their terms of trade.

Kenya relies heavily on hydropower generation and minimizing energy's contribution to climate change is a challenge. The need to address food security has led to increased Green House Emissions coupled with the depletion of forest cover as a results of rapid population growth. The question to ask is: does the depletion of natural resources, coupled with increased carbon dioxide emissions affect the growth rate of Kenya? This study's interest is to determine the linkage between depletion of natural resources, carbon dioxide emission and economic growth of Kenya.

Most studies on climate change and economic growth focus on the relationship between temperature change, carbon dioxide emissions, precipitation and economic growth using panel data analysis. The country specific macroeconomic studies revolve around Asian countries (Liu et al. 2020) and developed countries (Acaroglu & Güllü, 2022).

This research paper is a country specific empirical investigation focusing on Kenya, a country with low adaptation capacity and located in the tropics; a region that is persistently affected by climate change. The fact that Kenya is located in the tropics makes it experience the adverse effects of global warming and, therefore, a study that investigates the relationship between climate change and gross domestic product (GDP) growth provides insights into the possible environmental management policies to be adapted to mitigate climate change effects.

Additionally, this study includes depletion of natural resources to the nexus between climate change and economic growth which is an innovation to climate change debate. In Africa, studies on climate change focus on Sub Sahara Africa (Alagidede et al., 2014), on Africa (Abidoye & Odusola, 2015) and North Africa (Roson, 2012). These studies used temperature change and precipitation as the proxy for climate change. In this research paper, not only temperature is used

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as a measure of climate change but also the cost of damage as a result of carbon dioxide emissions. The results of this paper provide evidence that climate change not only negatively affects economic growth and development of Kenya, it also affects savings and investments. It also reduces both crop and livestock production. Additionally, depletion of natural resources cannot be ignored as an important factor in the climate change-economic growth nexus.

The remainder of this paper is organised as follows: The first section provides some trend analysis on the nexus between climate change, natural resource depletion and economic growth. Section 2 provides extant literature on the relationship between climate change and economic growth. Section 3 develops an econometric model that is used for the analysis of data. Section 4 presents the descriptive and econometric estimation results of the study and the last section concludes the study and provides some policy implementations.

Nexus Between Carbon Dioxide Emission, Natural Resource Depletion and Economic Growth in Kenya

This section shows the trend analysis of the relationship that exists between carbon dioxide damage as a percentage of gross national income (GNI), natural resource depletion (measured using depletion of forest cover), temperature change, sectoral carbon dioxide emissions, sectoral output and economic growth of Kenya. The carbon dioxide damage is measured by the cost of damage resulting from carbon dioxide emissions. The unit cost of damage is calculated as US $40 per ton of carbon dioxide emission. Figure 1 shows the relationship between GDP growth and carbon dioxide damage as a percentage of GNI.

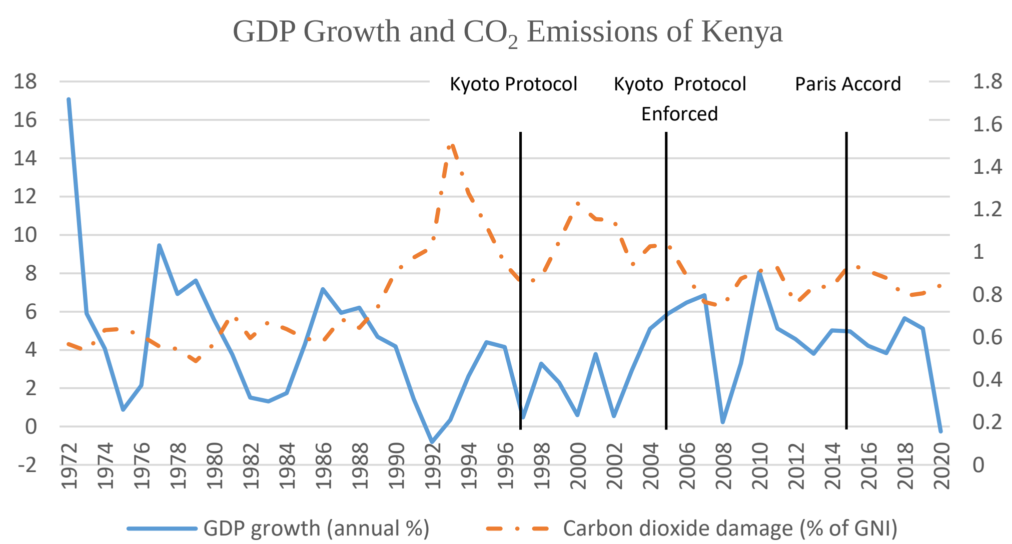

Fig. 1: Climate Change and Economic Growth

It is evident from Figure 1 that GDP growth and carbon dioxide damage move in opposite direction. Increases in cost of damage resulting from carbon dioxide emissions are accompanied by decreases in GDP growth of Kenya. Debate on how to combat climate change began in 1990s, a period in which carbon dioxide damage in Kenya surged and reached the highest level of about 1.5 percent in 1992. During this period, GDP growth slumped to the lowest level of about 1 percent. Cost of damage brought by carbon dioxide emissions (hence a decline in the cost of damage) declined from 1.5 percent of GNI in 1992 to 0.84 percent in 1997, the year the Kyoto

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Protocol was adopted. The Kyoto Protocol was the first legally binding climate change treaty in which countries committed towards reduction in carbon dioxide emissions. This period of declining in carbon dioxide emission was accompanied by increased GDP growth.

Without enforcement of the protocol, carbon dioxide emissions sharply increased and reached 1.2 percent in the year 2000. Prior to enforcement of the Kyoto protocol in 2005, carbon dioxide emissions recorded a steady decline. When Kyoto Protocol was adopted by countries, Kenya's GDP growth slightly improved before oscillating. As carbon dioxide emissions gradually declined, the GDP growth which had gone through a sudden slump in 2008 improved. The sudden slump was driven by the temporary political instability after announcement of general elections results. During the Paris Accord in 2015, countries strengthened climate change commitments on reducing greenhouse gas emissions but the amount of carbon dioxide keeps increasing. The relationship between carbon emission and GDP growth that is depicted by these diagrams lean towards the literature that asserts that environmental degradation reduces economic growth of less developing countries. In fact, Rezai et al. (2018) argue that climate change induced by greenhouse gas emissions lowers investments, profitability and cuts output in the short-run and long-run.

Climate change affects output from the agriculture sector; especially crop production and livestock production. Figure 2 shows the trend analysis of climate change (proxied by carbon dioxide damage as percent of GNI and temperature change).

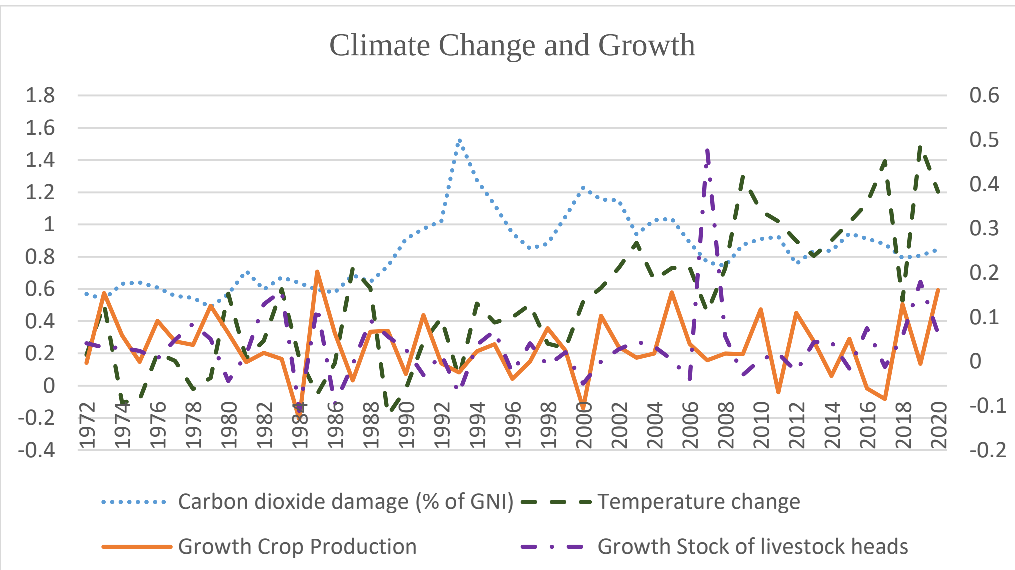

Fig. 2: Climate Change and Agriculture Output

From Figure 2, temperatures have gradually been rising with high temperatures recoded in the years 1980, 1983, 1987, 2003, 2009, 2017 and 2019. In fact, the years 2007 to 2009 as well as 2013 to 2017 recorded a rapid increase in temperatures. During these years, crop production and livestock production were at their lowest values; implying that perhaps the high temperatures contributed to the low production output in agriculture sector. In other words, temperature change and both crop and livestock production move in opposite direction; that is, positive changes in temperature lead to reduction in crop production and livestock production. A similar negative relationship is exhibited between carbon dioxide emissions and both crop and livestock production. The decrease in livestock production, during periods of high temperatures, can be explained by the

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fact that the pastoralist community that lives in the northern part of Kenya lose most of their domestic animals during periods of drought.

Apart from the trend analysis provided above, the nexus between depletion of natural resources, GDP growth and carbon dioxide emissions confirm the proposition that the depletion of natural resources increases temperatures and carbon dioxide emissions. As a consequence, growth in GDP declines. Results are presented in Figure 3.

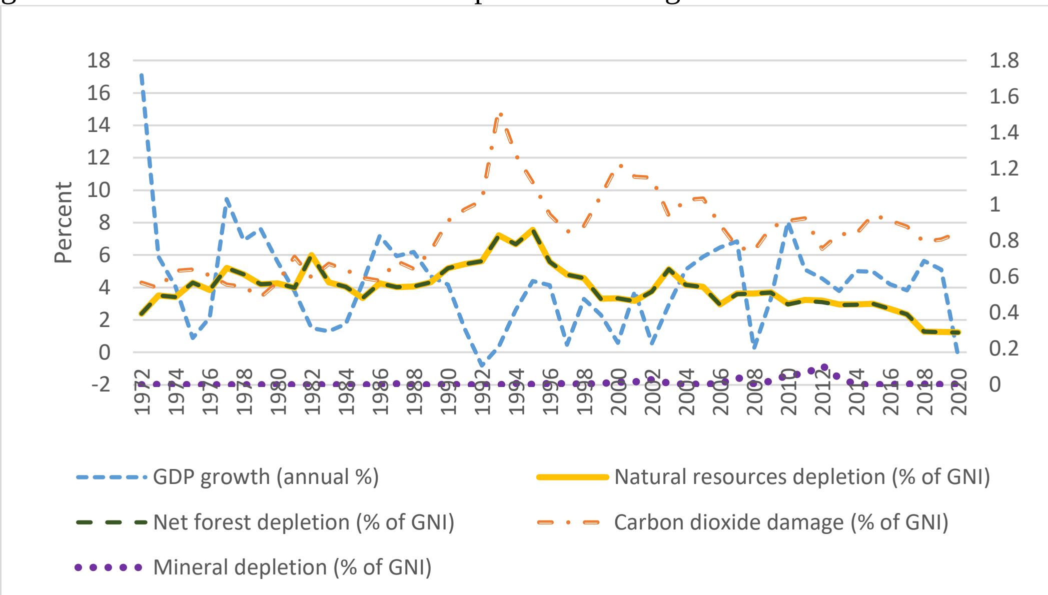

Fig. 3: GDP Growth, Natural Resource Depletion and Carbon Dioxide Emission

It is evident from Figure 3 that depletion of natural resources in Kenya is actually the depletion of forest cover. This depletion of the forest cover is accompanied by increases in carbon dioxide emissions. During the period in which Kenya experienced the highest carbon dioxide emissions, net forest depletion as a percent of GNI reached the all high point of about 7.55 percent of GNI. During 1989 to 1993, when there was logging and depletion of forest cover, carbon dioxide emissions tremendously increased in the atmosphere.

As from 1993, with the Green Belt Movement pushing for re-afforestation and protection of forests, depletion of forest cover reduced. The re-afforestation initiatives led to a decline in carbon dioxide emissions up to 1996, but emissions shot up again in 1999 as a result of increased consumption of liquid fuel as shown in Figure 4.

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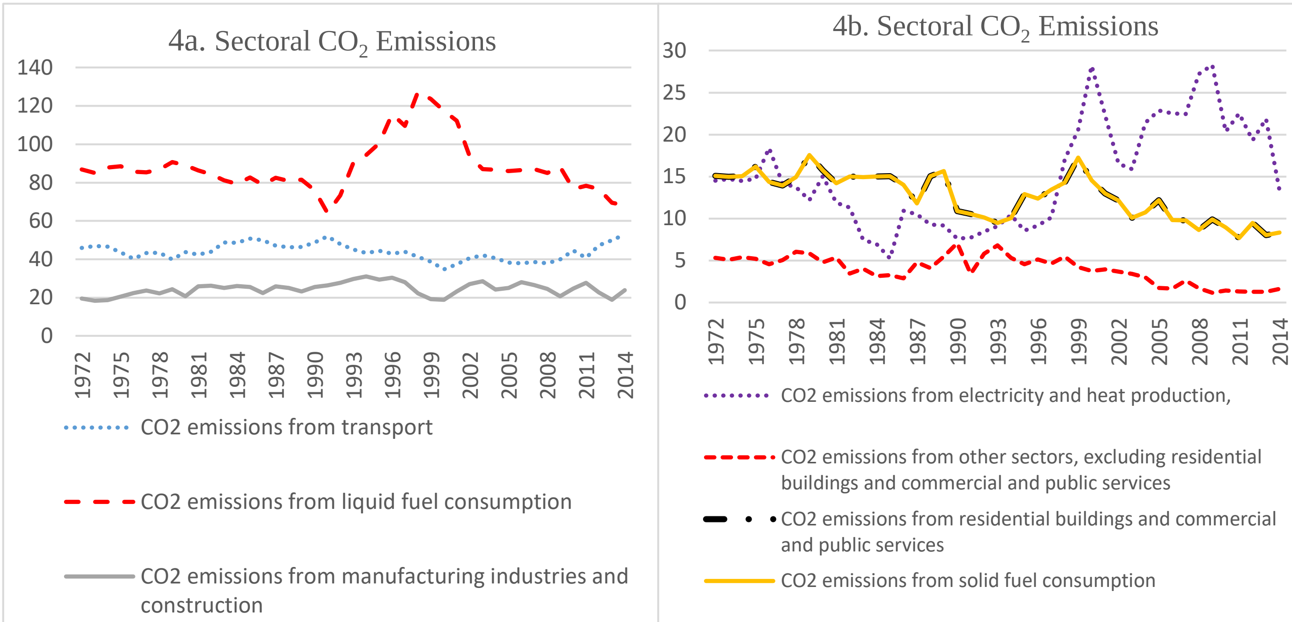

Fig. 4: Sectoral Carbon Dioxide Emissions

The results in Figure 4 (diagram 4a) show that carbon dioxide emissions from liquid fuel are the highest, with the peak in 1999, the year Kenya resulted in the use of fuel generators to supplement the supply from Uganda. The measures that the manufacturing sector put in place to address electricity shortages (such as switching to fuel generators for production) also led to increased emissions from electricity consumption as is evidenced by Figure 4 (diagram 4b). An interesting finding from the results in Figure 4 (diagram 4b) is that the carbon dioxide emissions from residential buildings, commercial and public services are equivalent to the carbon dioxide emissions from solid fuel consumption.

Literature on Climate Change and Economic Growth

There are multiple channels linking income to climate exposure such as adverse effects on health, labour productivity and possible reduction in human capital accumulation. Hsiang et al. (2017) found that low income USA Counties are more adversely affected by climate change than high income Counties. This finding confirms what Dell et al. (2009) found that higher temperatures have a substantial reducing effect on economic growth of poor countries but have little effect on rich countries. They also argue that higher temperatures reduce agricultural output, total investment, output from industrial sector and increases political instability.

In yet another study, Dell et al. (2012) sought to determine the relationship that exists between temperature shocks and economic growth. Their study demonstrated that hot countries tend to be poor, with national income falling by 8.5 percent per degree Celcius. They also found that a 1^{o}C rise in temperature in a given year reduces economic growth of poor countries by 1.3 percent. Additionally, in rich countries, changes in temperature do not have a robust observable effect on economic growth. Actually, temperature influences the level of output by affecting agricultural yields together with investments, consequently affecting the economy’s ability to grow.

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Eboli et al. (2010) explored the climate change feedback on economic growth using the dynamic general equilibrium model. They assessed the economic consequences of climate change on economic growth and the distribution of income in the world. Additionally, they verified if climate change feedback on economic scenarios brings about significant variations in estimates of greenhouse gas emissions. Their findings reveal that climate change works against income and equity convergence in the world. In fact, effects of climate change adjust productivity, resource endowment and consumption patterns of the world.

Prado, Jr. et al. (2016) reviewed Brazil's policies on energy security whilst accounting for uncertainty in prediction of economic growth and climate change. In consideration to the policies, they examined the role of climate change and the country's reliance on hydro-thermo in increasing socioeconomic and environmental risk. Their review demonstrated that when an electricity crisis happens, the political and economic consequences are large. For instance, when a drought occurs, there is severe rationing in the economy as a result of decreased production.

In a more recent study, Duan et al. (2022) empirically investigated the climate-economic relationship of 274 cities in China using a 27 year panel data. Their results show that a 1-degree temperature change is associated with 0.78 percent decrease in output. Additionally, their study reveals significant differences in the effects of climate change across regions. Specifically, the hotter southwest region of China suffers severely from an average warming whilst the cooler northeast China is non-significantly affected by global warming. Apart from temperature, Duan et al. (2022) also found that a 1 percent humidity is associated with 1.345 decrease in output.

Berg et al. (2023) added to the literature on climate change and economic growth by empirically exploring the responses of real GDP per capita growth from temperature variation. They used data for 137 countries spanning many years from 1960 to 2017. They decomposed country-level temperature into global and idiosyncratic temperature components. They found substantial heterogeneity across countries in the impulse responses of real GDP per capita growth to shocks in temperature. There are more negative than positive impulse responses of real GDP per capita growth to increases in idiosyncratic temperature. In fact, richer countries like the USA tends to experience negative impulse responses of real GDP per capita growth to increases in global temperature whilst some poorest countries experience positive responses.

Using panel data of MENA countries from 2000 to 2019, Amara et al. (2023) evaluated the relationship between carbon dioxide emissions and GDP. Their findings revealed a positive non-linear relationship between GDP and carbon dioxide emissions. Specifically, increases in GDP increased carbon dioxide emissions as well as eco-innovation activities. From this study, GDP is one of the main drivers of carbon dioxide emissions; this result mimics the findings by Amin et al. (2022) who confirmed that economic growth upsurge carbon emissions. Amara et al. (2023) also found that foreign direct investment (FDI) is linked to excess resource utilization and high pollution outputs.

Letta and Tol (2019) examined the impact of temperature change on total factor productivity (TFP) of a panel of 60 countries covering the period of 1960 to 2006. The findings show that temperature shocks negatively affect TFP growth rates. In fact, a 1^{o}C annual increase in temperature lowers growth rate of TFP by 0.49 percent.

Letta and Tol (2019) also interacted temperature change and a dummy for being poor (the dummy capturing poor is measured using observations that lie below the median of GDP per capita); the findings reveal that the negative effects of temperature on TFP are concentrated in poor countries. Their result on poor countries indicates that a 1^{o}C increase in temperature decreases TFP growth rates by about 1.5 percentage points. This finding corroborates the findings by

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Henseler and Schumacher (2019) who also established that total factor productivity of low income countries is negatively affected by temperature change.

On climate change and agriculture, studies on Brazil and India by Mendelsohn (2008), Mendelsohn and Dinar (1999) along with Kumar and Parikh (2001) suggest that agriculture is sensitive to warming. Marginal increases in temperature result in reductions in average net revenue and land value. Their results also revealed that not every farm in these countries would be affected in the same way. In fact, the wet Eastern Region of India mildly benefits from warming whereas the dry Western Region of India suffers large damages. The South Eastern Region of Brazil benefits from warming whilst the Amazonian and North Eastern Region of Brazil would be hurt. Additionally, their findings show that small farms find it profitable to switch between livestock and crops depending on the temperature. In contrast, large farms reduce their stock of livestock as temperatures increase.

The argument by Hsiang and Kopp (2018) that agriculture revolutions have transformed forests into farmlands and years of forest clearance has added hundreds of billions of tons of carbon to the atmosphere. Actually, every home lit by coal or natural gas-fired power plant, every petrol powered train, plane and motor vehicle has contributed to the net of carbon dioxide in the atmosphere. The emissions of CO_2, together with other greenhouse gases distort the planet's energy balance. Under normal circumstances, the sunlight that makes it to the Earth's surface is absorbed and then re-radiated to Space as an equal quantity of heat (technically infrared light). The accumulation of greenhouse gases in the atmosphere blocks some of this re-radiation, redirecting energy back toward the Earth's surface. This redirected energy is about 27 trillion Watts (0.05 Watts per square meter) per 1 percent increase in atmospheric CO_2 concentrations, equivalent to the energy of one Hiroshima-Scale atomic bomb spread over the surface of the Earth every 2.3 seconds.

Methodology

The drivers of economic growth, as stipulated by Solow's growth model are capital accumulation and labour. Solow's growth model puts emphasis on capital accumulation as the driver of economic growth. Studies have shown that climate change affects the economy through consumption of goods and services, savings and investments. Therefore, following Solow's growth model, the simple reduced form production function can be presented as follows:

$$Y_t = f(K_t) \tag{1}$$

Where K_t is capital and Y_t is output. Equation 1 can be presented as a Cobb-Douglas production function of the form:

$$Y_t = A_t K_t^{\alpha_1} \tag{2}$$

Where A_t is technological progress. If we add climate change to the production function then Equation 2 becomes:

$$Y_t = e^{\sum_{i-2}^{3} \alpha_{it} CC_{it}} A_t k_t^{\alpha_1} \tag{3}$$

Where CC represents climate change. Economic growth and technological progress boosts standards of living and this is achieved through natural resource depletion and the use of energy.

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So long as energy is derived from carbon-emitting fossil fuels, concentration of atmospheric carbon dioxide and other greenhouse gas emissions increases thus climate change worsens. Climate change can thus be entered into the production function using carbon dioxide emission and temperature change (T). The production function thus becomes:

$$Y_t = A_t k_t^{\alpha_1} e^{\alpha_2 CO_{2t} \alpha_3 T_t} \quad (4)$$

Thus, log linearizing Equation (4) and adding the natural resource depletion and mineral resource depletion variables, the regression model takes the form:

$$y_t = \alpha_0 + \alpha_1 lnK_t + \alpha_2 CO_{2t} + \alpha_3 T_t + \alpha_4 DepNR_t + DepMineral_t + \mu_t \quad (5)$$

Where $y_t = LnY_t$ is growth rate in output, CO_{2t} is carbon dioxide emission, T_t represents temperature change, $DepNR_t$ is natural resource depletion measured using depletion of forest cover and $DepMineral_t$ is the depletion of mineral resources. This production function is an extension of the natural resources and land baseline model by Romer (2006, pp 38).

On the aggregate demand, capital accumulation occurs through consumption of goods and services in the economy. Therefore, it can be replaced by consumption. The estimated equation becomes:

$$y_t = \alpha_0 + \alpha_1 lnC_t + \alpha_2 CO_{2t} + \alpha_3 T_t + \alpha_4 DepNR_t + DepMineral_t + \mu_t \quad (6)$$

Where C_t represents household consumption. Agriculture sector has been recorded in various economic surveys of Kenya as the main contributor to GDP growth. Therefore, growth in crop production as well as growth in livestock production are included in the regression model. The regression model is:

$$y_t = \alpha_0 + \alpha_1 lnC_t + \alpha_2 CO_{2t} + \alpha_3 T_t + \alpha_4 DepNR_t + DepMineral_t + \alpha_5 Crop_t + \alpha_6 Livestock_t + \mu_t \quad (7)$$

Where Crop is growth in crop production and livestock represents growth in livestock production.

Dell et al. (2012) posits that temperature influences the level of output by affecting agricultural yields. It also influences an economy's ability to grow by affecting savings and investments. In the second set of regressions, Equation (6) is estimated by interchangeably replacing GDP growth as the dependent variable with crop production, livestock production, investment and savings.

Results and Discussion

This section presents the descriptive results of the variables, the correlation relationship between variables and the regression analysis.

Data and Descriptive Results

The dataset covers the period 1970 to 2020 defined by the availability of climate change data. The data on carbon dioxide damage, net forest depletion, mineral depletion and GDP growth are from World Bank's World Development Indicators (WDI) whilst data on growth in crop production,

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growth in livestock heads and temperature change are from Food and Agriculture Organisation (FAO) dataset. The descriptive statistics for the variables are presented in Table 1.

Table 1: Descriptive Statistics

Variables / Statistics	Mean	Standard Deviation	Median	Skewness	Kurtosis	Maximum	Minimum
CO_2 Damage	0.833	0.222	0.838	0.727	3.539	1.532	0.487
Temperature Change	0.526	0.418	0.51	0.364	2.440	1.498	-0.183
Net Forest Depletion	3.971	0.833	3.993	0.406	3.593	7.551	1.223
Mineral Depletion	0.010	0.020	0.003	3.226	14.254	0.108	0.000
Growth Crop Production	0.034	0.071	0.025	0.103	2.940	0.203	-0.130
Growth Livestock Production	0.0336	0.087	0.027	2.754	15.367	0.477	-0.111
GDP Growth	4.175	3.026	4.192	1.447	7.996	17.082	-0.799

NB: Kurtosis value <3 means distribution is Platykurtic, >3 is leptokurtic and a value =3 is mesokurtic

The average cost of carbon dioxide damage is 0.833 with a maximum of 1.532 and a minimum of 0.487. Temperature change has a mean of 0.526 with a maximum of 1.498 and a minimum of -0.183. The average forest depletion as a percentage of GDP is 3.971 with a maximum of 7.551 and a minimum of 1.223. The average growth in crop production is 0.034 whilst that of livestock production is 0.0336. The percentage change in GDP growth over the study period is 4.175 percent with a maximum of 17 percent recorded in 1972 (a time when the country experienced agriculture boom) and a minimum of -0.799 percent that was recorded in 1992 (a period of economic sanctions from World Bank and IMF). The year 1992 also marks the upsurge in CO_2 emissions that result from increased depletion of forest.

Correlation Analysis

The correlation analysis is presented in Table 2 and the results show no high correlations between the independent variables.

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Table 2: Correlation Matrix

	GDP Growth	CO_2 Damage	Temperature Change	Forest Depletion	Mineral Depletion	Crop Production	Livestock Production
GDP Growth	1						
CO_2	-0.4145 (0.0031)	1					
Temperature Change	-0.0536 (0.7143)	0.2441 (0.0910)	1				
Forest Depletion	-0.2405 (0.0960)	0.2695 (0.0611)	-0.4984 (0.0003)	1			
Mineral Depletion	0.0662 (0.6512)	0.1284 (0.3791)	0.3545 (0.0125)	-0.2214 (0.1263)	1		
Crop Production	0.1560 (0.2843)	-0.2280 (0.1150)	-0.1232 (0.3989)	-0.1441 (0.3231)	0.0528 (0.7187)	1	
Livestock Production	0.1272 (0.3837)	-0.2059 (0.1559)	0.0387 (0.7919)	-0.1170 (0.4235)	0.0738 (0.6143)	0.0920 (0.5295)	1

The values in parenthesis are the *P*-values.

From the correlation analysis, GDP growth has a negative relationship with carbon dioxide damage, temperature change and forest depletion. Surprisingly, GDP growth has a weak positive relationship with crop production and livestock production. The correlation of GDP growth and temperature change along with forest depletion is very weak. Carbon dioxide damage also has a negative relationship with growth in crop production as well as growth in livestock production. Apparently, mineral depletion has a weak positive relationship with GDP growth.

Regression Analysis

Several regression models – with Newey-West Standard Errors – were estimated with different macroeconomic variables entering the regression model as dependent variables. Regression with Newey-West Standard Errors correct for autocorrelation in data. In fact, the results presented further down in Table 3 were similar to those analysed using heteroscedasticity consistent standard errors. In the first model (column 2), GDP per capita is the dependent variable and it is used as a proxy for economic development. In the second model, GDP growth enters as a dependent variable. The third and fourth models, whose results are presented in columns 4 and 5, use investments and savings as dependent variables, respectively. In the final models, the impact of climate change on crop and livestock production is estimated (using Equation 6) and these results are presented in columns 6 and 7 of Table 3.

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Table 3: Regression Results of Climate Change, Natural Resource Depletion and Growth

Variables	GDP per Capita	GDP Growth	Investment	Savings	Crop Production	Livestock Production
CO_2 Damage	-0.176 (-3.65)***	-4.916 (-2.96)***	-2.088 (-6.73)***	-3.137 (-5.10)***	-0.050 (-0.75)	-0.090 (-2.03)**
Temperature Change	-0.012 (-0.42)	-0.529 (-0.37)	0.559 (2.95)***	0.496 (1.68)*	-0.043 (-1.19)	0.013 (0.38)
Net Forest Depletion	0.004 (0.56)	-0.340 (0.66)	-0.083 (-1.38)	0.059 (0.65)	-0.009 (-0.83)	-0.0003 (-0.04)
Mineral Depletion	-0.807 (-2.21)**	15.677 (0.96)	1.265 (0.72)	-0.791 (-0.28)	0.359 (0.67)	0.346 (0.31)
Growth Crop Production	-	1.610 (0.24)	-0.246 (-0.31)	-0.004 (0.00)	-	-
Growth Livestock Production	-	-	0.194 (0.60)	-0.267 (-0.68)	-	-
Household Consumption	0.213 (9.01)***	-	-	-	0.008 (0.19)	-
Constant	2.201 (4.06)***	9.689 (2.88)***	19.912 (63.07)***	19.898 (39.27)***	-0.052 (-0.05)	0.100 (2.14)**
F	36.74) [0.000]	3.58 [0.0085]	15.04 [0.0000]	5.83 [0.0002]	1.20 [0.3271]	1.40 [0.2507]

The asterisks ***, **, and * represent significance at 1 percent, 5 percent and 10 percent, respectively. The values in parenthesis are the *t*-values whilst those in brackets are the *P*-values.

The results show that carbon dioxide emissions have a reducing effect on GDP per capita, GDP growth, investment, savings and crop production. A percentage increase in carbon dioxide reduces GDP per capita by 0.176 percent, GDP growth by 4.916 percent, investment by 2.088 percent, savings by 3.137 percent and livestock production by about 0.1 percent. The reduction of GDP by 4.9 percent slightly surpasses the projection by Simbanegavi and Arndt (2014) that climate change might cause a 4 percent loss of GDP in Africa; a continent that is hard hit by climate change. The net accumulation of carbon dioxide in the atmosphere is caused mainly by perhaps petrol powered trains, planes and motor vehicles together with greenhouse gases. This finding demonstrates the need to put up measures that reduce carbon dioxide emissions because of their resultant negative effect on the economy.

In being consistent with the study by Dell et al. (2012) and Duan et al. (2022), temperature change has a reducing effect on GDP growth. A 1^oC increase in temperature reduces Kenya's economic growth by about 0.53 percent. However, this temperature change has no discernible effect on economic growth given its insignificant nature. This insignificance contradicts the assertion by Dell et al. (2009) that temperature change only significantly reduces economic growth of poor countries but insignificantly reduces growth of developed countries. Perhaps the insignificance of temperature change on economic growth can be explained by the different climatic conditions in various regions of Kenya. Not all regions in Kenya are affected in the same way with warming. The Northern Region of the country, together with the Eastern side of Rift Valley are more affected with warming than the Western Region of the country. The Eastern side of the Rift Valley together with South Rift Region have recorded decreased forest cover and these

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regions have embraced the use of greenhouses in addressing food insecurity. The Western part of Kenya together with the North Rift region boast of the Rain Forest and convectional rain from Lake Victoria. These regions are not affected by temperature change and are the food basket of the country.

Although studies by Mendelsohn (2008); Mendelsohn and Dinar (1999); and Kumar and Parikh (2001) show that climate change affects GDP growth through its effect on agriculture, this study found that climate change insignificantly reduces agriculture crop yield but significantly affects livestock production. In fact, during periods of drought, Kenya loses a lot of livestock due to lack of pasture for animals. The insignificance of climate change on crop production can be explained by the fact that the western highlands of the Rift Valley, which is the food basket of the country, typically records adequate rainfall for food production whilst the northern region, together with the eastern highlands of Rift Valley normally face severe drought.

Net depletion of forest has an interesting result although insignificant. It improves welfare which means that the depletion of forest goes towards economically benefiting those who trade in solid fuel (charcoal). Surprisingly it also improves savings. However, it has a negative effect on GDP growth, investment, crop production and livestock production.

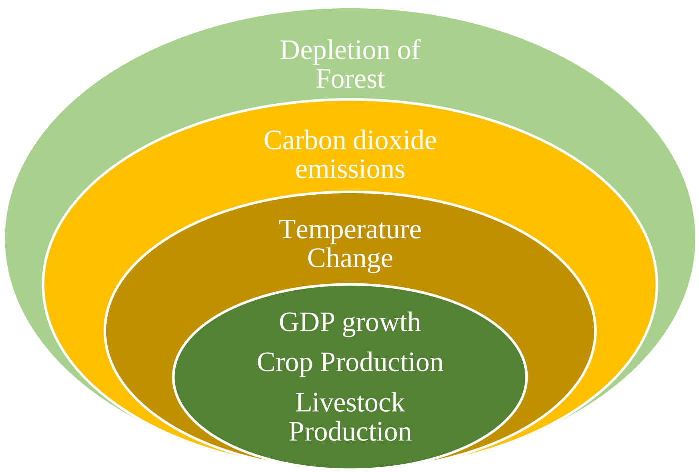

Fig. 5: Flow Chart of the Research Findings

Note: The flow chart is the author’s elaboration of the research findings.

Conclusion

Climate change has become a thorn in the flesh for the world economy. It metamorphosises like a chameleon in the global arena. Using regression analysis with Newey-West standard errors, this study empirically investigated the impact of climate change and natural resource depletion on economic growth of Kenya. The inclusion of resource depletion is an important addition to the analysis of the impact of climate change on economic growth. The results show that carbon dioxide emissions are an important climate change variable that significantly affects economic growth and development of Kenya. It also affects investments, savings and livestock production.

Given the disruptive growth effect of carbon dioxide emissions, the use of renewable energy should be highly encouraged especially the wind generated energy and solar energy. Perhaps there is need for the government to impose carbon taxes as a measure of reducing carbon dioxide emissions from greenhouses. Alternatively, policies suggested by various climate change protocols for carbon premiums should be enforced in Kenya to compensate for greening the environment,

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especially regions with greenhouses. Additionally, measures should be put in place for greening urban cities as well as reduction of environmental damage through pollution should be the central pillar of green growth policy of Kenya.

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