Effect of Trade Openness on Ecological Footprint in Sub-Saharan Africa

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Abstract

This study explores the effect of international trade measured by trade openness and foreign direct investment flows on environmental quality measured by ecological footprint in 23 Sub-Saharan African countries. It applies the Feasible Generalized Least Square method to the 1990-2015 panel data, after checking for cross-sectional dependence, serial correlation, heteroscedasticity, and the presence of cointegrating relationships to yield efficient and consistent coefficient estimates. Moreover, it deploys instrumental variable techniques to address the problem of endogeneity of trade openness and income. The results show that ecological footprint of consumption per capita decreases with an increase in trade openness and increases with an increase in foreign direct investment inflows. The results also confirm the presence of an Inverted-U shaped relationship between ecological footprint and GDP per capita. The study findings have policy implication for socioeconomic planning for sustainable development.

Keywords: openness; degradation; ecological footprint; EKC; Instrumental variable

JEL Classification Codes: F18, Q56,

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1. Introduction

The world has recently registered remarkable quantitative socioeconomic development outcomes (Krueger, 2004; Gomułka, 2017; Yueh, 2018). This accelerated development pace has continued to exert increased pressure on the environment to a level exceeding nature's capacity of sustaining life (Aydin & Turan, 2020). Whereas global biological capacity has grown by 27% in the past five decades, the ecological footprint has grown by 190% over the same period (WWF, 2018; Marti & Puertas, 2020), hence increasing the biocapacity deficit. According to data from the ecological footprint network, over 80 percent of the global population presently resides in nations whose ecological footprint (EF) exceeds the biological capacity for self-renewal available. Africa particularly sunk into an ecological deficit in 2009 because of a consistent increase its ecological footprint over the years (Marti & Puertas, 2020). The growing biocapacity deficit is responsible for rising temperatures and erratic climatic conditions, inhibiting the absorption of carbon emissions, reducing biodiversity, disrupting biological cycles and increasing natural disasters (Aydin & Turan, 2020; Marti & Puertas, 2020; Lu, 2020).

Many scholarly works on the trade-income-environment nexus have used specific pollutant emissions such as carbon emissions (Halicioglu, 2012; Shahbaz *et al*., 2013; Jebli *et al*., 2016; Bulut, 2017; Njindan & Ho, 2017; Cetin *et al*., 2018; Shahbaz & Sinha, 2019; Wang & Zhang, 2021). The use of CO2 emissions as an index of environmental degradation, arguably, contains numerous shortfalls attributable to CO2 emissions accounting for only an incredibly small proportion of the total decline environmental quality (Al-mulali et al., 2015a). Addressing these shortfalls could require the use of ecological footprint as an alternative indicator since it takes a holistic approach to evaluating the extent of ecological damage to the environment (Lu, 2020). The ecological footprint, developed by Rees (1992), measures environmental degradation by comparing the rate of consumption of resources and the rate of generation of wastes through human activity relative to the respective rates at which the resources are reproduced and that at which wastes are disposed of and biodegraded (Parsasharif *et al*., 2021).

Using the ecological footprint as an index of environmental quality, this study examines the effect of international trade on environmental quality in 23 selected Sub-Saharan African countries[1]. The study's contribution to literature on trade environment nexus is twofold. First, it applies instrumental variable techniques to the problem of endogeneity of trade openness and income. Existing studies have generally tended to ignore this problem, meaning that their results could be biased and inconsistent. Second, studies exploring the effect of trade on ecological footprint in Sub-Saharan Africa are hardly available and as far as the authors know, this may be one of the first multi-country studies that has examined this relationship in the region.

Analysis of the influence of foreign direct investment (FDI) on the environment depends on the modus operandi and direction of the investments. According to Fakher (2019), the lesser environmental standards in developing economies could attract channel foreign funding into dirty industries and result in further increase in environmental degradation. This negative effect of

[1] These countries include Benin, Botswana, Burkina Faso, Burundi, Cameroon, Chad, Congo, Cote d'Ivoire, Gambia, Ghana, Guinea-Bissau, Kenya, Madagascar, Malawi, Mali, Nigeria, Rwanda, Sierra Leone, South Africa, Tanzania, Togo, Uganda and Zimbabwe.

foreign direct investment on the environment of recipient countries is what is known as the pollution haven hypothesis (Xing & Kolstad, 1996; Dean et al., 2009; Selim & Rivas, 2020). On the other hand, FDI could have a positive effect on the environment of recipient countries. This case occurs when international corporations using cleaner production technologies governed by regulations in their parent countries extend the application those technologies to FDI recipient nations. Additionally, FDI could lead to increased investment in research and development and, thus, lead to cleaner production technologies and contribute effectively towards reducing pollutant emissions (Frankel & Romer, 1999). In cases where FDI improves the environment of countries receiving it the effect is referred to as pollution halo hypothesis (Zarsky, 1999; Eskeland & Harrison, 2003; Hoffmann et al., 2005; Pao & Tsai, 2011; Selim & Rivas, 2020).

This study contributes to the ongoing scholarly debate by addressing the following research questions: What is the effect of international trade on ecological footprint in Sub-Saharan Africa? Does international trade in Sub-Saharan Africa support the pollution haven/halo hypothesis? Can the environment Kuznets curve hold in the context of Sub-Saharan Africa? By addressing these questions, this paper outlines some policy implications on the options available for enhancing environmental sustainability within the region.

The remainder of this study is organized as follows. Whereas section 2 presents theoretical review, section 3 gives the methodology. Section 4 presents and discusses the estimated results. Section 5 concludes.

2. Literature Review

A growing body of research analysing the relationship between ecological footprint and international trade already exists. These studies have so far yielded mixed results: Some (Al-mulali *et al*., 2015b; Caviglia-Harris *et al*., 2009; Aşıcı, & Acar, 2016; Charfeddine, & Mrabet, 2017) have established a positive relationship whereas others (Ulucak & Bilgili, 2018; Destek *et al*., 2018; Alola *et al*., 2019; Destek & Sinha, 2020) found a negative relationship. As such, an open empirical question has remained unanswered.

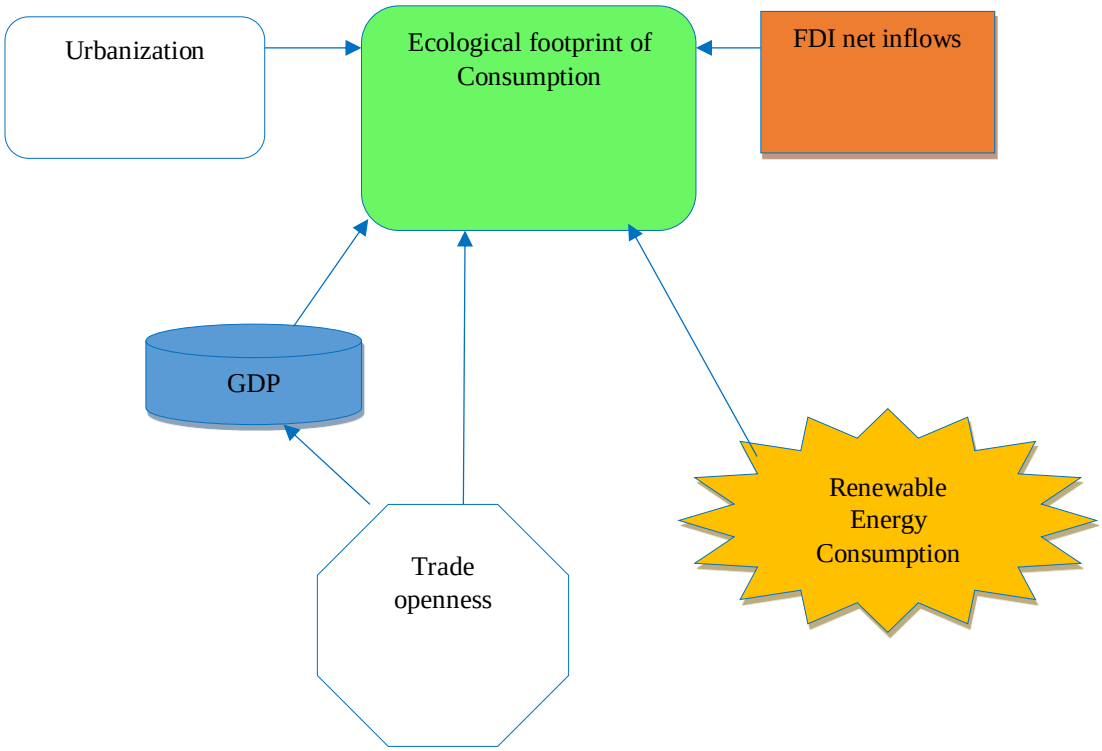
Carbon dioxide emission is the most used for measuring environmental quality. Studies that have used this method include Lean and Smyth (2010); Naranpanawa (2011); Al-Mulali (2011); Saidi & Hammami (2015); Gozgor, (2017); Chandia et al., (2018); Thombs, (2018, June); Liu and Hao (2018); Sun *et al*. (2019). However, the incompleteness of carbon emissions as a measure of environmental degradation is increasingly being recognised in literature (Lu, 2020). Primarily, the use of CO2 emissions as a measure of environmental degradation only captures a small proportion of the damage done to the environment while ignoring other damages linked to natural resources such as stocks of land, forests, and minerals (Lu, 2020). Stern (2014) in the recent times created a need for a more comprehensive measure of pollution. Studies that applied the ecological footprint as an alternative measure of environmental degradation include Al-Mulali *et al*. (2015b) and Ozcan *et al*. (2019) and have demonstrated its suitability.

The literature review revealed further that mixed outcomes from different studies on the relationship between trade openness and ecological footprint. Some specific multi-country

studies(Al-mulali et al., 2015b; Caviglia-Harris et al., 2009; Aşıcı, & Acar, 2016; Charfeddine, & Mrabet, 2017) returned positive relationships whereas others (Destek et al., 2018; Alola et al., 2019; Destek & Sinha, 2020) revealed an inverse relationship. There are also single country studies on trade-ecological footprint nexus that reported mixed results. Single country studies that arrived at a positive relationship between trade openness and ecological footprint include Mrabet and Alsamara (2017), Charfeddine (2017), and Imamoglu (2018). Mrabet and Alsamara (2017) apply the ARDL model with structural breaks to the 1980-2011 time series data for Qatar. Charfeddine (2017) applied the markov switching equilibrium correction model to time series data set for the 1970 - 2015 period and established that ecological footprint increased with an increase in trade openness. The same result was obtained by Imamoglu (2018), who had utilised the fully-modified OLS, dynamic OLS, and the Auto-Regressive Distributed Lag bounding test techniques on a 1970-2014 data set for Turkey.

Borucke et al. (2013) presents ecological footprint of consumption as a sum of the ecological footprint of production and ecological footprint embodied in imports less ecological footprint embodied in exports. In other words, ecological footprints embodied in imports raise the ecological footprint of consumption whereas the ecological footprints embodied in exports reduce ecological footprint of a country. The effect of trade openness on ecological footprint is based on theoretical literature on the trade environment nexus (Grossman & Krueger, 1991). The ecological footprint of consumption is also widely accepted as an indicator of environmental degradation used in multiple studies. Based on the literature reviewed, macroeconomic factors affecting ecological footprint of consumption include international trade (Mrabet & Alsamara, 2017; Charfeddine, 2017; Imamoglu, 2018), urbanisation (Charfeddine et al., 2018; Ozturk et al., 2016; Wang, 2019), Foreign direct investment flows (Xing and Kolstad, 1996; Dean et al., 2009; Selim & Rivas, 2020), per capita GDP(Aşici & Acar 2016; Uddin et al., 2017; Ulucak and Bilgili 2018), Energy Consumption(Bello et al., 2018), and tourism (Ozturk et al. 2016). A simplified conceptual framework in Figure 1 reflects the relationships analysed in this study.

Figure 1: Conceptual framework



3. Methodology

3.1 Variables and their data sources

The variables used in this study are presented in Table:1 alongside their sources:

Table:1 Variables and data sources

Name	Description	Measurement unit	Data Source
EcFP	Ecological footprint of consumption	Global hectares per capita	Global Footprint Network
PCGDP	Gross Domestic Product per capita	USD (constant 2010)	World bank indicators
REEN	Renewable energy consumption as a percentage of total energy consumption	Kilograms per capita	World bank indicators
TROP	The ratio of the sum of imports and exports to GDP	Percentage of GDP	Direction of trade statistics
URBAN	The ratio of urban to total population	Percentage of total population	United Nations Populations Division: World Urbanization Prospects:2018 revision
FDI	Net inflows of FDI	Percentage of GDP	World bank indicators

Variables in this study are linked together as Environmental Kuznet Curve (EKC) type of relationship has been widely documented in literature. This kind of relationship arises due to the role income plays in determining environmental outcomes (Krueger & Grossman, 1991; Antweiler et al., 2001), which are represented by the per capita GDP variable. Environmental quality is thus be modelled as a function of per capita gross domestic product ($PCGDP$) the square of per capita gross domestic product ($PCGDP^2$) and other variables such as trade openness ($TROP$), foreign direct investments (FDI), energy consumption ($ENERGY$), and the rate of urbanisation ($URBAN$)in equation (1):

$$Environmental \quad Quality = f(PCGDP, PCGDP^2, TROP, FDI, REEN, URBAN) \qquad 1$$

The inclusion of the square of per capita GDP helps to capture the change in slope and the turning point of the EKC (Perman *et al*., 2003; Selim & Rivas, 2020). Trade openness and foreign direct investment net inflows also influence the environmental quality directly (Kirkpatrick & Scrieciu, 2008; Solarin & Al-mulali, 2018) and are, thus, included as key variables of interest. Renewable energy use and urbanisation rates serve as control variables based on the literature reviewed (Al-Mulali & Ozturk, 2015; Al-Mulali et al., 2015b; Ulucak & Khan, 2020). This study considers both linear and log-linear functional forms to describe the relationship in equation (1) :

$$EcFP_{it} = \alpha_0 + \alpha_1 PCGDP_{it} + \alpha_2 PCGDP_{it}^2 + \alpha_3 TROP_{it} + \alpha_4 FDI_{it} + \alpha_5 REEN_{it} + \alpha_6 URBAN_{it} + \mu_{it} \qquad 2a$$

$$\ln EcFP_{it} = \gamma_0 + \gamma_1 \ln PCGDP_{it} + \gamma_2 \ln PCGDP_{it}^2 + \gamma_3 \ln TROP_{it} + \gamma_4 \ln FDI_{it} + \gamma_5 \ln REEN_{it} + \gamma_6 \ln URBAN_{it} + \varepsilon_{it} \qquad 2b$$

The model in equation (2a) expresses variables in levels implying that the resulting parameter estimates represent the changes in the dependent variable stemming from the unit changes in regressors. The advantage of this kind of expression over the log linear one lies in its suitability to deal with variables that contain negative values e.g. FDI negative inflows. In equation (2b), all the variables are transformed by taking their respective natural logarithms as several studies, for example Mrabet and Alsamara, (2017), Chen et al. (2019), and Khan et al. (2020) have done. The suitability of this log-linear transformation is based on its effect of reducing variance and skewedness of data compared to simple linear specification (Mrabet & Alsamara, 2017). Second, the resulting parameter estimates can be easily interpreted as elasticities of ecological footprint pertaining to respective independent variables.

To estimate relationships in equations (2a) and (2b), the study followed several steps. To begin with, the study undertook unit root tests to check the stationarity status of all the variables. Recent scholarly work on panel unit root analysis has generally classified panel unit root tests as first- and second-generation tests (Hurlin & Mignon, 2007; Baltagi & Pesaran, 2007; Palm et al., 2011). The choice of a suitable analysis depends on the presence or absence of cross-sectional dependence in the panels set for analysis (Palm et al., 2011; Gozgor, 2017). The Presence of cross-sectional dependence tends to occasion a bias in the coefficient estimates. To perform a cross-sectional dependence tests, the study used the Pesaran (2004) Cross-sectional Dependence test. The Pesaran CD test can be applied to variables directly before doing regressions, or residuals of AR (2) regression or residuals from other regression estimates (Pesaran, 2004).

3.1 Cross-sectional independence

Taking care of cross-sectional dependence when dealing with non-stationary time series is vital (Wagner, 2008). Ignoring the presence of cross-sectional dependence could result in biased inferences and distorted results in panel data analysis (Pesaran 2015; Sarkodie, 2018) due to common factors generated and eventually captured by the error term. Studies have mostly used the Breusch and Pagan (1980) to test the presence of cross-sectional dependence. This test has, however, demonstrated numerous shortcomings (Pesaran, 2004). Pesaran (2004) later developed a more robust test presented in equation (3) that can be utilised both in moderate and large panels:

$$CD = \sqrt{\frac{2T}{N(N-1)}\left(\sum_{I=1}^{N-1}\sum_{J=I+1}^{N}\hat{p}_{ik}\right)} \tag{3}$$

This study also applied the CD test shown in equation (3) to check for the presence of cross-sectional dependence. This test follows a normal distribution and is efficient under the null hypothesis of no cross-sectional independence. This test is also suitable for dynamic panels or panels with breaks in slope coefficients (Solarin & Al-Mulali, 2018).

3.2 Panel unit root and co-integration analysis

When cross-sectional independence is missing in panel data, conventional unit root tests become unsuitable instruments and it becomes necessary to use those unit root tests that consider the presence of cross-sectional dependence. One such test is the Pesaran (2007) unit root test for panel data with cross-sectional dependence.

This study used the Westerlund (2007) panel cointegration test to assess the presence of long-run relationships amongst series in the analysis. This test is based on the statistical significance of the error-correction term in a restricted panel error correction model. The choice of this technique is informed by the need to take care of the presence of cross-sectional dependence. A brief outline of the Westerlund (2007) panel cointegration test is as presented in equation (4):

$$\Delta g_{it} = \lambda_i^{'} d_i + \phi_i g_{it-1} + \eta_i^{'} x_{it-1} + \sum_{j=1}^{p_1}\phi_{ij}\Delta g_{it-j} + \sum_{j=1}^{p_3}\eta_{ij}x_{it-j} + \mu_{it} \tag{4}$$

Where ϕ_i is an error correction coefficient. This coefficient reflects the speed of adjustment back to the long-run equilibrium once the system is disequilibrium. $d_i = (1,t)^{'}$ is a vector of deterministic terms inclusive of constants and trend while $\lambda_i = (\lambda_{1i}, \lambda_{2i})^{'}$ is the vector of associated parameters. Based on the OLS estimates of ϕ_i and the associated t ratio for each cross section i, four Westerlund test statistics are thereby calculated and shown in equation (5) as follows:

$$G_\tau = \frac{1}{N}\sum_{i=1}^{N}\frac{\phi_i}{SE(\hat{\phi}_i)} \qquad G_\alpha = \frac{1}{N}\sum_{i=1}^{N}\frac{T\phi_i}{\phi_1^{'}(1)}$$

$$P_\tau = \frac{\hat{\phi}_i}{SE(\hat{\phi}_i)} \qquad P_\alpha = T\hat{\phi}_i \tag{5}$$

If all these statistics in (5) are statistically significant then the null hypothesis of no cointegration is rejected and the variables deemed to have a long-run relationship among them.

3.3 Dealing with endogeneity

Endogeneity of regressors is a problem that surfaces in econometric estimations. In this paper there are two endogenous regressors: Per capita GDP and trade openness. Endogeneity of per capita GDP requires the use of its differenced lagged values (Campbell & Mankiw, 1990) with the two-stage predictor inclusion (2SPI) method utilised to address the endogeneity problem of trade openness. The two-stage predictor inclusion method was first developed by Hausman (1978) as a method of testing and correcting for endogeneity, and has been dominantly applied in health economics. The functional form of equation (6) is linear in parameters, which makes this technique like 2SLS which, according to Greene (2003), yields consistent and unbiased estimates. The endogeneity problem is addressed in 2SPI method through the automatic transfer of the endogenous component of the endogenous regressor to the error term when the predicted values of endogenous regressors are used (Wooldridge, 2003; Terza et al., 2008).

The two-stage residual inclusion (2SRI) technique in which the second stage estimation includes the valued of endogenous regressor [instead of its predicted values] observed together with the residuals generated from the first stage regression is an alternative approach. According to Terza et al. (2008), this technique produces consistent parameter estimates for both linear and non-linear regression models. In the 2SRI method, inclusion of residuals generated from the first stage regression as one of the control variables in the second stage regression solves the endogeneity problem by accounting for the influence of any factors unidentified that influence the endogenous regressor (Terza et al., 2008). Since the first stage equation is linear, both 2SRI and 2SPI can yield identical and consistent coefficient estimates for the endogenous regressor in question (Terza et al., 2008; O'Malley et al., 2011).

In this study, trade openness is regressed against other regressors in the first stage represented in the reduced form equation specified as follows:

$$TROP_{it} = f(PCGDP_{it}, PCGDP_{it}^2, FDI_{it}, REEN_{it}, URBAN_{it}) \quad (6)$$

The predicted values of trade openness were then obtained after which the predicted error terms were generated.

$$ECFP_{it} = f(PCGDP_{it}, PCGDP_{it}^2, \hat{TROP}_{it}, \hat{RESID}_{it}, FDI_{it}, REEN_{it}, URBAN_{it}) \quad (7)$$

In the second stage of this technique, the original dependent variable "Ecological Footprint of Consumption per capita" was regressed against all other regressors; however, the predicted values of trade openness together with the generated residuals are used instead of the values of trade openness observed to test for the presence of endogeneity. The significance of the residuals confirms generated the presence of endogeneity. The residuals generated are subsequently dropped from the model and then only the predicted instrumental variable instead of the observed values of trade openness are included in the final regression equation.

$$ECFP_{it} = f(PCGDP_{it}, PCGDP_{it}^2, \hat{TROP}_{it}, FDI_{it}, REEN_{it}, URBAN_{it}) \quad (8)$$

In equation (8), the endogenous component of the trade openness is effectively transferred to the error term consistent with and unbiased against parameter estimates.

3.4 Regression model

To estimate the relationship given in equation (2), this study used the Feasible Generalised Least Square (FGLS) estimation technique because of its efficiency in estimating the relationship in the presence cross-sectional dependence and serial correlation and heteroscedasticity (Hoechle, 2007; Bai *et al*., 2021). The Panel Correlated Standard Errors by Driscoll and Kraay (1998) is an alternative technique. The PCSE technique is, nonetheless, suitable for cases with large N and small T (Driscoll & Kraay, 1998; Le & Nguyen, 2021). However, for this study T>N, hence the choice of FGLS.

4. Data Analysis

4.1 Descriptive Statistics

The data analysed is a panel of 23 countries covering a period 26 years which gives a total of 598 observations. The mean ecological footprint per capita is 1.338 Global Hactares (Gha) with a standard deviation of 0.608. The minimum ecological footprint per capita is 0.632 Gha whereas the maximum is 3.818 Gha which reflects significant variations in terms of consumption patterns across the region. The mean value of trade openness is 49.293 with a standard deviation of 36.469. Significant variations are also evident in trade openness whose the minimum value of trade openness is 11.28 and the maximum is 346.46 measured as a percentage of GDP. The descriptive statistics for study variables results are presented in
Table 2 :

Table 2 Descriptive Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
Year	598	2002.5	7.506279	1990	2015
Footprnt	598	1.33784	.6082321	.6316167	3.818476
Gdp	598	$3.40x10^{10}$	$8.03x10^{10}$	$6.21x10^{08}$	$4.62x10^{11}$
Pcgdp	598	3015.993	2960.913	542.6591	17264.44
trop	598	49.29229	36.46874	11.28426	346.4565
Renewable energy	598	75.96685	19.2976	15.57029	98.30371
Fdi	598	2.361349	4.139489	-8.70307	46.27524
Urban	598	33.80235	14.99505	5.416	67.155

4.2 Cross-sectional dependence test

A unit root analysis is undertaken to check whether the time series variables are stationary or not. The decision on the most appropriate unit root test for unit root for panel data analysis depends on whether there exists cross-sectional dependence in variables across panels (Palm et al., 2011; Gozgor, 2017). The presence of cross-sectional dependence implies that these economies depend on one another and that shocks are bound to be transmitted from one country to another (Destek & Sinha, 2020). To test for the presence of cross-sectional dependence, this study uses the testing tool developed by Pesaran, (2004). The results are summarized in Table 3. The p-values allows us

to reject the null hypothesis of the absence of cross-sectional dependence at 1% level of significance for all variables except for ecological footprint.

Table 3 Cross-sectional Dependence test results

Variable	CD-test	p-value	average joint T	mean Ï	mean abs(Ï)
Ecological footprint of consumption per capita	0.014	0.989	26.00	0.00	0.38
Urbanization rate	76.067	0.000	26.00	0.94	0.94
Population	80.179	0.000	26.00	0.99	0.99
Per capita GDP in PPP terms	23.656	0.000	26.00	0.29	0.59
Trade openness	11.257	0.000	26.00	0.14	0.30
Foreign Direct Investments (net inflows % of GDP)	16.385	0.000	26.00	0.20	0.27
Renewable energy	21.743	0.000	26.00	0.27	0.48

4.3 Unit root analysis

Having ascertained the presence of cross-sectional dependence across panels, this study adopted the CADF (Cross -Sectionally Augmented Dick-Fuller) and CIPS (Im, Pesaran and Shin, 2003) panel unit root tests developed by Pesaran (2007) because they accommodate the presence of cross-sectional dependence. The weakness of other second-generation unit root tests such as IPS and LLC (Levin, Lin and Chu, 2002), is that they assume the presence of cross-sectional independence. The results indicate that trade openness FDI are stationary at levels. Though the CIPS test shows that ecological footprint is not stationery at levels, CADF shows that the variable is stationery. Since variable did not have cross sectional dependence we test for unit. Table 4 presents the results of the Unit root analysis:

Table 4 Unit root analysis

Variable	Pescadf test		Xtcips test	
	Levels	First difference	Levels	First difference
Ecological footprint	-1.440(2) -1.386(1) -2.047(0)*	-2.587(2)*** -3.840(1)*** -5.508(0)***	-2.053(2) -2.047(1)	-5.508(2)***
Real GDP per Capita	-1.766(2) -1.756(1) -1.729(0)	-2.611(2)*** -3.073(1)*** -4.170(0)***	-1.844(2) -1.729(1)	-4.078(2)***
Real GDP per capita squared	-1.954(2) -1.844(1) -1.794(0)	-2.352(2)*** -2.719*** -3.865(0)***	-1.864(2) -1.794(1)	-3.805(2)***
Renewable energy	-1.687(2) -1.740(1) -1.854(0)	-2.573(2)*** -2.926(1)*** -4.566(0)***	-1.854(2) -1.854(1)	-4.586(2)***
Trade openness	-2.003(2) -1.944(1) -2.349(0)***	-2.828(2)*** -3.460(1)*** -5.139(0)***	-2.349(2)*** -2.349(1)***	-5.106(2)***
Foreign direct investment	-2.138(2)** -2.663(1)*** -2.980(0)***	-3.179(2)*** -4.013(1)*** -5.155(0)***	-2.997(2)*** -2.980(1)***	-5.155(2)***
Urbanization	-1.120(2) -1.561(1) -0.910(0)	-3.179(2)*** -4.013(1)*** -5.155(0)***	-1.646(2) -0.910(1)	-5.155(2)***

Archaic Information Criterial was used to choose optimal lags; * p<0.05, ** p<0.01, *** p<0.001

4.4 Heteroscedasticity and Serial correlation

Heteroscedasticity results from unreliable t and F statistics, which may lead to wrong decisions on whether to reject the null hypothesis (Gujarati, 2012). This study used xttest3 to check for the presence of the problem of heteroscedasticity. This test computes a modified Wald statistic for groupwise heteroscedasticity in the residuals of fixed effect regression according to the procedure given by Green (2008, p. 598). The results for the test, shown in Table 5, indicate that heteroscedasticity is an issue in the data considered in this study:

Table 5: Heteroskedasticity and Autocorrelation

Test	Null hypothesis	Computed Test statistic	P-value
Modified Wald test for groupwise heretoschedasticity (Chi2(23))	Sigma (i)^2= Sigma ^2	2102.38	0.000
Wooldridge Test autocorrelation test for panel data (F(1,22))	No first order autocorrelation	11.065***	0.0031

Additionally, the problem of serial correlation of error terms leads to inefficient coefficient estimates and biased standard errors (Baltagi, 2001). In this study, the presence of serial

correlation is tested using a test for serial correlation in the idiosyncratic errors of a linear panel-data model proposed by Wooldridge (2002). The null hypothesis of no serial correlation is rejected at 1% level of significance and it is evident that serial correlation is problematic in the study data.

4.5 Presence of cointegration

The Westerlund (2007) panel cointegration test assesses the existence of long-run relationships between variables. The choice of this technique is informed by the need to take care of cross-sectional dependence present in the data utilised in this study. The results in Table 6 contains very large p-values for all the four test statistics as outlined in the Westerlund (2007) panel co-integration test. Thus, it not possible to reject the null hypothesis of no co-integration amongst variables under study. As such, the study's conclusion is that the variables are not cointegrated.

Table 6: Westerlund ECM panel cointegration tests

Statistic	Value	Z-value	P-value
Ho: No cointegration; With 23 series and 6 covariates			
G_τ	-1.974	2.128	0.983
G_α	-0.765	7.527	1.000
P_τ	-7.568	2.200	0.986
P_α	-0.789	5.049	1.000

4.6 Dealing with the problem of Endogeneity

Literature on trade-income-environment nexus has adequately documented the problem of endogeneity of income and trade (Grossman & Krueger, 1993; Antweiler et al., 2001). A solution proposed the use of a suitable instrument in the place of the endogenous regressor (Frankel & Rose, 2005). There are two requirements that need to be fulfilled for an instrument to qualify to be used: Positive correlated with the endogenous regressor; and not correlated with the error term (Hall & Jones, 1999).

Several studies have used the gravity model of bilateral trade to solve the problem of endogeneity. In a departure from what most studies have applied to solve the problem of endogeneity of trade openness, this study has used a two-stage predictor inclusion method as a solution to the problem. Under this method two steps help to solve the endogeneity problem. Trade openness is first regressed against all other variables before the predicted values of trade openness are obtained. Both the predicted values of trade openness and the residuals obtained are used in the original regression. The significance of the predicted residuals indicates the presence of the endogeneity problem in the trade openness data. The model is then estimated using the predicted values of trade openness as an instrumental variable for trade openness. The results are as presented in Table 7:

Table 7: Testing for endogeneity

Outcome variable	Regression 1 Trade openness	Regression 2 Ecological footprint (FDI values are lagged)
GDP per capita	-0.0170***	0.000270***
	(-24.61)	(20.20)
Square of GDP per capita	0.000000902***	-1.10e-08***
	(33.20)	(-9.63)
Renewable Energy Consumption	0.132***	-0.00359***
	(6.34)	(-12.27)
Urbanization	1.536***	-0.00912*
	(4.41)	(-2.44)
Trade openness		0.00274***
		(5.90)
Predicted Residuals from Regression 1		0.0000752***
		(5.81)
FDI net inflows	0.519***	-0.00255***
	(42.00)	(-10.60)
Constant	47.38***	-0.129***
	(157.52)	(-5.73)
N	575	575

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001

On the other hand, the endogeneity of income is addressed using lagged differenced variables of per capita income. According to Campbell and Mankiw (1990), any lagged stationary variables of the endogenous regressor can act as valid instruments. After all, they do not only meet the orthogonality condition but also highly correlated with the endogenous regressor.

4.7 GLS Regression analysis

The generalised least squares regression can help estimate the existence of the first order autocorrelation within panels as well as in the presence of cross-sectional correlation and heteroskedasticity across panels. The GLS regression results for our analysis are in Table 8:

Table 8: Ecological Footprint Regression

	Variables transformed				Variables not transformed			
	Regression 1 With controls	Regression 2 without controls	Regression 3 Partial controls	Regression 4 Partial controls	Regression 5 With controls	Regression 5 without controls	Regression 7 Partial controls	Regression 8 Partial controls
Per capita GDP	0.202** (2.96)	0.150 (1.41)	0.241** (3.21)	0.0906 (0.88)	0.0000297*** (5.78)	0.000044*** (7.70)	0.0000417*** (6.43)	0.0000322*** (8.18)
Square of per capita GDP	-0.0158*** (-3.35)	-0.0110 (-1.48)	-0.0184*** (-3.54)	-0.00670 (-0.93)	-1.91e-09** (-3.07)	-2.96e-09*** (-5.16)	-2.51e-09*** (-3.69)	-2.44e-09*** (-5.16)
Trade openness	-0.243*** (-29.91)	-0.241*** (-19.53)	-0.218*** (-25.38)	-0.277*** (-21.12)	-0.00848*** (-32.47)	-0.00855*** (-32.88)	-0.00933*** (-29.35)	-0.00792*** (-42.62)
FDI	0.0347*** (19.31)	0.0364*** (13.52)	0.0323*** (17.36)	0.0396*** (13.92)	0.00471*** (23.38)	0.00487*** (24.67)	0.00524*** (22.21)	0.00446*** (29.96)
Renewable energy	-0.197*** (-27.10)	-	-0.209*** (-24.40)	-	-0.00246*** (-17.81)	-	-	-0.00250*** (-23.58)
Urbanization	-0.302*** (-8.71)	-	-	-0.356*** (-10.49)	-0.00866*** (-3.64)	-	-0.0124*** (-4.85)	-
Constant	0.865*** (30.40)	0.849*** (19.54)	0.769*** (25.36)	0.986*** (21.54)	0.405*** (31.80)	0.405*** (32.84)	0.447*** (28.99)	0.374*** (42.15)
Obs.No	552	552	552		552	552	552	552
EKC Turning point	597.291		698.48453		7774.869	7449.324	8306.7729	6598.361
Turning point ecological footprint	4.5296		4.75		0.520456	0.569257	0.59275	0.480234

t-statistics in parentheses *p<0.05, ** p<0.01, *** p<0.001

***Effect of trade openness**:* Trade openness has negative coefficient indicating that increased international trade has a direct effect of reducing the ecological footprint of consumption in the study countries. The results match with the findings of Destek et al. (2018), and Destek and Sinha (2020). Trade enables a country to improve the welfare of its citizens by availing goods produced elsewhere. Since production generates pollutant emissions, as by-products, the relatively low levels of production, especially in manufacturing sectors of the economy in sub-Saharan African countries (Melina & Portillo, 2018), could explain the positive environmental effects of trade.

Depending on the kind of commodities traded, the openness transaction might raise the ecological footprint of consumption. Trade increases ecological footprint in nations whose footprint of imports exceeds that of exports (Borucke et al., 2013). Implicitly, such a country depends on ecological goods and services generated by ecological assets found in other countries. SSA has over the years been a major exporter of biocapacity particularly raw materials from agricultural and mining sectors (Melina & Portillo, 2018). Moran et al.'s (2009) analysis of global footprint flows based on data from COMTRADE demonstrates that Africa's non-energy footprint flows in exports totalled to 29.4 M ha, which outstripped imports at 23.5M ha.

***Effects of FDI**:* FDI complements trade in goods and services by facilitating capital transfer from capital abundant to capital deficient countries to facilitate investment in increased production as authorities strive to reduce abject poverty. According to the results from this study, increased FDI inflows increases ecological footprint of consumption. Similar results were obtained by Baloch et al. (2019), and Majeed and Mazhar (2019). These results, however, contrasted with those of Solarin and Al-mulali (2018) as well as Destek and Okumus (2019). Solarin and Al-mulali (2018) conducted their study in a sample of countries consisting of both developed and developing countries and collectively found no significant effect of FDI. Destek and Okumus (2019), on the other hand, conducted their studies in newly-industrialised countries and found EFP to reduce FDI up to a certain threshold. At the country level results, Solarin and Almulali (2018) found that FDI and urbanisation had a positive effect on ecological footprint in developing nations but the opposite effect in developed nations.

This negative effect of FDI on the environment observed in this study could be attributable to the weak environmental regulations in developing relative to those in developed economies. In fact, the less stringent the environmental regulation the more competitive is advantage for less developed economies in terms of their ability to attract dirty industries that are being pushed out of production by more stringent regulations in their developed host countries. To save production costs associated the implementation of cleaner production technologies, these firms migrate their highly polluting production activities to less developed countries, hence creating a pollution haven in line with what has been termed in literature as the "pollution haven hypothesis".

***Effects GDP per capita**:* The results show that the coefficient of per capita GDP is positive and statistically significant and that of the square of per capita GDP is negative, implying that the relationship between per capita GDP measured in purchasing power parity terms and ecological footprint of consumption in study area is an inverted U-shape, which resonates well with the EKC hypothesis. These results are like those found by Ulucak and Bilgili (2018), and Sarkodie and Strezov (2018). The results, however, are incongruent with findings by Bagliani et al. (2008), Charfeddine and Mrabet (2017), Aşıcı and Acar (2018), Destek and Sinha (2020). Based on the

results, the the EKC hypothesis in the sub-Saharan African context is valid. According to the EKC hypothesis, the quality of the environment decreases as economies grow to a given threshold level of income and, subsequently, further economic growth leads to an increase in environmental quality. The average per capita GDP for Sub-Saharan Africa was 3,809 international dollars in 2015 based on 2017 PPP terms (World Bank, 2019) estimated turning point of 7,775 international dollars.

Effects of renewable energy use: The results of this study also show that increased use of renewable energy decreases ecological footprint of consumption. Similar results are evident in studies by Stöglehner (2003), Deakin and Reid (2018), Isman et al. (2018), and Destek and Sinha (2020). These results imply that heightened dependence on non-renewable energy sources to meet a country's energy needs leads to more pollutant emissions resulting in dirtier environment. In other words a nation that strives to meet its own and global sustainability goals must make deliberate efforts aimed to reduce the proportion of non-renewable energy in its energy exploitation portfolio.

Effects of Urbanisation: The study also found that Urbanization reduces ecological footprint. This segment of findings are like those of Danish and Wang (2018) and Ulucak and Khan (2020) but differ from those of Al-Mulali and Ozturk (2015) and Al-Mulali et al. (2015b). The negative and significant effect of urbanisation on ecological footprint to consumption may be accounted for multiple factors. As Danish and Wang (2018) argue that urbanisation generate positive externalities and is also responsible for the increases in returns to scale in the provision of public services such as water and waste management while leaving a large portions of land relatively less damaged. Additionally, increased incomes occurring alongside heightened access to educational opportunities in urban agglomerations Ulucak and Khan (2020) could generate increased public awareness, which plays a crucial role in generating demand for cleaner environment.

5. Conclusions

This paper has analysed the influence of trade openness on ecological footprint alongside the effects of other control variables such as per capita GDP, foreign direct investment, renewable energy use, and urbanisation. Results indicate that ecological footprint is inversely related with trade openness, directly related FDI inflows. The results also show that there is an inverted U-shaped relationship between real GDP per capita and ecological footprint. Urbanisation and renewable energy use also is inversely related to ecological footprint. These results invite numerous policy implications.

The negative effect of trade openness on ecological footprint points to the benefits of trade on environmental quality. According to Kirkpatrick and Scrieciu (2008), these effects could be attributable to stronger positive technological effects that exceed the negative scale effects engendered by liberalisation. The findings are consistent with the conclusions reached by Antweiler et al. (2001) and Copeland and Taylor (2004), who explain that trade improves economic activity and creates a positive net effect on the environmental quality.

Nations in Sub-Saharan Africa have an opportunity of leveraging on growth in clean production technologies to offset the negative scale effects that may be created because of rapid expansion of production activities. Several countries in the region have demonstrated commitment to shifting

the energy sources from highly polluting to cleaner ones (Amankwah-Amoah, 2015; Müller et al., 2020) through initiatives that are at different stages of implementation in different stages. Focusing particularly on the opportunities in solar energy in recent years, technological breakthroughs have led to increased affordability of solar panels and multiple flagship projects are in the offing across the region. Examples include Solar Energy Park in the Northern Cape Province in South Africa, HQMC Korea's investment project in Nigeria, Off-grid solar projects to electrify 24 rural communities in Ghana amongst many others (Amankwah-Amoah, 2015).

To contain environmental degradation resulting from increased FDI inflows, authorities in sub-Saharan Africa need to scrutinise the level of adherence to environmental sustainability policies of corporation before offering investment opportunities. Some multinational corporations investing in low-income economies maintain strict compliance with strict environmental standards of their parent countries. Such corporations may not only able to transfer capital to low-income countries through foreign direct investment but also participate in clean technology transfer. By so doing countries, which lack cleaner production technologies, can access these technologies from their trading partners with well-developed cleaner production technologies. This phenomenon can potentially generate some positive environmental consequences. Steps taken in this direction will help enhance environmental sustainability and contribute to solving the global problem of climate change.

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