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Abstract

Purpose: The interconnectedness between human development and environmental degradation is a complex issue that warrants investigation in Africa. Although there are a few studies on the economic growth and environmental degradation nexus for African countries, there is a huge scarcity of empirical research that explores the Environmental Kuznets Curve (EKC) postulation in the context of human development and environmental degradation in Africa. The study therefore empirically explored the relationship between Human Development and Environmental Degradation within the framework of the EKC using 50 African countries subdivided into High Human Development Index Countries (HHDICs), Medium Human Development Index Countries (MHDICs) and Low Human Development Index Countries (LHDICs) from 2000 to 2019. Data for the study were obtained from the World Bank's development indicators and the Human Development Reports of the United Nations Development Programme (UNDP-HDR).

Methodology: The study made use of the Panel Corrected Standard Error (PCSE) model and the Feasible Generalised Least Squares Regression model (FGLS) which are econometrically suitable to handle N > T and T > N panels respectively, and are both robust to cross sectional dependence, contemporaneous correlation, group wise heteroscedasticity and slope heterogeneity. Other econometric techniques such as Descriptive Statistics, Correlation Analysis, Variance Inflation Factor test (Multicollinearity), second generation unit root tests (CADF and CIPS), Durbin Watson, Breusch Godfrey tests (Serial Correlation) and the White Test (Heteroscedasticity) were also employed in the study.

Findings: The empirical results produced evidence that the data is integrated of order one I(1) and exhibits cross sectional dependence, slope heterogeneity and cointegration. The data was also found to be serially correlated and heteroscedastic. However, multicollinearity was absent. The panel estimates of the PCSE and the FGLS estimators showed that Human Development is a key driver of Environmental Degradation in Africa, with the greatest proportion of the impact on HHDICs, followed by MHDICs and then finally LHDICs. The results also revealed the validity of the EKC postulation only in the HHDICs, evidenced by the presence of an inverted U-shaped relationship between Environmental Degradation and Human Development. In The LHDICs and MHDICs on the other hand, U-shaped relationships between Environmental Degradation and Human Development were found, signalling the invalidity of the EKC. There was significant evidence for the support of the feedback hypothesis between Human Development and Environmental Degradation in HHDICs, MHDICs, LHDICs and all the 50 African countries at large. Based on the findings, Policymakers were given recommendations that took into consideration the uniqueness of the economic situations in HHDICs, MHDICs, LHDICs and Africa as a whole.

Unique Contribution to Theory, Practice and Policy: The study shows that the degree of environmental degradation is proportional to the level of human development in Africa and indicates that the validity of the EKC postulation in the context of human development) is exclusive to only the HHDICs in Africa. This provides an incentive for policy makers in the MHDICs and LHDICs of Africa to make human development a priority through industrialisation and other profitable economic activities. This is likely to help them afford innovations and technological developments that protect the environment through the greater use of cleaner energy than the naturally abundant fossil fuel as well as the institutionalisation of policies that protect the environment as human development appreciates.

Keywords: *Human Development, Environmental Degradation, Environmental Kuznets Curve, HHDICs, MHDICs, LHDICs, PCSE, FGL*

1.0 INTRODUCTION

Economic growth and its impact on environmental conditions have traditionally been at the centre stage of research, and at the heart of policy-making strategies at the global level in recent times. Africa has seen quite a number of empirical evidence in this regard (Ntarmah, Kong, & Manu, 2021; Tachega, Yao, Liu, Ahmed, Ackaah, Gabir, & Gyimah, 2021; Djellouli, Abdelli, Elheddad, Ahmed, Mahmood, 2022). However, in our contemporary globalised economy, there is overwhelming evidence of a keen desire among researchers and policymakers to shift their attention from the advancement of the economic productivity of countries to improving human welfare at large. According to Li and Xu (2021), “the development of human society not only requires economic growth, but it also demands progress in other aspects of life like education and medical treatment”. The human development index (HDI) has in our contemporary age of research been discovered as a criterion that focusses on people and their capabilities (Sadiq, Riazullah, Muhammad, Ilhan & Aktham., 2022). HDI helps in the determination of a country’s potential for individual human development by serving as a quintessential metric for evaluating a country’s level of development besides considering standard economic growth statistics, such as gross domestic product (GDP). About 50% of the Sustainable Development Goals (SDGs) for Africa have their focus on human development and environmental quality (Beyene, 2022). According to the 2020 UNDP-*HDR*, the HDI for Africa increased from about 0.456 in 2000 to 0.576 in 2019 representing about 26.32 % appreciation in 20 years. Within the same period, the HDI of HHDICs grew from 0.658 to 0.741 representing an increase of 12.61%. The HDI of MHDICs also appreciated from 0.484 to 0.605, representing 25% appreciation, whiles that of the LHDICs grew from 0.369 to 0.490, representing 32.79% rise.

In today’s rapidly industrialised world, the issue of environmental degradation has become a grave concern. Among the various factors contributing to this problem, Carbon Dioxide (CO_2) emissions have emerged as the foremost culprit. As CO_2 is emitted into the atmosphere through human activities such as combustion of fossil fuels, deforestation, and industrial processes, its impact on the environment has been profound. The consequences of excessive CO_2 emissions are far-reaching and devastating, from climate change and global warming to ocean acidification and loss of biodiversity. The CO_2 emissions per capita on the African continent grew from 1.011 metric tons to 1.450 metric tons according to the World Development Indicators (WDI) 2020, representing an increase of about 43.56% in Africa. Within the same period, the CO_2 emissions per capita of HHDICs grew from 3.758 to 4.430 representing 17.88% increase. The CO_2 emissions per capita of MHDICs also appreciated from 0.842 to 1.059 representing 25.77% appreciation, whiles that of the LHDICs grew from 0.183 to 0.278, representing 51.91% rise in value. The CO_2 emissions per capita of the HHDICs reportedly had the least increment, whiles that of the LHDICs had the highest incremental value.

There are currently several HDI-environmental studies at the global level. These empirical studies, however, have diverse results. Some of the empirical evidence suggested a linear relationship between HDI and environmental degradation (Peters, Marland, Quèrè, Boden, Canadell, & Raupach, (2011); Permanyer & Torres 2016; Afzal Hossain & Chen 2021, Beyene 2022; Samimi, 2011, Bergh & Botzen, 2018; Lai & Chen, 2020; Nathaniel, 2021; Zulham, Dawood, Farlian, Saputra, Juliansyah & Hadi 2021; Sadiq *et al.*, 2022). A few others also showed no significant relationship (Kamyar, 2021; Afzal Hossain & Chen, 2021). Finally, there are others that provide evidence to suggest an inverted U-shaped relationship (Shaista, 2012; Hussain & Dey, 2021; Li & Xu, 2021; Beyene 2022). The various samples, periods, methodological frameworks, and analytical methodologies used in the published research are substantially to blame for the inconsistent outcomes. Interestingly, empirical literature on the HDI-Environmental relationships for only African countries within the EKC framework are limited to the studies conducted by Asongu & Odhiambo, 2019, Lawson, 2020; and Beyene, 2022. These studies only focused on Sub-Saharan African countries as well as a section of African countries without consideration for heterogeneity (HHDICs, MHDICs and LHDICs) among the African countries. The existence of the heterogeneity associated with the varying levels of human development among African countries makes it possible for the analysis of the entire samples to result in the realisation of misleading policy directions (Li *et al*.,2022). This study therefore seeks to investigate the relationship between HDI and EDD to fill this literature gap. The aim of this study is categorised into five key groups. Firstly, the study examines the HDI-EDD relationships for the whole of Africa. Secondly, it tests for the existence of the EKC postulation in Africa as a whole, under the context of human development. Thirdly, it investigates HDI-EDD relationships specifically for the HHDICs, MHDICs and LHDICs in Africa. Fourthly, the study evaluates the possibility of the existence of the EKC hypothesis specifically in the HHDICs, MHDICs and LHDICs in Africa. Finally, it examines the feedback mechanisms between HDI and EDD.

2.0 LITERATURE REVIEW

2.1 Theoretical Literature

2.1.1 The Environmental Kuznets Curve Hypothesis

This study was inspired by Simon Kuznets' (1955) model, which posited an inverted U-shaped link between income and economic inequality. The inverted U-shaped Kuznets curve grew in scope and was used in a variety of fields over time. The Financial Kuznets Curve (FKC) suggested by Greenwood and Jovanovic (1990), the Environmental Kuznets Curve (EKC) suggested by Grossman and Krueger (1991), the Obesity Kuznets Curve (OKC) offered by Grecu and Rotthoff (2015), the Suicide Kuznets Curve (SKC) suggested by Antonakakis and Collins (2018), and the Health Kuznets Curve (HKC) offered by Costa-Font *et al.,* (2018) are some of these extended models. The EKC postulation is perhaps the most widely accepted amongst them. Grossman and Krueger (1991), who first tested the EKC hypothesis, described the interaction between environmental quality and economic growth (income level) as an inverted-U shape, with the implication that environmental degradation initially increases with increasing income level, but after a certain point in time, economic expansion aids in the resolution of environmental issues. Grossman and Krueger (1991) found three ways in which income level influences the environment. The first impact is referred to as the "scale effect." This impact suggests that there is an affirmative link between income and environmental pollution. The increased demand for energy pollutes the environment as economic progress increases the use of fossil fuels. The "composition effect," which is the second effect, is brought on by modifications in nations' production strategies. It is anticipated that the growth in income will have a favourable influence on the environment through the decrease in energy intensity if economies shift from knowledge-intensive to agriculture and industry-intensive sectors. The EKC curve's slope is now inverted because environmental pollution will now start to decline. Finally, the adoption of more advanced and eco-friendly technology explains the "technique effect." efforts that are heavily reliant on technology will raise income levels, and these economies frequently make efforts to lessen environmental pollution.

By preventing environmental deterioration while maintaining economic growth, these expenditures significantly lower the slope of the EKC curve. GDP is the monetary value of the finished goods and services generated over time in the nation and serves as a measure of economic growth. However, this measurement disregards a number of factors, including human wellbeing, environmental deterioration, human health as a result of environmental pollution, and the amount of environmental education in society (Costanza *et al*., 2014). As a result, in addition to economic activity, the analysis of the effects of environmental degradation should also consider the society's level of education, health, and income (Kassouri and Altintas, 2020). The HDI is a holistic measure that incorporates both economic activity and factors including social welfare, health, and education. Hanif *et al*., (2019) proposed the human capital Kuznets curve theory in this regard by substituting HDI for GDP. Due to the current utilisation of antiquated technologies at a low HDI level, there is a scale impact. However, the composition and technical impacts lead to enhancing the environmental quality at medium and high HDI levels (Pata *et al*., 2021).

2.1.2 Empirical Literature

The HDI and CO_2 emissions are two critical aspects that shape the trajectory of the growth and well-being of a nation. With Africa emerging as a continent on the cusp of rapid development, the issue of CO_2 emissions becomes increasingly crucial. However, the inevitable dynamics of Africa’s unique socio-economic landscape and developmental challenges pose the question of whether the EKC validity, which posits an inverted U-shaped relationship between income per capita and environmental degradation, holds significance based on the level of development in Africa with consideration for an indicator (HDI) broader than income per capita. The importance of the validity of the EKC in Africa is central to understanding the trade-offs between economic development and environmental sustainability in the continent’s pursuit of human development.

Most EKC related empirical literature focus more on the relationship between environmental degradation and economic growth (income growth) than the relationship between EDD and HDI. Economic growth measured by GDP per capita is only one of the components of HDI (Li *et al*., 2022). The HDI considers three dimensions: Health, education, and standard of living (Gross national income per capita). Fundamentally, advancing HDI is the ultimate objective of every economic activity. This means that the focus on economic growth is very narrow as far as the EKC postulation is concerned.

Using provincial panel data from 2004 to 2017 in China, Li and Xu (2021) evaluated the link between overall environmental quality and human development. To quantify environmental pollution and human development, they employed the Environmental Degradation Index (EDI) and HDI, and they used the Simultaneous Equations Model (SEM) to analyse their relationship. Their research established an inverted U-shaped relationship between environmental contamination and human development and discovered a strong connection between six EDI and HDI subdimensions. Li and Xu opined that the Chinese government as a matter of urgency needs to accelerate human development to cross the inverted U-shaped curve's turning point as quickly as feasible. Saqib *et al.,* (2022) conducted a study to investigate the potential of the conventional environmental Kuznets curve (EKC) with an extension for developing industrialised nations including Brazil, China, India, Indonesia, Russia, Mexico, and Turkey (E-7 economies), covering the period from 1995 to 2019. The design of the experimental framework is based on second-generational panel econometrics methods such as Cross-Sectional Augmented Autoregressive Distributive Lag (CS-ARDL), Augmented Mean Group (AMG), and Dumitrescu-Hurlin causality tests. The study supported the EKC phenomenon's existence in E-7 economies, where income growth was valued more highly than environmental sustainability. The authors were of the view that the usage of renewable energy sources, technological advancement, and human development were rated as the three magic bullets for lowering carbon emissions over the period under investigation. However, the study conducted by Pata *et al.*, (2021) invalidated the EKC hypothesis under the context of human development for the top ten countries with the largest ecological footprint. The study examined how environmental degradation in the top ten countries (China, US, UK, India, Russia, Japan, Indonesia, Germany, and Mexico) with the largest ecological footprints were affected by globalisation, the use of renewable energy, the abundance of natural resources, and the HDI from 1992 to 2016, using the Lagrange multiplier bootstrap cointegration and the Augmented Mean Group estimator.

Asongu and Odhiambo (2019) used data from 44 countries in sub-Saharan Africa for the period 2000 to 2012 to examine how rising economic advancements affect the green economy in terms of CO_2 emissions. For the empirical analysis, the Generalized Method of Moments was employed. These key conclusions were established: First, rising inclusive human development created an inverted U-shaped EKC, but increasing economic growth and population expansion created a U-shaped pattern in relation to CO_2 emissions. Second, expanding the GDP beyond 25% of annual growth was detrimental to the development of a green economy. Third, a population growth rate of above 3.089% per annum had a positive effect of CO_2 emissions. Fourth, an inequality-adjusted HDI of above 0.4969 was found to be beneficial for a green economy because it was associated with a reduction in CO_2 emissions.

According to Jha and Murthy (2003), the relationship between economic development and the degree of global environmental degradation (GED) has been overlooked in the research on the environmental Kuznets curve (EKC). They continued by saying that the current EKC technique is ineffective with respect to figuring out how economic development and environmental deterioration are related. Regarding the empirical foundation for the GED, they posited that there was disagreement about the empirical basis for the GED. The existence of an inverted U-shaped EKC was therefore tested by the two opposing viewpoints. In order to create a global EKC (GEKC) for 174 nations, they used the Principal Components Analysis (PCA) approach, which placed special emphasis on the degree of environmental deterioration and connected it to HDI. They empirically verified a global EKC with an inverted N-shape. The distribution of environmental degradation among nations was also considered in this report. Extreme disparities were found in how low, medium, and high HDI nation groups contribute to GED, with the low group successfully reducing it and the high group countries significantly escalating it.

In a study conducted for 114 countries made up of 28 developed and 86 developing countries from 2006 -2010, Samimi *et al*., (2011) used panel data regression to determine the relationship between HDI and Environmental Performance Index (EPI). They found evidence that supports a positive and significant relationship between EPI and HDI for the entire countries including the sample of developed countries. However, the study revealed that considering the developing countries that have become extremely vulnerable to the impacts of environmental degradation, the results indicated that higher levels of HDI did not necessarily account for the improvement in the environmental performances in these countries. Asongu *et al*., (2018) used fixed effects and tobit regressions to examine the effect of increasing CO_2 emissions on inclusive human development in 44 Sub-Saharan African countries for the period 2000-2012. The data set of the study was divided into the basic properties of inclusive human development and environmental degradation to improve upon the policy significance of the study. The various divisions were based on income levels, legal origins, religious denomination, openness to the sea, resource-wealth, and political instability. The authors found out that all the computed thresholds were within the policy range and that beyond these thresholds, CO_2 emissions negatively affects inclusive human development.

Hu (2008) proposed implementing global emission reduction measures in accordance with the HDI of countries and the tenet that the big emitters of carbon dioxide should take the lead in reducing emissions. In order to assess the total CO_2 emissions necessary for developing nations to achieve high human development, Costa *et al.,* (2011) used the positive connection between HDI and CO_2 emissions per capita to compute each country's relative emission cutback in relation to HDI. Most research works on the decoupling of carbon emissions and HDI occur at the national and local levels. Chen *et al.,* (2020) evaluated the decoupling status between carbon emissions per capita and the HDI of four provinces in South-west China from 2000 to 2015 based on the Tapio decoupling model and LMDI decomposition. The findings indicated that South-west China's overall decoupling effect was steadily growing. In Bangladesh from 1990 to 2018, Hossain and Chen (2021) showed modest and substantial decoupling between HDI and CO_2 emissions, with economic activity serving as the main driver of CO_2 emissions relative to other contributing factors.

3.0 METHODOLOGY

3.1 Model Construction and Justification from the Literature

A presentation of a theoretical justification for the selection of the study's variables before outlining the econometric methodology for examining the link between HDI and EDD. In the model, EDD is the outcome variable commonly proxied by CO_2 emissions per capita according to Akadiri *et al*., (2019), Destek and Sinha (2020), Dimnwobi *et al*., (2021), Ntarmah *et.al*., (2021), Tachega *et al*., (2021), Djellouli *et al*., (2022) and (Li *et al*., 2022) among others. HDP (Human Development), proxied by HDI is selected in the model as the main independent variable based on the assertion that the EKC postulation is more substantive and holistic when considered in the context of HDP than GDP as indicated by Costanza *et al*., (2014), Hanif *et al*., (2019), Kassouri and Altintas, (2020), Li and Xu (2021), Pata *et al*., (2021) and Li *et al*., (2022). Theoretically, studies on the relationship between HDP and EDD need some specific and notable control variables to reduce the impact of uncertainties in a typical model.

Energy intensity (ENE) is considered as one of the controlled variables based on the theoretical concepts of resource scarcity and technological progress as well as the empirical concepts of policy implications. In terms of resource scarcity, a higher ENE indicates a higher consumption of energy resources. The introduction of ENE as a control variable allows for the assessment of the impact of energy resource scarcity on the relationship between HDP and EDD. Theoretical models suggest that when energy resources become scarce, countries may shift towards cleaner and more efficient technologies, leading to a decline in CO_2 emissions despite an increase in HDP. In terms of the technological progress, higher ENE can also represent less advanced technology or inefficient practices that lead to higher CO_2 emissions. The inclusion of ENE as a control variable therefore makes it possible to capture the influence of technological progress on the relationship between HDP and EDD. ENE varies broadly across countries and sectors. Developed countries tend to have lower energy intensity due to the adoption of more efficient technologies and practices. On the other hand, developing countries often tend to have higher energy intensity as they rely on less efficient technologies and have a greater share of energy-intensive industries. In terms of policy direction consideration, empirical studies have shown that controlling for ENE can provide insight into the effectiveness of policy interventions. For instance, if a country's CO_2 emissions are relatively high despite a high HDP, it could indicate inefficiencies in energy use or failure of energy saving policies. Wiedmann *et al*., (2007), Ang *et al*.,(2009), Chien *et al*.,(2010) and Wang & Chen (2014) as well as other studies provide empirical evidence to support the inclusion of ENE as a control variable when studying the relationship between HDP and EDD.

Globalisation (GBN) is proxied by trade openness in this study as another control variable. The inclusion of GBN as a control variable allows for assessing the role of international trade in the relationship between HDP and EDD as GBN can facilitate the transfer of technology, knowledge, and cleaner production processes, which can accelerate the decline of CO_2 emissions even at low HDP levels. Furthermore, GBN can contribute to the relocation of industries from countries with stricter environmental regulations to countries with more lenient regulations. The pollution haven hypothesis suggests that countries with higher trade openness may experience higher CO_2 emissions due to transfer of polluting industries. The inclusion of GBN as a control variable enables researchers to examine whether trade is an accelerator or an inhibitor of CO_2 emissions, controlling for potential pollution effects. Empirical studies such as Cole *et al*., (2006); De Bruyn *et al*., (2007); De Vita *et al*., (2015) and Ḅöhringer *et al*., (2016) support the inclusion of trade openness or GBN in the study of the relationship between HDP and EDD as it helps researchers to unravel the complexity in the relationship and draw more nuanced conclusions for policy-making and sustainable development efforts.

In accordance with the proposed arguments highlighted, the study suggests a function to evaluate EDD in a multivariate model as follows:

$$EDD = f\,(HDP,\ ENE,\ GBN) \qquad (1)$$

where *EDD* (environmental degradation) is the response variable and HDP (Human Development), ENE (Energy Intensity) and GBN(Globalisation) are the predictor variables. The above equation can be presented in a linear panel data time series form as follows:

$$EDD_{it} = \alpha_i + \beta_1 HDP_{it} + \beta_2 ENE_{it} + \beta_3 GBN_{it} + \varepsilon_{it} \tag{2}$$

Where β_1, β_2 and β_3 are the coefficients of HDP_{it}, ENE_{it} and GBN_{it} respectively. α_i denotes the time-invariable country-specific effect; ε_{it} is the unsystematic white noise error term; *i* and *t* represent specific individual countries and periods respectively.

The EKC hypothesis is presented by the modification of (2) as follows:

$$EDD_{it} = \sigma_i + \Theta_1 HDP_{it} + \Theta_2 HDP_{it}^2 + \Theta_3 ENE_{it} + \Theta_4 GBN_{it} + \mu_{it} \tag{3}$$

The EKC model is presented by (3), in which HDP^2 is the quadratic version of HDP. EKC is duly validated when Θ_1 and Θ_2 are significantly positive and negative respectively. Consequently, four models are presented based on (3) to provide representation for the three distinct categories of human development in the HHDICs, MHDICs and LHDICs as well as ALL 50 African countries under review. The models are presented as follows:

$$\mathrm{EDD}_{\mathrm{it}_{\mathrm{HHDICs}}} = \sigma_{\mathrm{i}_{\mathrm{HHDICs}}} + \alpha_1 \mathrm{HDP}_{\mathrm{it}_{\mathrm{HHDICs}}} + \alpha_2 \mathrm{HDP}_{\mathrm{it}_{\mathrm{HHDICs}}}^2 + \alpha_3 \mathrm{ENE}_{\mathrm{it}_{\mathrm{HHDICs}}} + \alpha_4 \mathrm{GBN}_{\mathrm{it}_{\mathrm{HHDICs}}} + \mu_{\mathrm{it}_{\mathrm{HHDICs}}} \tag{4}$$

$$\mathrm{EDD}_{\mathrm{it}_{\mathrm{MHDICs}}} = \gamma_{\mathrm{i}_{\mathrm{MHDICs}}} + \Theta_1 \mathrm{HDP}_{\mathrm{it}_{\mathrm{MHDICs}}} + \Theta_2 \mathrm{HDP}_{\mathrm{it}_{\mathrm{MHDICs}}}^2 + \Theta_3 \mathrm{ENE}_{\mathrm{it}_{\mathrm{MHDICs}}} + \Theta_4 \mathrm{GBN}_{\mathrm{it}_{\mathrm{MHDICs}}} + \mu_{\mathrm{it}_{\mathrm{MHDICs}}} \tag{5}$$

$$\mathrm{EDD}_{\mathrm{it}_{\mathrm{LHDICs}}} = \tau_{\mathrm{i}_{\mathrm{LHDICs}}} + \partial_1 \mathrm{HDP}_{\mathrm{it}_{\mathrm{LHDICs}}} + \partial_2 \mathrm{HDP}_{\mathrm{it}_{\mathrm{LHDICs}}}^2 + \partial_3 \mathrm{ENE}_{\mathrm{it}_{\mathrm{LHDICs}}} + \partial_4 \mathrm{GBN}_{\mathrm{it}_{\mathrm{LHDICs}}} + \mu_{\mathrm{it}_{\mathrm{LHDICs}}} \tag{6}$$

$$\mathrm{EDD}_{\mathrm{it}_{\mathrm{ALL}}} = \lambda_{\mathrm{i}_{\mathrm{ALL}}} + \delta_1 \mathrm{HDP}_{\mathrm{it}_{\mathrm{ALL}}} + \delta_2 \mathrm{HDP}_{\mathrm{it}_{\mathrm{ALL}}}^2 + \delta_3 \mathrm{ENE}_{\mathrm{it}_{\mathrm{ALL}}} + \delta_4 \mathrm{GBN}_{\mathrm{it}_{\mathrm{ALL}}} + \mu_{\mathrm{it}_{\mathrm{ALL}}} \cdots\cdots \tag{7}$$

3.2 Data Sources

This study used annual data from 50 African countries (consisting of 9 HHDICs, 14 MHDICs and 27 LHDICs) for all the variables spanning 20 years (2000 – 2019). The data (as described in Table 1) were obtained from World Bank through World Development Indicators (WDI) and the UNDP Human development Reports. The period and sample of 50 countries were chosen based on data availability. The HHDICs are Seychelles, Mauritius, Algeria, Tunisia, Libya, Botswana, Egypt, South Africa, and Gabon. The MHDICs are Cape Verde, Morocco, Namibia, Republic of Congo, Equatorial Guinea, Ghana, Zambia, Sao Tome and Principe, Kenya, Eswatini, Angola, Cameroon, Zimbabwe, and Comoros, and the LHDICs are Mauritania, Benin, Uganda, Rwanda, Nigeria, Cote D'Ivoire, Tanzania, Madagascar, Lesotho, Djibouti, Togo, Senegal, Sudan, Gambia, Ethiopia, Malawi, Congo DR, Liberia, Guinea, Mozambique, Burkina Faso, Sierra Leone, Mali, Burundi, Chad, Central African Republic, and Niger.

Table 1: Variable Description and Data Sources

Variable	Description/Proxy Used for Measurement	Source
Environmental Degradation (EDD)	CO2 emissions (metric tonnes) per capita	WDI (2020)
Human Development (HDP)	Human Development Index (0 -1)	UNDP (2020)
Energy Efficiency (ENE)	Energy intensity level of primary energy (MJ/$2017 PPP GDP)	WDI (2020)
Globalisation (GBN)	Trade Openness (% of GDP)	WDI (2020)

3.3 Econometric Techniques

The datasets for this study are grouped into long panel data (time, *T* is greater than the number of African countries, *N*) and short panel data (the number of African countries, *N* is greater than the time, *T*) A combination of a long and short panel data estimation procedures are therefore recommended for estimating the models. A detailed panel estimation procedure consists of the following six steps: (1) Cross-sectional Dependence (CSD) testing, (2) Second Generation Panel Unit Root Testing (3) Slope Homogeneity Testing, (4) Westerlund Panel Unit Root Estimation (5) Tests for Serial Correlation and Heteroscedasticity (6) Feasible Generalised Least Squares Regression (FLGS) and Panel-Corrected Standard Error (PCSE) and, (7) Dumitrescu-Hurlin Granger Causality Test.

3.3.1 Cross-sectional Dependence and Slope Homogeneity Testing

There is a good chance that data from the various African nations will demonstrate cross-sectional interdependence because of the inevitable socioeconomic interactions among them, according to studies (Sarkodie *et al.,* 2020; Mensah *et al*., 2021; Li *et al*., 2022). To choose the best panel econometric tests for estimating the results, testing for CSD and parameter heterogeneity is used as a guide. Estimations could be wrong if cross-sectional connections are ignored (Li *et al*., 2021). Because of this, the study used CSD among the Pesaran (2004) CSD tests to determine whether there were dependencies in the panels or not. Moreover, the study made use of the Pesaran-Yamagata (2008) approach to assess the heterogeneity assumption since a lack of understanding about heterogeneity could result in incorrect extrapolations and estimates (Musah *et al*., 2021).

3.3.2 Second Generation Panel Unit Testing

This study employed the Cross-sectional Im, Pesaran and Shin (CIPS) and Covariate Augmented Dickey-Fuller (CADF) unit root test to see if there were any unit roots in the data. The CIPS and CADF are the most popular second-generation unit root tests when it comes to handling heterogeneous panels with cross-sectional dependencies. Due to their applicability, these two tests have been widely accepted and have been used to locate unit roots in several panel data analyses (Ssali *et al*., 2019).

3.3.3 Westerlund Cointegration Testing

In this study, two-panel cointegration tests were used to check for cointegration. The first test is the cointegration test from 2008 by Persyn and Westerlund. The test employs Westerlund (2007) four-error correction-based tests. The second test, created by Westerlund in 2008, is the Durbin-Hausman Panel Cointegration test. The Durbin-

Hausman Panel Cointegration (Westerlund 2008) uses the Durbin-Hausman Panel (DHP) and Durbin-Hausman Group (DHG) tests. Both of Westerlund's (2007; 2008) tests were rated appropriate because of how well they handled CSD and slope heterogeneity. When calculating panel cointegration, the tests have also proven to be reliable (Persyn and Westerlund 2008; Ntarmah *et al*., 2021).

3.4 Panel Model Estimations

3.4.1 Feasible Generalised Least Squares Regression Model (FGLS)

The FGLS was the first estimator used to investigate the relationships between human development and environmental degradation for only the HHDICs and MHDICs. It is a static panel technique suitable for long-run analysis. In the presence of non-spherical innovations with an unknown covariance matrix, Feasible Generalised Least Squares Regression (FGLS) determines the coefficients of a multiple linear regression model and their covariance matrices.

The FGLS estimation procedure involves the construction of a matrix inverse of the estimated variance-covariance Matrix (EVCM) of the errors to transform the regression equation. This transformation considers the within-panel correlation and produces consistent and efficient estimates of the coefficients. The FGLS is suitable for panels with a greater number of time periods, T than the number of cross-sectional units, N (Sarit *et al*., 2022). In $N < T$ panels, the estimator exploits cross-sectional variations in addition to the within-panel information to effectively address heteroscedasticity, slope heterogeneity and serial correlation. In this study, $N= 9; T=20$ and $N = 14; T = 20$ for the HHDICs and MHDICs respectively. Thus, these $N < T$ panels were specifically estimated by the FGLS model. Variance Inflation Factors (VIFs) were found to ensure that the models did not suffer from multicollinearity. Heteroskedasticity and serial correction tests (AR (1)) and Durbin Watson) were conducted prior to the use of the FGLS to ensure that they were adjusted within the FGLS model.

3.4.2 Panel Corrected Standard Error Model (PCSE)

The second estimator utilised to investigate the relationships between human development and environmental degradation, specifically across LHDICs and ALL 50 African countries, is the panel-corrected standard error (PCSE) technique. It is also a static panel technique suitable for long-run analysis. Issues with autocorrelation, group-wise heteroscedasticity, and cross-sectional dependence (CSD) are frequently observed in panel data. According to Doku *et al*., (2019); and Sandow *et al*., (2021), the PCSE model addresses the issues of CSD, autocorrelation, and heteroscedasticity. Additionally, Nickell (1981) showed that PCSE can handle bias in dynamic models with fixed effects when slope heterogeneity is present. Additionally, this model is appropriate when the dataset comprises greater cross-sectional units (N) than the time period (T), or when $N > T$, according to Hoechle (2007), Kumari *et al*., (2021) and Sarit *et al*., (2022). In this study, cross-sectional units for the LHDICS and ALL the 50 African countries are 27 and 50 respectively, which are greater than the time period (20 years). As a result, the PCSE model was used to handle these specific datasets in this research. The PCSE approach has recently been applied by a number of research scholars (Bailey and Katz 2011; Nathaniel *et al*., 2021; Kumari *et al*., 2021; Adeleye *et al*., 2023). In the presence of the simultaneous effect of serial correlation, contemporaneous correlation and heteroscedasticity, this model nevertheless produces reliable results (Hoechle, 2007; Bailey & Katz, 2011). Variance Inflation Factors (VIFs) were found to ensure that the models did not suffer from multicollinearity.

Heteroskedasticity and serial correction (AR (1) and Durbin Watson) were conducted prior to the use of the PCSE to ensure that they were adjusted within the PCSE model. Consequently, the Prais-Winsten Regression Correlated version of the PCSE was used.

3.5 Dumitrescu-Hurlin Granger Causality Testing

The Dumitrescu and Hurlin (2012) was employed to estimate the directional causal link among EDD, HDP, ENE and GBN across the panels. This causality test was employed because it performs very well in the presence of slope heterogeneity and cross-sectional dependence (Dumitrescu and Hurlin 2012; Gyamfi *et al*., 2021; Mahalik *et al*., 2021). The test is based on the null hypothesis of no causation. The Dumitrescu and Hurlin panel Granger causality test's underlying regression is expressed as:

$$Y_{it} = \alpha_i + \sum_{k=1}^{K} \gamma_{ik} Y_{i,t-k} + \sum_{k=1}^{K} \beta_{ik} X_{i,t-k} + \varepsilon_{it} \tag{8}$$

Where $Y_{i,t}$ and $X_{i,t}$ are inter-related variables. The coefficients (γ_{ik} and β_{ik}) vary across individual observations under the time-invariant assumption. The lag order is denoted as K.

Taking into consideration the Human Development heterogeneity among African countries and the need to provide valid and reliable results, the African countries were sub-grouped into their respective levels of Human Development— HHDICs, MHDICs and LHDICs according to the UNDP-Human Development Reports (2020) based on the following specifications: High HDI African Countries (HDI = 0.70-0.80), Medium HDI African Countries (HDI = 0.55-0.70) and Low HDI African Countries (HDI = 0-0.55). This does not only allow in-depth analysis, but also conditions countries into their respective human development levels to produce valuable results.

4.0 EMPIRICAL RESULTS AND DISCUSSIONS

4.1 Descriptive Statistics

Table 2 shows the descriptive statistics for the whole sample as well as the sub-grouped samples. According to Table 2, there were 1000 observations (from ALL 50 African countries) in Africa, 180 observations for HHDICs, 280 observations for MHDICs and 540 observations for LHDICs countries. This critically implies that studies that are unable to account for this heterogeneity may provide untrustworthy results and put policies on the wrong track on the African continent. In terms of the variables, HHDICs has the highest mean HDP (*M* = 0.6985, *SD* = 0.0526), EDD (*M* = 4.1845, *SD* = 2.351) and GBN (*M* = 93.1393, *SD* = 40.1535) amongst the MHDICs and LHDICs of Africa as shown in Table 2. This provides an obvious indication that the HHDICs of Africa are the most proportionately advanced in terms of HDP, EDD and GBN amongst the other two groups in Africa. However, the LHDICs and MHDICs have the highest and lowest means for ENE respectively. It is therefore understandable from the descriptive statistics that whiles the HHDICs are the highest polluters in Africa, the LHDICs have the highest energy consumption per US Dollar of GDP and MHDICs have the least energy consumption per US Dollar of GDP. These descriptions show how different HHDICs, MHDICs and LHDICs are in terms of Human Development-Environmental consequences in Africa. In terms of kurtosis, the data is described as leptokurtic (*kurtosis value > 3*) except for the data for HDP, which is platykurtic (*kurtosis value <* *3*) as far as the whole sample is concerned. HDP is negatively skewed in the HHDICs, MHDICs and LHDICs, but positively skewed in the whole sample. EDD, ENE and GBN are all positively skewed across the samples. In general, the descriptive outcomes demonstrate that the data are not normally distributed. The Jacque-Bera and probability results provide more evidence for this assertion. Therefore, models for heterogeneous panel data are certainly suitable for estimating such outcomes (Li *et al.*, 2021).

Table 2: Descriptive Statistics

Variable	Obs.	Mean	Median	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis	Jarque-Bera	P-Value
ALL										
EDD	1000	1.2067	0.3744	10.3515	0.0209	1.9937	2.6004	9.4470	2858.8910	0.0000
HDP	1000	0.5076	0.4890	0.8040	0.2530	0.1196	0.4339	2.5508	39.7870	0.0000
ENE	1000	6.5459	5.3900	26.9100	1.0300	3.9966	1.6057	5.9796	799.6603	0.0000
GBN	1000	73.5763	63.3308	311.3541	19.1008	37.2552	1.6753	7.8098	1431.6630	0.0000
HHDICs										
EDD	180	4.1845	3.1044	9.8172	1.5695	2.3511	0.9860	2.5061	30.9984	0.0000
HDP	180	0.6985	0.7020	0.8040	0.5760	0.0526	-0.1295	2.4873	2.4747	0.2902
ENE	180	4.8874	3.9400	13.7600	2.1300	2.2847	1.1983	3.6905	46.6522	0.0000
GBN	180	93.1393	88.8241	225.0231	30.2466	40.1535	1.2090	4.3059	56.6435	0.0000
MHDICs										
EDD	280	1.1747	0.6734	10.3515	0.1598	1.7457	3.5989	16.0152	2580.6950	0.0000
HDP	280	0.5422	0.5445	0.6860	0.3940	0.0608	-0.0791	2.3861	4.6886	0.0959
ENE	280	4.7597	3.6750	16.3400	1.0300	2.6912	1.8406	6.2753	283.2573	0.0000
GBN	280	86.6421	79.2168	175.7980	33.1562	32.2466	0.5947	2.6712	17.7661	0.0001
LHDICs										
EDD	540	0.2306	0.1660	0.9017	0.0209	0.1926	1.1749	3.5950	132.2013	0.0850
HDP	540	0.4260	0.4310	0.5460	0.2530	0.0649	-0.3863	2.4266	20.8277	0.0060
ENE	540	8.0249	6.6250	26.9100	1.8900	4.3995	1.3013	4.7167	218.7162	0.0952
GBN	540	62.3545	54.2427	311.3541	19.1008	34.6715	2.8141	15.9849	4506.3830	0.0000

4.2 Correlation Analysis

This study performed multicollinearity analysis to find the multicollinearity outcomes in addition to the descriptive statistics. Table 3 shows a moderate correlation between the variables, indicating possible linkages. This offers a preliminary defense for researching how the explanatory variables affect the outcome variable. Additionally, the variance inflation factor (VIF) values less than 5 shows that multicollinearity is not a concern in this study.

Table 3: Correlation Matrix

LOHD	Variables	EDD	HDP	ENE	GBN	*VIF*
ALL	**EDD**	1				
	HDP	0.6740	1			1.39
	ENE	-0.1960	-0.3122	1		1.19
	GBN	0.3273	0.3783	-0.0845	1	1.18
HHDICs						
	EDD	1				
	HDP	0.1816	1			1.34
	ENE	0.6666	-0.3122	1		1.14
	GBN	0.0726	0.3783	-0.3476	1	1.48
MHDICs						
	EDD	1				
	HDP	0.2642	1			1.23
	ENE	-0.2762	-0.3122	1		1.28
	GBN	0.4081	0.3783	-0.1906	1	1.04
LHDICs						
	EDD	1				
	HDP	0.5415	1			1.12
	ENE	-0.4081	-0.3122	1		1.14
	GBN	0.0912	0.3783	0.2025	1	1.12

PV*:P-value;* **LOHD***: Level of Human Development*
Rule of thumb: VIF< 5 denotes the absence of multicollinearity.

Table 4 demonstrates that all variables have significant statistics under the null hypothesis of no cross-sectional dependence, indicating the existence of cross-sectional dependence throughout ALL the African countries as well as the HHDICs, MHDICs, and LHDICs. Additionally, Table 5 shows the outcome of the Pesaran and Yamaga (2008) test for slope homogeneity. The findings disprove the null hypothesis that ALL countries, as well as the HHDICs, MHDICs, and LHDICs in Africa, have homogeneous slope coefficients. Based on the findings, the econometric techniques used in this study are required to be resistant to cross-sectional dependence and slope heterogeneity in order to consider any potential series distortions. (Musa *et al*., 2020; Mensah *et al.*, 2021).

Table 4: Cross Sectional Dependence Test

	ALL	HHDICs	MHDICs	LHDICs
Variable	**Statistic**	**Statistic**	**Statistic**	**Statistic**
EDD	52.38***	6.6***	12.71***	29.81***
HDP	138.27***	15.56***	40.24***	79.82***
ENE	25.41***	5.78***	7.97***	14.38***
GBN	10.73***	6.56***	6.85***	7.04***

**** denotes 1% significance level*

Table 5: Slope Homogeneity Test

	ALL	HHDICs	MHDICs	LHDICs
Delta	**Statistic**	**Statistic**	**Statistic**	**Statistic**
Δ	22.551***	9.243***	10.614***	21.742***
ΔAdjusted	26.039***	10.673***	12.256***	25.106***

**** denotes 1% significance level*

4.3 Panel Unit Root Results

According to the CIPS and CADF results in Table 6, the variables are non-stationary at levels across the countries and levels of human development. However, they exhibit stationarity in their first differences in all the unit root test specifications. This shows that all of the variables employed in the estimations are integrated of order I(1).

Table 6: Panel unit Root Test

		ALL		**HHDICs**		**MHDICs**		**LHDICs**		**I(d)**
CADF	**Var.**	**level**	**Δ**	**level**	**Δ**	**level**	**Δ**	**level**	**Δ**	
	EDD	-1.458	-3.016	-2.301	-2.904	-0.760	-3.372	-1.995	-2.498	I(1)
	HDP	-1.245	-3.407	-2.053	-2.501	-1.943	-3.020	-1.976	-2.779	I(1)
	ENE	-2.170	-3.115	-0.968	-2.467	-1.820	-2.909	-2.036	-3.020	I(1)
	GBN	-1.259	-2.847	-1.432	-2.952	-1.992	-2.916	-1.808	-3.879	I(1)
CIPS										
	EDD	-1.336	-3.925	-1.221	-3.895	-0.569	-3.878	-1.882	-3.966	I(1)
	HDP	-1.654	-2.741	-2.119	-3.687	-2.262	-4.324	-2.306	-4.261	I(1)
	ENE	-1.916	-3.829	-0.875	-3.803	-1.488	-3.791	-1.815	-3.967	I(1)
	GBN	-1.491	-4.210	-2.027	-4.307	-1.979	-4.015	-1.988	-4.329	I(1)

Δ = First difference operator

4.4 Westerlund Panel Cointegration Results

Table 7 presents Westerlund's cointegration results for ALL countries, HHDICs, MHDICs and LHDICs in Africa. Westerlund (2007; 2008) test the null hypothesis of no cointegration. The results show that the null hypothesis of no cointegration is rejected, indicating that cointegration exists among the variables.

Table 7: Westerlund Cointegration Test Results (2007;2008)

Statistic	**ALL**	**HHDICs**	**MHDICs**	**LHDICs**
		Westerlund (2007)		
Gt	-5.881***	-5.592***	-4.987***	-8.363***
Ga	-6.942***	-8694***	-6.887***	-6.425***
Pt	-8.633***	-11.111***	-5.622***	-12.664***
Pa	-10.11***	-13.254***	-9.311***	-11.388***
		Westerlund (2008)		
DHG	2.451***	2.443***	3.088***	2.987***
DHP	3.011***	2.688***	3.015***	2.8841***

**** denotes 1% significance level*

4.5 Autocorrelation and Heteroscedasticity Results

Prior to the use of the PCSE and FGLS, it is necessary to find out whether or not the data are characterised by autocorrelation and heteroscedasticity. This makes it easy to adjust the econometric details for the PCSE and FGLS estimations to be effective and accurate. According to Table 8, the Durbin Watson and Breusch Godfrey Tests confirm the existence of autocorrelation in both the specific samples and the entire sample, whiles the White test indicates the presence of heteroscedasticity in the data.

Table 8: Autocorrelation and Heteroskedasticity Results

	Autocorrelation		Heteroscedasticity
LOHD	**Durbin Watson Statistic**	**Breusch Godfrey Chi^2**	**White test Chi^2**
HHDICs	0.88	25.87***	72.87***
MHDICs	1.02	44.84***	84.44***
LHDICs	1.22	61.31***	85.14***
ALL	0.98	88.66***	193.87***

**** denotes 1% level of significance*

4.5 PCSE and FGLS Results

To achieve econometric consistency, the FGLS was used to estimate results for the HHDICS and MHDICs due to the presence of $T>N$ panels, whiles PCSE was employed to estimate for the LHDICS and ALL the 50 African countries under consideration due to the presence of $N>T$ panels. In Table 9, the FGLS and PCSE results indicate that HDP had a significant and positive influence on EDD among ALL the African countries. In the same way, HDP had positive and significant impacts on the EDD of HHDICs, MHDICs and LHDICs in Africa. The magnitude of the impact was directly proportional to the level of HDP. This implies that HDP significantly induces EDD, with the HHDICs being the highest culprits and followed by the MHDICs. Finally, LHDICs are the least inducers of EDD in Africa. This significantly positive impact of HDP on EDD connotes that human development in its initial stages, leads to a greater level of environmental degradation in Africa by the emission of substantial amounts of CO_2 into the environment. This outcome is in contradiction to the findings of Lawson (2021) who argued that human development is not responsible for carbon dioxide emissions for 41 sub-Saharan African countries and Asongu & Odhiambo (2019), who revealed that human development is associated with reduction in CO_2 emissions for 44 sub-Saharan African countries. It also contradicts the discovery made by Osei-Poku *et al*., (2022) that a rise in human development (measured by the human development index, education, and human capital) improves environmental sustainability by reducing ecological footprint, emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs), and exposure to air pollution. Conversely, the outcome of this study supports the studies of Jorgenson *et al*., (2016) who discovered that human development is positively correlated with CO_2 emissions.

The outcome of the study further indicates that an increase in energy consumption per unit of economic output is associated with appreciation in the pollution of the environment for HHDICs. This means that ENE had a significantly positive effect on EDD for HHDICs. This outcome is supported by Afrane & Ozturk (2020), Jebli &

Youssef (2016) and Ouedraogo (2013;2014). These studies provide empirical evidence supporting the claim that higher energy intensity in highly developed African countries are associated with higher CO_2 emissions and therefore higher EDD. However, ENE had no significant relationship with EDD for Africa at large. This finding is an indication that energy intensity is not generally accountable for environmental pollution through the emission of CO_2 in Africa. On the other hand, there was a significantly negative effect on EDD for MHDICs and LHDICs in the continent, albeit very low in magnitude. Furthermore, GBN had a significant positive predominating impact on EDD across the HHDICs, MHDICs and Africa at large. This outcome is supported by Tamazian *et al.,* (2009), Cole *et al.,* (2005) and Frankel & Rose (2005), who all concluded that globalisation in the form of trade openness leads to higher emissions of CO_2 due to weaker environmental regulations and trade liberalisation that call for higher energy consumptions. However, there was no significant relationship between GBN and EDD for LHDICs of Africa. These outcomes suggest that even though GBN is essential, failure to regulate it could cause higher emissions of CO_2 particularly for the HHDICs and MHDICs of Africa. In terms of diagnostic statistics, the Wald Chi^2 values are significant at the 1% level, suggesting that the distribution of the variables fits well with the CO_2 model.

Table 9: FLGS and PCSE Estimates

	FLGS		**PCSE**	
	Dependent Variable: EDD			
	HHDICs	**MHDICs**	**LHDICs**	**ALL**
Variable	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
HDP	23.428***	4.003***	1.025***	9.016***
ENE	0.403***	-0.059***	-0.005***	-0.021*
GBN	0.004***	0.008***	0.011*	0.002***
Wald Chi^2(3)	771.330***	1144.960	121.620***	173.220***

**** denotes 1% significance level*

**denotes 10% significance level*

4.6 EKC Results

Table 10 presents the EKC results from the PCSE and FGLS estimators. Using ALL the African countries collectively, the results in Table 10 indicate that the coefficient of the linear term of HDP is negative and significant, while the coefficient of the quadratic term of HDP (HDP^2) is positive and significant. This indicates a U-shaped relationship between HDP and EDD, invalidating the EKC hypothesis in Africa. Similarly, the results from the perspective of MHDICs and LHDICs in Africa show that the coefficients of HDP are negative and significant, while the coefficients of the HDP^2 are both significant and positive. Thus, the EKC hypothesis is invalidated amongst MHDICs and LHDICs in Africa. This outcome is supported by Jha and Murthy 2003;Tran *et al*., (2019) and Pata *et al*.,(2021) who did not find any empirical support for the validity of the EKC hypothesis using a sample of 174, 90 and 9 countries respectively. On the other hand, this outcome contradicts the outcomes of Asongu & Odhiambo (2019), who provided the evidence of EKC in 44 Sub-Saharan African countries. The largest portion of Sub-Saharan African countries are LHDICs. The evidence of U-shaped relationship or invalidity of the EKC hypothesis amongst MHDICs, LHDICs and Africa at large implies that EDD initially declines as economic development increases until certain threshold limits of HDP are respectively realised for the different categories of African countries, beyond which EDD begins to rise with increasing HDP. This means that pollution initially is low as the developmental levels of these countries begin to rise, until a certain point where further increase in development leads to increase in pollution levels. Based on the outcome of the study, the threshold levels of HDP beyond which EDD increases with increasing HDP are 0.405 and 0.302 respectively for MHDICs and LHDICs in Africa. This is primarily the case of underdeveloped and developing African countries, which form a greater percentage of the countries on the African continent. These economies are characterised by extremely low levels of industrialisation, where raw material production and exports are prioritised over the production and exportation of finished goods, leading to deficits in trade and balance of payment. The predominance of agriculture and labour-intensive methods of production are indicators of their early economic development. Low levels of industrialisation are closely linked to very low carbon footprints. At this stage of economic development, most of these nations are unable to invest in environmental improvements and tend to ignore the negative environmental effects of economic development (Sarkodie and Strezov 2019). As industrialisation levels begin to increase through the help of the State and Foreign Direct Investment (FDI), pollution levels rise in juxtaposition with development beyond a certain threshold. However, due to the absence of strict environmental regulations, industry standards, and investment in research and development resulting in new, cleaner, and environmentally friendly technologies to replace old technologies that emit large quantities of pollution, pollution continues to increase with increasing levels of development. Eventually, MHDICs and LHDICs in Africa start to have serious concerns about the integration of environmental consciousness with economic development and the desire for a high-quality, sustainable environment (Beckerman 1992; Komen *et al*., 1997; Liang and Yang 2019).

In contrast, the results from the perspective of the HHDICs show that the coefficient of HDP is both positive and significant, while HDP^2 is both significant and negative. Thus, the EKC hypothesis is validated amongst HHDICs in Africa. This indicates an inverted U-shaped relationship between HDP and EDD. This indicates that EDD brought on by scale effect during later stages of human development can be reversed by composition and technique effects. Thus, as the level of development improves for HHDICs, pollution initially rises along with it until a certain point, at which stricter environmental regulations, industry standards, and investments in research and development lead to the development of new, cleaner, and environmentally friendly technologies that eventually replace older ones responsible for the emission of large amounts of pollution (Li *et al*.,2022). This outcome supports the findings of the studies done by Asongu & Odhiambo (2019), Li & Xu (2021) and Saqib *et al*., (2022), which provide sufficiently important reasons for the need for policy makers to focus on increasing HDP beyond their current levels as a triggering mechanism for the reduction of CO_2 emissions in the environment. In this study, it was discovered that the threshold HDP beyond which CO_2 reductions can be realised within the EKC framework for HHDICs in Africa is 0.6099. The significance of the Wald Chi^2 suggests that the distribution of the variables fits well with the CO_2 model and is characterised by high predictive power.

Table 10: EKC Results

	FLGS		PCSE	
	Dependent Variable: EDD			
	HHDICs	**MHDICs**	**LHDICs**	**ALL**
Variable	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
HDP	134.765***	-19.118***	-1.585**	-27.432***
HDP^2	-110.481***	21.221***	2.626**	33.769***
ENE	0.506***	-0.027***	-0.050***	-0.033*
GBN	0.003***	0.005***	-0.001*	0.002**
HDP Threshold	**0.6099**	**0.405**	**0.302**	**0.406**
Wald Chi^2(3)	1416.220***	195.980***	69.610***	213.520**

**** denotes 1% significance level*

***denotes 5% significance level*

**denotes 10% significance level*

NB: *The threshold HDP's were calculated by differentiating the respective quadratic functions for HHDICs, MHDICs, LHDICs and ALL (including their respective coefficients obtained from the FGLS &PCSE estimations) and solving for HDP at maximum turning points, where* $\frac{dEDD}{dHDP} = 0$

4.7 Dumitrescu-Hurlin Causality Results

As indicated earlier, the D-H Granger causality test was conducted to explore the causalities among the variables. The study navigates the causalities of the entire sample and the respective human development categories of the African countries. Tables 11&12 present the results of the Granger causality tests. The D-H causality results show that there are bidirectional causal links between HDP and EDD in all countries, HHDICs, MHDICs and LHDICs in Africa. This implies that while higher levels of human development often involving industrialisation and increased energy consumption (mostly fossil fuel energy) in African countries leads to higher levels of EDD, higher levels of EDD (Higher emissions of CO_2 and climate change also tend to adversely affect human development in the form of rising temperatures, changing rainfall patterns and extreme weather events capable of affecting agriculture, water resources, and overall economic productivity. The findings support studies conducted by Stern (2004), Bentrán *et al*., (2015), Sun *et al*., (2017) and Guo *et al*., (2018), that established a bidirectional relationship between human development and CO_2 emissions. Similar to this, there are bidirectional causal relationships between EDD and ENE for all African nations, HHDICs, MHDICs, and LHDICs, indicating that an increase in energy intensity leads to higher levels of CO_2emissions, while higher CO_2 emissions also promote higher energy intensity. This also means that there are detrimental consequences like fossil fuel energy consumption related pollution on the potential for industry-driven economic development on the African continent. These findings support studies by Amulali *et al*., (2015), Hossain (2011) and Ang (2007), who found a bidirectional causal link between energy intensity and CO_2 emissions.

Table 11: Dumitrescu-Hurlin Granger Causality Results: ALL & HHDICs

	ALL		**HHDICs**	
	Z-Bar Tilde	**Causality**	**Z-Bar Tilde**	**Causality**
EDD- HDP	6.9304***		8.8022***	
HDP-EDD	11.9681***	Bidirectional	2.7099***	Bidirectional
EDD- ENE	8.4903***		5.3676***	
ENE- EDD	7.7567***	Bidirectional	3.3563***	Bidirectional
EDD- GBN	6.7997***		3.5187***	
GBN- EDD	4.2107***	Bidirectional	0.3531*	Unidirectional
HDP-ENE	10.2086***		6.1946***	
ENE- HDP	4.2242***	Bidirectional	2.2720**	Bidirectional
HDP - GBN	6.4524***		1.284*	
GBN- HDP	4.0716***	Bidirectional	2.4902**	Bidirectional
ENE- GBN	6.2517***		2.0284**	
GBN- ENE	3.0369***	Bidirectional	2.8691***	Bidrectional

**** denotes 1% significance level*
***denotes 5% significance level*
**denotes 10% significance level*

While bidirectional causal links exist between EDD and GBN among all the African countries and LHDICs in Africa, unidirectional causal links from GBN to EDD exist in the HHDICs and MHDICs. Bidirectional causality between EDD and GBN among ALL the African countries and the LHDICs in Africa implies that not only does globalisation (trade openness) lead to higher CO_2 emissions through industrialisation, but higher CO_2 emissions also lead to globalisation. With a good number of African countries being less developed and poor, they are likely to adopt less stringent environmental regulations aimed at attracting foreign investments and promote exportation of goods and services. This leads to industrialisation under weak environmental protection conditions that brings about EDD, including water pollution, deforestation, and ecosystem destruction. These countries and the whole of Africa need to gradually shift from relying significantly on FDI's and develop policies that will build local industries to adequately compete in quality and quantity on the international markets.

Table 12: Dumitrescu-Hurlin Granger Causality Results: MHDICs & LHDICs

	MHDICs		**LHDICs**	
	Z-Bar Tilde	**Causality**	**Z-Bar Tilde**	Causality
EDD- HDP	2.9120***		2.2523**	
HDP-EDD	9.3025***	Bidirectional	8.0234***	Bidirectional
EDD- ENE	6.0910***		4.0688***	
ENE- EDD	8.0592***	Unidirectional	2.8144***	Bidirectional
EDD- GBN	1.4992*		6.1420***	
GBN- EDD	2.3545**	Unidirectional	3.8307***	Bidirectional
HDP-ENE	6.2327***		5.8208***	
ENE- HDP	1.1429*	Unidirectional	3.6136***	Bidirectional
HDP - GBN	2.8768***		5.9677***	
GBN- HDP	3.4614***	Bidirectional	1.6106*	Unidirectional
ENE- GBN	1.6625*		6.1392***	
GBN- ENE	2.4770**	Unidirectional	0.6926*	Unidirectional

denotes 1% significance level
***denotes 5% significance level*
**denotes 10% significance level*

This level of independence will give them the freedom to adopt more stringent environmental regulations to control environmental degradation resulting from globalisation. This outcome is supported by other studies conducted by Shahbaz *et al*., (2018), Lean & Smyth (2010) and Managi *et al*., (2009), who posited the existence of a bidirectional causality between trade openness and CO_2 emissions in the context of developing or poor countries.

Unidirectional causality from GBN to EDD amongst the HHDICs and MHDICs in Africa implies that globalisation leads to higher emissions of CO_2 in these African countries. These developed and mid-developed African countries are often regarded as significant contributors to global CO_2 emissions due to their high levels of industrialisation and consumption. The impacts of carbon leakage, economic competitiveness, policy response and climate change leadership reinforce the need for these developed or mid-developed African countries to proactively create a global momentum towards the mitigation of CO_2 emissions. This outcome is supported by Frankel & Rose (2005) and Cole & Elliot (2003), who concluded that there is a unidirectional causality from trade openness to CO_2 emissions in developed countries.

The bidirectional causal links from HDP to ENE among all the African countries, HHDICs and LHDICs, implies that increased access and efficiency of energy use leads to an improvement in human development, while improving human development can influence energy intensity by increasing energy consumption and enhancing efficient utilisation of energy in both poor and developed African countries. Apergis & Payne

(2010) supports this outcome. On the other hand, a unidirectional causal link exists from ENE to HDP in the MHDICs. This is an indication that higher energy consumption is associated with higher human development levels in the medium developed or partially developed African countries. Although other factors such as governance, technology, education, and institutional quality also play important roles in shaping human development, attention is required when it comes to ensuring that there is a safe trade-off between energy conservation and energy consumption to protect the environment in medium or partially developed African countries. Studies conducted by Salehin & Salleh (2017) and Rafindadi &Ozturk (2017) support this outcome of the study.

The bidirectional causality link between HDP and GBN among ALL the African countries, HHDICs and MHDICs indicates that improvements in trade openness positively influences human development outcomes through increased access to wider international markets, foreign direct investments, transfer of technology and knowledge spillovers, whiles higher levels of human development provide a favourable environment for trade openness. By investing in education, institutional quality, technological capability, health, and labour productivity as well as poverty alleviation, these African countries can enhance their competitive advantage and integration into the global trade system. This outcome is sync with studies conducted by Serfilippi *et al*., (2016) and Herzer & Nunnenkamp (2012). The unidirectional causal link from GBN to HDP in the LHDICs is an indication of the significant influence of increased trade openness on the improvement in human development in these countries. Rajapksa & Prema-Chandra (2019) and Wagle (2006) supported the outcome of this study.

A bidirectional causal link between ENE and GBN was found to exist among all the African countries and HHDICs. This outcome means that higher energy intensity can support industrialisation and enhance production capabilities, thereby promoting trade and economic development. At the same time, trade openness leads to increased energy consumption and intensity as economic activities expand these African countries. Furthermore, as trade openness leads to high energy consumption, prominent levels of CO_2 emissions that are detrimental to human health and development can occur. A balance between trade openness and sustainable energy practices as well as environmental regulations are crucial in the mitigation of the negative environmental impacts. Shahbaz (2014) confirmed the existence of a bidirectional causal relationship between trade openness and energy consumption. However, unidirectional causal links exist from GBN to ENE and ENE to GBN in the MHDICs and LHDICs, respectively. This is an indication that whiles trade openness significantly influences energy intensity in developing or medium developed African countries, energy intensity significantly increases trade openness in underdeveloped African countries.

5.0 CONCLUSION AND RECOMMMENDATIONS

5.1 Conclusion

The impact of HDP on EDD is proportional to the level of human development in Africa. This means that the impact is the highest in HHDICs; followed by MHDICs. The LHDICs experience the lowest impact of HDP on EDD in Africa. Moreover, the EKC postulation is invalidated in Africa as well as in the MHDICs and LHDICs, indicating the presence of a U-shaped relationship between HDP and EDD in the MHDICs and LHDICs and Africa as a whole, whereas the EKC postulation is valid in the HHDICs of Africa, indicating the presence of an inverted U-shaped relationship between HDP and EDD in the HHDICs of Africa. This conclusion implies that the social and economic developments of the HHDICs, MHDICs, LHDICs and Africa at large contribute to the rise in the continent's EDD. However, even though the HHDICs experience the most elevated levels of EDD in the preliminary stages of their HDP's, they can experience significant decline in EDD beyond a certain threshold of development.

5.2 Recommendations

The HHDICs need the formulation and promulgation of policies that focus on green industry and innovation to reduce the over-reliance on fossil fuel energy consumption, which is responsible for elevated EDD realised in their initial stages of HDP. This involves the adoption of clean technologies and green practices within their highly industrialised environments.

The failure of policymakers in the MHDICs and LHDICs to integrate the principles of sustainable development into economic policies and planning processes to ensure that development is conducted in an environmentally friendly manner in the long run, will obliterate their aim of achieving both economic development and protection of the environment. Policymakers from individual countries within these categories of HDP, must ensure that any attempt to increase HDP is supported by environmentally friendly policies to minimise the EDD associated with socio-economic development. The MHDICs are admonished to strengthen and enforce existing environmental regulations and introduce new ones, if need be, to ensure that as they become more industrialised, industries and businesses whether local or FDI adhere strictly to these regulations or face the consequences in the event of non-compliance. LHDICs are encouraged to crucially prioritise sustainable development strategies such as environmental education and improvement of access to affordable, reliable, and clean energy sources such as solar, wind and hydropower to reduce reliance on fossil fuels to mitigate the pollution of the environment as they invest in industrialisation. It must be noted that if MHDICs and LHDICs are able to reorient their policies to attain high levels of human development in the long run, they can transform the U-shaped HDP-EDD relationship into an inverted U-shaped (EKC) relationship outcome, ensuring the mutual benefit of the feedback effect between HDP and the environment.

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