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Threshold Effects of Inward Foreign Direct Investment and Growth on Environmental Sustainability in Africa

Stanley Emife Nwani*
Pan-Atlantic University
*Corresponding author

Fredrick Ikpesu
Pan-Atlantic University

Sunday Enebeli-Uzor
Zenith Bank Plc.

Abstract
The study explores the thresholds of inward foreign direct investment and per capita income on environmental sustainability in Africa. The study is motivated by Africa's rising contribution to the global carbon emission rate at 4.6% per annum and the projection to exceed 30% in 2030, which threatens global sustainability. The ex-post facto research design guided us in collecting panel data for African countries between 1990 and 2019. The Environmental Kuznets Curve and Pollution Haven Hypothesis underpinned our models, which are analyzed using the Bai-Perron Panel Threshold Regression technique. The Bai-Perron Panel Threshold Regression results established that inward foreign direct investment positively impacts environmental degradation. Also, at the initial stage of growth carbon emission increases, and the growth rate beyond the turning point leads to a decline in carbon emission. However, we did not validate the Environmental Kuznets Curve since the coefficient of the second-order polynomial was not statistically significant. Further, we established the thresholds of $21,890 per capita gross domestic product and $3,941.12 per capita foreign direct investment values are needed to attain long-run environmental sustainability objectives in Africa. We suggest that policymakers formulate specific growth, foreign direct investment, trade and finance policies guided by the established thresholds of $21,890 per capita gross domestic product and $3,941.12 per capita foreign direct investment value to attain long-run environmental sustainability objectives. These can be driven by sustained green growth and cleaner foreign direct investment attraction strategies that are mindful of Africa's environmental limits. We developed five empirical models to estimate the turning points, which the few empirical studies on Africa's environmental sustainability drive were not interested in despite its tremendous policy significance.

Keywords
Foreign Direct Investment, Economic Growth, Environmental Sustainability, Threshold Regression, Turning Points

1. Introduction
One of the major problems on the continent of Africa is environmental degradation, which raises concerns among environmental policymakers, research scholars and developmental economists. Although the general belief that the inflows of Foreign Direct Investment (FDI) are beneficial to the African continent is widely accepted among the academic community, this has also raised the concern that inward FDI flows can harm the environment via carbon emission (CO_2) (Koçak, & Şarkgüneşi, 2018; Mert *et al.*, 2019, Lin, 2021). In addition, while economic growth is the desire of every government, some studies have posited that this can result in environmental degradation (Mikayilov *et al.*, 2018 Muhammad, 2019). These scholars argued that growth leads to an increase in carbon emissions (CO2).

Motivated by Africa's rising contribution to the global emission rate at 4.6% per annum and with the projection to exceed 30% in 2030, which would negate the global environmental sustainability agenda, we explore the impact and thresholds of inward FDI, and per capita Gross Domestic Product (GDP) on environmental sustainability in Africa. We developed five empirical models to ascertain the nonlinear relationships and turning points of the predictors of environmental sustainability. We observed that the few empirical studies on Africa's environmental sustainability drive are either descriptive in approach (Ayompe, *et al.*, 2021) or were not interested in turning points analysis (Asongu *et al.*, 2020; Saint Akadiri *et al*., 2019; Mesagan, 2021; Chen *et al*., 2022; Jahanger *et al*., 2022; Rafei *et al*., 2022), despite its tremendous policy significance. So, we extend the frontier of existing literature in this research space by estimating the threshold points at which the impacts of FDI and growth on environmental degradation change from positive to negative. Our findings are that inward FDI has a positive impact on environmental degradation in Africa, thus validating the Pollution Haven Hypothesis (PHH). Our result also reveals that at the initial stage of growth, carbon emission increases, while a sustained growth rate beyond the turning point leads to a decline in carbon emission. However, we could not affirm the Environmental Kuznets Curve (EKC) theory for Africa since the estimates of the second-order polynomial are not statistically significant. In addition, we established the thresholds of $21,890 per capita GDP and $3,941.12 per capita FDI value needed to attain long-run environmental sustainability objectives in Africa.

The remainder of this paper is arranged in the following order. Section 2 reviews theories and related literature. Section 3 gives a brief description of the data, and the methodology deployed. Section 4 reports and discusses the outcome of the study. Section 5 concludes the paper with some policy implications.

2. Theory and Review Related Literature

Our study builds on the EKC, the Pollution Haven Hypothesis and the Pollution Haloes Hypothesis. According to the Environmental Kuznets Curve theory, as a country begins to develop, it results in the deterioration of the environment but after a certain level of growth, the level of degradation declines. However, some critics have argued that the level of growth that will sustain and improve the environment cannot be guaranteed. The EKC theory exemplified the association between per capita income and environmental degradation. The theory which was named after Simon Kuznets (who advocates that inequality in income first increases and then declines as the country develops) showed that there exists an inverted U- shape in the link between per capita income and CO_2 emissions.

Besides, our study also relies on the theory of the Pollution Haven Hypothesis. According to this theory, advanced economies often impose tougher policies relating to the environment than most less advanced economies. Thus, motivation multinational corporations in advanced economies to shift their core operations to less advanced economies where environmental policies exist. Hence, making the less developing countries become pollution havens. In other words, based on the theory of pollution haven hypothesis it is multinationals that contribute to pollution in the host economy. On the other hand, the pollution haloes hypothesis theory affirmed that the inflows of inward FDI result in clean technology which thus improves and enhances the environment leading to the reduction of carbon emissions (CO_2).

Research Hypothesis I: The threshold at which growth reduces environmental degradation falls outside the statistical range, African policymakers should pursue a growth-enhancing strategy to curb rising carbon emissions.
Research Hypothesis II: The turning for FDI to promote environmental sustainability falls outside the statistical range; policymakers in Africa should pursue FDI attraction strategies to address environmental degradation.

Consequently, we examine two strands of literature. The first strand of literature examined whether the inward FDI reduces or increases CO_2 emissions, and the second strand examined whether growth reduces or increases CO_2 emissions. On the first strand of literature, our review shows mixed results as some studies argued that FDI has led to the reduction of CO_2 emissions, thus supporting the pollution halo hypothesis (Sbia *et al*., 2014; Öztürk, & Damla, 2016; Mert, & Bölük, 2016; Zhang, & Zhou, 2016; Khan, & Ozturk, 2020; Guo, 2020; Zubair, 2020; Neves *et al*., 2020; Ghazouani, 2021). The views of these authors are that the inflows of FDI have led to the reduction of CO_2 emissions because of the use of green technology. While others opposed that the inflows of inward FDI increase CO_2 emissions thus supporting the pollution haven hypothesis (Tang, & Tan, 2015; Seker *et al*., 2015; Kumar, & Chander, 2016; Baek, 2016; Jun *et. al*., 2018; Koçak, & Şarkgüneşi, 2018; Mert *et al*., 2019, Lin, 2021).

On the second strand of literature, our reviews of pieces of literature show that the outcome is mixed. Some scholars opine that growth reduces CO_2 emissions (Aye, & Edoja, 2017; Magazzino, 2017, Namahoro *et al*., 2021; Mujtaba, & Jena, 2021). Others reported otherwise that growth increases CO_2 emissions (Zhand & Wang, 2013; Alam *et al*., 2016; Ahmad, & Du, 2017; Bekhet *et al*., 2017; Mikayilov, Galeotti, & Hasanov, 2018; Muhammad, 2019) implying that the EKC model does not hold. Our work extends the literature by estimating the impact and thresholds of FDI and growth beyond which environmental sustainability becomes attainable in Africa.

3. Data and Methodology

3.1 Description of Data

We leveraged the existing literature to develop empirical modelling that enables us to analyse the impact and thresholds of inward FDI and per capita income on environmental sustainability in Africa over the period 1990 and 2019. To this end, we uniquely propose a panel of Eastern and Southern Africa, Western and Central Africa, and Sub-Saharan Africa. The choice of these African regions follows the 4.6% growth rate in CO_2 emissions on the continent between 1990 and 2017 (Ayompe *et al*., 2021). If this rate of growth is consistent, in 2030, Africa’s contributions to carbon emissions will increase by 30% from the present 4% to the global fossil fuel emissions (Ayompe *et al*., 2021). If these emissions intensity driven by population explosion and per capita income growth is unchecked, Africa’s growth would be at the expense of the international climate goals.

Despite these frightening projections for Africa, earlier studies (Ahmed *et al*., 2021; Hysa *et al*., 2020; Khan *et al*., 2022; Philip *et al*., 2021; Saleem *et al*., 2020; Sarkodie *et al*., 2020; Xie and Sun, 2020) focused on rich economies, believing that the African continent does not contribute more than 5% to the global fossil fuel emissions. Few studies (Asongu et al., 2020; Ayompe, *et al*., 2021; Saint Akadiri *et al*., 2019; Mesagan, 2021) that investigated environmental sustainability for Africa employed either trends analysis to describe the movement in CO_2 emission or neglected the threshold analysis which is relevant for policy purposes. More so, other studies on growth and trade never consider their nexuses with the environment (Anetor, 2019; Asamoah *et al*., 2019; Ikpesu *et al*., 2019; Nwani, 2021). We addressed these and other notable empirical gaps and extended the analyses to include the determination of the threshold of per capita income, FDI per capita, financial development, human capital and trade openness that policymakers should target for the continent to operate within the confines of her environmental limits. Theoretically, we augmented the Environmental Kuznets Curve (EKC) models and the Pollution Haven Hypothesis (PHH) with the estimation of the turning points for financial development, human capital and trade openness, the first of its kind for Africa.

More so, we followed the works of Omri *et al.* (2019), to adopt CO_2 emissions per capita in metric tonnes as a measure of environmental degradation; we measure economic growth using per capita GDP (constant 2015 US$); FDI is measured as per capita FDI net inflows (current US$)[1]. Considering the existing studies (Omri *et al*., 2019; Uche and Effiom, 2021), we incorporated financial development measured by domestic credit provided by financial sector (% GDP) into the model as one of the control variables. Other control variables include trade openness in line with (Khan *et al*., 2022), captured by the ratio of total trade to GDP (Ahmed *et al*. 2021). Also, Omri *et al.* (2019) argue that human capital is a notable determinant of environmental sustainability, thus, we considered human capital variable proxy by life expectancy rate as rationalised in the literature (Adeleye *et al*., 2022; Khan and Chaudhry, 2019).

Table 1 Variable, Description and Data Sources

Variable	Description	Source
Environmental degradation (CO_2)	CO2 emissions per capita (in metric tons)	World Bank (https://data.worldbank.org/)
Economic Growth (GDP)	Per capita GDP (constant 2015 US$)	World Bank (https://data.worldbank.org/)
Foreign Direct Investment (FDI)	Per capita FDI net inflows (BoP Current US$)	Computed using data from the World Bank (https://data.worldbank.org/)
Financial Development (FinD)	Domestic credit provided by the financial sector (%GDP)	World Bank (https://data.worldbank.org/)
Trade Openness (TrO)	Trade % GDP	World Bank (https://data.worldbank.org/)
Human Capital (HmC)	Life expectancy at birth	World Bank (https://data.worldbank.org/)

Further descriptions of the data and sources are presented in Table 1 above, while Table 2 contains the summary of the descriptive statistics and correlations among the variables employed in the model.

Table 2 Summary of descriptive statistics and correlations

Statistic	CO_2	FDI	GDP	FinD	HmC	TrO
Mean	0.747	24.146	1437.590	44.142	53.994	51.558
Std. Dev.	0.197	16.573	211.112	26.789	4.393	8.140
Maximum	1.057	68.005	1894.322	94.990	64.005	74.620
Minimum	0.430	0.291	1148.384	7.592	48.817	36.297
CO_2	1.000					
FDI	-0.100	1.000				
GDP	-0.169	0.826	1.000			
FinD	0.958	-0.069	-0.154	1.000		
HmC	0.319	0.625	0.755	0.283	1.000	
TrO	0.506	0.393	0.082	0.498	0.292	1.000

Source: Authors' computation (2022)

[1] We computed per capita FDI net inflows by establishing the ratio of FDI net inflows (current US$) to population for the period under consideration.

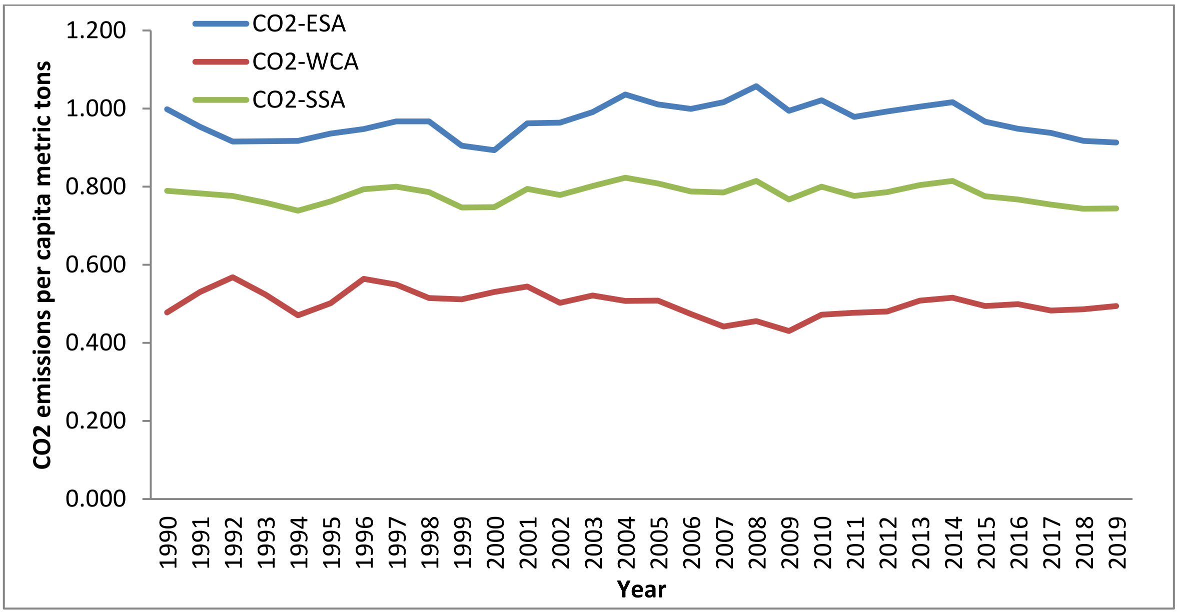

Fig. 1 Trends of carbon emissions per capita in select African regions (***Source:*** *Authors' presentation using World Bank Data*)

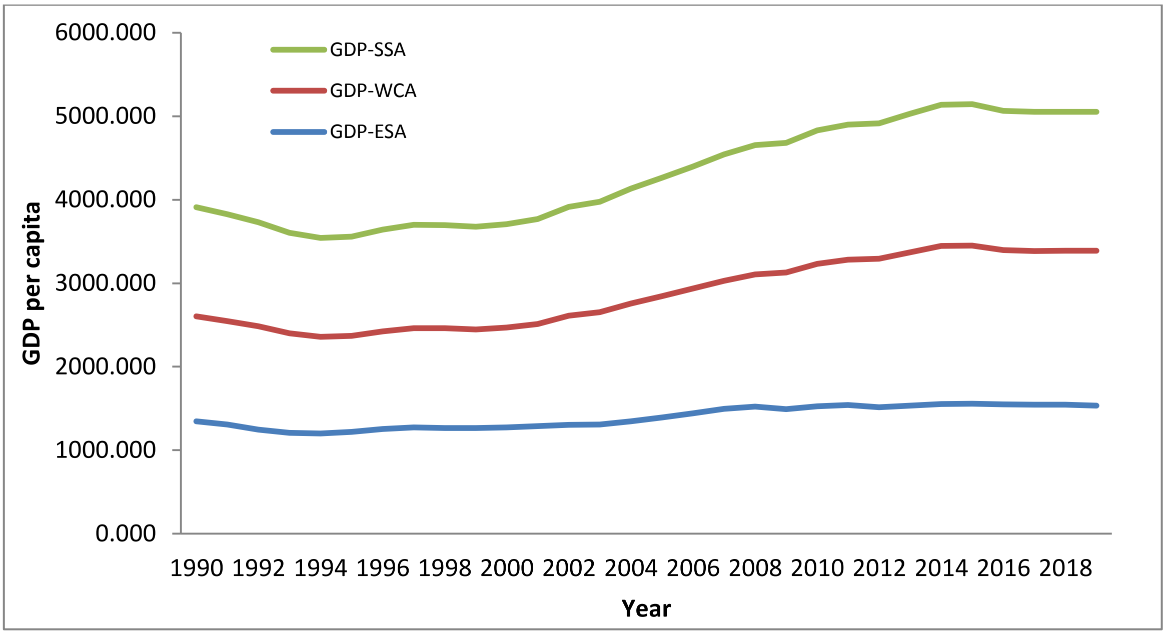

Fig. 2 Trends of GDP per capita in select African regions (***Source:*** *Authors' presentation using World Bank Data*)

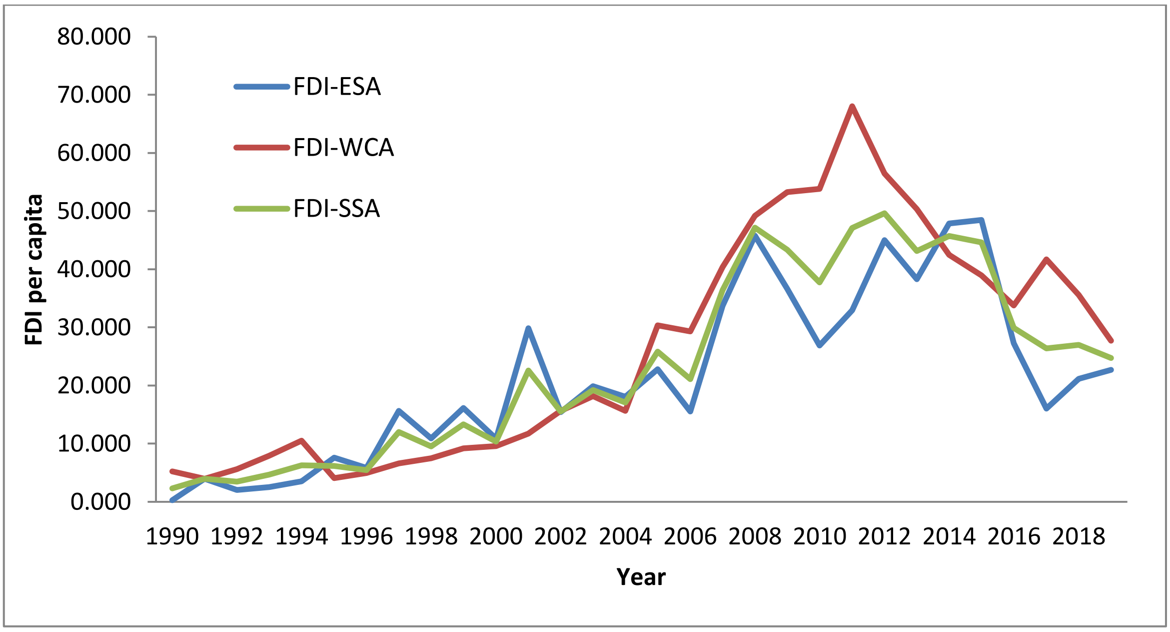

Fig. 3 Trends of FDI per capita in select African regions (***Source:*** *Authors' presentation using World Bank Data*)

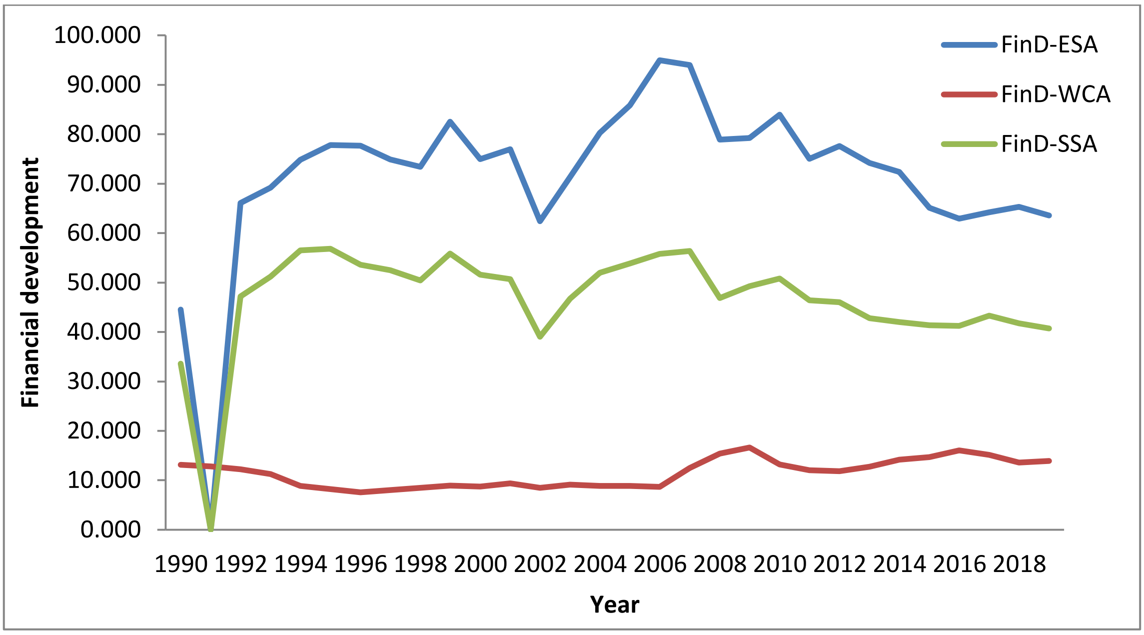

Fig. 4 Trends of financial development in select African regions (***Source:*** *Authors' presentation using World Bank Data*)

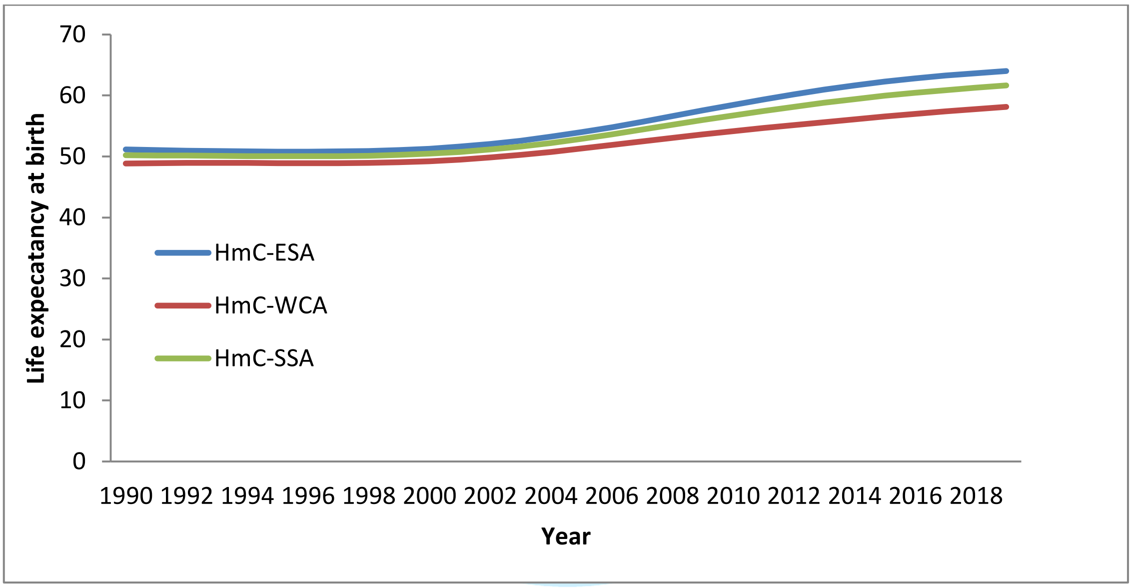

Fig. 5 Trends of human capital in select African regions (***Source:*** *Authors' presentation using World Bank Data*)

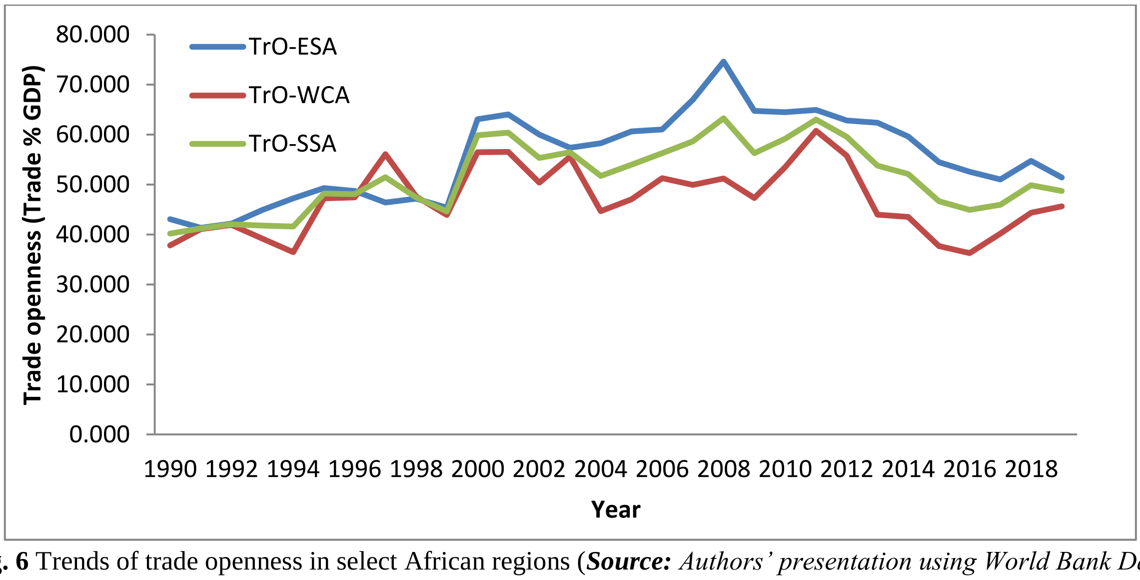

Fig. 6 Trends of trade openness in select African regions (***Source:*** *Authors' presentation using World Bank Data*)

Table 2 summarizes some descriptive statistics and correlations of the variables in our model. An environmental degradation variable (CO_2) emission ranges between 0.430 and 1.057 metric tonnes per capita. Foreign direct investment per capita, net inflow ranges from 0.291US$ to 68.005US$ and GDP per capita ranges from 1148.384US$ to 1894US$.

With regards to financial development, the range is from 7.592% to 94.990% in terms of the proportion of domestic credit provided by financial sector in GDP. More so, the human capital variable shows a range of 48.817 years to 64.005 years in terms of life expectancy, while the proportion of trade to GDP ranges from 36.297% to 74.620% in Africa from 1990 – 2019.

This table reveals further that financial development and trade openness have the highest positive correlation with per capital CO_2 emissions, while human capital has a lower positive correlation with environmental degradation. Conversely, per capita FDI and GDP per capita have an inverse correlation with per capita CO_2 emissions. The preliminary descriptive analysis implies that FDI and growth have a positive associational relationship with environmental sustainability, while financial development and trade exhibit a negative associational relationship with environmental quality. Within the same discussion, per capita FDI is strongly correlated with GDP per capita and human capital, meaning that FDI is a key factor in fostering economic growth and human capital development.

Nevertheless, as depicted in Figure 1, Africa's CO_2 emissions remain a growing concern. For instance, for the period 1990 – 2019, the annual average of per capita emissions is 0.747 metric tonnes. The concern is most serious in the Eastern and Southern Africa region (ESA), followed by sub-Saharan Africa (SSA) and least serious in the Western and Central Africa (WCA) regions (see Fig. 1). Also, figure 3 shows that the annual average of per capita FDI stands at 24.146US$, with WCA region attracting the highest FDI inflows per person, followed by SSA region and the ESA hosting the least FDI per head in Africa. The above trends point to the fact that the region that attracts the highest FDI is the least emitter of CO_2, while the ESA that attracts the least FDI has the most concerns about CO_2 emissions, earlier evidence that FDI promotes environmental quality (subjected to further empirical tests). In Figure 2, the annual average GDP per capita remains at 1437.590 US$, with the SSA region as the richest, followed by WCA and ESA respectively. Again, we observed that ESA which attracted the least FDI per head has the poorest income per head, this is not unexpected!

Nonetheless, trends in financial development as presented in Figure 4 show that domestic credit to the private sector provided by the financial sector stands at an annual average of 44.142% of Africa's gross domestic product. Among the regions that made up the Africa panel data used for the study, the ESA region is the most financially developed compared to the SSA and WCA regions respectively. In figures 5 & 6, the Eastern and Southern Africa region records the highest human capital in terms of life expectancy and is the most open in terms of degree of trade openness than the SSA and WCA regions. Specifically, the annual average life expectancy at birth for the continent is 53.994 years and 51.558% of trade openness. Thus, we could suspect that the ESA region with the greatest environmental challenge is the most open to global trade, which is a source of environmental degradation (Ling *et al*., 2020).

3.2 Methods

3.2.1 Model Specifications

Guided by the theoretical, empirical, and methodological literature, we propose the following standard model (see eqn 1) and other models to achieve the objectives of the study.

$$C02_{it} = f(GDP_{it}, FDI_{it}, FinD_{it}, HmC_{it}, TrO_{it}) \quad \ldots\ldots\ldots\ldots \mathbf{1}$$

To ensure better controllable results, smoothen out sharp spikes and for data stability, we carried out a logarithmic transformation of the variables as suggested by earlier studies (Fernández and Steel, 1998; Shahbaz *et al*. 2012). Specifically, to estimate the turning point/thresholds for the model, we formulate the following specifications:

$$lnCO2_{it} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnGDP^2{}_{it} + \beta_3 lnFDI_{it} + \beta_4 lnFinD_{it} + \beta_5 lnHmC_{it} + \beta_6 lnTrO_{it} + e_{it} \quad \ldots\ldots\ldots \mathbf{2}$$

$$lnCO2_{it} = \beta_0 + \beta_1 lnFDI_{it} + \beta_2 lnFDI^2{}_{it} + \beta_3 lnGDP_{it} + \beta_4 lnFinD_{it} + \beta_5 lnHmC_{it} + \beta_6 lnTrO_{it} + e_{it} \quad \ldots\ldots\ldots \mathbf{3}$$

$$lnCO2_{it} = \beta_0 + \beta_1 lnFinD_{it} + \beta_2 lnFinD^2{}_{it} + \beta_3 lnGDP_{it} + \beta_4 lnFDI_{it} + \beta_5 lnHmC_{it} + \beta_6 lnTrO_{it} + e_{it} \ldots\ldots\ldots \mathbf{4}$$

$$lnCO2_{it} = \beta_0 + \beta_1 lnHmC_{it} + \beta_2 lnHmC^2{}_{it} + \beta_3 lnGDP_{it} + \beta_4 lnFDI_{it} + \beta_5 lnFinD_{it} + \beta_6 lnTrO_{it} + e_{it} \ldots\ldots\ldots \mathbf{5}$$

$$lnCO2_{it} = \beta_0 + \beta_1 lnTrO_{it} + \beta_2 lnTrO^2{}_{it} + \beta_3 lnGDP_{it} + \beta_4 lnFDI_{it} + \beta_5 lnFinD_{it} + \beta_6 lnHmC_{it} + e_{it} \ldots\ldots\ldots \mathbf{6}$$

In model 2, CO_2 is a function of GDP per capita (GDP), per capita foreign direct investment (FDI), financial development (FinD), human capital (HmC) and trade openness (TrO). The Environmental Kuznets Curve hypothesis identified a nonlinear relationship between growth and environmental degradation such that the a-prior expectation as $dCO2/dGDP > 0$ and $dCO2/d\,GDP^2 < 0$. According to the pollution haven model, the expected sign $dCO2/dFDI > 0$, and $dCO2/d\,FDI^2 < 0$ allow for a nonlinear relationship between FDI and emissions. It implies that inward FDI increases emissions initially and declines it when it reaches a threshold level. SiA similar analogy applies to the control variables as such, $dCO2/dFinD > 0$ and $dCO2/d\,FinD^2 < 0$ (income effect); $dCO2/dHmC > 0$ and $dCO2/d\,HmC^2 < 0$ (technique effect); $dCO2/dTrO > 0$ and $dCO2/d\,TrO^2 < 0$ (substitution effect). We further applied the turning point model espoused in (Omri et al., 2019; Pata, 2018) to determine the threshold level that reduces environmental degradation.

3.2.2 Estimation Techniques

We carried out a stationarity test following Im *et al.* (2003) to determine existence of unit root in the variables before proceeding to estimate the models specified earlier. The unit root result, which is a requirement for panel cointegration modelling (see Table 3) shows that the variables contain unit root in their levels, but became stationary in their first difference, I(1), thus, suggesting the existence of a long-run relationship between environmental degradation and its determinants as modelled in this study.

Table 3[2] Result of Im, Pesaran and Shin (2003) Unit Root tests

Variable	Im, Pesaran and Shin W-stat	
	Level	Δ
$lnCO_2$	-1.8099	-10.097***
lnFDI	-4.6569***	-13.522***
$lnFDI^2$	-2.6362*	-11.146***
lnFinD	-1.3570	-7.6602***
$lnFinD^2$	-1.3627	-7.9963***
lnGDP	-1.4255	-7.5578***
$lnGDP^2$	-1.4323	-7.5881***
lnHmC	-1.7186	-8.9538***
$lnHmC^2$	-1.7196	-8.9578***
lnTrO	-3.2762**	-8.4774***
$lnTrO^2$	-3.2612**	-8.5063***

Source: *Authors' computation (2022)*

Guided by the theoretical position of the EKC model, which establishes a turning point or threshold between carbon emissions and GDP per capita, we estimate the threshold regression models for equations 2 to 6 using the Bai and Perron (2003) tests. The Bai-Perron threshold sequentially determined result for threshold variables is presented in Table 4 above.

4. Results and Discussions

Table 3 presents the result of Im *et al*. (2003) test for stationarity of logarithmic panel series at levels and first differences. The test indicated that all the panel series are integrated at the first difference, that is, of order one I (1). The result reveals the existence of a unit root at the first difference; thus, we accepted the null hypothesis that the panel series is stationary in the first difference. This preliminary finding connotes the possibility of a long-run equilibrium relationship between environmental degradation, GDP per capita, per capita FDI, financial development, human capital development and trade openness in Africa. To determine the turning point in line with the EKC model extended by our study, we reported the Bai-Perron Threshold sequentially determined in Table 4. We established the following findings from Table 4 on the impact and threshold of inward FDI, growth, financial development, human capital and trade openness on environmental degradation in Africa.

Table 4 Bai-Perron Threshold Regression Results

Regressor	*Dependent variable: CO_2 emissions*									
	Model 1		*Model 2*		*Model 3*		*Model 4*		*Model 5*	
	Coef	*Prob*	*Coef*	*Prob*	*Coef*	*Prob*	*Coef*	*Prob*	*Coef*	*Prob*
lnGDP	192.408	0.1605	1.399**	0.0237	2.1857***	0.0085	-1.981***	0.0025	-1.916***	0.0002
$lnGDP^2$	-31.174	0.1542	-	-	-	-	-	-	-	-
lnFDI	-0.108***	0.0002	5.100	0.3991	0.017	0.5683	-0.151***	0.0000	-0.069	0.3123
$lnFDI^2$	-	-	-0.308	0.3710	-	-	-	-	-	-
lnFinD	0.509***	0.0000	0.743***	0.0000	10.650	0.1994	0.517***	0.0000	0.570***	0.0000
$lnFinD^2$	-	-	-	-	0.5334	0.2009	-	-	-	-
lnHmC	6.782***	0.0029	3.120***	0.0023	-2.112**	0.0101	139.529*	0.0602	3.113***	0.0000
$lnHmC^2$	-	-	-	-	-	-	-38.849*	0.0644	-	-
lnTrO	-0.167	0.5183	1.144***	0.0011	0.020	0.9033	0.623***	0.0002	4.153	0.7062
$lnTrO^2$	-	-	-	-	-	-	-	-	-0.876	0.7800
Intercept	-309.069***	0.0000	-17.414***	0.0042	-13.296	0.1146	-120.821*	0.0569	-5.024	0.6109
Thresholds	$21,890.00	-	$3,941.12	-	na	-	na		na	
Adjusted R^2	0.983	-	0.980	-	0.994		0.953		0.964	

Note: *, ** and *** indicate 10%, 5% and 1% significance levels, respectively. n.a implies not applicable

[2] In table 2, readers should note: *,** and *** imply values at 10%, 5% and 1% significance levels, respectively, while Δ indicates unit root test of variables in their first difference.

Thresholds/T. P computed using the Stern (2004) equation = exp ($-b_1/2*b_2$)
Model 1 (eq.2): CO_2 = f (GDP, GDP^2, FDI,FinD,HmC,TrO)
Model 2 (eq.3): CO_2 = f(FDI,FDI^2,GDP,FinD,HmC,TrO)
Model 3 (eq.4): CO_2 = f(FinD,$FinD^2$,GDP,FDI,HmC,TrO)
Model 4 (eq.5): CO_2 = f(HmC,HmC^2,GDP,FDI,FinD,TrO)
Model 5 (eq.6): CO_2 = f(TrO,TrO^2,GDP,FDI,FinD,HmC)

First, in model 1, the EKC model for Africa with evidence of a quadratic relationship between per capita GDP and environmental degradation seems not to be valid. This is because the coefficients of the first-order and second-degree polynomials are not statistically significant. Although our estimates show that at the initial stages of economic development, the increase in GDP per head leads to more carbon emissions, however, after GDP per capita rises above a certain threshold ($21,890), carbon emissions would begin to decline, thus, the inverted U-shaped EKC model may be validated at that level. But now, Africa is yet to reach the turning point, as its GDP per head stood at $1,437.590 from the selected regions for our study. Our finding is unique and differs from existing studies that validated the EKC model for sub-Saharan Africa (Tenaw and Beyene, 2021); and for oil-producing African countries (see Onifade, 2022).

More so, we observed closely that the coefficient of the linear per capita GDP is higher than that of the nonlinear per capita GDP; it follows that an increase in per capita GDP would not have a significant impact on environmental degradation in the long run, thus, the p-value for squared per capita GDP is statistically insignificant. The implication is that current efforts at containing environmental degradation through growth driven strategies would be less effective for Africa due to the recent average 4.6% carbon emissions rate in Africa, the highest globally (Ayompe, *et al*., 2021). Moreover, policymakers should be interested most in the threshold of per capita GDP that could promote environmental sustainability in Africa. We established a threshold of $21,890, which is critical to promote environmental sustainability on the continent of Africa. Since the estimated threshold falls outside the statistical range, policymakers in Africa are prompt to pursue growth-enhancing strategies that would attain a minimum of $21,890 per capita GDP to reverse the rising CO_2 emissions trends.

Second, from the results of model 2, we established that GDP per capita, per capita FDI, financial development, human capita and trade positively affect environmental degradation, while it is negatively impacted by the square of per capita FDI. Since the second-order polynomial is not statistically significant, our finding from the second model does not validate the pollution haven hypothesis for Africa, meaning that, although a quadratic relationship exists between inward FDI and carbon emissions, Africa is yet to attract FDI to the point that it begins to promote environmental quality. Thus, FDI increases environmental degradation initially but starts to promote environmental quality beyond a threshold level of $3,941.12 FDI per capita. The ability of FDI to improve environmental quality as established in our model 2 is supported by the adoption of clean technology and better management practices by Multinational Corporations, however, the success rate hinges on the regulatory framework of the continent and the quality of human capital (Anetor, 2020; Nwani, 2021). The policy significance from model 2 is the identification of the critical threshold level of $3,941.12 per capita FDI that would drive environmental quality in Africa. From the descriptive statistics, the average per capita FDI on the continent stands at $24.146, which is significantly less than the threshold. Policymakers are expected to augment per capita FDI at the threshold level to achieve environmental sustainability in Africa. Our results corroborate the position of Gyamfi et al. (2021) for sub-Saharan Africa and Nwani and Imhanzenobe (2022) for Nigeria, but neither of their works considered the threshold level.

Third, the estimated outcome of model 3 reveals that carbon emission is positively impacted by per capita income, FDI, financial development, squared of financial development and trade. We established evidence of a non-quadratic relationship between per capita financial development and carbon emissions, which always shows that improvement in financial development increases the level of environmental degradation. Although this estimate does not follow the expected outcome, we observed that, as per capita domestic credit to the private sector provided by the financial sector (see Table 1) increases, economic activities would continue to expand, and more carbon is emitted. Our position is unique and departs sharply from earlier studies; Omri *et al*. (2019) found a quadratic relationship between financial development and the environment of Saudi Arabia.

Regarding the nonlinearity of human capital and environmental degradation (see model 4) and trade openness (see model 5), their linear coefficients are positive, while the coefficient of their square is negative. This result shows that an inverted U-shaped relationship exists between environmental degradation, human capital and trade openness in Africa. Undoubtedly, the technique effect model supports our findings that improved human capital in terms of literacy and quality of life would increase the desire for improved environmental quality (Ahmed *et al*., 2021; Sarkodie *et al*., 2020). More so, for trade openness, similar evidence was recorded by Khan et al. (2022). This position is rooted in the substitution effect model. These findings have policy significance.

5. Conclusion and Policy Implications

In this paper, we have examined how inward FDI and growth impact environmental sustainability in Africa. First, we tested whether the EKC theory holds in Africa. Second, we also tested whether the pollution haven hypothesis holds in Africa. Lastly, we also ascertained the threshold of FDI and growth beyond which environmental sustainability becomes a concern in Africa. The key findings we establish are summarized as follows; first, we observed that at the initial stage of growth carbon emission increases, while a sustained growth rate tends to reduce carbon emission. Unfortunately, Africa is yet to reach the turning point, the EKC model seems not valid for Africa.

Secondly, we established that inward FDI has a positive impact on environmental degradation in Africa, thus validating the pollution haven hypothesis (PHH). Third, we also observed that the established thresholds of $21,890 per capita GDP and $3,941.12 per capita FDI values are needed to attain long-run environmental sustainability objectives. We admonish policymakers in Africa to formulate specific growth and FDI policies guided by the established turning points of $21,890 per capita GDP, and $3,941.12 per capita FDI to attain long-run environmental sustainability objectives. Since the thresholds are higher than the maximum level of these variables from the descriptive statistics, we encourage aggressive but technologically driven growth strategies that are mindful of Africa's environmental limits. However, since Africa's development strategies are outward-oriented, FDI attraction are essential component of her growth and sustainability agenda, Africa requires constant FDI inflows and the associated technology transfer and other benefits with the precondition of an improved human capital. In this regard, our findings are like (Chakraborty & Mukherjee, 2013; Omri *et al*., 2019) that FDI increases productivity and environmental quality through technological upgrading and human capital development.

Therefore, we encourage a sub-regional approach to the environmental sustainability agenda in Africa. Specifically, Eastern and Southern Africa should pay more attention to growth-enhancing and FDI attraction policies, the Western and Central Africa region should be strategic in developing their financial sector and promote human capital development, while sub-Saharan Africa needs to strengthen FDI inflows, trade relations, financial sector, and the quality of human capital if the attainment of environmental sustainability would be a reality in Africa. Policymakers on the continent must note that FDI inflows and growth strategies require human capital development, trade openness and financial development to attain the thresholds that promote environmental sustainability.

6. Future Research Direction

The threshold effects of FDI and growth on environmental sustainability are the main contribution of this study to the literature. We suggest that future studies in this research space could estimate the thresholds for all developing countries across continents, to arrive at more robust environmental sustainability strategies that promote a global agenda of sustainable development.

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