World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Research Article)

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Nexus between energy intensity and Environmental Quality SSA: Evidence from GMM

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World Journal of Advanced Research and Reviews, 2022, 16(02), 193–210

Publication history: Received on 29 September 2022; revised on 31 October 2022; accepted on 02 November 2022

Article DOI: https://doi.org/10.30574/wjarr.2022.16.2.1136

Abstract

Ecosystem protection is a priority for all nations, particularly developing nations. This state has the most active economic policy debate and development because of its commitment to equitable economic growth, environmental protection, energy conservation, and universal access to adequate energy. This article argues that Sub-Saharan Africa's economic progress and ecological sustainability are intertwined (S.S.A.). The Environmental Kuznets Curve (EKC) theory proposes a U-shaped relationship between increased per capita income and emissions of nitrous oxide (N2O), agricultural methane (ACH4), and carbon monoxide (C.O.) (CO2). The dynamics between GDP expansion, energy intensity, foreign direct investment, human capital, and carbon dioxide emissions are also investigated. We observed that trade significantly raises emissions of N2O, ACH4, and CO2 for the whole United States and its income categories (Upper-Middle-Income Countries (UMIC), Lower-Middle-Income Countries (LMIC), and Low-Income Countries (LIC)) (L.I.C.). We believe the EKC demonstrates the feasibility of further emission reductions in the future since economic expansion in SSA nations is uniformly detrimental to the environment. The findings demonstrated the need for energy-efficient and secure industry while revealing the drawbacks of freer local commerce and foreign influence on the economy.

Keywords: Environmental quality; Trade; Energy intensity; Foreign direct investment; Environmental Kuznets curve

1. Introduction

Since the "General Agreement on Tariffs and Commerce" (GATT) was established, there has been a notable rise in commerce between nations due to the lowering of trade barriers and subsequent broadening of trade liberalization. As GATT's successor, the World Trade Organization (W.T.O.) has the potential to be just as influential. Newly proposed to boost international commerce is the "Commerce Facilitation Agreement" (TFA) (W.T.O., 2017). The world's poorer countries will profit the most from the predicted $1 trillion yearly increase in international commerce. At the same time, the TFA considers the global consequences of negative externalities. The environmental Kuznets curve (EKC) has been the focus of much academic attention because of concerns about the negative effects that rising prosperity has on the environment see [1-3]. Kuznets [4] first presented the EKC hypothesis, positing that income inequality would increase initially but decrease as the economy grew. While Grossman and Krueger first used the EKC concept [5], it has now gained broad acceptance. Environmental degradation followed the same inverted U-shaped trend as G.D.P. per capita. The results of this research confirm the presence of the EKC SSA region. However, they do so with caveats about the actual duration of that area's existence (in percentages). Concern among politicians, economists, and the general public has been raised by studies suggesting a connection between CO2 emissions and trade openness.

Compared to other economic indicators like real income and population growth, carbon emissions from global supply networks are increasing at a far faster pace [6]. According to conventional economic theory, growth in the number of

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transactions is expected to strengthen the economy. Additionally, increasing emissions that harm the environment have been related to economic growth. As a result, nations in crosshairs will be forced to adopt greener production methods.

Greater prosperity is an urgent need for the countries in Africa south of the Sahara (S.S.A.). Despite recent gains in economic progress, the subcontinent is still confronted with difficult challenges in its efforts to eliminate poverty. These challenges include insufficient housing, inadequate education, poor health, and short life expectancies. Commerce is only one of several factors that might influence the overall economic growth of a country, but it is an important one. However, most economists and academics believe that trade contributes to the expansion of economies Dollar [7-13]. The debate around whether or not the trade is helpful or destructive to the environment has sparked a discussion amongst academics. There is no agreement among environmental and trade economists on whether or not trade benefits the environment. The environment's influence on global trade is complicated by several interrelated elements, each of which may have good or negative effects. As for how much commercial activity impacts overall pollution levels, scholarly research is divided. Using disparities in environmental policy models to promote trade between countries may increase emissions, as shown by Helbling et al. [14]. Emissions are predicted to decrease after liberalization when implemented models account for differences in national endowments to promote trade between countries

To answer your question, how much do you anticipate spending? Sub-Saharan Africa's economy must expand, but we must not lose sight of the need to achieve progress in a sustainable and long-term way. Because of this, eco-friendly expansion strategies need to be given top priority. This particular illustration is the most illustrative illustration of the relationship between commercial activity and the natural environment in sub-Saharan Africa. When nations choose to specialize in producing and exporting products and services in which they have a competitive advantage, it benefits the whole world's economy. The value of exports has increased from $59 billion in 1948 to $15.5 trillion in 2016; this represents a percentage of G.D.P. comparable to 29 percent (W.T.O., 2017). Globalization has, for the most part, been helpful to the economic world, but it has also had unforeseen repercussions for economies and the environment. The consequences of climate change on natural catastrophes such as storms, floods, and droughts pose a threat to many nations in Sub-Saharan Africa. African nations do not have the resources necessary to enact sufficient legislation, reduce the effects of the repercussions, or adapt to them. This ineptitude, considering the extent of the issues it generates, impedes commerce and slows down the development of the economy.

According to several research, freer trade is associated with reduced pollution levels. Antweiler et al. [15],[16-18] employed panel cointegration techniques to analyze the link between trade liberalization and carbon dioxide emissions (CO2). Depending on the kind of nation, their results indicate that trade liberalization may have positive or negative impacts on pollution output. Boleti et al. [19] investigated the relationship between economic complexity and environmental performance using data from 88 industrialized and developing countries between 2002 and 2012. One of their research findings was that technical sophistication did not add to environmental deterioration, and another was that a more complex economy might result in improved environmental performance.

In contrast, they found a positive correlation between economic complexity and air quality, which suggests greater exposure to PM2.5 and CO2 emissions. Pei et al. [20] produced a unique micro dataset for China in 2007 by integrating two large firm-level datasets; utilizing this data, they observed that export status and export intensity were related to lower sulfur dioxide emissions (SO2). It is shown that trade has resulted in a significant rise in emissions of nitrous oxide (N20), agricultural methane (ACH4), and carbon dioxide (CO2) across Sub-Saharan Africa and its sub-regions (UMIC, LMIC, and L.I.C.). It is evident from this research that commerce has a negative influence on the natural environment over all of Sub-Saharan Africa.

Using the classic KAYA identification, carbon dioxide (CO2), nitrogen oxide (N2O), and acetylene (ACH4) emissions are now being examined. According to the KAYA identification, total CO2 emissions may be stated as the product of population, G.D.P. per capita, energy intensity (as a percentage of G.D.P.), and carbon intensity (emissions divided by energy consumed) [21,22]. This is a more specific variant of the more general equation I=PAT, which establishes a link between the many factors that influence the amount humans contribute to global warming. Here, the core KAYA or I=PAT model regresses population, energy intensity, and G.D.P. per capita [23-27]. Recent research [28–31] has suggested an alternative to the KAYA or I=PAT paradigm. This research improves the KAYA model by a regression analysis of greenhouse gas emissions (CO2, N2O, and ACH4) versus other parameters, including trade, income per capita growth, energy intensity, FDI, and human capital. To avoid the issue of changeable omission bias, it is advantageous to incorporate commerce (revenue from natural resources), which helps to account for fluctuating emissions (CO2, N2O, and ACH4). If business activity grows, it may boost economic activity and necessitate a rise in energy production, which would raise the export of natural resources, which may be seen as a proxy for trade revenues. It is essential to include commerce in attempts to explain these inconsistencies [32], given that global business is growing while GHG emissions are declining, particularly in wealthy nations.

The present focus in the environment-resource-growth literature is on the dependence on or availability of these resources, and this is true not just in terms of economic development but also in terms of greenhouse gas emissions and climate change. In summary, the following are examples of how the current study adds to the expanding body of knowledge on environmental challenges and resource development: Before diving into the specifics, it is important to note that resource dependence and abundance have been the dominant theoretical frameworks for studying the effects of trade on GHG emissions in recent years (GHGs). Brunnschweiler [33], using the ratio of resource exports to GDP. as an example, argued that this statistic is endogenous, calling into question the findings of Sachs and Warner (1995). Exports divided by economic size are a metric that may not be unbiased, given the impact of economic policies and institutions on GDP. Level and growth. As a result of the preceding, we decided to use the "Natural Resources Revenues" proxy to measure trade openness instead of the more conventional approaches, particularly in the S.S.A. region, where the volatility of exchange rates can impact the accuracy of G.D.P. estimates based on imports and exports.

The remainder of the paper is laid out as follows: the second section provides an overview of trade and the environment in Sub-Saharan Africa. The Literature Review is included in Section 3. The Methodology is covered in Section 4. Section 5 discusses the presentation and interpretation of the results, while Section 6 gives policy recommendations and conclusions.

2. Literature review

Several researchers have investigated the EKC hypothesis, including Saboori and Sulaiman [34] and Chien et al. [35]; however, their papers have shown incongruent findings. An N-shaped connection, a linear correlation, and a U-shaped correlation were also discovered, among many others. Omitted-variable bias detection is a major shortcoming of these exploratory investigations. For this reason, recent studies have included various variables that have caused environmental deterioration, such as trade openness, urbanization, energy consumption, and economic development. However, the results of this multivariate analysis have been contradictory concerning EKC theory [36–39]. Panel vector autoregression (PVAR) and the generalized method of moments (G.M.M.) were used to examine the dynamic relationship between G.D.P. growth, energy usage, and CO2 emissions for 116 nations between 1990 and 2014. They discovered that changes in real G.D.P. had little impact on either national or international energy use. Finally, some data from S.S.A. nations corroborate the EKC theory but not data from the MENA area. Gorus and Aydin [40] utilize several Granger causality models to analyze the connection between energy use, real G.D.P., and pollution in eight MENA oil-rich nations from 1975 to 2014. Like the causal correlations shown in the time domain, the panel frequency domain analysis reveals a cause-and-effect relationship between the fundamental variables in various contexts. Previous studies did not categorize countries by area or economic level. Thus, it is unknown how much actual wealth and energy consumption affect environmental degradation in this cluster of countries.

Because it is often believed that pollution is an unavoidable byproduct of economic expansion, it is usually anticipated that increasing production would increase pollution. It is important to recognize the complicated relationship between pollution and economic development, with the potential for variations among regions. Some individuals think that, beyond a certain point, a booming economy may help make the earth a better place, while others are worried that a successful economy might ultimately hurt the environment. As a consequence of Simon Kuznets' investigation into the connection between economic development and income inequality, the Environmental Kuznets Curve was developed (EKC). It was used to relate the PCI of inhabitants to ambient SO2 concentrations in 47 cities across 31 nations [42]. PCI and sulfur dioxide levels eventually form an inverted U-shaped curve. The EKC is conceptually based on the effects of industrialization, which include a shift from the industrial output in urban centers to agricultural commodities produced in rural regions. As the industrial sector modernizes, pollution levels are anticipated to rise. However, when per capita wealth increases, new emission-reducing technologies can become accessible [43]. The move toward service production is anticipated to cut emissions once economies in emerging nations reach a certain level of development. There will be more requests for cleaner environments, which will catch the attention of the political elites and maybe lead to the passing of legislation and making investments that are advantageous to the environment [44]. Scale, composition, and technology have been recognized as the three factors at the core of this issue.

Copeland and Taylor first put out the pollution haven hypothesis (P.H.H.) [45] to explain the effects of global commerce on the environment. According to this theory, countries with stricter environmental restrictions risk losing business to nearby nations with laxer regulations. Therefore, the P.H.H. may be described as a circumstance in which certain nations have a competitive edge over others due to their more environmentally friendly policies. As a result of economic liberalization, many products that produce much pollution may be produced in underdeveloped countries, where environmental laws and regulations are sometimes seen as being laxer or less enforced. Even yet, this might obscure the effects of global trade on this problem by causing emissions to rise in some places while falling in others. The beneficial environmental benefits of trade liberalization may be fully explained by considering size, composition, and technology effects [15,27]. Global commerce has led to the possibility of classifying products as "clean," "green," or "dirty" [46]. Uncertainty exists over the impact of this incident on global pollution levels. Regional differences might be the result, however. The displacement theory provides the reason for this. The "pollution haven notion" is connected to several economic and production restrictions supporting the relocation hypothesis[47,48].

Similarly, it has been shown that trade liberalization in South Africa harms the country's emissions. South Africa, Kenya, and Togo have not profited from international commerce since they have not yet achieved complete integration. Most of their exports are natural resources, whereas most of their imports are manufactured goods. Due to price volatility in critical commodities, they could not invest in clean technology since addressing core needs took precedence [49]. According to one school of thought [25], because real income, energy consumption, and carbon dioxide (CO2) emissions are interconnected, it makes sense to address them simultaneously. For instance, both the short-term and long-term values for Sub-Saharan Africa's Congo are negative, demonstrating that economic development decreases emissions [54,55]. For instance, between 1975 and 2008, the income elasticity in Mauritius grew substantially. The EKC pattern could not be validated using this method. In Mauritius, imported fossil fuels account for around 82% of total energy use. Approximately 81 percent of the nation's CO2 emissions [56] are attributed to the production of electricity and the transportation of liquid fuels. Another research used Ethiopian time series data from 1970 to 2010 to determine the country's evolution. Even though economic expansion boosts energy consumption over the medium and long term, the data indicate that CO2 emissions are decoupled from growth over the long term. As a result, Ethiopia has constructed a green economy powered by hydrodynamic and geothermal energy [57-64]. For instance, recent studies by the EKC have shown that rising wages contribute to an increase in pollution [50]; Balsalobre-Lorente et al. [51]. Since energy consumption impacts environmental quality, it is prudent to evaluate both of these factors using the same criteria to minimize the possibility of error. The BRICS nations of Pao and Tsai [52], the United Kingdom's Keppler and Mansanet-Bataller [53], India's Ghosh (2010), and China's Zhang et al. (2009) all advocate for a unified approach that takes into account the interdependencies between these factors. Nevertheless, they arrived at divergent conclusions due to variations in approach, information, and study sites. There is substantial empirical evidence for the EKC hypothesis, which predicts an inverted U-shaped relationship between income and pollution.

3. Methodology

3.1. Specification of the Model

That being the case, we defined our models as follows:

$$N_2O_{it} = f\left(TRD_{it,} Y_{it,} EI_{it,} FDI_{it,} HC_{it}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots.(1a)$$

$$CO_{2it} = f\left(TRD_{it,} Y_{it,} EI_{it,} FDI_{it,} HC_{it}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots(1b)$$

$$ACH_{4it} = f\left(TRD_{it,} Y_{it,} EI_{it,} FDI_{it,} HC_{it}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots(1c)$$

$$\ln(N_2O)_{it} = \alpha 1 + \beta_1 ln(TRD)_{it,} + \lambda_1 ln(Y)_{it} + \lambda_2 ln(EI)_{it} + \lambda_3 ln(FDI)_{it} + \lambda_4 ln(HC)_{it} + \eta_{1i} + \varepsilon_{1it} \dots\dots\dots\dots(2a)$$

$$ln(CO2)_{it} = \alpha 2 + \beta_2 ln(TRD)_{it,} + \lambda_5 ln(Y)_{it} + \lambda_6 ln(EI)_{it} + \lambda_7 ln(FDI)_{it} + \lambda_8 ln(HC)_{it} + \eta_{2i} + \varepsilon_{2it} \dots\dots\dots\dots(2b)$$

$$ln(ACH_{4it}) = \alpha 3 + \beta_3 ln(TRD)_{it,} + \lambda_9 ln(Y)_{it} + \lambda_{10} ln(EI)_{it} + \lambda_{11} ln(FDI)_{it} + \lambda_{12} ln(HC)_{it} + \eta_{3i} + \varepsilon_{3it} \dots\dots\dots\dots(2c)$$

3.2. Estimation Techniques

Following the research carried out by Ghani et al. [65], Vlastou [66], and Madsen [67], the current investigation makes use of a dynamic panel technique to address the possibility of endogeneity issues within the data. Specifically, it applies the procedures laid out by Arellano and Bover [68] and Blundell and Bond [69]. The use of the first difference transformation, which is shown by the following equation (3), results in the development of this kind of dynamic panel framework:

$$ep_{it} - ep_{i,t-i} = (\alpha - 1)ep_{i,t-1} + \beta' X_{i,t} + \eta_i + \varepsilon_{i,t} \dots\dots\dots\dots..(3)$$

$$ep_{i,t} = \alpha' ep_{i,t-1} + \beta' X_{i,t} + \eta_i + \varepsilon_{i,t} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(4)$$

Changing equation (4) into the first difference gives the equation seen below:

$$ep_{i,t} - ep_{i,t-1} = \alpha'[ep_{i,t-1} - ep_{i,t-2}] + \beta'[X_{i,t} - X_{i,t-1}] + [\varepsilon_{i,t} - \varepsilon_{i,t-1}] \dots \dots (5)$$

Last but not least, in line with the hypothesis that serves as the foundation for the EKC research, we investigate whether or not there is a connection in the form of an inverted U-shape between the growth of income per capita and the emissions of N2O, ACH4, and CO2. We could generate Equation (3) by adding the square of the increase in per capita income to Equation (2). This allowed us to: (6). We were able to assess whether or not our model supported the EKC hypothesis by applying these equations and seeing whether or not they produced the expected results. Our EKC hypothesis was formulated in the following way, in agreement with the findings of the study that Shahbaz et al. [70] conducted:

$$\ln(N_2O)_{it} = \alpha 1 + \beta_1 ln(TRD)_{it,} + \lambda_1 ln(Y)_{it} + \lambda_2 ln(Y^2)_{it}\, \lambda_3 ln(EI)_{it} + \lambda_4 ln(FDI)_{it} + \lambda_5 ln(HC)_{it} + \eta_{1i} + \varepsilon_{1it} \dots \dots \dots \dots (6a)$$

$$ln(CO2)_{it} = \alpha 2 + \beta_2 ln(TRD)_{it,} + \lambda_6 ln(Y)_{it} + \lambda_7 ln(Y^2)_{it} + \lambda_8 ln(EI)_{it} + \lambda_9 ln(FDI)_{it} + \lambda_{10} ln(HC)_{it} + \eta_{2i} + \varepsilon_{2it} \dots \dots \dots \dots (6b)$$

$$ln(ACH_{4it}) = \alpha 3 + \beta_3 ln(TRD)_{it,} + \lambda_{11} ln(Y)_{it} + \lambda_{12} ln(Y^2)_{it} + \lambda_{13} ln(EI)_{it} + \lambda_{14} ln(FDI)_{it} + \lambda_{15} ln(HC)_{it} + \eta_{3i} + \varepsilon_{3it} \dots \dots \dots \dots (6c)$$

The estimated turning points are determined by equations (7a, b and c)

$$x_1^* = \exp\left(-\frac{\lambda_1}{2\lambda_2}\right) \dots \dots \dots \dots \dots \dots \dots \dots \dots (7a)$$

$$x_2^* = \exp\left(-\frac{\lambda_6}{2\lambda_7}\right) \dots \dots \dots \dots \dots \dots \dots \dots \dots (7b)$$

$$x_3^* = \exp\left(-\frac{\lambda_{11}}{2\lambda_{12}}\right) \dots \dots \dots \dots \dots \dots \dots \dots (7c)$$

4. Analysis of results

Following the study commenced the empirical investigation with elementary analysis. Table 1 displayed the results of SHT and CDST. According to the test results, study revealed all the variables are sharing certain common dynamic and cross-sectionally dependence.

Table 1 Results of SHT, CSDT

	LM_{BP}	LM_{PS}	LM_{adj}	CD_{PS}	**Δ**	**Adj.Δ**
lnED	244.927***	41.817***	226.697***	55.022***	22.529***	81.909***
lnEC	156.336***	21.721***	229.414***	45.972***	28.097***	65.63***
lnFDFS	347.397***	21.311***	207.149***	28.976***	46.498***	146.859***
lnFDB	272.935***	18.834***	136.404***	43.652***	90.538***	124.995***
lnGLO	345.006***	39.632***	130.503***	51.272***	47.146***	95.596***
lnFDI	414.225***	29.752***	217.344***	42.377***	73.187***	120.39***
IQ	205.141***	43.883***	169.294***	52.296***	48.16***	70.77***
FD	154.123***	36.929***	152.861***	9.715***	88.531***	146.718***
TO	233.857***	42.275***	211.201***	15.24***	40.482***	72.934***
Y	173.186***	20.939***	123.557***	28.221***	88.18***	91.971***

Note. ----- implies not applicable, (*) (**) and (***) represent significance at the 10%, 5%, and 1% levels respectively.

The results of first generation panel unit root test displayed in Table -1, following LLC test, IPS test and ADF test. In terms of variables order of integration, all the variables have exposed stationary after the first difference.

Table 2 Results of FGPURT

	LLC		**IPS**		**ADF -**	
	t	**t&c**	**t**	**t&c**	**t**	**t&c**
Panel –A: Al level						
lnED	-2.269	-2.308	-0.596	-3.291	58.169	42.696
lnEC	-0.298	-1.521	-0.774	-2.563	51.452	45.384
lnFDFS	-0.012	-0.581	-1.226	-0.912	42.406	36.943
lnFDB	-2.131	-2.502	-2.631	-3.922	46.032	54.438
lnGLO	-0.259	-3.12	-1.377	-2.755	41.583	54.118
lnFDI	-3.87	-3.449	-0.031	-1.918	33.133	56.518
lnY	-0.387	-1.821	-2.696	-3.934	55.272	45.604
TO	-3.712	-3.957	-3.004	-0.905	58.542	35.043
FD	-2.259	-0.418	-0.43	-1.299	52.497	45.663
Y	-1.423	-2.356	-2.116	-2.919	48.046	32.736
Panel –B: After the first difference						
lnED	-11.943***	-20.301***	-21.326***	-10.927***	177.065***	124.361***
lnEC	-9.712***	-13.335***	-18.038***	-9.069***	195.351***	94.027***
lnFDFS	-12.127***	-16.004***	-6.578***	-9.598***	269.224***	168.59***
lnFDB	-12.097***	-16.737***	-19.548***	-8.804***	302.394***	140.186***
lnGLO	-5.514***	-6.193***	-11.548***	-9.858***	159.933***	190.167***
lnFDI	-11.55***	-22.571***	-18.454***	-9.545***	177.736***	162.319***
lnY	-8.094***	-10.834***	-16.504***	-8.441***	272.116***	128.162***
TO	-10.764***	-17.2***	-18.673***	-9.404***	107.663***	132.79***
FD	-11.895***	-9.976***	-11.316***	-6.761***	134.108***	150.8***
Y	-10.206***	-18.173***	-19.479***	-8.431***	270.24***	119.361***

Note. ----- implies not applicable, (*) (**) and (***) represent significance at the 10%, 5%, and 1% levels respectively.

Moreover, following the CDS test results, the study has investigated the stationary test by employing the PCIPS and PCADF test. The test statistics of PCIPS and CADF has reported in Table 3 and confirmed all the variable are stationary after the first difference.

Table 3 Results of PCIPS and PCADF

	CIPS		CADF	
	At level		**Δ**	
lnED	-2.326	-3.273***	-1.038	-2.317***
lnEC	-2.69	-6.276***	-1.831	-6.824***
lnFDFS	-2.936	-2.038***	-1.533	-4.567***
lnFDB	-2.458	-5.904***	-1.195	-4.435***
lnGLO	-2.023	-6.262***	-2.404	-7.845***
lnFDI	-1.084	-4.077***	-2.758	-7.787***
lnY	-1.496	-7.378***	-1.925	-7.278***
FD	-2.788	-7.865***	-2.549	-5.198***
TO	-1.702	-4.679***	-2.001	-7.87***
Y	-2.154	-7.568***	-1.939	-2.543***

Note. ----- implies not applicable, (*) (**) and (***) represent significance at the 10%, 5%, and 1% levels respectively.

The long-run association in the empirical equation has documented by employing the PCT following PPCT, KPCT, and WECBPCT. The results of PCT displayed in Table 4. As per the coefficient, it is apparent that test statistics are statistically significant at a 1% level, suggesting the rejection of null hypothesis. Alternatively established the long-run association.

Table 4 Results of PPCT, KPCT, and WECBPCT

	[1]	**[2]**	**[3]**
Panel v-Statistic	2.585	1.921	1.311
Panel rho-Statistic	-4.31	-5.451	-4.822
Panel PP-Statistic	-8.404	-10.865	-8.278
Panel ADF-Statistic	-6.473	-6.418	-3.084
Panel v-Statistic	-1.503	-1.274	-1.458
Panel rho-Statistic	-10.504	-8.168	-6.206
Panel PP-Statistic	-8.318	-7.105	-8.603
Panel ADF-Statistic	-11.403	-8.546	-6.386
Group rho-Statistic	-7.9	-8.543	-6.551
Group PP-Statistic	-11.588	-7.691	-6.942
Group ADF-Statistic	-4.975	-4.341	-2.678
ADF	-2.9726***	-1.5814***	-2.8971***
Model			
Gt	-15.287***	-10.987***	-15.017***
Ga	-12.858***	-4.754***	-5.593***
Pt	-6.559***	-8.549***	-11.344***
Pa	-9.192***	-8.046***	-11.563***

Note. ----- implies not applicable, (*) (**) and (***) represent significance at the 10%, 5%, and 1% levels respectively.

4.1. Regression Analysis results

While estimating the equations to a given level, the study applies the Hausman specification test to differentiate between the random and fixed effects models. We use the whole sample, which includes Sub-Saharan African nations. We categorize Sub-Saharan African countries into three categories—upper-Middle-Income Countries (UMIC), Lower-Middle-Income Countries (LMIC), and Low-Income Countries—to account for disparities in income levels (L.I.C.). As dependent variables, three environmental quality measures were employed. Regression is then conducted for each of the sub-economic groups for each environmental quality indicator to see whether differences in income levels across sub-regions affect the relative effects of the independent factors on the dependent variables. The regression results displayed in Table 5

Table 5 Panel Estimation Results: LNN_2O as the Dependent Variable

Variables	UMIC			LMIC			LIC		
	FE	RE	SYS	FE	RE	SYS	FE	RE	SYS
Constant	6.4919 (11.91) ***	-8.8075 (-42.03) ***	-----	8.0243 (15.40) ***	7.8931 (11.41) ***	-----	7.1147 (6.84) ***	6.7892 (6.26) ***	-----
$LNN_2O(-1)$	-----	-----	0.784065 (12.45) ***	-----	-----	11.3899 (3.71) ***	-----	-----	0.8542 (22.84) ***
LNTRD	0.0638 (2.56) **	0.3973 (81.18) ***	0.0394 (2.23) **	0.0707 (4.03) ***	0.0750 (4.30) ***	0.1222 (2.19) **	0.1242 (3.00) ***	0.1359 (3.32) ***	0.0457 (2.96) ***
LNY	-0.1726 (-2.68) ***	0.3407 (16.67) ***	-0.1034 (-1.82) *	-0.1701 (-3.043) ***	0.1695 (3.03) ***	-2.3644 (1.79) *	0.0905 (2.11) **	0.0918 (2.14) **	0.0209 (4.79) ***
LNEI	-0.2823 (-14.11) ***	1.2941 (37.84) ***	-0.0313 (-0.73)	-0.4822 (-4.62) ***	-0.4601 (-4.42) ***	-0.0523 (-0.15)	-0.1068 (-2.63) ***	-0.0817 (-0.97)	0.0946 (2.12) **
LNFDI	-0.0217 (-0.71)	-1.0295 (-38.11) ***	0.0435 (1.32)	0.0857 (2.08) **	0.0834 (2.03) **	0.2090 (0.79)	-0.1116 (-2.59) ***	-0.1120 (-2.61) ***	-0.0208 (-10.43) ***
LNHC	0.0362 (0.51)	1.7773 (58.12) ***	0.0211 (0.63)	-0.0841 (-1.72) *	-0.0848 (-1.73) *	-0.5994 (-1.80) *	-0.1554 (-3.03) ***	-0.1490 (-2.92) ***	-0.1074 (-1.75) *
No. of Obs.	168	168	162	280	280	270	448	448	416
R^2	0.9941	0.7057	-----	0.9682	0.2298	-----	0.9210	0.0712	-----
F-Statistics	2654.663 (0.000) ***	77.692 (0.000) ***	-----	576.331 (0.000) ***	16.354 (0.000) ***	-----	249.029 (0.000)	6.777 (0.000) ***	-----
Hausman Test	$Chi^2(5)$ = 7701.88(0.0000) ***		-----	$Chi^2(5)$ = 10.18(0.0703) *		-----	$Chi^2(5)$ = 4.72(0.4506)		-----
AR(2)	-----	-----	0.9889	-----	-----	0.9866	-----	-----	0.9966
Sargan Test	-----	-----	$\chi2$ = 21.22 (0.6921)	-----	-----	$\chi2$ = 24.66 (0.734)	-----	-----	$\chi2$=82.52 (0.772)

Note. The variables are expressed in log form, and t –values are reported in parenthesis (except for the Hausman test and F-statistics where probabilities are reported in parenthesis), ----- implies not applicable, (*) (**) and (***) represent significance at the 10%, 5%, and 1% levels respectively. The variables entering the Dynamic model are in first difference, and their coefficients are interpreted as growth elasticities. Both the fixed and random-effects models are in levels

Table 6 Panel Estimation Results: $LNACH_4$ as the Dependent Variable

Variables	UMIC			LMIC			LIC		
	FE	RE	SYS	FE	RE	SYS	FE	RE	SYS
Constant	6.2929 (13.33) ***	-12.695 (-69.99) ***	-----	9.2487 (16.73) ***	9.0914 (12.58) ***	-----	2.2717 (1.80) *	1.9631 (1.53)	-----
$LNACH_4$(-1)	-----	-----	6.1023 (12.94) ***	-----	-----	13.9089 (3.68) ***	-----	-----	0.8016 (8.29) ***
LNTRD	-0.0451 (-2.54) **	0.5113 (120.67) ***	0.0429 (2.42) **	0.0541 (2.9095) ***	0.0589 (3.19) ***	0.7894 (2.07) **	0.2995 (5.13) ***	0.3142 (5.48) ***	0.1212 (2.86) ***
LNY	0.3835 (21.43) ***	0.4434 (25.07) ***	-0.2089 (-3.13) ***	-0.1656 (-2.79) ***	-0.1646 (-2.77) ***	-1.3071 (-3.96) ***	-0.0032 (-0.04)	0.3477 (7.12) ***	-0.0389 (-4.98) ***
LNEI	-0.0839 (-1.33)	1.3994 (47.27) ***	-0.0602 (-0.95)	-1.1373 (-10.26) ***	-1.1084 (-10.04) ***	-0.9691 (-2.15) **	-0.0903 (-0.83)	-0.0801 (-0.7485)	-0.0939 (-0.46)
LNFDI	-0.6404 (-100.82) ***	-1.2681 (-54.22) ***	-0.0158 (-0.61)	0.1879 (4.30) ***	0.1847 (4.23) ***	0.5473 (2.02) **	-0.0231 (-0.44)	-0.3143 (-2.87) ***	-0.0312 (-4.43) ***
LNHC	0.0652 (1.07)	2.0729 (78.31) ***	0.0932 (1.48)	0.0840 (1.62)	0.0853 (1.64)	-0.6549 (-1.89) *	0.0776 (1.25)	0.0681 (1.10)	-0.0969 (-2.38) **
No. of Obs.	168	168	162	280	280	270	448	448	416
R^2	0.9972	0.6561	-----	0.9652	0.4102	-----	0.8840	0.1603	-----
F-Statistics	5654.345 (0.000) ***	61.817 (0.000) ***	-----	525.190 (0.000) ***	38.114 (0.000) ***	-----	162.730 (0.000) ***	16.876 (0.000) ***	-----
Hausman Test	19341.51(0.0000) ***		-----	12.37(0.0301) **		-----	2.83(0.7267)		-----
AR(2)	-----	-----	0.9984	-----	-----	0.9909	-----	-----	0.4166
Sargan Test	-----	-----	30.07 (0.701)	-----	-----	24.84 (0.774)	-----	-----	23.24 (0.375)

Note. The variables are expressed in log form, and t –values are reported in parenthesis (except for the Hausman test and F-statistics where probabilities are reported in parenthesis) , ----- implies not applicable, (*) (**) and (***) represent significance at the 10%, 5%, and 1% levels respectively. The variables entering the Dynamic model are in first difference, and their coefficients are interpreted as growth elasticities. Both the fixed and random-effects models are in levels

Table 7 Panel Estimation Results: $LNCO_2$ as the Dependent Variable

Variables	SSA			UMIC			LMIC			LIC		
	FE	**RE**	**SYS**	**FE**	**RE**	**SYS**	**FE**	**RE**	**SYS**	**FE**	**RE**	**SYS**
Constant	3.4127 (8.02) ***	3.1629 (6.91) ***	-----	-3.4775 (-2.09) **	-6.6102 (-10.32) ***	-----	4.0351 (7.43) ***	3.4062 (5.97) ***	-----	-1.1494 (-1.56)	-1.5133 (-2.05) **	-----
$LNCO_2(-1)$	-----	-----	0.8250 (84.37) ***	-----	-----	-1.7424 (-1.21)	-----	-----	-1.6045 (-0.48)	-----	-----	0.8035 (7.21) ***
LNTRD	0.2179 (13.74) ***	0.2266 (14.58) ***	0.0951 (28.44) ***	0.4377 (6.99) ***	0.3988 (26.66) ***	0.4585 (8.49) ***	0.1287 (7.05) ***	0.1518 (8.50) ***	0.5473 (2.02) **	0.4207 (12.37) ***	0.4328 (13.00) ***	0.0613 (6.90) ***
LNY	-0.1172 (-2.25) **	-0.1161 (-2.23) **	0.0141 (3.36) ***	-0.1326 (-2.04) **	-0.0189 (-0.30)	-0.1642 (-2.99) ***	0.1549 (2.66) ***	0.1562 (2.6836) ***	2.4000 (1.66) *	0.0693 (1.99) **	-0.0712 (-1.63)	0.1035 (1.38)
LNEI	-0.4854 (-8.55) ***	-0.4569 (-8.19) ***	-0.0073 (-0.84)	0.4139 (1.87) *	1.3089 (12.53) ***	0.2114 (1.09)	-0.2079 (-1.91) *	-0.1042 (-0.97)	-0.3954 (-0.99)	-0.5220 (-8.23) ***	-0.4836 (-7.78) ***	-0.1164 (-1.78) *
LNFDI	-0.0976 (-2.70) ***	-0.1027 (-2.84) ***	0.0376 (5.79) ***	-0.2668 (-2.86) ***	-0.6164 (-7.47) ***	-0.2964 (-3.77) ***	-0.0156 (-0.36)	-0.0304 (-0.71)	0.1168 (0.3919)	0.0358 (1.18)	0.0370 (1.22)	0.0278 (1.66) *
LNHC	-0.4374 (-14.69) ***	-0.4433 (-14.97) ***	-0.0721 (-7.26) ***	-0.9570 (-4.46) ***	-1.7219 (-18.43) ***	-0.5577 (-2.91) ***	-0.4723 (9.27) ***	-0.4641 (-9.16) ***	0.3552 (0.94)	-0.2440 (-6.73) ***	-0.2472 (-6.87) ***	-0.0627 (-2.08) **
No. of Obs.	892	892	827	168	168	162	280	280	270	448	448	416
R^2	0.9520	0.5585	-----	0.9317	0.7939	-----	0.9593	0.4538	-----	0.9295	0.7004	-----
F-Statistics	471.052 (0.000) ***	224.164 (0.000) ***	-----	214.066 (0.000) ***	124.857 (0.000) ***	-----	447.238 (0.000) ***	45.538 (0.000) ***	-----	281.283 (0.000) ***	206.675 (0.000) ***	-----
Hausman Test	$Chi^2(5)$ = 22.93(0.0003) ***		-----	$Chi^2(5)$ = 316.39(0.0000) ***		-----	$Chi^2(5)$ = 41.95(0.0000) ***		-----	$Chi^2(5)$ = 12.94(0.0239) ***		-----
AR(2)	-----	-----	0.3705	-----	-----	0.9985	-----	-----	0.9978	-----	-----	0.7923
Sargan Test	-----	-----	$\chi2$=43.01 (0.6471)	-----	-----	$\chi2$=48.32 (0.637)	-----	-----	$\chi2$ = 28.33 (0.548)	-----	-----	$\chi2$ = 20.46 (0.558)

Note. The variables are expressed in log form, and t –values are reported in parenthesis (except for the Hausman test and F-statistics where probabilities are reported in parenthesis) , ----- implies not applicable, (*) (**) and (***) represent significance at the 10%, 5%, and 1% levels respectively. The variables entering the Dynamic model are in first difference, and their coefficients are interpreted as growth elasticities. Both the fixed and random-effects models are in levels.

Tables 5, 6, and 7, the research utilizing a panel dynamic model, displays the long-term effects of trade, income per capita growth, energy intensity, FDI, and human capital on the three environmental quality measures (N2O, ACH4, and CO2) . Each nation in Sub-Saharan Africa and each of the three sub-income groups is represented in the findings of this panel regression study.

No correlation exists between the explanatory variables and the effects of S.S.A., UMIC, and LMIC by nation. It is clear from the bottom half of Tables 5 and 6 that the fixed-effects model excels above the random-effects model in levels of regression for these subgroups. However, the L.I.C. suggests that the random-effects model be chosen over the fixed-effects one. It is clear from the results of the Hausman specification tests in the bottom section of Table 7 that the fixed-effects model performs better than the random-effects model for all groups (S.S.A., UMIC, LMIC, and L.I.C.) because unobserved country-specific effects are unrelated to the explanatory variables. Sargan test findings in the bottom rows of Tables 5, 6, and 7 demonstrate that the instruments are valid in all dynamic panel regressions for the dynamic model. In conclusion, the dynamic panel regressions face no difficulty from serial correlation, as shown by testing for second-order serial correlation in the residuals.

5. Discussion

Only in LMICs is a statistically significant and positive relationship between FDI and N2O when using a model with fixed factors. Using a model with random effects, however, we uncover a statistically significant and negative association in L.I.C.s. There is a statistically significant negative relationship between the number of low-income nations and the number of low-income countries in Sub-Saharan Africa, according to the dynamic model (SSA.). For each percentage point increase in FDI, N2O emissions in S.S.A. and L.I.C. decrease by 0.3% and 0.2%, respectively. Fixed-effects and random-effects models reveal a negative and statistically significant relationship between N2O emissions and Human Capital for the whole sample of Low and Middle-Income Countries (LMICs) and Low and Middle Income Developing Countries. On the other hand, countries with a high per capita income do not have this difficulty (UMIC). Low- and middle-income nations (LMICs) and LMICs revealed a statistically significant negative relationship between N2O emissions and H.C. in the dynamic model. This occurred because N2O is a powerful greenhouse gas (LICs) . This is not anything that the UMCI would consider noteworthy. This demonstrates that in S.S.A., LMIC, and L.I.C., an increase in human capital leads to a decrease in N2O emissions but not UMIC. When human capital increases by ten percent, N2O emissions decrease by around five percent in sub-Saharan Africa, nearly six percent in LMICs, and approximately one percent in L.I.C.s.

Table 6 displays the relative impacts of trade, per capita income growth, energy intensity, foreign direct investment, and human capital on ACH4 emissions, another indicator of environmental quality. Table 6 shows that the trade variable (N.R.R.) coefficient is positive and statistically significant for S.S.A. countries, LMICs, and L.I.C.s when using the fixed/random-effects model. The specialists at UMIC, on the other hand, see this as quite concerning. Panel dynamic model research findings of the long-term effects are also included in Table 6. Agricultural commerce increases emissions of agricultural methane (ACH4) in all S.S.A. countries, as well as in UMICs, LMICs, and L.I.C.s, as shown by the currently available data. It has been estimated that a 10% increase in trade between S.S.A., UMIC, LMIC, and L.I.C. will increase ACH4 emissions by 0.2%, 0.4%, 7.9%, and 1.2%, respectively, assuming that all other parameters remain the same. Findings are consistent with those of [71]. The rising demand for meat, dairy, and other animal products might help account for the environmental damage caused by the business...

Increasing incomes per capita (Y) is associated with both rising agricultural methane emissions (ACH4) and falling atmospheric carbon dioxide concentrations (C2). According to the fixed/random-effects model findings, income inequality harms ACH4 emissions in all S.S.A. member nations and LMIC. In the UMIC and L.I.C., increasing per capita income has a considerable beneficial effect on ACH4 emissions, according to regression analysis findings. The dynamic model demonstrates that alterations in per capita income in UMICs, LMICs, and L.I.C.s negatively and significantly impact ACH4 emissions. For every 10 percent increase in per capita income, there is a corresponding drop in atmospheric ACH4 emissions of 2.1% in the UMIC, 13.7% in the LMIC, and 0.4% in the L.I.C. Developing nations are more likely to minimize their ACH4 emissions if they increase their gross domestic product (G.D.P.) . However, panel data indicate that increased per capita income greatly and positively influences ACH4 emissions in all S.S.A. countries. This shows that a 10% increase in per capita income (with all other explanatory factors held constant) results in a 0.3% rise in atmospheric ACH4 concentration.

As shown in Table 6, when examining the relationship between energy intensity (E.I.) and agricultural methane (ACH4) emissions, it can be seen that the coefficient of the E.I. variable is negative across all panels (S.S.A., UMIC, LMIC, and

L.I.C.) , although it is only statistically significant in the S.S.A. and LMIC groups. The panel dynamic model shows that the coefficient of energy intensity is negative for all four panels (S.S.A., UMIC, LMIC, and L.I.C.) , but is only statistically significant for the LMIC panel. Increasing energy intensity by 10% is predicted to decrease atmospheric ACH4 emissions by 5% for LMICs, according to the dynamic model (while holding all other control variables constant) . This trend may be explained by the increased use of solar and other renewable energy sources in farming in these countries (LMIC) . Using a fixed/random-effects model, we find that FDI and ACH4 emissions are positively and statistically significant for all S.S.A. countries and LMICs, but in a negative and statistically significant way for UMICs and L.I.C.s. The dynamic model has a negative link between all S.S.A., UMIC, and L.I.C. countries. Nevertheless, this extra level of care is only needed in Sub-Saharan Africa (S.S.A.) and the Least Developed Countries (L.D.C.s) (L.I.C.) . When FDI emissions go up by 10%, ACH4 emissions go down by the same amount in both S.S.A. and L.I.C. Any way you look at it, and this is great news for the LMIC. When FDI in LMIC goes up by 10%, ACH4 emissions also go up by 5.5%. The fixed/random-effects model reveals a negative and statistically significant association between human capital (H.C.) and ACH4 emissions across all Sub-Saharan African (S.S.A.) countries in the dataset. The importance of this finding is reduced in high-income, low-middle-income, and low-income countries (L.I.C.) . The dynamic model demonstrates statistically significant anti-clockwise relationships between ACH4 emissions and H.C. in S.S.A., LMICs, and L.I.C. The UMIC finds it to be both useful and superfluous. As a result, it seems that increasing human capital reduces ACH4 emissions at the 1%, 10%, and 5% significance levels in S.S.A., LMIC, and L.I.C., respectively. That is why for every 10% increase in human capital in S.S.A., LMICs, and L.I.C.s, emission rates of ACH4 fall by 0.5 percentage points, 6.5 percentage points, and one percentage point, respectively.

The rate of carbon dioxide production is often used as a surrogate for global environmental health. We also analyze N.R.R.'s effect on G.D.P. growth, energy usage, FDI, hc, and GHG emissions. Table 3 displays the results of the fixed-effects regression analysis, revealing that the trade variable's N.R.R. coefficient is positive and statistically significant across all panels (S.S.A., UMIC, LMIC, and L.I.C.) . There are additional findings from future research based on a panel dynamic model in Table 3. The empirical evidence presented throughout all sections supports the notion that business activity considerably increases CO2 emissions. CO2 emissions grow by 1%, 4.6%, 5.5%, and 0.6%, while commerce increases by 10% in S.S.A., UMIC, and LMIC. The findings are consistent with the work of Managi, Hibiki, and Tsurumi [32], Xu, Qamruzzaman, and Adow [60], et al. (2009) , and Frankel and Rose (2007) . (2005) . Many variables may contribute to the trade's impact on CO2 emissions, including a region's dependence on coal or fossil fuel-powered industrial activities, the preference of inhabitants for traditional energy sources (fossil fuels) , and the concentration of polluting firms in a given area.

The correlation between rising per capita income (Y) and increased CO2 emissions has shown contradictory findings. Rising per capita income worsens CO2 emissions, as shown by the total S.S.A. member states and UMIC for the fixed-effects model. As well as crucial. However, the analysis findings show that rising per capita income positively and statistically significant effects on CO2 emissions in LMICs and L.I.C.s. Rising G.D.P. has a large and detrimental effect on UMIC CO2 emissions in the dynamic model. The results show that a relative improvement in the environmental quality of 1.6% occurs for every 10% increase in per capita income. In order to lower their CO2 emissions and enhance their environmental quality, countries at these income levels should increase their economic development. This finding supports the findings of Frankel and Rose (2005) . The panel data, however, demonstrate that in Sub-Saharan African (S.S.A.) and Least Developed Country (L.D.C.) states, rising wealth per capita has a positive and sizable effect on CO2 emissions. This suggests that a 1% rise in CO2 levels in the atmosphere occurs in S.S.A. nations for every 10% increase in income per capita growth (while controlling for all other factors) . Omri [36], Aka [74], Xia et al. [75], JinRu and Qamruzzaman [76], and Fodha and Zaghdoud [77] have all found results that are consistent with these. Similar to the L.I.C., the per capita income growth coefficient is positive but not statistically significant.

In Table 7, we can see that the E.I. variable has a negative and statistically significant coefficient in the fixed-effects model for all countries in S.S.A., LMICs, and L.I.C.s, which makes sense given the strong relationship between E.I. and CO2 emissions. On the other hand, this is a good thing for UMIC. The panel dynamic model predicts a significantly negative coefficient of energy intensity only for the L.I.C. panel. The dynamic model predicts that raising energy intensity by 10% (while keeping all other parameters the same) would reduce LIC CO2 emissions to the environment by 12% [60, 78–82]. The LMIC panel only partially verified the EKC concerning CO2 emissions, while the L.I.C. panel did not confirm it. The results of our EKC experiment agreed with those of Omri [36], Qamruzzaman [39], and Li and Qamruzzaman [83]. These results indicate that environmental emissions increase when a certain level of economic growth is attained, then level off.

5.1. Implications and Conclusions

5.1.1. Implications for Policy

This research demonstrates that Sub-Saharan Africa has the same environmental impacts due to international commerce. According to the findings of the panel Dynamic model, trade increases emissions (N2O, ACH4, and CO2) for all S.S.A., UMIC, LMIC, and L.I.C. countries studied. While trade has an effect on the environment in the S.S.A. sample as a whole, it has a far greater impact on the environment in LMICs than in UMICs and L.I.C.s for the same variables (N2O, ACH4, and CO2) . In the short term, trade increases all three types of emissions in S.S.A., UMIC, and LMIC states; in L.I.C., trade increases CO2 emissions but decreases N2O and ACH4 emissions. Nevertheless, the research findings suggest that the existence of the EKC offers promise for future reductions in these emissions. The results of this research indicate that policymakers seeking to improve environmental quality should examine the trade practices of S.S.A. states. Due to the lack of clarity around the possible results of implementing stricter environmental regulations, there is a general reluctance to do so worldwide. It is necessary to implement environmental measures gradually since this may be the key to getting the intended results. Human activity is the primary cause of environmental degradation; thus, measures based on trade reforms that would enhance environmental quality must be implemented immediately. It is also feasible that environmental policies, such as encouraging green investment, may contribute to reducing emissions and improving air quality.

As shown by our findings and those of other researchers, such as Copeland and Taylor [45], Qamruzzaman [39], and Frankel and Rose [16], it will require a combination of regulations and policy approaches to simultaneously improve environmental quality and ensure the long-term viability of economic development. For instance, "green investment" was conceived to promote ecological compatibility, climate change adaptation, and economic diversity. It asks governments to account for fiscal and monetary systems when planning their budgets and to develop effective climate change measures. However, success needs cooperation from all stakeholders, not just those who stand to gain but everyone who has a stake in the result. According to EKC results, different clusters have distinct tipping thresholds, implying that environmental regulations in various nations would need to be modified to meet global development objectives shared by all nations. Thus, politicians must gradually embrace significant changes, first with trade policies and then moving on to environmental measures [3, 39, 48, 75, 84-88].

6. Conclusion

This study intends to demonstrate the link between trade and pollutant emissions (N2O, ACH4, and CO2) and other key control factors, including income per capita growth, energy intensity, foreign direct investment, and human capital. In-depth analysis was performed using data from several different Sub-Saharan African countries, stratified by income level (UMIC, LMIC, and L.I.C.) . Using the hypothesis that higher incomes are associated with lower emissions of carbon dioxide (CO2) , methane (CH4) , and nitrous oxide (N2O) , this paper investigates the existence of EKC (N2O) . To conclude, the Hausman specification tests consistently reject the null hypothesis that unobserved country-specific effects are uncorrelated with the explanatory variables, suggesting that the fixed-effects model is more appropriate for the CO2 variable than the random-effects model.

Ultimately, our findings show that the effectiveness of environmental reforms depends on major trade reform measures that promote a cleaner environment. In order to better the environment, governments should prioritize enacting trade policies that raise environmental standards. This is because poor trade policy may damage ecosystems. While our study contributes to the literature on the topic, it is crucial to note that when enacting and implementing trade agreements to reduce environmental pollution in the atmosphere while preserving real G.D.P. growth, additional macroeconomic drivers than those we employed should be taken into consideration. A broad variety of additional indicators are required to evaluate environmental quality thoroughly. To further this study in Sub-Saharan African countries, researchers may seek to account for other factors such as innovation, consumption-based commerce, urbanization, transportation, and environmental protection laws.

Compliance with ethical standards

Acknowledgments

I would like to expresses my sincere gratitude to the editorial member for appropriate guidance in publishing this manuscript.

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