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Trade Expansion, Governance and Environmental Degradation: New Evidence from Africa and Asia

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Abstract
The purpose of this study is to examine how trade expansion and governance influence the quality of our environment in selected countries in Sub-Saharan Africa and Asia where environmental poverty appears to be alarmingly high. As globalization propelled by technology and digitalization disrupt trade barriers across nations, regions, and continents, some of its consequences are the race to the bottom and pollution haven. We used panel data for 26 African and Asian countries based on Grossman and Krueger's model to regress carbon emission on trade, governance, foreign direct investment, and gross domestic product for the period 1996 to 2021 due to consistent data availability. We employed the panel autoregressive distributed lag modeling estimator to obtain the following results. First, both regions, we established that the influence of trade on environmental quality is significantly mediated by the quality of governance. Emphatically, the interactive effects of governance indicator and trade are negative and statistically significant in the long run for Africa. This result is worrisome as it justifies that Africa remains a pollution haven and her governance quality is weak. Second, in the short run, while environmental quality is adversely impacted by trading activities, governance quality appears to not matter in its interactions with trade on environmental quality. So, we concluded that the interactive role of governance in trade-environment nexus is a long run concerns as against a short run consideration.

Keywords
Trade, Governance, Environmental Degradation, Asia, Africa

1. Introduction
The linkages between international trade and environmental quality have been a subject of intense debate in scientific literature in recent years (Frutos-Bencze *et al.*, 2017; Khan *et al.*, 2020; Rahman & Vu, 2020). The wave of globalization which blew across all regions of the world has brought "Pollution Haven" and "Race to the Bottom" to the front-burner of environmental economics. For instance, several empirical and theoretical works (Shen, 2008; Asiedu *et al.*, 2021; Yameogo *et al.*, 2021; Huang *et al.*, 2022; Udeagha & Ngepah, 2022) have argued that trade expansion is strongly connected to environmental degradation. Trade expansion may influence environmental quality through the influx of technology, foreign investment inflows, and aids. It also accelerates economic performance and energy consumption, which invariably raises the level of environmental pollution (Iorember et al., 2021; Munir & Ameer, 2022). Sub-Saharan Africa and Asia are adjudged to be the two regions of the world where environmental degradation is alarmingly high (Munir & Ameer, 2022). Environmental degradation has been attributed to economic activities (trade, investment, imports, exports, deforestation, agricultural and industrial activities) which are associated with humans. Furthermore, it has not only adverse impacts on human lives (health and wealth) but also on non-humans. Sequel to the role of economic activities in the degradation of the natural environment, some scholars Yameogo *et al.* (2021) and Udeagha & Ngepah (2022) have argued that global trade expansion in recent years is a major cause of environmental degradation. Compared to other regions of the world, statistics has revealed that Africa's trade to GDP ratio grew from 48% in 2020 to 53% in 2021 and that of Asia grew from 50% to 56%, while that of the world grew from 52% to 56% within the same period (WDI, 2022). However, in terms of environmental quality, Africa and Asia countries such as India-83.2, Nepal-83.1,

Niger-80.1, Qatar-76 and Nigeria-70.4 had the highest average PM 2.5 concentration of micrograms per cubic meter of (μ/M3) in 2021 making them the most polluted regions globally (World Bank, 2020).

Environmental degradation is also viewed as an impediment to sustainable economic development goals (Shahbaz *et al.*, 2018). Sustainable economic development and low environmental degradation is a function of a country's or region's quality of governance and economic performance. Therefore, factors such as government effectiveness, rule of law, regulatory standard, voice and accountability, absence of violence and control of corruption which the indicators of governance and economic factors such as agricultural and industrial activities, import and export trade must play a critical role in the environmental and economic sustainability process of nations (Yasmeen *et al.*, 2018; Ali *et al.*, 2020). Trade expansion and governance have positive and negative impact on environmental quality (Amuakwa-Mensah & Adom, 2017; Evans & Mesagan, 2022). Consequently, studies such as Alfsen and Greaker (2007) reported the existence of "race to the bottom" theory, which posits that environmental standards are deliberately compromised by national governments to attract more cross-border investment inflows into their countries to boost economic performance. Moreover, the "race to the top" theory suggests that the national governments in emerging economies do not need to compromise environmental standards to attract cross-border investments. Rather, clean industries which enhance healthy competition are attracted to emerging economies that strengthen their governance system thereby improving their economic performance (Zhang & Zhou, 2016). Therefore, the enforcement of strict environmental regulations in an economy is a function of the nation's quality of governance. Against this backdrop, it is pertinent to examine the role of governance in the nexus between trade expansion and environmental degradation in relation to the Asian and African economies. Governance plays a critical role in the trade-environment relationship across various national economies. However, this relationship has received very little scholarly attention in the context of Africa and Asia, which are the two regions of the world that have been bedeviled with the issues of environmental degradation for decades. On this note, this present study is motivated by the quest to fill this apparent gap by investigating the linkages among trade expansion, environmental degradation and governance in the context of both regions economies. Beyond that, this also examined the interactive effects of trade expansion and governance on both regions' environmental quality.

The remaining parts of the study are outlined as follows: Section 2 presents the literature review, while section 3 covers the methodology and data. Section 4 explains the empirical results and discussion, and Section 5 concludes the study.

2. Literature Review

2.1 Theoretical Framework of EKC Hypothesis

Several studies in the environmental economics examine the validity of the environmental Kuznets curve (EKC) model, as environmental problems have grown in prominence over the last few decades. According to Grossman and Krueger (1991), the linkage between trade and environmental quality relies heavily on governance, irrespective of the size and level of development. The proponents of free trade have noted that the concept is the outcome of efficient production practices in countries participating in trade by resource allocation.

The traditional EKC theory opines that environmental degradation should be quantified in terms of CO_2 emission which is largely determined by real income. Given that real income is measured by output and energy consumption is the primary mode of sustenance, energy is suggested as the next important aspect of carbon emission that should be considered (Fakih and Marrouch, 2019; Aydogan & Vadar, 2020; Kirikkaleli et al. 2021; Sarpong et al., 2020). Grossman and Krueger (1991) developed the EKC hypothesis to explain the inverted U-shaped relationship between economic growth and environmental quality. Therefore, many studies have been conducted to empirically test the validity of the theory (Shahbaz *et al.*, 2013; Chandran & Tang, 2013; Al-Mulali, 2015; Heidari *et al.*, 2015; Ahad and Khan, 2016; Le & Quah, 2018; Aslan *et al.*, 2018; Fakih and Marrouch, 2019; Aydogan & Vadar, 2020; Kirikkaleli et al. 2021; Sarpong et al. 2020; Nwani, 2023). Most of these empirical studies adopted the EKC framework to assess the link between economic growth and environmental quality, implying a relationship between economic advancement and environmental conservation, while ecological deterioration is an increasing feature of economic growth until a critical threshold is reached, after which higher earnings rates contribute to a decline in environmental degradation.

2.2 Trade and Environmental Quality Nexus

In the economic and management literature, several studies have been conducted to interrogate the linkages between trade expansion and environmental quality. However, their results remain mixed and inclusive. For instance, Boulatoff and Jenkins (2010) found evidence of a negative long-term relationship between trade and oil-related carbon emissions across different income groups of countries. The study suggests that an increase in trade liberalization leads to a decline in environmental pollution due to improved technology occasioned by free trade. Atici (2012) examined the interaction between trade and environment among ASEAN countries by adopting panel data from 1970 to 2006. The results show that CO2 emissions exhibit an inverted S-shaped curve in this region. In particular, exports play a crucial role in CO2 emissions in ASEAN countries. The findings show no evidence that FDI has a positive impact on environmental quality. Furthermore, the imports of Japan from the region probably do not cause pollution, while the imports of China can encourage pollution per capita. Akin (2014) used data from 85 nations across the globe to examine the impact of trade liberalization and energy consumption on environmental quality and revealed that trade liberalization causes a decline in

environmental degradation in the long-run. Similarly, Shahbaz *et al.* (2014) posited that trade openness has a positive impact on Tunisia's environmental quality. It is suggested that environmental fallouts of trade expansion differ as a result of compositional, technique, and scale effects. Mavragani *et al.* (2016) examined the effects of global trade expansion and governance on environmental quality in 75 European economies and G20 nations. The study revealed that environmental quality improved as governance indicators improved. Li *et al.* (2015) explored the nexus between trade and environmental degradation in 134 economies from 1961 to 2004. The result indicates an inverse relationship between trade and environmental quality.

In contrast, Shahbaz *et al.* (2016) explored the association among trade openness, environmental pollution and economic performance using data in 105 nations. The study provides evidence that trade openness reduces environmental quality among countries, but the impact varies widely according to each group of countries.

Solarin et al. (2017) investigated the relationship between trade liberalization, governance and environmental quality from 1980 to 2012. The study revealed that trade liberalization positively impacted environmental quality while governance adversely affected environmental quality. Baliamoune-Lutz (2017) studied the effects of trade, governance and environmental quality in Africa from 1990 to 2008. The findings from the generalized moments of methods (GMM) approach indicate that exert a negative impact on environmental quality. Also, Huag and Ucal (2019) investigated the relationship among trade, foreign direct investment (FDI) and environmental degradation in Turkey. The study used annual time series data from 1974 to 2014 and the new auto-regressive distributed lag (NARDL) as its analytical technique. The result shows that FDI and urbanization raised the level of environmental degradation. In addition, FDI and trade liberalization reduces environmental quality.

In summary, after the empirical examination of the nexus between trade and environmental degradation, it is revealed that the findings are mixed. Therefore, hypothesis one is proposed to test the relationship between trade and environmental degradation.

Hypothesis 1: Trade has no significant relationship with environmental degradation.

2.3 Governance and Environmental Degradation Nexus

The literature on environmental degradation has grown tremendously in recent years, but little attention has been paid to examine environmental degradation as induced by governance framework. For instance, Gani (2012) assessed the interaction between governance indicators such as political stability and control of corruption can be critical determinants of environmental regulations. The study confirmed that the governance indicators contribute significantly to the decline in Co2 emission per capita. Hosseini and Kaneko (2013) examined the impact of governance on environmental degradation using data from 129 countries from 1980 to 2007. The study revealed that environmental quality is determined by the quality of governance across the world. Amuakwa-Mensah and Adom (2017) examined the association between governance and environmental quality from 1990 to 2010. The findings from the 43 Sub-Sahara African nations revealed that the quality of governance plays a critical role in reducing environmental degradation in the region. Eregha and Mesegan (2016) studied the relationship between governance and environmental quality in oil-producing African countries. The study reported that weak governance proxied by institutional quality is a major cause of environmental degradation in those countries. Egbetokun *et al.* (2018) explored the role of governance in attaining the Environmental Kuznets Curve (EKC) in Southern and Northern Africa from 1996 to 2015 using the Generalized method of moments (GMM) approach. The study revealed that none of the regions achieved the EKC target based on the three indicators of environmental quality employed in the study. However, the quality of governance had no impact on environmental quality in both regions. Ali *et al.* (2020) examined the relationship between governance and environmental degradation in a panel of 47 emerging economies from 1990 to 2012. The result shows that the quality of governance improves environmental quality and also added that trade expansion and economic growth raises the level of environmental degradation. Adekunle (2021) explored the role of governance on environmental sustainability in Africa using the dynamic system generalized method of moment (DSGMM) estimator from 1996 to 2017. The study revealed a positive association between regulatory quality and rule of law and environmental sustainability. However, it also reported an inverse relationship between government effectiveness and environmental sustainability.

In contrast, Samimi *et al.* (2012) examined the impact of good governance on the environmental quality of 21 Middle-East and North Africa (MENA) countries for the period 2002 to 2007. The study used the generalized moments of method (GMM) analytical technique and the result indicates that governance has a negative impact on the environmental quality of MENA countries. Similarly, Halkos and Tzeremes (2013) posited that there is a non-monotonic relationship between governance quality and environmental degradation in different countries. Their result revealed that good governance does not always contribute to the reduction of environmental degradation. Also, Sowman and Wynberg (2014) in their grand findings on governance for justice and environmental sustainability in sub-Saharan Africa natural resource sector contended that institutional bureaucracy and administrative bottlenecks are the most critical challenges to the attainment of environmental sustainability in SSA. In their study, Asongu and Odhiambo (2020) assessed the role of governance on environmental sustainability in sub-Saharan Africa. The study found that political governance is positively related to environmental quality, while institutional governance is negatively related to environmental quality.

Stemming from the empirical examination of the relationship between governance and environmental degradation, hypothesis two is stated below.

Hypothesis 2: Governance has no significant relationship with environmental degradation.

2.4 Economic Growth and Environmental Degradation Nexus

The linkages between economic growth and environmental degradation have gained the attention of researchers and policymakers in the past five decades. A plethora of the studies (Shahbaz *et al.*, 2013; Chandran & Tang, 2013; Al-Mulali, 2015; Heidari *et al.*, 2015; Ahad and Khan, 2016; Le & Quah, 2018; Aslan *et al.*, 2018; Fakih and Marrouch, 2019; Aydogan & Vadar, 2020) focused on examining the validity of the Environmental Kuznets Curve hypothesis, which illustrates an inverted U-shaped nexus between CO_2 emission and per capita income. For instance, Fodha and Zaghoud (2010) assessed the association between economic growth and environmental degradation in Tunisia from 1961 to 2004. The study reported the existence of a long-run cointegration relationship between per capita Co2 and So2 emissions and per capita GDP. It also revealed the presence of an inverted U-shaped linkage between CO_2 and SO_2 emissions and GDP. Similarly, Shahbaz *et al.* (2013) examined the relationship between economic growth and environmental degradation in Indonesia using quarterly data from 1975 to 2011. The result indicates that rising economic growth led to a decline in environmental degradation in the long-run. Ahad and Khan (2016) used the auto-regressive distributed lag (ARDL) approach to assess the relationship between energy use, economic growth and environmental degradation in Bangladesh from 1972 to 2015. The study reported the existence of a positive association between energy use and environmental degradation, while economic growth had a positive impact on environmental quality. Le and Quah (2018) explored the environment-growth relationship for 14 economies in the Asia-Pacific region from 1984 to 2012. The study confirmed the validity of the EKC model for high-income economies like South-Korea and Hong-Kong but not for the middle-income and low-income economies in the region. Aslan *et al.* (2018) used a bootstrap rolling window estimation of the vector autoregressive technique to examine the nexus between economic growth and environmental degradation in the USA from 1966 to 2013. The study revealed that the impact of economic growth on environmental degradation rose between 1982 and 1996, but declined from 1996 to 2013. Aydogan and Vadar (2020) analysed the nexus between economic growth, Co2 emissions, agricultural value added and energy consumption in E7 economies from 1990 to 2014. The study indicated the presence of an inverted U-shaped EKC model in the long-run and bidirectional causality between Co2 emissions and non-renewable energy consumption.

On the other hand, other studies have found contrasting evidence about the relationship between economic growth and environmental degradation and the EKC model. For instance, Chandran and Tang (2013) investigated the impact of economic growth on Co2 emissions for five ASEAN economies using the Johansen cointegration test within the VECM framework. The result of the bidirectional test found a bi-causal linkage between economic growth and Co2 emissions in the long-run. Moreover, it revealed that unidirectional causality run from economic growth to Co2 emission in the short-run, although the study failed to confirm the existence of EKC hypothesis. Also, Al-Mulali (2015) utilised the ARDL technique to assess the causal relationship between economic growth and Co2 emissions in Vietnam from 1981 to 2011. The study found that economic growth is positively linked to Co2 emission in the short-run and long-run implying the rejection of the EKC hypothesis in the country. Heidari *et al.* (2015) also rejected the existence of a linear relationship between energy consumption, CO2 emissions, and economic growth in five ASEAN economies. The study suggests the existence of a non-linear relationship among the variables; however, it did not confirm the existence of the EKC model. Fakih and Marrouch (2019) employed a non-parametric framework to analyse the nexus between CO2 emissions and economic activity in the Middle-East and North Africa from 1980 to 2010. The study confirmed the nonexistence of the EKC hypothesis in the region. Koc and Bulus (2020) studied the causality relationship among economic growth, energy consumption, trade openness, and CO2 emissions for the Korean economy over the period of 1971–2017. The empirical results do not support the EKC hypothesis.

Following the conflicting evidence observed in the economic growth-environment literature, hypothesis three is proposed to test the relationship between economic growth and environmental degradation.

Hypothesis 3: Economic growth has no significant impact on environmental degradation.

In summary, most of the extant studies either examined the direct link between trade and environment, economic and environmental quality, or governance and environmental quality in country-specific or multi-country analysis. However, to the best of our knowledge, none of the previous studies leaped further to explore the interactive effects of trade expansion and governance on the economic and environmental sustainability of African and Asian economies in the economic literature.

3. Data and Methods

3.1 Data Sources

As depicted on table 1 below, the data on environmental degradation was proxied as C02 emission (metric tons per capita), foreign direct investment (FDI) is net FDI inflow as a percentage of GDP, and the data on GDP is real GDP annual growth rate. The data on energy consumption is represented as energy consumption per capita measured in kg of oil equivalent per capita. While the data on trade expansion was proxied as trade open-ness (the sum of export and import as a % of Gross Domestic Product (GDP). All these date where obtained from World Bank database, World Development Indicators. However, the data on governance, which is regulatory quality reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development was obtained from the database of the world governance indicators (WGI). The study period covers from 1996 to 2021 for both African and Asian countries namely Niger, Nigeria, Egypt, Mauritania, Cameroon, Central African

Republic, Somalia, Burkina Faso, South Africa, Chad Rep, Bangladesh, Pakistan, China, India, Nepal, Qatar, Bahrain, Iraq, Oman, Tajikistan, Bangladesh, India, the Maldives, Nepal, Pakistan and Sri Lanka.

Table 1 Description of Variables and Sources

Variables	Definition	Sources
CO2	CO2 Emission (metric tons per capita)	World Development Indicator (2021)
FDI	Foreign direct investment, net inflows (% of GDP)	World Development Indicator (2021)
GOV	Regulatory Quality	World Governance Indicator (2021)
RGDP	GDP growth (annual %)	World Development Indicator (2021)
ENG	Energy consumption per capita measured in kg of oil equivalent per capita	World Development Indicator (2021)
TOP	Trade openness (the sum of export and import as a % of Gross Domestic Product GDP)	World Development Indicator (2021)

The measurement and definition of the variables are illustrated in Table 1. The panel datasets were obtained from the World Development Indicators (WDI) and World Governance Indicators (WGI).

3.2 Model Specification

The model is based on the Grossman and Krueger's (1995) Environmental Kuznets Curve (EKC) model adapted from recent studies (Alshubiri and Elheddad, 2019; Doytch and Uctum, 2016 Iheanachor *et al.*, 2023). Thus, the model is specified in the form of panel regression model in which carbon emission is expressed as a function of energy consumption, trade expansion, GDP, FDI and governance.

The model is implicitly expressed as follows:

$$\boldsymbol{CO_{2t} = f(Energy_{it}, Openness_{it}, GDP_{it}, FDI_{it}, Governance_{it})} \ \ldots\ldots\ldots (\mathbf{3.1})$$

The econometric form of the models is stated as:

$$\boldsymbol{lAfricaCO_{2t} = \gamma_1 + \gamma_2 lEnergy\_africa_t + \gamma_3 lOpenness\_africa_t + \gamma_4 lGDP\_africa_t + \gamma_5 lFDI\_africa_t + \gamma_6 lGovernance\_africa_t + \mu_t} \ \ldots\ldots\ldots \mathbf{(3.2)}$$

Equation 3.3 below shows the interacting effect of governance with trade expansion

$$\boldsymbol{lAsiaCO_{2t} = \gamma_1 + \gamma_2 lEnergy\_asia_t + \gamma_3 lOpenness\_asia_t + + \gamma_4 lGDP\_asia_t + \gamma_5 lFDI\_asia_t + \gamma_6 lGovernance\_asia_t + \gamma_7 (openness * governance) + \mu_t} \ \ldots\ldots\ldots \mathbf{(3.3)}$$

The autoregressive Distributed Lag (ARDL) technique by Pesaran *et al.* (1999) and Pesaran *et al.* (2001) is employed to investigate the short run and long-run dynamics among the variables. ARDL is preferred to the traditional cointegration technique given its flexibility, provision of unbiased for long run relationship and long-run parameters and its capability to adequately address autocorrelation and endogeneity problems (see Rahman & Kashem, 2017). Our ARDL model is specified as:

$$\boldsymbol{\Delta AfricaCO_{2t} = \beta + \sum_{i=1}^{n} \theta_1 \Delta AfricaCO_{2t-1} + \sum_{i=1}^{n} \theta_2 \Delta Energy_{t-1} + \sum_{i=1}^{n} \theta_3 \Delta Openness_{t-1} + \sum_{i=1}^{n} \theta_4 \Delta GDP\_africa_{t-1} + \sum_{i=1}^{n} \theta_5 \Delta lFDI\_africa_{t-1} + \sum_{i=1}^{n} \theta_5 lGovernance\_africa_{t-1} + \delta_1 CO_{2t-1} + \delta_2 Energy_{t-1} + \delta_3 Openness_{t-1} + \delta_4 GDP\_africa_{t-1} + \delta_5 FDI\_africa_{t-1} + \delta_6 Governance\_africa_{t-1} + \varepsilon_t} \ \ldots\ldots\ldots \mathbf{(3.4)}$$

In eq. (3.4), the short-run effects are captured by the estimates assigned to the first-differenced variables and long-run effects are represented by the estimates of $\delta_2 - \delta_6$ normalized on δ_1. According to Pesaran et al. (2001), the $F - test$ is applied to examine the existence of a long run relationship and joint significance of the lagged variable. The hypotheses are stated as:

$$\boldsymbol{H_0: \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0}$$
$$\boldsymbol{H_1: \delta_0 \neq 0;\ \delta_1 \neq 0;\ \delta_2 \neq 0;\ \delta_3 \neq 0;\ \delta_4 \neq 0;\ \delta_5 \neq 0;\ \delta_6 \neq 0}$$

4. Data Analysis and Results

4.1 Descriptive Analysis

This sub-section provides the summary statistics of the variables being examined, such as carbon emission (CO_2), net foreign direct investment (*FDI*), net foreign assets (*NFA*), real GDP per capita (*GDPC*), energy usage (*ENG*) and trade openness (*TOP*).

Table 2 Descriptive Statistics

Variables	Mean	Std.	Min.	Max.	Skew.	Kurtosis	JB
lCO_2_africa	11.20	0.18	10.89	11.43	-0.43	1.77	2.24
lCO_2_asia	14.26	0.45	13.58	14.81	-0.31	1.50	2.63
$lEnergy\_africa$	0.05	0.17	-0.23	0.28	-0.27	0.28	2.18
$lEnergy\_asia$	2.90	0.38	2.31	3.46	-0.07	1.58	2.03
$lGDP\_africa$	1.27	0.88	-2.30	2.11	-3.27	14.44	173.65
$lGDP\_asia$	1.78	0.15	1.36	2.01	-0.65	3.62	2.07
$lopennessa\_frica$	4.02	0.06	3.90	4.10	-0.20	2.22	0.75
$lopenness\_asia$	3.68	0.11	3.54	3.85	0.13	1.40	2.51
$lFDI\_africa$	0.88	0.65	-0.64	1.88	-0.72	2.71	2.18
lFD_Iasia	0.29	0.26	-0.06	0.88	0.66	2.64	1.88
$lGova\_frica$	-0.62	0.12	-0.80	-0.37	0.12	2.47	0.33
$lGov\_asia$	-0.55	0.13	-0.70	-0.16	1.98	6.70	28.11

Source: Authors' computation

Table 2 presents the descriptive statistics of variables employed in the study. The mean values show that the rate of carbon (CO_2) emission in Asia is higher than in Africa. This implies higher rate of environmental degradation in Asia compared to Africa. The standard deviation indicates higher variability of CO_2 emission in Asia than in Africa. Similarly, the mean values of energy consumed are higher in Asia than Africa, implying higher intensity energy consumption in Asia. Further, the standard deviation value suggests higher variability of energy consumption in Asia than in Africa. The mean values also show that output (GDP) in Asia is higher than GDP in Africa, indicating more growth in Asia than Africa. However, GDP seems to be more volatile in Africa than Asia, going by the values for standard deviations. But the mean values of trade openness show that Africa is more open to trade than Asia. Similarly, the mean values show that Africa received more FDI than Asia. Last, the mean values indicate that governance quality in Asia is higher than Africa, implying better institutional quality in Asia than Africa.

Table 3 Correlation Matrix Table for Africa

Variables	lCO_2	$lEnergy$	$lopen$	$lGDP$	$lFDI$	Gov
lCO_2	1					
$lEnergy$	0.99** (0.00)	1				
$lopen$	0.472** (0.02)	0.448** (0.03)	1			
$lGDP$	-0.143 (0.15)	-0.186 (0.396)	0.094 (0.669)	1		
$lFDI$	0.514** (0.01)	0.459** (0.028)	0.521** (0.011)	0.001 (0.996)	1	
$Gova$	-0.48** (0.02)	-0.517** (0.012)	0.03 (0.89)	0.364 (0.089)	-0.115 (0.604)	1

Source: Authors' computation

Note: ****, ** and * denote statistical significance at 1%, 5% and 10% respectively*

Table 3 presents the correlation coefficients for Africa and Asia respectively. In Table 3, the estimates show that carbon emission is positively and significantly correlated with energy, trade openness, and FDI. This implies that energy, trade openness and FDI contribute positively to CO_2 emission in Africa. Further, the estimates show that CO_2 emission is negatively and significantly correlated with governance. This implies that governance quality decreases the rate of CO_2 emission. Last, the results show that the correlation between CO_2 emission and GDP is negative and insignificant.

Table 4 Correlation matrix for Asia

Variables	lCO_2	$lEnergy$	$lopen$	$lGDP$	$lFDI$	Gov
lCO_2	1					
$lEnergy$	0.998** (0.00)	1				
$lopen$	0.573** (0.004)	0.542 (0.008)	1			
$lGDP$	0.337 (0.115)	0.34 (0.113)	0.339 (0.114)	1		
$lFDI$	0.113 (0.607)	0.082 (0.709)	0.76** (0.000)	0.18 (0.411)	1	
$Gova$	0.335 (0.118)	0.354 (0.097)	-0.071 (0.748)	0.247 (0.256)	-0.229 (0.293)	1

Source: Authors' computation

Note: ****, ** and * denote statistical significance at 1%, 5% and 10% respectively*

In Table 4, the results show that carbon emission is positively and significantly correlated with energy and trade openness, but has positive and insignificant relations with other variables. This implies that energy and trade openness positively contribute to CO_2 emission in Asia.

4.2 Presentation of Results

The ARDL bound tests are reported in Table 5. The computed $F-Stat$ is far greater than the upper critical bound value at all significant levels once carbon emission is used as the independent variable. This indicates the presence of cointegration between the variables over the sample period.

Table 5 Bound Test Result

Critical values	Pesaran			
	Africa		Asia	
	Lower $I(0)$	Upper $I(1)$	Lower $I(0)$	Upper $I(1)$
1%	3.06	4.15	3.06	4.15
5%	2.39	3.38	2.39	3.38
10%	2.03	3.00	2.08	3.0
$F-Stat$	**20.201**		**11.46**	

Source: Authors' computation

The estimates for short and long-run dynamics are provided in Table 6 and 7 respectively. The estimates for Africa show that energy consumption has significant positive effects on CO_2 emission both in the short and long run. A one percent change in energy consumption induces 3.7 percent and 1.1 percent rise in CO_2 emission in the short and long run, respectively. This is similar to the findings by Rahman and Abul Kashem (2017). Further, the estimates indicate that trade openness has an insignificant negative effect on CO_2 emission in the short run but a significant positive effect in the long run. A one percent change in openness causes 0.358 percent rise in CO_2 emission in the long-run. The positive effect in the long run is similar to the conclusion by Shahzad *et al*. (2017). In line with the theory, a rise in the GDP causes an increase in CO_2 in both the short run and long run. Moreover, FDI has insignificant effects on CO_2 emissions in both the short and long run. Last, our estimates show that governance has insignificant positive effects in the short run and insignificant negative effect in the long run.

For Asian countries, the results reveal that energy consumption has significant positive effects on CO_2 emission both in the short and long run. A one percent change in energy consumption induces 5.19 percent and a 9.72 percent rise in CO_2 emission in the short and long-run, respectively. Further, the results show that trade open-ness has an insignificant negative effect on CO_2 emission in the short run but a significant positive effect in the long run. The results indicate GDP has insignificant effects on CO_2 in both the short run and long run. Moreover, the estimates show FDI has significant short-run effects on CO_2 emissions in the short but insignificant negative effects in the long run. Last, our estimates show that governance has significant positive effects in the short run and long run.

Table 6 Short-run estimate: Dependent variable: $\Delta lnCO_2$

Ind. Variables	Africa			Asia		
	Coeff.	Std. error	t-ratio	Coeff,	Std. error	t-ratio
$\Delta lenergy$	3.774*	0.463	8.16	0.519**	0.126	4.135
$\Delta lenergy(-1)$	-1.82*	0.244	-7.443	-0.271*	0.122	-2.221
$\Delta lopenness$	-0.101	0.028	-3.653	-0.039	0.072	-0.556
$\Delta lopenness(-1)$	-0.679*	0.01	-6.794	-0.062	0.071	-0.871
$\Delta lgdp$	0.071*	0.009	7.662	-0.003	0.016	-0.022
$\Delta lgdp(-)$	-0.018	0.003	-6.078	---	---	---
$\Delta lFDI$	-0.189	0.033	-5.681	-0.065*	0.029	-2.263
$\Delta lFDI(-1)$	0.165	0.029	5.705	-0.04*	0.02	-2.011
$\Delta Governance$	0.281	0.041	6.884	0.042*	0.018	2.459
$\Delta Governance(-1)$	0.175	0.03	5.907	-0.049	0.023	-1.752
ECM	-2.89	0.092	-31.46	-1.119	0.058	-19.245

Source: Authors' computation

Note: ****, ** and * denote statistical significance at 1%, 5% and 10% respectively*

Table 7 Long run estimates: Dependent variable: $lnCO_2$

Ind. Variables	Africa			Asia		
	Coeff.	Std. error	t-ratio	Coeff.	Std. error	t-ratio
$lenergy$	1.106**	0.01	111.69	0.972***	0.023	42.51
$lopen$	0.358*	0.049	7.284	0.265**	0.099	2.674
$lgdp$	0.046*	0.005	9.678	0.044	0.029	1.517
$lFDI$	-0.071	0.013	-5.669	-0.04	0.028	-1.45
$governance$	-0.133	0.024	-5.569	0.245**	0.053	4.649
$Constant$	9.619***	0.209	46.01	3.563***	0.293	12.171

R^2	0.99	0.99
Adj. R^2	0.99	0.98
$F-stat$	1871.94	424.56
χ^2_{sec}	0.46	0.43
χ^2_R	0.43	0.29
χ^2_N	0.54	0.28
χ^2_H	0.29	0.42

Source: Authors' computation
Note: ****, ** and * denote statistical significance at 1%, 5% and 10% respectively*

Table 6(a) and 6(b) presents the results on interaction of governance with trade expansion. This is to evaluate the whether governance influences the effects of trade on CO_2 emission. The results for Africa revealed that trade negative coefficient of -0.101 in the first estimation without the interactive variable increased to 0.119 in the second estimation with interacting effects of governance. This implies a positive emission effect of 0.018% from the interaction of the governance variable with trade (Openness * Governance). The positive CO_2 emission interactive effect value is the difference between the initial impact of trade on carbon emission without interaction and the new impact of governance on CO_2 emission with governance interaction. Thus, governance plays no vital interactive role in the effect of trade on CO_2 emission in African countries in the short-run. Further, the results for Asia revealed that trade negative coefficient of -0.039 in the first estimation without the interactive variable reduced to -0.011 in the second estimation with interacting effects of governance. The result indicates a positive emission effect of 0.018% from the interaction of the governance variable with trade (Openness * Governance). The positive CO_2 emission interactive effect value is the difference between the initial impact of trade openness on carbon emission without interaction and the new impact of governance on CO_2 emission with governance interaction. Thus, governance plays no vital interactive role in the effect of trade on CO_2 emission in Asian countries in the short-run.

Regarding the long run, the results for Africa revealed that trade positive coefficient of 0.358 in the first estimation without the interactive variable reduced to -0.256 in the second estimation with interacting effects of governance. This implies a negative emission effect of -0.614% from the interaction of the governance variable with trade (Openness * Governance). The negative CO_2 emission interactive effect value is the difference between the initial impact of trade on carbon emission without interaction and the new impact of governance on CO_2 emission with governance interaction. Thus, governance plays a vital interactive role in the effect of trade on CO_2 emission in African countries in the long run. Moreover, the estimates for Asia revealed that trade positive coefficient of 0.265 in the first estimation without the interactive variable reduced to 0.199 in the second estimation with interacting effects of governance. The result implies a negative emission effect of -0.066% from the interaction of the governance variable with trade (Openness * Governance). The negative CO_2 emission interactive effect value is the difference between the initial impact of trade openness on carbon emission without interaction and the new impact of governance on CO_2 emission with governance interaction. Thus, governance plays a vital interactive role in the effect of trade on CO_2 emission in Asia countries in the long run.

Generally, the estimates suggest that governance plays no vital role in the effects of trade on CO_2emissions in African and Asian countries in the short run. The results, however, indicate that governance plays a vital role on the effects of trade on CO_2emissions in African and Asian countries in the long run.

Table 8 Short run estimate: Dependent variable: $\Delta lnCO_2$

Ind. Variables	Africa			Asia		
	Coeff.	Std. error	t-ratio	Coeff.	Std. error	t-ratio
$\Delta lenergy$	1.804**	0.044	41.459	0.443**	0.029	15.28
$\Delta lenergy(-1)$	0.429*	0.0351	12.226	-0.377*	0.03	12.562
$\Delta lopenness$	0.119	0.069	1.725	-0.011	0.017	-0.641
$\Delta lopenness(-1)$	.1.531*	0.055	-27.883	-0.143*	0.018	-8.012
$\Delta lgdp$	-0.002	0.001	-4.144	0.007	0.033	0.198
$\Delta lgdp(-)$	0.012*	0.001	14.657	-0.221*	0.031	-7.019
$\Delta lFDI$	0.003	0.001	2.967	-0.062*	0.008	-7.391
$\Delta lFDI(-1)$	0.012*	0.002	7.982	-0.043*	0.005	-8.291
$\Delta Governance$	-2.009	0.429	-4.681	0.048*	0.004	12.807
$\Delta Governance(-1)$	9.128	0.35	26.065	-0.079	0.006	-13.873
$\Delta Trade\_Governance$	0.522	0.107	4.898	0.011*	0.002	6.947

Source: Authors' computation
Note: ****, ** and * denote statistical significance at 1%, 5% and 10% respectively*

Table 9 Long run estimate: Dependent variable: $\Delta lnCO_2$

Ind. Variables	Coeff.	Std error	t-ratio	Coeff.	Std error	t-ratio
$lenergy$	1.154**	0.008	136.48	0.981***	0.005	205.31
$lopen$	-0.256	0.101	-2.54	0.199*	0.019	10.30
$lgdp$	-0.028**	0.002	-18.204	0.419*	0.038	11.058
$lFDI$	0.02**	0.001	17.97	0.006	0.007	0.877
$governance$	-0.245	0.546	-0.448	0.194	0.01	20.31
$Trade\_Governance$	0.128	0.133	0.959	-0.017**	0.059	-9.238
$Constant$	12.334	0.412	29.934	3.417	0.059	57.815

Source: Authors' computation

Note: ****, ** and * denote statistical significance at 1%, 5% and 10% respectively*

Given the statistical significance of trade on CO_2 emission in the long run, we reject the null hypothesis that trade has no significant relationship with environmental degradation. This indicates that trade influences environmental degradation in African countries. Based on the statistical non-significance of governance on CO_2 emission, we cannot reject the null hypothesis that governance has no significant relationship with environmental degradation in Africa. This indicates that governance does not influence environmental degradation in African countries. Last, given the statistical significance of growth on CO_2 emission, we reject the null hypothesis that growth has no significant relationship with environmental degradation. This indicates that growth influences environmental degradation in African countries.

For Asian countries, the estimates show statistical significance of trade on CO_2 emission in the long run, hence; we reject the null hypothesis that trade has no significant relationship with environmental degradation. This indicates that trade influences environmental degradation in Asian countries. Based on the statistical significance of governance on CO_2 emission, we reject the null hypothesis that governance has no significant relationship with environmental degradation in Asia. This indicates that governance influences environmental quality in Asian countries. Last, given the non-statistical significance of growth on CO_2 emission, we cannot reject the null hypothesis that growth has no significant relationship with environmental degradation in Asia. This indicates that growth does not influence environmental degradation in African countries.

4.3 Diagnostic Test for Africa Results

We applied the cumulative sum of recursive (CUSUM) and CUSUM squared residuals to examine the long-run stability test for the ARDL model. Fig.1 is the CUSUM and fig. 2 is the CUSUM squared of residual. Both the plots indicate that the plot of the residuals lies within two pairs of straight lines (drawn at the 5% level) that are; the plots of both the CUSUM and CUSUMSQ are within the boundaries. Therefore, these estimates confirm the model stability and that there is no systematic change identified in the coefficients at 5% significance level over the study period.

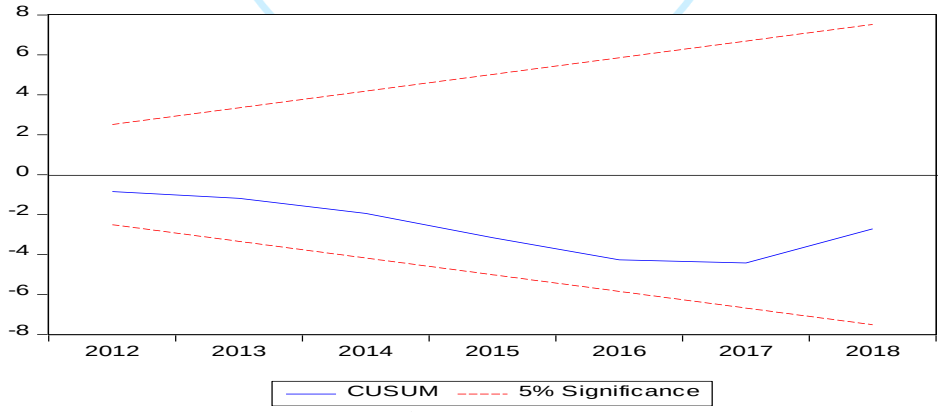

Fig. 1 CUSUM

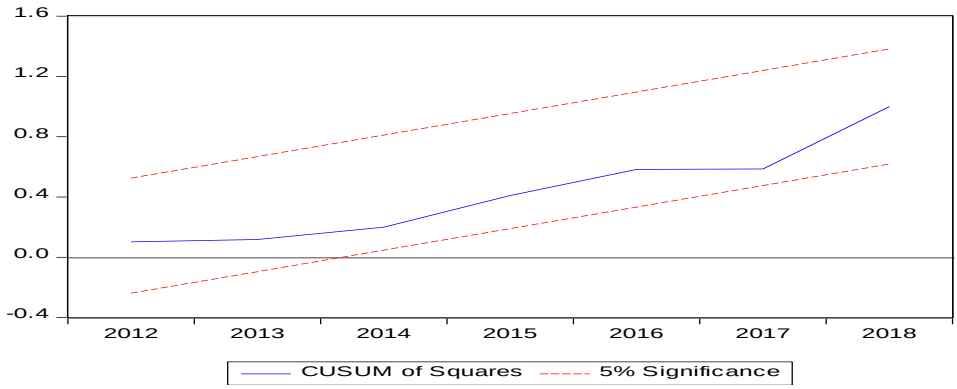

Fig. 2 CUSUM Squared

4.4 Diagnostic test for Asia results

We applied the cumulative sum of recursive (CUSUM) and CUSUM squared residuals to examine the long-run stability test for the ARDL model. Fig.3 is the CUSUM and fig. 4 is the CUSUM squared of residual. Both the plots indicate that the plot of the residuals lies within two pairs of straight lines (drawn at the 5% level) that is, the plots of both the CUSUM and CUSUMSQ are within the boundaries. Therefore, these estimates confirm the model stability and that there is no systematic change identified in the coefficients at 5% significance level over the study period.

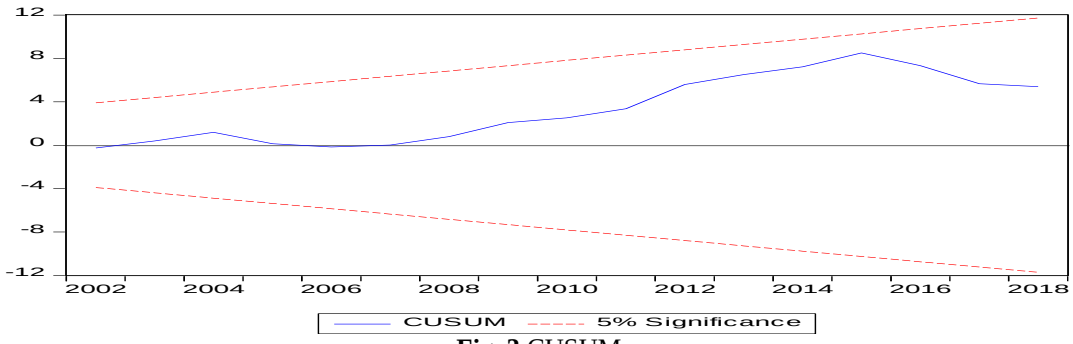

Fig. 3 CUSUM

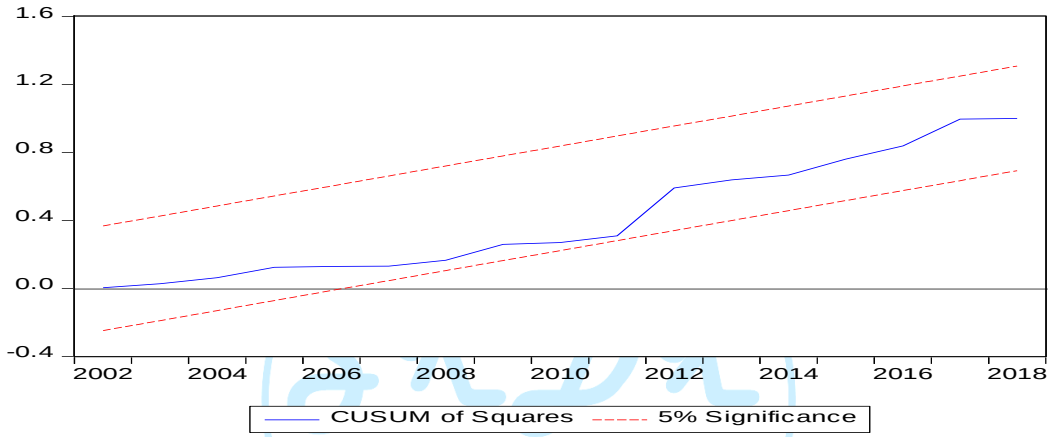

Fig. 4 CUSUM Squared

5. Discussion of findings

The estimates for Africa show that energy consumption has significant positive effects on CO_2 emission both in the short and long run. A one percent change in energy consumption induces 3.7 percent and 1.1 percent rise in CO_2 emission in the short and long run, respectively. This is similar to the findings by Rahman and Kashem (2017). Further, the estimates indicate that trade openness has an insignificant negative effect on CO_2 emission in the short run but a significant positive effect in the long run. A one percent change in openness causes 0.358 percent rise in CO_2 emission in the long run. The positive effect in the long run is similar to the conclusion by Shahzad *et al*. (2017). In line with the theory, a rise in the GDP causes an increase in CO_2 in both the short run and long run. Moreover, FDI has insignificant effects on CO_2 emissions in both the short and long-run. For Asian countries, the results reveal that energy consumption has significant positive effects on CO_2 emission both in the short and long-run. A one percent change in energy consumption induces 5.19 percent and a 9.72 percent rise in CO_2 emission in the short and long run, respectively. Further, the results show that trade openness has an insignificant negative effect on CO_2 emission in the short run but a significant positive effect in the long-run. The results indicate that GDP has insignificant effects on CO_2 in both the short run and long-run. Moreover, the estimates show FDI has significant short-run effects on CO_2 emissions in the short but insignificant negative effects in the long run. Last, our estimates show that governance has significant positive effects in the short run and long-run.

Regarding the interactive effects of governance and trade on $C0_2$ emissions, the result for Africa shows that there is no significant between the interaction of trade and governance in the short-run period. Thus, governance plays no vital interactive role in the effect of trade on CO_2 emission in African countries in the short run. Similarly, the result for Asia shows that there is no significant between the interaction of trade and governance in the short-run period. Therefore, governance plays no vital interactive role on the effect of trade on CO_2 emission in Asian countries in the short-run.

In the long-run, the result indicates that the interaction between trade and governance exerted a negative and significant effect on C02 emission. This implies that governance plays a vital interactive role on the effect of trade on CO_2 emission in African countries in the long-run, this is consistent with other empirical finding (Amuakwa-Mensah & Adom, 2017; Ali *et al.*, 2019; Adekunle, 2020). Consequently, the result for Asia also shows that the interaction between trade and governance exerted a negative and significant effect on C02 emission. Thus, governance plays a vital interactive role on the effect of trade on CO_2 emission in Asia countries in the long run, this result aligns with revelation of previous studies (Samimi *et al.*, 2012; Hosseini & Kaneko, 2013; Asongu & Odhiambo, 2020). Finally, the estimates suggest that

governance plays no vital role on the effects of trade on CO_2emissions in African and Asian countries in the short run. The results, however, indicate that governance plays a vital role on the effects of trade on CO_2emissions in African and Asian countries in the long-run.

6. Conclusion

This study investigated the direct relationship between trade, governance and environmental quality (C02 emission) among some selected African and Asian economies. In addition, the study examined the interaction effects of trade and governance on environmental quality in both continents. The dataset contains 10 countries from each continent from 1996 to 2021 and ensured 25 observations for each country. The study employed the autoregressive distributed lag (ARDL) technique by Peseran *et al.* (2001) to determine the dynamics among the tested variables in the short-run and long-run. The technique was chosen for its flexibility, unbiasedness for long-term relationship and long-term parameters, and its capability to adequately address autocorrelation and endogeneity problems (Rahman & Kashem, 2017). The long-term interactive results, which are the main crux of this study revealed that the interaction between trade and governance exerted a negative and significant effect on C02 emission. This implies that governance plays a vital interactive role on the effect of trade on environmental quality (CO_2 emission) among the selected African countries in the long-run. Furthermore, the result for Asia also shows that the interaction between trade and governance exerted a negative and significant effect on environmental quality ($C0_2$ emission). Thus, governance plays a vital interactive role on the effect of trade on CO_2 emission in Asia countries in the long-run. Finally, the estimates suggest that governance plays no vital role on the effects of trade on CO_2emissions in African and Asian countries in the short run. The results, however, indicate that governance plays a vital role on the effects of trade on CO_2emissions in African and Asian countries in the long-run.

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