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Trade and FDI Thresholds of CO_2 emissions for a Green Economy in Sub-Saharan Africa

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Abstract

This research focuses on assessing how improving openness influences CO_2 emissions in Sub-Saharan Africa. It is based on 49 countries in SSA for the period 2000-2018 divided into: (i) 44 countries in SSA for the period 2000-2012; and (ii) 49 countries for the period 2006-2018. Openness is measured in terms of trade and foreign direct investment (FDI) inflows. The empirical evidence is based on the Generalised Method of Moments. The following main findings are established. First, enhancing trade openness has a net positive impact on CO_2 emissions, while increasing FDI has a net negative impact. Second, the relationship between CO_2 emissions and trade is a Kuznets shape, while the nexus between CO_2 emissions and FDI inflows is a U-shape. Third, a minimum trade openness (imports plus exports) threshold of 100 (% of GDP) and 200 (% of GDP) is beneficial in promoting a green economy for the first and second sample, respectively. Fourth, FDI is beneficial for the green economy below critical masses of 28.571 of Net FDI inflows (% of GDP) and 33.333 of net FDI inflows (% of GDP) for first and second samples, respectively. It follows from findings that while FDI can be effectively managed to reduce CO_2 emissions, this may not be the case with trade openness because the corresponding thresholds for trade openness are closer to the maximum limit. This study complements the extant literature by providing critical masses of Trade and FDI that are relevant in promoting the green economy in Sub-Saharan Africa.

JEL Classification: C52; O38; O40; O55; P37

Keywords: CO_2 emissions; Economic development; Africa; Sustainable development

1. Introduction

The importance of globalisation in development outcomes is still open to debate in scholarly and policy-making circles. The positioning of this research on openness thresholds for CO_2 emissions in Sub-Saharan Africa (SSA) is motivated by two main factors in the literature, namely: (i) the importance of trade globalisation vis-à-vis financial globalisation in development outcomes and (ii) gaps in the attendant literature on the relevance of environmental pollution in the shared goals of the post-2015 development agenda. These factors are expanded in turn.

First, since the 2008 financial crisis, the longstanding debate on the relevance of openness in development outcomes has been resurfaced (Prasad & Rajan, 2008; Asongu, 2014; Price & Elu, 2014; Motelle & Biekpe, 2015). The theoretical and empirical literature are consistent with the position that some initial domestic development conditions are necessary for countries to benefit from the dynamics of globalisation, notably, on trade and financial fronts (Henry, 2007; Kose *et al.*, 2011; Asongu, 2017). The present study focuses on the initial conditions of financial and trade openness, in the consequences for carbon dioxide (CO_2) emissions, owing to an apparent gap in the scholarly literature.

Second, the environmental degradation literature has fundamentally focused on nexuses between CO_2 emissions, energy consumption and development outcomes. This attendant literature can be categorised into two main strands. The first strand is concerned with interrelationships between economic growth and the degradation of the environment, while the second is tilted towards, linkages between energy use and economic development. In this latter strand, we find research that has: (i) assessed bivariate connections between the use of energy and economic development (Jumbe, 2004; Ang, 2007; Odhiambo, 2009a, 2009b; Apergis & Payne, 2009; Menyah & Wolde-Rufael, 2010; Ozturk & Acaravci, 2010; Bölük& Mehmet, 2015; Begum *et al.*, 2015) and (ii) focused on trivariate linkages between economic growth, environmental pollution and the use of energy (Mehrara, 2007; Olusegun, 2008; Akinlo, 2008; Esso, 2010).

Conversely, the second strand of the literature has focused on testing the Environmental Kuznets Curve (EKC)[1] hypothesis (Diao *et al.*, 2009; Akbostanci *et al.*, 2009; He & Richard, 2010). Accordingly, the EKC hypothesis pertains to the non-linear relationship

[1]"The EKC hypothesis postulates that in the long term, there is an inverted U-shaped relationship between per capita income and environmental degradation".

between income levels and environmental standards. The present study is closer to this second strand, compared to the first strand. Furthermore, the current research also departs from the second strand by assessing the EKC hypothesis in the perspective of trade and financial openness. Such a positioning departs from the engaged literature on two main fronts. On the one hand, the attendant literature has focused on a limited number of variables with particular emphasis on the non-linear relationship between income per capita and environmental pollution. This present research departs from the underlying by focusing on three variables, namely: trade openness, financial openness and CO_2 emissions. On the other hand, the research argues that it is not enough to provide policy makers with directions on linkages between the two variables of interest motivating the EKC hypothesis. Accordingly, such connections have less policy relevance unless they are robust to specific policy thresholds underlying the inflexion points. In other words, disclosing a specific critical mass at which increasing a macroeconomic variable either increases or decreases CO_2 emissions is more informative for policy makers because they are provided with concrete policy actions that should be taken in order to lower CO_2 emissions. Furthermore, an extension of the EKC hypothesis in the light of threshold analysis is particularly relevant in the post-2015 development agenda, which centres on the promotion of the green economy.

The green economy is particularly vital for Sustainable Development Goals (SDGs) for a plethora of relevant imperatives and cautions documented in contemporary development literature (Akinyemi *et al*., 2015; Akpan *et al*., 2015; Mbah & Nzeadibe, 2016; Asongu *et al*., 2016a; Akinyemi *et al*., 2018; Efobi *et al*., 2019; Anyangwe, 2014; Odhiambo, 2010, 2014a, 2014b). With specific regard to Africa, it has been documented that policy makers in sub-Saharan Africa are very concerned because the consequences of global warming are most harmful in the sub-region (Shurig, 2015; Kifle, 2008; Akpan & Akpan, 2012; Huxster *et al*., 2015; Asongu et al., 2017, 2018). This positioning of this study on openness thresholds for a green economy in SSA is consistent with the underlying policy concerns because this research aims to provide critical masses of openness that are favorable for a green economy in the sub-region.

The theoretical underpinnings motivating this study are both relevant to the EKC and the anticipated economic development benefits from globalization. We take them in turn. First, the EKC hypothesis is an extension of the Kuznets curve theoretical hypothesis on the nexus between income inequality and per capita income. These underpinnings have been substantially documented in the environmental literature (He & Richard, 2010; Akbostanci *et* *al*., 2009; Diao *et al*., 2009). The present research builds on this established EKC underpinnings to provide specific thresholds in openness variables that either positively or negatively affect CO_2 emissions. Hence, this research is also positioned as a theory-building exercise – because beyond establishing evidence of an EKC, it also provides specific policy thresholds that are relevant in the openness "CO_2 emissions" nexus. This theory-building framework accords with the literature that is sympathetic to the view that applied econometrics is not exclusively limited to the acceptance and rejection of existing theoretical notions (Narayan *et al*., 2011; Asongu & Nwachukwu, 2016a). Accordingly, applied econometrics may also be tailored to extend existing theoretical underpinnings.

Second, the theoretical framework underlying the importance of openness in development outcomes is mixed at best. As expanded in Section 2, various strands in the literature are positioned in favour and against the positive ramifications of globalisation. Whereas from the theoretical background, openness is rewarding because it represents a mechanism of sharing risks and enhancing financial allocation efficiency, especially for less developed countries (Kose *et al*., 2006; Kose *et al*., 2011; Asongu et al., 2015)[2], another strand of the theoretical debate supports the perspective that complete capital and trade openness are detrimental to domestic economies because domestic economies become more exposed to global economic and financial crises (Rodrik, 1998; Bhagwati, 1998; Stiglitz, 2000). A third strand is of the view that the benefits and costs of openness are contingent on certain initial domestic conditions of economic development (Henry, 2007; Asongu, 2014; Asongu & De Moor, 2017). The present research is most aligned with this third strand because it aims to provide specific critical masses at which openness (trade and financial) affects CO_2 emissions.

It is also important to note that while various studies (Antweiler *et al*., 2001; Shahbaz & Sinha, 2019; Tran, 2019) have investigated the EKC hypothesis, the main premise of an EKC is the relationship between two variables: one with a negative signal (i.e. outcome variable) and the other (i.e. independent variable of interest) considered as a positive signal. In this study CO_2 emission per capita which is the outcome variable is a negative signal or policy syndrome while trade and foreign direct investment (FDI) which can be considered as positive

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[2]This strand of theoretical underpinnings posits that less developed countries are relatively lacking capital but abundantly blessed with cheap labour. Therefore, it is in their interest to open to their economies to foreign capital and trade in labour-intensive products. The thesis also supports the perspective that compared to developing countries, openness-driven output volatility is less apparent in developed countries (Kose *et al*., 2011).

signals are the independent variables of interest. Moreover, the positioning of the study departs from contemporary literature on linkages between CO_2 emissions, trade and FDI which have largely focused on: differences between developing and developed countries in nexuses between trade, FDI and CO_2 emissions (Essandoh *et al.*, 2020); nexuses between urbanization, trade and CO_2 emissions (Muhammad et al., 2020); and the connection between trade and CO_2 emissions in top CO_2 emitters (Ansari *et al.*, 2020).

The rest of the paper is structured as follows. The theoretical highlights are expanded in section 2, whereas the data and methodology are covered in section 3. The findings are discussed in section 4 before the research concludes with implications and further research directions in section 5.

2. Hypothesis development

The decision of making a transition from a "partial open" trade and financial account to an economic regime of "full openness" of these accounts remains a debate in the contemporary literature (Asongu & De Moor, 2017). According to the attendant literature, there are two main views on the policy importance of openness in developing countries, such as in SSA.

On the one hand, a perspective on "allocative efficiency" and international risk-sharing, as advantages from openness is fundamentally premised on the neoclassical model developed by Solow (1956). This neoclassical model maintains that the liberalisation of capital account enhances the allocation of international resources in an efficient manner. According to the theoretical framework, whereas rich countries have abundant capital at their disposal, they are equally characterised by scarcity in cheap labour. This is contrary to less developed countries which are wealthier in cheap labour but less abundantly blessed with capital. The theoretical postulations rest on the assumption that capital should flow from capital-rich countries to capital-scarce nations where the return of capital is comparatively low. The positive economic development rewards in poor countries include: enhanced investment opportunities, reduced cost of capital, and broad-based economic prosperity that are likely to improve the standards of living (Fischer, 1998; Obstfeld, 1998; Rogoff, 1999; Summers, 2000; Batuo & Asongu, 2015). These theoretical arguments have been instrumented to support the policy relevance of developing countries' decisions to open their economies to foreign trade and capital. This strand is also relevant to a perspective of empirical literature which maintains that the evolving globalisation has fast-tracked the transition of many countries from low-income to middle-income status while simultaneously consolidating economic stability in more developed countries (Fischer, 1998; Summers, 2000).

Conversely to the above, another sceptical strand of the literature maintains that openness has negative consequences in terms of trade distortions and financial volatilities. According to this strand, the supposed theoretical advantages of openness do not converge with practical tendencies of capital and trade account openness (Batuo & Asongu, 2015). This sceptical dimension is best supported by Rodrik (1998) and Rodrik and Subramanian (2009) with provocative titles like “Who Needs Capital-Account Convertibility?” and “Why Did Financial Globalization Disappoint?”, respectively. Rodrik (1998) maintains that the nexus between financial openness and “investment and growth rates” in developing countries is not apparent. He goes further to conclude that whereas the benefits of such openness cannot be easily established, the costs of financial openness are more apparent from recurrent global financial meltdowns which are increasingly evident both in terms of frequency and magnitude of occurrence. Rodrik and Subramanian (2009) more recently also establish that the crisis in sub-prime mortgages in the United States of America (USA) and the resulting global economic crisis have reignited scepticism surrounding the economic rewards of contemporary developments in financial engineering.

In summary, this strand of the literature has argued that the justifications for international risk-sharing and allocation efficiency are surreptitious attempts to extending the international benefits of trade to potential rewards from financial assets. This is mainly because while there is a consensus on the benefits of international trade in economic development, the rewards of international finance remain subject to debate in scholarly and policy-making circles (Asongu, 2017). This leads to the following hypothesis that will be tested in the empirical section.

Hypothesis: Enhancing trade globalisation is anticipated to mitigate CO_2 emissions compared to financial globalisation in sub-Saharan Africa.

3. Data and methodology

3.1 Data

In the light of the motivation of this study, the research uses data for the period 2000-2012 from forty-four countries in SSA[3]. Two main data sources are used for the empirical analysis, notably, the: (i) World Development Indicators of the World Bank for the CO_2 emission, globalization and some control variables and (iii) World Governance Indicators of the World Bank for a control variable (i.e. regulation quality). The sampled countries and periodicity are motivated by data availability constraints at the time of the study.

The outcome variable is CO_2 emissions per capita, in the light of recent environmental degradation literature (Asongu, 2018a). Trade openness and foreign direct investment (FDI) are also adopted as openness variables in accordance with recent literature on nexuses between information and communication technology, openness and environmental degradation (Asongu, 2018b). Still in line with Asongu (2018b), four main control variables are adopted in the conditioning information set, namely: population growth, education quality, regulation quality and gross domestic product (GDP) growth. While these variables are expected to affect CO_2 emissions, the anticipated signs cannot be established with certainty because they are contingent on *inter alia*: the equitable distribution of fruits from economic prosperity and quality of regulation. For instance, economic growth that is not broad-based is associated with reduced consumption on the part of the poor and by extension less contribution of the poor to greenhouse gas emissions. This narrative is even more apparent when the population growth is considerably from poor factions of the population. Moreover, regulation quality is a variable that has both positive and negative signals. Hence, a negatively skewed regulation quality can be interpreted as poor governance instead of good governance. Therefore, poor governance is logically associated with more environmental degradation. These above conditions are apparent in some SSA countries because: (i) despite enjoying more than two decades of growth resurgence, about half of countries in the sub-region failed to achieve the Millennium Development Goal (MDG) extreme poverty target (Tchamyou, 2019, 2020; Tchamyou *et al.*, 2019; Asongu & Nwachukwu, 2017a, 2017b); (ii) the rich in Africa prefer the quality of children to the quantity of children and hence, the poor contribute

[3]The 44 countries are: "Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo Democratic. Republic., Congo Republic, Cote d'Ivoire, Djibouti, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome & Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda and Zambia".

relatively more to population growth (Asongu, 2013) and (iii) governance standards in African countries are on average negatively skewed. The third point is directly apparent from the summary statistics disclosed in the appendix. Accordingly, the regulation quality variable ranges from -2.110 to 0.983, with a mean of -0.604. This is an indication that the left or negative side of regulation quality weighs more in the distribution of the variable.

3.2 Methodology

3.2.1 GMM: Specification, identification and exclusion restrictions

Four principal factors motivate the adoption of the Generalised Method of Moments (GMM) as our empirical strategy. (i)When the numerical value of agents being studied (i.e. cross sections) substantially exceeds the number of periods in each agent, the GMM approach is a good fit. This is the case with the present data structure because the research is focused on 44 countries for the period 2000-2012. (ii) The CO_2 emission indicator depicts persistence given that, the correlation between its level and first difference values is greater than 0.800, which is the established rule of thumb threshold for confirming that a variable is persistent (Asongu & le Roux, 2017). (iii) In light of the panel data structure of the study, cross-country differences are taken on board in the regressions. (iv) The concern about endogeneity is also addressed from two angles: reverse causality is tackled with the adoption of instruments, while the unobserved heterogeneity is also controlled for by means of time-invariant variables. It is also relevant to note that the Generalised Least Squares (GLS) method focuses on the concerns about efficiency that are the result of shortcomings in classical regression assumptions while GMM applies when endogenous variables are apparent in the model.
Consistent with recent empirical literature (Asongu & Nwachukwu, 2016b; Boateng *et al.*, 2018; Tchamyou *et al.*, 2019), this research adopts the Roodman (2009a, 2009b) improvement of Arellano and Bover (1995) because it has better properties in terms of reducing instrument proliferation with the collapse of instruments.

The following equations in level (1) and first difference (2) summarise the standard *system* GMM estimation procedure.

$$C_{i,t} = \sigma_0 + \sigma_1 C_{i,t-\tau} + \sigma_2 O_{i,t} + \sigma_3 OO_{i,t} + \sum_{h=1}^{4} \delta_h W_{h,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (1)$$

$$\begin{aligned} C_{i,t} - C_{i,t-\tau} &= \sigma_1 (C_{i,t-\tau} - C_{i,t-2\tau}) + \sigma_2 (O_{i,t} - O_{i,t-\tau}) + \sigma_3 (OO_{i,t} - OO_{i,t-\tau}) \\ &+ \sum_{h=1}^{4} \delta_h (W_{h,i,t-\tau} - W_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + (\varepsilon_{i,t} - \varepsilon_{i,t-\tau}) \end{aligned} \quad (2)$$

where, $C_{i,t}$ is the carbon dioxide emission variable of country i in period t, σ_0 is a constant, O entails openness (Trade and FDI), OO denotes quadratic interactions between openness dynamics ("Trade" × "Trade", and "FDI" × "FDI"), W is the vector of control variables (*population growth, education quality, regulation quality* and *GDP growth*), τ represents the coefficient of auto-regression which is one within the framework of this study because a year lag is enough to capture past information, ξ_t is the time-specific constant, η_i is the country-specific effect and $\varepsilon_{i,t}$ is the error term. The two globalization variables are modelled distinctly in order to facilitate the computation of thresholds. For the purpose of clarity, readability and flow, an explanation of how thresholds are computed is provided in Section 4.2.

3.2.2Identification and exclusion restrictions

Still motivated by the attendant literature, this research devotes space to elucidating properties of identification and exclusion restrictions that are indispensable for a robust GMM specification. These studies have defined the strictly exogenous variables as years or time-invariant variables and the explanatory variables as the predetermined or endogenous explaining variables (Asongu & Nwachukwu, 2016c; Tchamyou & Asongu, 2017; Tchamyou *et al*., 2019; Boateng *et al*., 2018). The identification strategy is supported by Roodman (2009b) who has argued that time-invariant indicators cannot feasibly be endogenous after a first difference[4].

The connection between the underlying identification strategy and corresponding exclusion restrictions assumption is based on whether the identified strictly exogenous variables can influence the outcome variable exclusively through the exogenous components of the identified predetermined variables. A rejection of the alternative hypothesis of the Difference in Hansen Test (DHT) which confirms this exclusion assumption, is not dissimilar to less complex instrumental variable approaches in which, a failure to reject the null hypothesis of the Sargan test indicates that the instruments do not influence the outcome variable beyond the identified endogenous explaining mechanisms (Beck *et al*., 2003; Asongu & Nwachukwu, 2016d).

[4]Hence, the procedure for treating *ivstyle* (years) is 'iv (years, eq(diff))' whereas the *gmmstyle* is employed for predetermined variables.

4. Empirical results

4.1 Presentation of results

Table 1 discloses the empirical results performed with the Stata 13.0 software. The findings are divided into two main sections. Whereas the left-hand side shows trade-related regressions, the right-hand discloses the corresponding FDI-oriented estimations. For estimations pertaining to either of the two openness dynamics, three main specifications are apparent: the first without a conditioning information set (or control variables); the second with two control variables and the third with the full conditioning information set (or four control variables). It is worthwhile to emphasise that the incremental engagement of control variables can also be considered as a measure of robustness check because the empirical literature based on GMM estimations employs zero control variable (Osabuohien & Efobi, 2013) and two control variables (Bruno *et al*., 2012). Hence, the models in which no control variables are engaged are also worthwhile. Moreover, four main criteria are used to assess the overall validity of the GMM estimates[5]. On the basis of these criteria, it can be established that except for the second specification pertaining to FDI (i.e. that which is based on two control variables), the estimated models overwhelmingly pass the post-estimation diagnostic tests. The underlying second specification on the right-hand side does not pass post-estimation diagnostic tests because the null hypothesis of the Hansen test is rejected. The null hypothesis of this test is the position that the instruments are valid. Moreover, a rule of thumb is to prefer the Hansen test to the Sargan test, contingent on the absence of proliferated instruments. In essence, the Hansen test is robust but sensitive to instrument proliferation, while the Sargan test is not robust but not sensitive to instrument proliferation. Hence, it isthe rule of thumb to use the Hansen test and limit instrument proliferation by ensuring that for every specification, the number of instruments is less than the corresponding number of countries.

In order to examine the total effect of enhancing openness on environmental pollution, net impacts are calculated in accordance in with the attendant literature on quadratic (Asongu & Odhiambo, 2019a) and interactive (Asongu & Odhiambo, 2019b; Tchamyou, 2019b) regressions. These total effects entail: (i) the marginal or conditional effect resultsfrom the

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[5] "*First, the null hypothesis of the second-order Arellano and Bond autocorrelation test (AR (2)) in difference for the absence of autocorrelation in the residuals should not be rejected. Second, the Sargan and Hansen over-identification restrictions (OIR) tests should not be significant because their null hypotheses are the positions that instruments are valid or not correlated with the error terms. In essence, while the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In order to restrict identification or limit the proliferation of instruments, we have ensured that instruments are lower than the number of cross-sections in most specifications. Third, the Difference in Hansen Test (DHT) for exogeneity of instruments is also employed to assess the validity of results from the Hansen OIR test. Fourth, a Fischer test for the joint validity of estimated coefficients is also provided*" (Asongu & De Moor, 2017, p.200).

interactive or quadratic estimated coefficients and (ii) the corresponding unconditional estimates. For instance, in the fourth column of Table 1 pertaining to trade estimations, the total effect from enhancing trade is 0.0009 (2×[-0.00002× 76.756] + [0.004]). In this computation, the mean value of trade openness is 76.756, the marginal impact of trade openness on CO_2 emissions is -0.00002, whereas the unconditional impact of trade openness on CO_2 emissions is 0.004. The leading 2 on the first term is from the differentiation of the quadratic term. In the same vein, in the fifth column of the table, the net effect from enhancing FDI is -0.0036(2×[0.00003× 5.381] + [-0.004]). In this calculation, the average value of FDI is 5.381, the unconditional effect of FDI is -0.004, while the marginal effect is 0.00003. Accordingly, the leading 2 on the first term is from the differentiation of the quadratic term. Using the same computational analogy, the net effect in the last column of the table is -0.0032(2×[0.00007× 5.381] + [-0.004]).

The following main findings can be established from Table 1. Enhancing trade openness has a net positive effect on CO_2 emissions, while increasing FDI has a net negative effect. The significant control variables have the anticipated signs in the light of the discourse in the data section. The tested hypothesis is not validated because enhancing FDI reduces CO_2 emissions instead. This finding can be explained from the perspective that FDI activities are more associated with environmental activities and corporate social responsibility, compared to trade activities. However, testing the hypothesis does not exhaustively address the problem statement motivating this study. Accordingly, thresholds can be established from nexuses between the corresponding marginal and unconditional effects. This extended analysis is the focus of the next section.

Table 1: Empirical Analysis

	Dependent variable: CO_2 emissions per capita					
	Trade Openness (Trade)			Financial Openness (FDI)		
CO_2 emissions (-1)	**0.825*** (0.000)**	**0.898*** (0.000)**	**0.892*** (0.000)**	**0.836*** (0.000)**	**0.951*** (0.000)**	**0.903*** (0.000)**
Trade	-0.004 (0.177)	0.003 (0.100)	**0.004*** (0.000)**	---	---	---
FDI	---	---	---	**-0.004*** (0.000)**	-0.001 (0.134)	**-0.004*** (0.004)**
Trade ×Trade	0.00001 (0.203)	-0.00001 (0.101)	**-0.00002*** (0.000)**	---	---	---
FDI × FDI	---	---	---	**0.00003*** (0.001)**	**0.00004*** (0.008)**	**0.00007*** (0.002)**
Population Growth	---	**-0.100*** (0.000)**	**-0.087*** (0.000)**	---	**-0.086*** (0.000)**	**-0.056*** (0.000)**
Education	---	**-0.004** (0.018)**	**-0.003*** (0.009)**	---	**0.005*** (0.004)**	-0.0003 (0.824)
Regulation Quality	---	---	0.060 (0.132)	---	---	**0.206*** (0.000)**
GDP Growth	---	---	**-0.002*** (0.005)**	---	---	-0.0006 (0.413)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Net effects	na	na	0.0009	-0.0036	na	-0.0032
Thresholds	na	na	100	66.666	na	28.571
AR(1)	**(0.128)**	**(0.128)**	**(0.129)**	**(0.129)**	**(0.146)**	**(0.136)**
AR(2)	**(0.287)**	**(0.227)**	**(0.161)**	**(0.286)**	**(0.229)**	**(0.170)**
Sargan OIR	(0.001)	(0.000)	(0.000)	(0.018)	(0.000)	(0.000)
Hansen OIR	**(0.354)**	**(0.661)**	**(0.316)**	**(0.432)**	(0.061)	**(0.706)**
DHT for instruments						
(a)Instruments in levels						
H excluding group	---	**(0.229)**	**(0.251)**	---	**(0.193)**	**(0.222)**
Dif(null, H=exogenous)	**(0.693)**	**(0.717)**	**(0.355)**	**(0.446)**	**(0.068)**	**(0.801)**
(b) IV (years, eq(diff))						
H excluding group	---	---	**(0.331)**	---	---	**(0.491)**
Dif(null, H=exogenous)	---	**(0.791)**	**(0.339)**	**---**	**(0.138)**	**(0.718)**
Fisher	**374.36*** **	**4442.95*** **	**12897.62*** **	**676.10*** **	**46425.19*** **	**16786.21*** **
Instruments	22	29	36	22	29	36
Countries	44	44	43	44	44	43
Observations	441	325	294	451	325	295

"*, **, ***: significance levels of 10%, 5% and 1% respectively. *DHT*: Difference in Hansen Test for Exogeneity of Instruments' Subsets. Dif: Difference. *OIR*: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients, Hausman test and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the *AR(1)* and*AR(2)* tests; and b) the validity of the instruments in the Sargan *OIR* test. Na: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant. The mean values of trade openness and FDI are respectively, 76.756 and 5.381. Constants are included in the regressions.

4.2 Empirical analysis on policy thresholds

It is apparent from the results in Table 1 that the conditional effect of trade and FDI are, respectively, negative and positive. A direct implication is that thresholds can be established at which; (i) enhancing trade reduces CO_2 emissions, and (ii) increasing FDI increases CO_2 emissions. These thresholds directly complement the established net effects in the perspective that: (i) where net effects are positive, policy makers can build on established thresholds to avoid the positive effect and (ii) where net impacts are negative, policy makers can build on the computed thresholds to maintain the negative effect.

In the light of the above, for trade openness, a threshold of 100 (0.004/ [2×0.00002]) % of GDP is required for the increasing levels of trade to have a negative effect onCO_2 emissions. That is, when trade (imports + exports) is at 100 (% of GDP), its net effect on CO_2 emission is zero (2×[-0.00002× 100] + [0.004] =0). Therefore, the minimum threshold required in sampled countries for the enhancement of trade not to be detrimental to building a green economy is 100 (% of GDP). Hence, above this threshold, trade is beneficial in promoting a green economy. This established threshold makes economic sense and has policy relevance because it is within the policy range (i.e. minimum to maximum) disclosed in the summary statistics (i.e. 20.964 to 209.874).

Building on the same analogy for FDI-oriented specifications, the thresholds are 66.666 (0.004/ [2×0.00003]) and 28.571 (0.004/ [2×0.00007]), respectively, for the first and third specifications on the right-hand side. Hence, thresholds of between 28.571 and 66.666 FDI inflows (% of GDP) are required for FDI inflows not to have a detrimental effect on the green economy. Above these thresholds, FDI becomes detrimental to the green economy because it increases CO_2 emissions. Given that the third estimation involves control variables, while the first estimation does not, the former is more consistent with reality and hence 28.571 is our better threshold. This choice is also consistent with the estimations from the left-hand side because the net effect and corresponding threshold have been established from the third specification, involving all elements of the conditioning information set.

In the light of the above clarification, when FDI inflow is 28.571 (% of GDP), its negative net effect on CO_2 emissions becomes zero (2×[0.00007× 28.571] + [-0.004]=0). Therefore, for the sampled countries, the maximum limit required for the enhancement of net FDI inflows not to be detrimental to the building of a green economy is 28.571 (% of GDP). Hence, below this threshold, a net FDI inflow is beneficial in promoting the green economy. This established threshold makes economic sense and has policy relevance because it is within the policy range (i.e. minimum to maximum) disclosed in the summary statistics (i.e. -6.043 91.007).

The conception and definition of the above threshold is broadly in line with recent literature (see Batuo, 2015; Asongu & Odhiambo, 2019c) and the basis for U-shapes and Kuznets shapes (Ashraf & Galor, 2013). Hence, in the light of the motivation of this study, while the EKC hypothesis literature has been extended with the establishment of thresholds and net effects, it is also relevant to interpret the findings in the light of the attendant literature that this research has expanded. This leads to the following complementary findings: the relationship between CO_2 emissions and trade has a Kuznets shape (owing to decreasing marginal effects), while the nexus between CO_2 emissions and FDI inflows has a U-shape (given the increasing marginal effects). Consistent with the motivation of the study, simply investigating the EKC hypothesis to establish U shape and inverted U-shape nexuses is not enough to inform policy makers on actionable measures: net effects and policy thresholds are also worthwhile.

4.3 Robustness checks: more countries with contemporary data

In order to assess whether the findings withstand empirical validity, for robustness checks, the sample is extended to the existing 49 SSA countries and a more updated periodicity with 13 years (i.e. 2006-2018) is adopted[6]. Hence, this robustness section departs from the previous section which is based on 44 countries in SSA for the period 2000-2012 (i.e. 13 years). The motivation for adopting another periodicity entailing 13 years is to avoid concerns of instrument proliferation in post-estimation diagnostics tests. The corresponding summary statistics and correlation matrix are provided in Appendix 4 and Appendix 5, respectively.

Table 2 is a replication of Table 1, taking into account the changes discussed above. The same information criteria are used to assess the validity of models and the procedures for computing net effects and thresholds are also similar. The findings are consistent with those of Table 1 in terms of net effects. However, as concerns thresholds, the minimum trade openness thresholds doubles whereas the maximum FDI threshold increases by approximately 5 units of Net FDI inflows (% of GDP) (i.e. 33.333-28.571).

[6] Of the 54 African countries, the North African countries excluded from the SSA sample are: Algeria, Egypt, Libya, Morocco and Tunisia.

Table 2: Robustness checks: more countries with contemporary data

	Dependent variable: CO2 emissions per capita					
	Trade Openness (Trade)			Financial Openness (FDI)		
CO2 emissions (-1)	**1.001*** (0.000)**	**0.924*** (0.000)**	**0.898*** (0.000)**	**0.991 (0.000)**	**0.948*** (0.000)**	**0.925*** (0.000)**
Trade	0.002 (0.108)	**0.008*** (0.000)**	**0.004*** (0.000)**	---	---	---
FDI	---	---	---	-0.001 (0.167)	**-0.001** (0.029)**	**-0.002*** (0.005)**
Trade ×Trade	-0.000009 (0.113)	**-0.00002*** (0.000)**	**-0.00001*** (0.000)**	---	---	---
FDI × FDI	---	---	---	**0.00001* (0.095)**	0.00001 (0.112)	**0.00003** (0.010)**
Regulation Quality	-0.075 (0.335)	**-0.174*** (0.001)**	-0.005 (0.872)	-0.029 (0.639)	**-0.231*** (0.000)**	-0.025 (0.430)
GDP Growth	**-0.003*** (0.009)**	**-0.004*** (0.001)**	**-0.006*** (0.000)**	**-0.002* (0.083)**	**-0.003*** (0.000)**	**-0.004** (0.027)**
Population Growth	---	**0.260*** (0.000)**	**0.151*** (0.000)**	---	**0.260*** (0.000)**	**0.107*** (0.000)**
Education	---	---	-0.001 (0.654)	---	---	-0.001 (0.380)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Net effects	na	nsa	0.0024	na	na	-0.0016
Thresholds	na	nsa	200	na	na	33.333
AR(1)	**(0.108)**	**(0.119)**	**(0.130)**	**(0.110)**	**(0.113)**	**(0.136)**
AR(2)	**(0.124)**	**(0.148)**	**(0.173)**	**(0.126)**	**(0.137)**	**(0.188)**
Sargan OIR	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hansen OIR	**(0.769)**	(0.059)	**(0.216)**	**(0.461)**	**(0.242)**	**(0.623)**
DHT for instruments						
(a)Instruments in levels						
H excluding group	**(0.392)**	**(0.148)**	**(0.114)**	**(0.256)**	**(0.253)**	**(0.289)**
Dif(null, H=exogenous)	**(0.877)**	**(0.096)**	**(0.463)**	**(0.626)**	**(0.307)**	**(0.792)**
(b) IV (years, eq(diff))						
H excluding group	**(0.562)**	**(0.102)**	**(0.095)**	**(0.583)**	**(0.449)**	**(0.233)**
Dif(null, H=exogenous)	**(0.750)**	**(0.138)**	**(0.636)**	**(0.337)**	**(0.144)**	**(0.954)**
Fisher	**3266.03*** **	**3494.09*** **	**6720.90*** **	**3904.75*** **	**5353.20*** **	**13135.27*** **
Instruments	28	32	36	28	32	36
Countries	47	47	46	48	48	47
Observations	445	445	331	459	459	341

*, **, ***: significance levels of 10%, 5% and 1% respectively. *DHT*: Difference in Hansen Test for Exogeneity of Instruments' Subsets. Dif: Difference. *OIR*: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients, Hausman test and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the *AR(1)*and *AR(2)* tests and; b) the validity of the instruments in the Sargan *OIR* test. na: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant. nsa: not specifically applicable because the model is not valid. The mean values of trade openness and FDI are respectively, 76.929 and 5.286. Constants are included in the regressions.

5. Conclusion and future research directions

This research focuses on assessing how improving openness influences CO_2 emissions in 49 countries in SSA for the period 2000-2018 divided into: (i) 44 countries in SSA for the period 2000-2012 and (ii) 49 countries for the period 2006-2018. Openness is measured in terms of trade and foreign direct investment (FDI) inflows. The empirical evidence is based on the Generalised Method of Moments. The following main findings are established. First, enhancing trade openness (imports + exports) has a net positive effect on CO_2 emissions, while increasing FDI has a net negative effect. Second, the relationship between CO_2 emissions and trade has a Kuznets shape (owing to decreasing marginal effects), while the nexus between CO_2 emissions and FDI inflows has a U-shape (given the increasing marginal effects). Third, a minimum trade openness (imports plus exports) threshold of 100 (% of GDP) and 200 (% of GDP) is beneficial in promoting a green economy for first and second sample respectively. Hence, above this threshold, trade is beneficial in promoting a green economy. As a policy implication, trade should be encouraged beyond the established thresholds. Fourth, the maximum limit required for the enhancement of net FDI inflows not to be detrimental to the construction of a green economy is 28.571 (% of GDP) and 33.333 (% of GDP) for first and second samples, respectively. Hence, below this threshold, net FDI inflows are beneficial in promoting the green economy. As a policy implication, FDI above the established thresholds should be accompanied with robust policy action designed to: (i) limit CO_2 emissions; and (ii) encourage environmental-related corporate responsibility from Multinational Corporations. These established thresholds make economic sense and have policy relevance because they are within the policy ranges (i.e. minimum to maximum) disclosed in the summary statistics. In summary, from a practical standpoint, while FDI can be effectively managed to reduce CO_2 emissions, this may not be the case with trade openness because the corresponding thresholds are closer to the maximum limits.

Future studies can assess whether the established findings are relevant within country-specific frameworks. This recommendation is premised on the fact that country-specific effects are eliminated from the empirical strategy in order to address concerns of endogeneity. It is worthwhile to note that the research failed to consider embodied emissions in trade owing to globalization. This was mainly due to data availability constraints at the time of this study. This caveat also serves a pointer for future research on this topic.

Appendices

Appendix 1: Definitions of variables

Variables	Signs	Definitions of variables (Measurements)	Sources
CO_2per capita	CO2mtpc	CO_2emissions (metric tons per capita)	World Bank (WDI)
Trade Openness	Trade	Imports plus Exports of goods and services (% of GDP)	World Bank (WDI)
Foreign investment	FDI	Foreign Direct Investment inflows (% of GDP)	World Bank (WDI)
Educational Quality	Educ	Pupil teacher ratio in Primary Education	World Bank (WDI)
Population growth	Popg	Population growth rate (annual %)	World Bank (WDI)
Regulation Quality	RQ	"Regulation quality (estimate): measured as the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development"	World Bank (WDI)
GDP growth	GDPg	Gross Domestic Product (GDP) growth (annual %)	World Bank (WDI)

WDI: World Bank Development Indicators. UNDP: United Nations Development Program.

Appendix 2: Summary statistics (2000-2012)

	Mean	SD	Minimum	Maximum	Observations
CO_2per capita	0.911	1.842	0.016	10.093	532
Trade Openness	76.759	35.381	20.964	209.874	519
Foreign Investment	5.381	8.834	-6.043	91.007	529
Educational Quality	43.892	14.775	12.466	100.236	397
Population growth	2.335	0.876	-1.081	6.576	495
Regulation Quality	-0.604	0.542	-2.110	0.983	496
GDP growth	4.801	5.054	-32.832	33.735	530

S.D: Standard Deviation. The uniform sample sizes in Appendix 3 and 5 are based on a balanced panel dataset. This is done automatically by the Stata software for a correlation matrix. However, the values in Appendix 2 and Appendix 4 take into account missing observations and hence, the corresponding panel is unbalanced. This explains the differences in terms of observations.

Appendix 3: Correlation matrix (uniform sample size: 347)

	CO2mtpc	Trade	FDI	Educ	Popg	RQ	GDPg
CO2mtpc	1.000						
Trade	0.174	1.000					
FDI	-0.069	0.344	1.000				
Educ	-0.445	-0.385	-0.096	1.000			
Popg	-0.537	-0.437	0.086	0.440	1.000		
RQ	0.399	0.065	-0.140	-0.307	-0.283	1.000	
GDPg	-0.082	-0.029	0.172	0.116	0.206	-0.085	1.000

CO2mtpc:CO_2emissions (metric tons per capita).Trade: Trade Openness. FDI: Foreign Direct Investment. Educ: Equality Quality. Popg: Population growth. RQ: Regulation Quality. GDPg: Gross Domestic Product growth. The uniform sample sizes in Appendix 3 and 5 are based on a balanced panel dataset. This is done automatically by the Stata software for a correlation matrix. However, the values in Appendix 2 and Appendix 4 take into account missing observations and hence, the corresponding panel is unbalanced. This explains the differences in terms of observations.

Appendix 4: Summary statistics (2006-2018)

	Mean	SD	Minimum	Maximum	Observations
CO_2per capita	0.977	1.879	0.022	10.428	526
Foreign Investment	5.286	9.297	-6.369	103.337	608
Trade Openness	76.929	43.063	19.100	134.997	585
Regulation Quality	-0.722	0.634	-2.645	1.127	632
GDP growth	4.386	4.812	-46.082	20.715	603
Population growth	2.478	0.915	-2.628	5.027	630
Educational Quality	40.712	13.724	12.467	100.236	440

S.D: Standard Deviation. The uniform sample sizes in Appendix 3 and 5 are based on a balanced panel dataset. This is done automatically by the Stata software for a correlation matrix. However, the values in Appendix 2 and Appendix 4 take into account missing observations and hence, the corresponding panel is unbalanced. This explains the differences in terms of observations.

Appendix 5: Correlation matrix (uniform sample size: 364)

	CO2mtpc	FDI	Trade	RQ	GDPg	Popg	Educ
CO2mtpc	1.000						
FDI	0.052	1.000					
Trade	0.359	0.357	1.000				
RQ	0.327	-0.044	0.033	1.000			
GDPg	-0.095	0.075	0.022	0.050	1.000		
Popg	-0.296	0.020	-0.367	-0.382	0.078	1.000	
Educ	-0.476	-0.135	-0.493	-0.313	0.123	0.344	1.000

CO2mtpc:CO_2emissions (metric tons per capita). FDI: Foreign Direct Investment. Trade: Trade Openness. RQ: Regulation Quality. GDPg: Gross Domestic Product growth. Popg: Population growth. Educ: Equality Quality. The uniform sample sizes in Appendix 3 and 5 are based on a balanced panel dataset. This is done automatically by the Stata software for a correlation matrix. However, the values in Appendix 2 and Appendix 4 take into account missing observations and hence, the corresponding panel is unbalanced. This explains the differences in terms of observations.

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