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# RESEARCH ARTICLE

## NATURAL RESOURCES, GOVERNANCE, GOVERNMENT EXPENDITURE, AND ENVIRONMENTAL SUSTAINABILITY IN EAST AFRICA: A DYNAMIC PANEL ANALYSIS

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### ABSTRACT

Global warming and carbon dioxide emissions are critical global challenges that threaten environmental sustainability. This study examines the impact of natural resources, government expenditure, governance, economic growth, industry, population growth, and agricultural emissions on environmental sustainability in Uganda, Tanzania, and Kenya in selected East African countries using data from the World Bank Indicators (1990–2023). Governance and environmental sustainability are represented by regulatory quality, the rule of law, and $CO_2$ emissions, respectively. The study employs the Im, Pesaran and Shin and Fisher Panel unit root tests as well as the Kao panel cointegration test. Panel unit roots reveal that all variables are non-stationary at level and stationary at first difference. The study identifies long-run relationships among these variables. The system dynamic panel technique results indicate that $CO_2$ emissions, government expenditure, industry, and population growth contribute to environmental degradation, while natural resources, governance, and economic growth enhance sustainability. These findings suggest that governments in East Africa should strengthen environmental policies, promote green energy adoption, and enhance governance quality to mitigate environmental harm.



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# INTRODUCTION

Growth of the economy and environmental sustainability are intricately linked, with economic activities profoundly impacting environmental conditions. In East Africa, the quest for rapid development to meet increasing human needs has intensified environmental pressures, particularly through rising carbon emissions. Global warming, driven by emissions from greenhouse gases, fossil fuel combustion, urbanisation, and population growth, has become a critical concern. As highlighted by Otim *et al*. (2023), East African countries face significant challenges in balancing economic growth with environmental sustainability—an urgent issue for policymakers and researchers alike. The Environmental Kuznets Curve (EKC) hypothesis suggests that environmental downgrade at the start escalates with economic growth but start to go down once a development achieved at certain level (Dincer & Rosen, 1999; Arouri *et al*., 2012). However, this relationship has not manifested in East Africa. Despite ongoing economic growth, carbon emissions continue to rise, propelled by rapid population growth and increased fossil fuel consumption. This persistent rise in emissions exacerbates global warming and environmental degradation (Demissew & Kotosz, 2020; Shah *et al*., 2024).

The sector of energy is the substantial factor to global emissions, reckoned about 73.2% of the emission in total, while agriculture, land use, and forestry contribute around 18.4% (Charfeddine & Kahia, 2019). Urbanisation in cities like Dar es Salaam, Nairobi, and Kampala has significantly increased energy consumption and environmental degradation. Key emission sources include transportation, industrial activities, and agriculture—all critical to the region's economic growth (Chowdhury *et al*., 2024). East Africa's rich natural resources, including oil, gold, and phosphate, complicate sustainability efforts. Their exploration and extraction have led to deforestation, soil erosion, and pollution, threatening long-term environmental viability (Sun *et al*., 2022). Moreover, the region's population, projected to exceed 1 billion by 2050 (UNICEF, 2023), will likely heighten demand for energy and natural resources, further straining the environment. Despite these challenges, East African governments are actively addressing sustainability through governance frameworks and policy interventions. Environmental authorities like NEMC and NEMA play crucial roles in mitigating the environmental impacts of economic activities. These bodies implement regulations aimed at reducing emissions and promoting sustainable resource management (Chowdhury *et al*., 2024).

However, the effectiveness of these measures remains uncertain due to limited resources and competing developmental priorities. The interplay between natural resource management, governance, and environmental sustainability in East Africa is underexplored, despite its importance for the region's economic and environmental future. This paper tries to fill this gap by investigating the governance structures, public expenditure, and natural resource management influence environmental sustainability. Using dynamic panel analysis, the research aims to provide empirical insights into the interactions between economic growth, governance, and sustainability, contributing to the growing literature on sustainable development in Africa and offering valuable policy recommendation. While East Africa confronts significant environmental challenges, this research will illuminate the roles of governance and public expenditure in addressing these issues and fostering sustainable development. The findings will have important implications for policymakers and researchers striving to achieve economic growth without compromising environmental integrity in the region. The remainder of the paper is organized as follows. The literature review is presented in Section 2. Sections 3 and 4 contain the research methodology and discussion of the findings, respectively. The conclusion and policy recommendations are given in section 5.

# LITERATURE REVIEW

**Theoretical Literature Review:** Economic growth, environmental sustainability, governance, and natural resource management are intricately linked, especially in developing regions like East Africa. This section critically examines the EKC hypothesis, which serves as a framework for understanding how natural resources, governance, and government expenditure influence environmental sustainability, supported by established literature and empirical studies. The hypothesis suggests a non-linear association connecting the growth of economy and environmental downgrade, indicating that degradation start to increases during early industrialisation but decreases as a country achieves higher economic development, enhanced environmental awareness, advanced technologies, and stronger regulations (Grossman & Krueger, 1995; Dinda, 2004). This inverted U-shaped curve has been extensively studied in both developed and developing economies. In East Africa, the EKC hypothesis illustrates the region's challenge of rising carbon emissions despite economic growth. Many East African countries, still in early industrial stages, show a positive correlation betwixt economic growth and environmental downgrade (Arouri *et al*., 2012). However, the EKC has faced criticism for oversimplifying the intricate dynamics betwixt economic growth and quality of the environmental, particularly in low-income countries with reliance on fossil fuels and weak governance structures (Demissew & Kotosz, 2020). Governance significantly influences environmental outcomes. The "good governance" framework highlights transparency, accountability, and participation as essential for effective environmental management (World Bank, 1992). Weak governance in East Africa often leads to ineffective policies and enforcement, resulting in higher environmental degradation (Wright & Cummings, 2016; Mulugetta, 2019). Furthermore, government expenditure on environmental protection can enhance natural resource management, yet in East Africa, financial constraints often limit such investments. Targeted spending in areas like renewable energy and waste management can improve environmental quality, contingent upon efficient public financial management (OECD, 2001; UNEP, 2020). Empirical Literature Review and Hypotheses Development. This study utilizes the EKC premise to investigate the relationships between natural resources, government expenditure, governance, and environmental sustainability in East Africa. Governance is represented through regulatory quality and the rule of law, while control variables encompass economic growth (proxied by GDP), industry, population, and agricultural emissions. Apart from the EKC hypothesis, Keynesian theory suggests that government expenditure can stimulate economic growth, which correlates with $CO_2$ emissions (Grossman & Krueger, 1995; Dinda, 2004; Taher, 2024). Thus, an interplay between the EKC hypothesis and Keynesian theory is expected.

Empirical studies have produced mixed results regarding the EKC hypothesis. For instance, Azam *et al*. (2024) identified a negative correlation between natural resource abundance and $CO_2$ emissions in France, noting that government expenditure also negatively impacted emissions, while economic growth showed a positive corroboration with $CO_2$ emissions. This highlights the varying impacts of natural resource abundance and government spending based on contextual factors. Research by Sun *et al*. (2022) indicated that economic pressures, population growth, and industrialisation significantly contribute to environmental degradation in East Africa. Their findings emphasised that economic growth and population pressures exacerbate environmental harm, with industrialisation and transportation being critical factors.

Several studies report differing impacts of governance and government expenditure on environmental sustainability. Ibrahiem (2016) found that while economic growth positively affects $CO_2$ emissions, consumption of energy and growth of population negatively impact emissions in Egypt. Similarly, Hariyani *et al*. (2024) highlighted the significant roles of energy consumption and renewable power in environmental downgrade across BRICS and East Asia Pacific countries. Despite existing literature, few studies have specifically addressed environmental issues in East Africa, particularly regarding agricultural emissions and industrialisation. Chowdhury *et al*. (2024) explored the outturn of tourism and afforestation on $CO_2$ emissions but did not encompass the broader spectrum of factors affecting environmental sustainability. The study intent to fill the gap by exploring the effects of natural resources, government expenditure, governance, economic growth, industry, population growth, and agricultural emissions on environmental sustainability in East Africa.

**The study's conceptual model is presented as follows:**

H1: Natural Resources Abundance positively influence $CO_2$ Emissions
H2: Government Expenditure positively influences $CO_2$ Emissions
H3: Regulatory Quality negatively influences $CO_2$ Emissions
H4: Rule of Law negatively influences $CO_2$ Emissions

H5: Gross Domestic Product (GDP) positively influences $CO_2$ Emissions
H6: Industry positively influence $CO_2$ Emissions
H7: Population positively influence $CO_2$ Emissions
H8: Agricultural Emissions positively influence $CO_2$ Emissions.

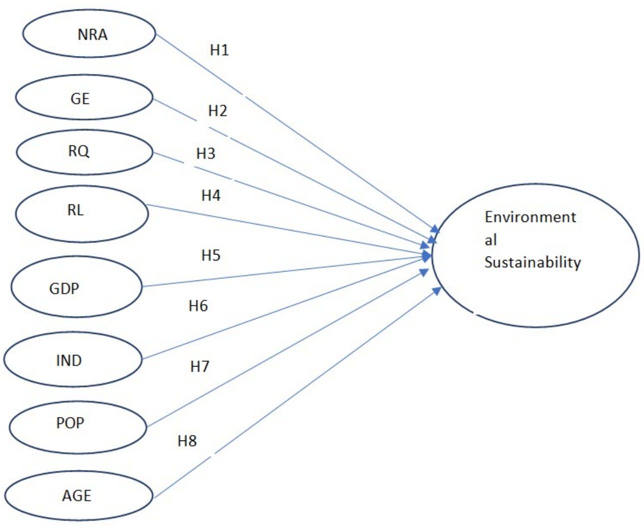


**Figure 1. Conceptual model**

# METHODS

***Data and Variables:*** The study examines the relationships among various variables using a dynamic panel dataset from three selected East African countries, chosen for their data availability and geographical proximity. The dataset covers the period from 1990 to 2023, as many variables were incomplete before 1990. To assess environmental sustainability, this research uses $CO_2$ emissions (measured in thousand metric tons) as a proxy for the dependent variable.

The independent variables include natural resource abundance, government expenditure, and governance. Natural resource abundance is represented by ores and metals exports reflecting the extraction of minerals in these East African nations. Government expenditure is encompassing spending on education, healthcare, infrastructure, national defense, and environmental conservation. Governance is assessed through two indicators: regulatory quality and rule of law. Additionally, this study incorporates control variables for a more comprehensive analysis of environmental sustainability. Growth of the economic is measured by GDP in current US dollars, indicating its relationship with environmental sustainability. The industrial sector is represented by value added in current US dollars, highlighting the impact of industrial activities. Population dynamics are quantified as the total population of the selected countries, acknowledging demographic influences on consumption and production.

Agricultural emissions are measured in $CO_2$ equivalents (thousand metric tons) and focus on nitrous oxide emissions from sources such as animal manure and synthetic fertilizers. All study variables are collected from the World Bank Indicators (2024). Table 1 gives a detailed representation of the variables.

**Model Specification:** This study employs dynamic panel data analysis to investigate the relationships betwixt natural resources, government expenditure, and governance on environmental sustainability in selected countries, specifically Uganda, Kenya, and Tanzania, from 1990 to 2023. Dynamic panel data analysis is particularly suitable for addressing endogeneity issues inherent in panel data. This approach eliminates individual fixed effects while instrumenting differenced variables. System GMM is preferred over difference GMM due to its reduced information loss (Barbieri, 2009). Before system GMM estimation, the study performed panel unit root tests using IPS (2003), which accommodates both stationary and non-stationary series. This test was employed outlined in Equation 1.

$$\Delta Yit = \alpha_{0i} + p_i Yit + \sum_{j=1}^{pi} \phi ij \Delta Yit - j + \varepsilon_{it} \quad (1)$$

**Fisher's Panel Unit Root Test:** To verify the results obtained from the IPS test, the Fisher's test was also conducted.
This test is a powerful alternative as it integrates both the LLC and IPS tests. By addressing the limitations inherent in both the IPS and LLC tests, the Fisher test offers a more comprehensive testing strategy.

$$Yit = dit + X_{it} \quad (2)$$

$$d_{it} = \alpha_{i0} + \alpha_{i1}t + \ldots\ldots\ldots\ldots + \alpha_{imi}t^{mi} \quad (3)$$

$$X_{it} = \boldsymbol{p}_i X_{i(t-1)} + U_{it} \quad (4)$$

Hence the Fisher panel unit root type test was estimated as

$$P = -2\sum_{i=1}^{N} lnPi \quad (5)$$

$\boldsymbol{p}_i$ is a panel unit root's p-value for transversely of individual $i$,

**Panel Cointegration:** After confirming that variables are coherent in the same order of integration then the present study employed Kao (1999) cointegration test. The regression analysis uses the equation 6.

$$Yit = \alpha i + \beta Xit + u_{it} \quad (6)$$

but $\beta$ and $X_{it}$ are vectors of row and column respectively whereas $u_{it}$ is a regression error term.

**Panel Regression Model**

This paper utilises the dynamic panel data to determine the contribution of natural resources abundance, government expenditure and governance on environmental sustainability. Before the formulation of the dynamic panel model then a normal panel model was developed as shown in Equation 7.

$$Yit = \beta_1 Xit + \varepsilon_{it} \quad (7)$$

$Yit$ stands for dependent variable while $Xit$ represent the independent variables and $\varepsilon_{it}$ is the error term containing the unobserved individual effect (μi) and (Vit). The study employed a semi-long model.

It instituted the natural logarithms to all variables except natural resource abundance as shown in equation 8. This is done to minimize the problems of outliers in the variables. Study variables are inserted from equation 8 to 9.

$$LnESit = \alpha_i + \beta_1 NRAit + \beta_2 LnG\text{Eit} + \beta_3 LnGVi\text{t} + \beta_4 LnCVi\text{t} + \varepsilon_{it} \quad (8)$$

Where $ES_{it}$ is environmental sustainability proxied by carbon dioxide mission, $NRA_{it}$ is Natural Resource Abundance, $GE_{it}$ is government expenditure, $GV_{it}$ stands for governance and this include the regulatory quality (RQ) and rule of law (RL). $CV_{it}$ is control variables include the Gross Domestic Product (GDP), Industrialization (IND), Population (POP), and Agricultural Emission (AGE). The study extended equation 8 by including control variables in equation 9.

$$LnESit = \alpha_i + \beta_1 NRAit + \beta_2 LnG\text{Eit} + \beta_3 LnRQi\text{t} + \beta_4 LnRLi\text{t} + \beta_5 LnGDPi\text{t} + \beta_6 LnINDi\text{t} + \beta_7 LnPOPi\text{t} + \beta_8 LnAGEi\text{t} + \varepsilon_{it} \quad (9)$$

The present study utilises the dynamic panel model because some variables had some missing values in some years. As such the dynamic panel model was imperative and was expressed in equation 10.

$$LnESit = \alpha_i + \beta_1 LnESi\text{t} - 1 + \beta_2 NRAit + \beta_3 LnG\text{Eit} + \beta_4 LnRQi\text{t} + \beta_5 LnRLi\text{t} + \beta_6 LnGDPi\text{t} + \beta_7 LnINDi\text{t} + \beta_8 LnPOPi\text{t} + \beta_9 LnAGEi\text{t} + \varepsilon_{it} \quad (10)$$

In this model, $LnESit$ represents environmental sustainability, measured by carbon dioxide emissions, with independent variables including $LnESi\text{t} - 1$ (lagged environmental sustainability), NRA (natural resource abundance), $LnGDPi\text{t}$ (government expenditure), $LnRQi\text{I}$ (regulatory quality), $LnRLi\text{t}$ (rule of law), $Ln\,GDPi\text{t}$ (gross domestic product), $LnINDi\text{t}$ (industry), $LnPOPi\text{t}$ (population), and $nAGEi\text{t}$ (agricultural emissions). Coefficients $\beta_1, \beta_2, ...\beta_9$. each $\beta$ reflects the predictive changes in environmental sustainability per unit change in independent variables, with $\alpha_i$ the intercept and $\varepsilon_{it}$ as the error term.

# RESULTS AND DISCUSSION

**Panel Unit Root Results**

The results in Table 2 indicate that all variables are non-stationary at levels, I(1), but become stationary at first difference, I(0). This suggests the variables share the same order of integration, ensuring valid empirical results. The Fisher panel unit root test corroborates these findings, showing similar results in table 3.

**Fisher Panel Unit Root Test Results:** The findings in Table 3 both ADF and PP versions of the Fisher test were utilised to ensure robustness. The variables tested include carbon emissions, natural resource abundance, government expenditure, regulatory quality, rule of law, GDP growth, industrialization, population, and agricultural emissions. The tests were performed at levels and first differences to account for potential regional disparities within East Africa, with results offering crucial insights for environmental sustainability and governance.

**Carbon Emissions (LNCO2):** The p-values for all test statistics at levels exceeding 0.05 indicate non-stationarity, but after differencing, stationarity is confirmed with p-values at 0.0000. The persistence of carbon emissions aligns with the EKC premises, which suggests that environmental downgrade start to worsens with the growth of economic before improving as economies transition to greener technologies. For environmental sustainability, East African policymakers should focus on cleaner energy and stringent environmental regulations.

**Natural Resource Abundance (NRA):** Natural resource abundance is non-stationary at levels ($p > 0.05$) but becomes stationary after differencing ($p = 0.0000$). This supports the resource curse theory, where economies with abundant natural resources often experience slower growth due to governance challenges. Institutional reforms and economic diversification are critical for overcoming this resource dependence.

**Government Expenditure (LNGE):** Government expenditure follows a similar pattern of non-stationarity at levels but stationarity after differencing ($p = 0.0000$). This reflects long-term changes in fiscal policies, aligning with Keynesian theory, which advocates for government intervention to stabilise economies. Strategic allocation of expenditure towards sustainable infrastructure is vital for long-term stability in East Africa.

**Regulatory Quality (LNRQ):** The regulatory quality is non-stationary at levels but at first differences becomes stationary ($p = 0.0000$). This persistence in regulatory quality highlights institutional inertia, reinforcing the need for stronger regulatory institutions to promote sustainable development.

**Rule of Law (LNRL):** The results show non-stationarity at levels but stationarity after differencing ($p = 0.0000$). Weak enforcement of legal frameworks and persistent corruption undermine environmental governance. Reforms in legal institutions are necessary for enhancing compliance with environmental regulations and reducing degradation.

**GDP (LNGDP):** GDP is non-stationary at levels ($p = 0.9971$) but stationary after differencing ($p = 0.0000$). While GDP reflects long-term structural changes, short-term fluctuations align with sustainable development theory. Rapid growth, driven by industrialisation, must be accompanied by policies promoting cleaner industries and energy sources.

**Population (LNPOP):** Population growth is non-stationary at levels but after differencing becomes stationary ($p = 0.0004$). This aligns with Malthusian theory, indicating that unchecked population growth strains natural resources, exacerbating sustainability challenges. Population control measures should be implemented to manage resource consumption.

**Agricultural Emissions (LNAGE):** The variable shows persistence at levels but stationarity after differencing ($p = 0.0000$). The results suggest that the agricultural emissions exhibit long-term persistence, with significant short-term variations.

**Table 1. Variable Descriptions**

| Variable | Measurement | Sources |
|---|---|---|
| Environmental Sustainability | "$CO_2$ emissions (kt). Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring". | WDI (2024) |
| Natural Resource Abundance NRA | Ores and metals exports (% of merchandise exports) | WDI (2024) |
| Government Expenditure | "General government final consumption expenditure" (current US$) | WDI (2024) |
| Regulatory Quality (RQ) | "Regulatory Quality: Percentile Rank, Upper Bound of 90% Confidence Interval. Regulatory Quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. Percentile rank indicates the country's rank among all countries covered by the aggregate indicator, with 0 corresponding to lowest rank, and 100 to highest rank. Percentile ranks have been adjusted to correct for changes over time in the composition of the countries covered by the WGI". | WGI (2024) |
| Rule of Law (RL) | "Rule of Law: Percentile Rank. Rule of Law captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. Percentile rank indicates the country's rank among all countries covered by the aggregate indicator, with 0 corresponding to lowest rank, and 100 to highest rank. Percentile ranks have been adjusted to correct for changes over time in the composition of the countries covered by the WGI. Percentile Rank Upper refers to upper bound of 90 percent confidence interval for governance, expressed in percentile rank terms". | WGI (2024) |
| Gross Domestic Product (GDP) | GDP (current US$) | WDI (2024) |
| Industry (IND) | "Industry (including construction), value added (current US$)" | WDI (2024) |
| Population (POP) | "Population, total" | WDI (2024) |
| Agricultural Emission (AGE) | "Agricultural nitrous oxide emissions (thousand metric tons of $CO_2$ equivalent). Agricultural nitrous oxide emissions are emissions produced through fertilizer use (synthetic and animal manure), animal waste management, agricultural waste burning (nonenergy, on-site), and savanna burning". | WDI (2024) |

Source: Researcher's compilation, 2024. Note: WDI and WGI are "World Development Indicators" and "World Governance Indicator" respectively.

**Table 2. Im-Pesaran-Shin unit root test results**

| Im-Pesaran-Shin Test Results | | | | | |
|---|---|---|---|---|---|
| **AT LEVEL** | | | **AT FIRST DIFFERENCE** | | |
| **Variables** | **P-values** | **Decisions** | **Variables** | **P-values** | **Decisions** |
| $LNCO_2$ | 0.9980 | *I(1)* | $LNCO_2$ | 0.0000 | *I(0)* |
| NRA | 0.1499 | *I(1)* | NRA | 0.0000 | *I(0)* |
| LNGE | 0.9776 | *I(1)* | LNGE | 0.0000 | *I(0)* |
| LNRQ | 0.5706 | *I(1)* | LNRQ | 0.0006 | *I(0)* |
| LNRL | 0.3240 | *I(1)* | LNRL | 0.0011 | *I(0)* |
| LNGDP | 0.9977 | *I(1)* | LNGDP | 0.0000 | *I(0)* |
| LNIND | 0.9639 | *I(1)* | LNIND | 0.0000 | *I(0)* |
| LNPOP | 0.9633 | *I(1)* | LNPOP | 0.0123 | *I(0)* |
| LNAGE | 0.9853 | *I(1)* | LNAGE | 0.0000 | *I(0)* |

Source: Researcher's computation, 2024 Note: Fixed-N exact Critical Values 1%, 5% and 10%.

Agricultural emissions in East Africa influence economic activities and environmental policies. This align with the endogeneity growth **theory** that suggests an internal factor are the key drivers into economic growth as compared to external factors as such affecting economic productivity and environmental outcomes. Agricultural emissions may exert more pressure on environmental resources due to higher production patterns.

**Panel Cointegration Results:** The Kao test for panel cointegration revealed that the variables are cointegrated, consistent with findings by Dauda *et al*. (2019) and Hariyani *et al*. (2024) for MENA, BRICS, and East Asia Pacific countries. This suggests a long-run relationship among environmental sustainability, natural resource abundance, government expenditure, regulatory quality, rule of law, GDP, industrial activities, population dynamics, and agricultural emissions.

Effective management of these factors, such as enforcing regulatory quality and increasing environmental expenditure, could achieve future sustainability. Table 4 confirms statistical significance at the 5% level, rejecting the $H_0$.

**System Dynamic Panel Regression Estimation Results:** Table 5 showing the dynamic panel results, demonstrating key factors affecting environmental sustainability in selected East African countries. The findings indicate that carbon dioxide ($CO_2$) emissions from the previous year have a statistically significant positive effect on current emissions, with a 1% increase in prior emissions leading to a 0.5256% rise in the current year, suggesting a continuing detrimental impact on environmental sustainability. Natural resource abundance, though statistically insignificant, has a slight negative impact, reducing emissions by 0.0053%.

**Table 3. Fisher Panel Unit Root Test Results**

| Fisher Test Results | | | | | |
|---|---|---|---|---|---|
| | AT LEVEL | | | AT FIRST DIFFERENCE | |
| Variables | | Statistic | P-values | Statistic | P-values |
| $LNCO_2$ | Inverse chi-squared (6) P | 0.6726 | 0.9951 | 59.6796 | 0.0000 |
| | Inverse normal Z | 2.7081 | 0.9966 | -6.7542 | 0.0000 |
| | Inverse logit t(19) L* | 2.8398 | 0.9948 | -9.7736 | 0.0000 |
| | Modified inv. chi-squared Pm | -1.5379 | 0.9380 | 15.4960 | 0.0000 |
| NRA | Inverse chi-squared(6) P | 9.0232 | 0.1723 | 79.4721 | 0.0000 |
| | Inverse normal Z | -1.0526 | 0.1463 | -7.8794 | 0.0000 |
| | Inverse logit t(19) L* | -1.0549 | 0.1524 | -13.0149 | 0.0000 |
| | Modified inv. chi-squared Pm | 0.8727 | 0.1914 | 21.2096 | 0.0000 |
| LNGE | Inverse chi-squared(6) P | 0.9164 | 0.9886 | 91.0709 | 0.0000 |
| | Inverse normal Z | 2.0651 | 0.9805 | -8.5102 | 0.0000 |
| | Inverse logit t(19) L* | 2.0304 | 0.9717 | -14.9145 | 0.0000 |
| | Modified inv. chi-squared Pm | -1.4675 | 0.9289 | 24.5579 | 0.0000 |
| LNRQ | Inverse chi-squared(6) P | 4.7543 | 0.5757 | 45.4130 | 0.0000 |
| | Inverse normal Z | 0.2760 | 0.6087 | -5.1250 | 0.0000 |
| | Inverse logit t(19) L* | 0.2462 | 0.5959 | -7.3559 | 0.0000 |
| | Modified inv. chi-squared Pm | -0.3596 | 0.6404 | 11.3776 | 0.0000 |
| LNRL | Inverse chi-squared(6) P | 8.4773 | 0.2052 | 36.8451 | 0.0000 |
| | Inverse normal Z | -0.5310 | 0.2977 | -4.5233 | 0.0000 |
| | Inverse logit t(19) L* | -0.6165 | 0.2725 | -5.9982 | 0.0000 |
| | Modified inv. chi-squared Pm | 0.7151 | 0.2373 | 8.9042 | 0.0000 |
| LNGDP | Inverse chi-squared(6) P | 0.3530 | 0.9992 | 42.4810 | 0.0000 |
| | Inverse normal Z | 2.7590 | 0.9971 | -5.4341 | 0.0000 |
| | Inverse logit t(19) L* | 2.7883 | 0.9941 | -6.9561 | 0.0000 |
| | Modified inv. chi-squared Pm | -1.6301 | 0.9485 | 10.5312 | 0.0000 |
| LNIND | Inverse chi-squared(6) P | 0.9057 | 0.9889 | 55.0344 | 0.0000 |
| | Inverse normal Z | 1.9148 | 0.9722 | -6.3890 | 0.0000 |
| | Inverse logit t(19) L* | 1.8393 | 0.9592 | -9.0127 | 0.0000 |
| | Modified inv. chi-squared Pm | -1.4706 | 0.9293 | 14.1550 | 0.0000 |
| LNPOP | Inverse chi-squared(6) P | 6.8943 | 0.6102 | 17.5714 | 0.0074 |
| | Inverse normal Z | 0.1189 | 0.5473 | -2.5985 | 0.0047 |
| | Inverse logit t(19) L* | -1.0837 | 0.1460 | -2.7446 | 0.0064 |
| | Modified inv. chi-squared Pm | 4.0317 | 0.1346 | 3.3404 | 0.0004 |
| LNAGE | Inverse chi-squared(6) P | 0.6390 | 0.9957 | 101.5989 | 0.0000 |
| | Inverse normal Z | 2.2437 | 0.9876 | -9.2530 | 0.0000 |
| | Inverse logit t(19) L* | 2.1933 | 0.9795 | -16.6388 | 0.0000 |
| | Modified inv. chi-squared Pm | -1.5476 | 0.9391 | 27.5970 | 0.0000 |

Source: Researcher's computation, 2024

**Table 4. Panel Cointegration Results**

| Kao (1999) Test | | |
|---|---|---|
| | Statistic | p-value |
| Modified Dickey–Fuller t | -2.3824 | 0.0086 |
| Dickey–Fuller t | -2.7983 | 0.0026 |
| Augmented Dickey–Fuller t | -2.9527 | 0.0016 |
| Unadjusted modified Dickey–Fuller t | -3.0330 | 0.0012 |
| Unadjusted Dickey–Fuller t | -2.9778 | 0.0015 |

**Table 5. System Dynamic Panel-Data Estimations**

| $LNCO_2$ is the dependent Variable. | | | | |
|---|---|---|---|---|
| Variables | Coef. | Std. Err. | z | P>\|z\| |
| $LNCO_2$ L1. | .5255677 | .1066607 | 4.93 | 0.000 |
| NRA | -.0053066 | .0038969 | -1.36 | 0.173 |
| LNGE | .0351258 | .0926562 | 0.38 | 0.705 |
| LNRQ | -.3832439 | .1333595 | -2.87 | 0.004 |
| LNRL | -.1952164 | .0930143 | -2.10 | 0.036 |
| LNGDP | -.5278098 | .2685892 | -1.97 | 0.049 |
| LNIND | .5638055 | .2296282 | 2.46 | 0.014 |
| LNPOP | 1.079727 | .3998068 | 2.70 | 0.007 |
| LNAGE | -.2675535 | .1389168 | -1.93 | 0.054 |
| C | -10.88637 | 4.754815 | -2.29 | 0.022 |

Source: Researcher's computation, 2024.

This implies that resource extraction does not significantly harm environmental sustainability, provided environmentally conscious methods are applied. Government expenditure on environmental conservation, while positive, is statistically insignificant, indicating that current investments are inadequate. A 1% rise in expenditure increases emissions by 0.0351%, suggesting the need for greater environmental funding. Governance, measured by regulatory quality and the rule of law, has a statistically significant negative effect, reducing $CO_2$ emissions by 0.3832% and 0.1952%, respectively. This underscores the function of good governance in promoting sustainability.

Gross domestic product (GDP) similarly shows a statistically significant negative relationship with emissions, with a 1% increase in GDP reducing emissions by 0.5278%, highlighting that economic growth does not compromise environmental sustainability. Conversely, industrial activity and population growth have statistically significant positive effects on emissions, increasing them by 0.5638% and 1.0797%, respectively, suggesting they pose threats to environmental health. In contrast, agricultural emissions have a statistically significant negative effect, reducing $CO_2$ emissions by 0.2676%, indicating that agricultural practices in these countries are largely sustainable.

# DISCUSSION

The empirical findings of this study reveal nuanced relationships between key variables and environmental sustainability in selected East African countries. While some variables promote sustainability, others pose significant challenges, offering both theoretical insights and practical policy recommendations. These results fill out the literature of economics of environment, governance, and sustainability. The study confirms that carbon dioxide ($CO_2$) emissions from the previous year have a statistically significant positive coefficient at the 5% level, affirming their harmful impact on environmental sustainability. This aligns with prior research by Baloch & Wang (2019) and Dash *et al*. (2024), which demonstrated that rising $CO_2$ emissions perpetuate environmental degradation. Given the cointegration among variables, reducing $CO_2$ emissions is critical for achieving long-term environmental improvements in East Africa. Policymakers must develop robust regulatory frameworks and incentivize businesses to adopt cleaner technologies, as highlighted by Azam *et al*. (2023). Efforts to curb deforestation and promote reforestation should also be prioritized.

Natural resource abundance, while statistically insignificant, has a negative coefficient, suggesting a potential adverse impact on environmental sustainability. This is consistent with Azam *et al*. (2023), who underscored the environmental risks associated with resource extraction, such as deforestation and pollution. Even without statistical significance, governments should enforce stringent environmental regulations in the natural resource sector and promote sustainability-focused policies, as advocated by Chhabra *et al*. (2023). Although government expenditure on environmental issues has a positive coefficient, it remains statistically insignificant. This contrasts with Azam *et al*. (2023), who found a significant link between government spending and environmental outcomes in more developed contexts. The findings suggest that East African nations need to increase targeted investment in environmental protection. Farooq *et al*. (2023) recommend focusing on developmental expenditure to address environmental concerns more effectively. Governments should allocate larger budgets for environmental protection and foster public-private partnerships, as suggested by Demissew & Kotosz (2020).

Governance, measured by regulatory quality and the rule of law, has a statistically significant negative coefficient, implying that improved governance reduces $CO_2$ emissions and promotes sustainability. This supports the findings of Baloch & Wang (2019) and Chhabra *et al*. (2023), call attention to a strong institutions, accountability, and enforcement in achieving environmental sustainability. Economic growth (GDP) has a statistically significant negative coefficient at the 5% level, suggesting that it does not compromise environmental sustainability in East Africa. This contradicts studies in MENA and BRICS regions, where GDP growth has been linked to environmental degradation. The discrepancy may reflect East Africa's lower industrialisation levels, where environmental pressures associated with higher GDP growth are less pronounced. As Hariyani et.al (2024) argue, sustainable economic growth in developing countries requires adopting eco-friendly technologies. Industrial activity significantly contributes to environmental degradation, with a positive and statistically significant coefficient. This mirrors the findings of Dash *et al*. (2024), who examined the environmental toll of industrialisation in high-polluting nations. The region's depending on fossil fuels underscores the need for progressing to sources of energy that are renewable like geothermal, wind, and solar, as suggested by Hariyani et.al (2024). Population growth, also with a statistically significant positive coefficient, exacerbates environmental degradation, consistent with Dash *et al*. (2024). Rapid urbanisation necessitates targeted urban planning and environmental education, as proposed by Chhabra *et al*. (2023). Finally, agricultural emissions negatively impact environmental sustainability, as evidenced by a statistically significant negative coefficient. This suggests that East African agricultural practices are relatively sustainable, in line with Demissew & Kotosz (2020). However, as agricultural intensification grows, policies must minimise emissions, promoting techniques such as organic fertilization and conservation agriculture (Azam *et al*., 2023). In summary, the study highlights the critical need to reduce $CO_2$ emissions, strengthen governance, and foster sustainable economic and industrial practices in East Africa. Future research should explore the dynamic relationship between governance, natural resources, and environmental outcomes to guide effective policy development.

## CONCLUSION AND RECOMMENDATIONS

A study examined the relationship between natural resources, government expenditure, governance, and key control variables—including economic growth (proxied by GDP), industry, population, and agricultural emissions—on environmental sustainability in selected East African countries. Employing a dynamic panel dataset from 1990 to 2023, the study used IPS and Fisher panel unit root tests, confirming variables were non-stationary at levels but at first difference became stationary. The Kao panel cointegration test indicated that variables have long-run relationship. The findings divulge that past carbon dioxide emissions significantly affect current emissions, underscoring the persistence of environmental degradation in the region. Interestingly, natural resource abundance negatively impacted environmental sustainability, possibly reflecting mismanagement or over-exploitation linked to the "resource curse" common in developing countries. In contrast, government expenditure positively influenced sustainability, suggesting that well-targeted public investment can mitigate environmental damage. Measuring governance by regulatory quality and rule and order, had mixed effects, implying that gaps in enforcement or governance inefficiencies may be hindering sustainability goals. Economic growth, proxied by GDP, had a neutral effect, indicating that early-stage industrial development in these countries does not yet compromise environmental sustainability. However, industrial activities and population growth exerted significant pressure, contributing to emissions and resource depletion. Notably, agricultural emissions had a negative impact, suggesting that agricultural practices are relatively environmentally sustainable compared to other sectors.

Based on these results, policymakers should prioritise better governance of natural resources to prevent over-exploitation and mismanagement. Strengthening regulatory frameworks, particularly in natural resources and agriculture, and ensuring effective implementation are essential for promoting sustainability. Increasing government expenditure on environmental conservation, particularly through awareness campaigns and incentives for sustainable practices, is crucial. The introduction of green taxes tailored to local industries could further reduce carbon emissions. Future research should explore the causal mechanisms between governance and sustainability, focusing on governance effectiveness and enforcement. Additionally, examining the region-specific impacts of government expenditure and the effectiveness of green taxes across different sectors would provide valuable policy insights.

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**SUMMARY**

Global warming and carbon dioxide emissions are critical global challenges that threaten environmental sustainability. This study examines the impact of natural resources, government expenditure, governance, economic growth, industry, population growth, and agricultural emissions on environmental sustainability in Uganda, Tanzania, and Kenya in selected East African countries using data from the World Bank Indicators (1990–2023). Governance and environmental sustainability are represented by regulatory quality, the rule of law, and $CO_2$ emissions, respectively. The study employs the Im, Pesaran and Shin and Fisher Panel unit root tests as well as the Kao panel cointegration test. Panel unit roots reveal that all variables are non-stationary at level and stationary at first difference. The study identifies long-run relationships among these variables. The system dynamic panel technique results indicate that $CO_2$ emissions, government expenditure, industry, and population growth contribute to environmental degradation, while natural resources, governance, and economic growth enhance sustainability. These findings suggest that governments in East Africa should strengthen environmental policies, promote green energy adoption, and enhance governance quality to mitigate environmental harm. Furthermore, based on these results, policymakers should prioritise better governance of natural resources to prevent over-exploitation and mismanagement. Strengthening regulatory frameworks, particularly in natural resources and agriculture, and ensuring effective implementation are essential for promoting sustainability. Increasing government expenditure on environmental conservation, particularly through awareness campaigns and incentives for sustainable practices, is crucial. The introduction of green taxes tailored to local industries could further reduce carbon emissions.

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