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RESEARCH PAPER

Structural Change, Financial Development, and Carbon Dioxide Emissions: Does Evidence Support EKC for Sub-Sahara Africa?

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Abstract
There are clear signs of climate change in Africa, while the continent has limited economic and financial muscle to generate clean, low-carbon, greener, and energy-efficient production activities needed to improve environmental quality. Hence, this paper examines the impact of structural change and financial development on carbon dioxide emissions and tests whether the EKC hypothesis is supported for 31 sampled Sub-Saharan African countries between 1990 and 2017. The study utilizes the pooled mean group heterogeneous panel data. The study finds that the EKC exists for all income groups. The deterministic role of financial development is observed for low and lower-middle-income countries while the influential role of financial development was obtained for upper-middle and high-income countries. Structural change, industrialization, and agriculture increase the level of CO_2 in upper-middle and high, lower-middle, and low-income countries, respectively. To minimize climate change in Africa, there is a need to invest in energy-efficient industrialization and agricultural practices which could be achieved through targeted financial support.
Keywords: Structural Change, Financial Development, Carbon Dioxide Emissions, Sub-Saharan Africa, Income Group.
JEL Classification: G29, O13, Q56.

Introduction

Since the writing of the Brundtland Commission report in 1987, there has been a debate on whether economic growth could resolve environmental threats like the accumulation of carbon dioxide (CO_2) in the atmosphere. Some argue that economic growth must cease and the world must take to a steady-state economy (see, Daly, 1991). Beckerman (1992) and Bartlett (1994) indicate that the surest way to improve the quality of the environment is by becoming well-off. In support of Beckerman and Bartlett, Hoffmann (2011) argues that developing countries like those in sub-Sahara Africa (SSA) attract ‘dirty’ and material-intensive domestic and industrial activities that generate high CO_2 emissions. Meanwhile, industrialized countries have the economic and financial muscle to generate clean, low-carbon, greener, and energy-efficient technology innovations that improve environmental quality.

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Empirical studies hypothesized and tested the claims of Hoffmann (2011) by investigating the link between CO_2 emissions and income for developed and developing countries using the Environmental Kuznets Curve (EKC) model (for example, Piaggio and Padilla, 2012; Mitić et al., 2017). Such studies are criticized for being vulnerable to the problem of omitted variables bias (Stern, 2004). Thus, the question of whether the level of income is the only development-related variable that matters became pertinent (Panayotou, 1997). Other empirical studies (for example, Pandelis, 2012; Casey and Galor, 2017) included economic variables, like the share of industry in GDP, population density, trade openness, energy consumption, and so on, and the variables are found to affect CO_2 emissions. Economic activities experience dynamic changes as a result of many factors such as improvement in the process of production in either the industrial or agricultural sector or both. These structural changes may also affect CO_2 emissions. Since these factors occur in the development process of many SSA countries, empirical evidence on how such structural change affects emissions in SSA is very terse in the literature. This is a novel contribution to this paper.

Yassin and Aralas (2017) identify the two stages of structural change as industrialization and tertiarisation. Being a set of developing countries with a high number of low-income countries that are considered to be agricultural-based (UNCTAD, 2012), the first stage of structural change is the common phenomenon for SSA. Because of this, the paper uses the proxy of value-added to portray the gradual shift from agricultural-based economic activities to industrialization. The value-added measure is supported by the extract of the explanation of the EKC that “as the share of agriculture falls, the share of industry rises” (Panayotou, 2003).

De Groot (2003) affirms that structural change can result in more production and consumption of goods with less pollution as income increases in advanced economies. Marsiglio et al. (2016) confirmed this condition for European Union countries that are industrialized while Yassin and Aralas (2017) found evidence that supports the increase in pollution due to industrialization and decrease in pollution due to tertiarisation for Asian countries. None of the earlier studies considered this issue for SSA. Besides contributing to the empirical literature by focusing on SSA, the study will observe the role of the financial sector in the specified models of previous studies. This is because this was absent in the models specified by earlier studies that considered how structural change affects pollution.

Lanoie et al. (1998) and Dasgupta et al. (1998) argue that the financial sector can reduce CO_2 emissions through the provision of finance to willing firms to procure cleaner technologies and low-emission driven investments. The sector can also facilitate foreign capital inflows and offer to hedge for financially weak firms that would like to procure environmental-friendly types of machinery (Claessens and Feijen, 2007). The alternate opinion to the aforesaid role that financial development plays expresses that, since developing countries attract material-intensive commodities (Hoffmann, 2011), the financial system would mostly provide credit assistance for the production and consumption of carbon-related commodities in developing countries (World Bank, 2000). This, expectedly, would increase the volume of emissions even with good environmental policies (Jensen, 1996).

Consequently, the financial sector may influence CO_2 emissions on one hand and stimulate the technological progress that would reduce CO_2 emissions on the other in SSA. However, none of the studies reviewed considered the influence of structural change and financial development on CO_2 emissions. Studies on CO_2 emissions and financial development apply the domestic credit to the private sector to GDP (Charfeddine and Khediri, 2016 and Javid and Sharif, 2016) and the ratio of deposit money bank assets to GDP (Tamazian et al., 2009) as the proxy for financial development. The main reason for this wide use is because the measures depict the ease with which industrialists can obtain finance. However, the measures capture only the asset side of banks’ balance sheets while ignoring the liability side. This study contributes to the literature by applying the ratio of bank credit to bank deposit as the measure of financial development. This portrays the financial stability of the sector (and not the depth) and captures both the liability and asset sides (Onanuga and Onanuga, 2016).

Given the above, this study examines how structural change and financial development contribute to carbon dioxide emissions. It equally tests whether the EKC hypothesis is supported for Sub-Sahara Africa (SSA). Unlike earlier studies that used the growth of manufacturing and services sectors (Marsiglio et al., 2016) and energy intensity to portray structural change (Yassin and Aralas, 2017), this study portrays structural change based on the differential between the two sectors' value-added i.e. agricultural output and industrial production. This is done by obtaining the difference between the share of industry and the share of agriculture in the gross domestic product (GDP) to measure structural change. The inter-sector differentials would be higher and or positive as the share of agriculture falls and the share of industry rises (Panayotou, 2003). It would be lower and or negative as the share of agriculture is rising and the share of industry is falling. The rest of the paper is divided into four sections. Section two discusses the literature review, section three contains the methodology adopted for the study, sections four and five focus on the discussion of findings and conclusion and recommendation.

Literature Review

Theoretical Review

Although the STIRPAT equations pose that the environmental impact depends on the levels of population, affluence, and technology (Dietz and Rosa, 1997), the EKC hypothesis proposes that environmental degradation is a function of income (affluence). The shape of the EKC is an inverted U curve that is explained using the process of structural change or growth. For this study, the former explanation is adopted. In the early stages of development i.e. moving from being a pre-industrial economy to an industrial economy (see Figure 1), there is a deterioration of environmental quality as the share of agriculture falls and the share of industry rises (Panayotou, 2003). This would happen as a consequence of increasing physical capital intensive over human capital intensive activities which in turn would make production, income per capita, and consumption grow gradually (UNCTAD, 2012). As the society becomes well-off, the share of the industry starts to decline and that of services increases i.e. moving from being an industrial economy to post-industrial, resulting in an expected improvement in environmental quality (Panayotou, 2003). This means that, at the turning point (which is under industrial economies) in Figure 1, environmental indicators would start to display improvements (UNCTAD 2012).

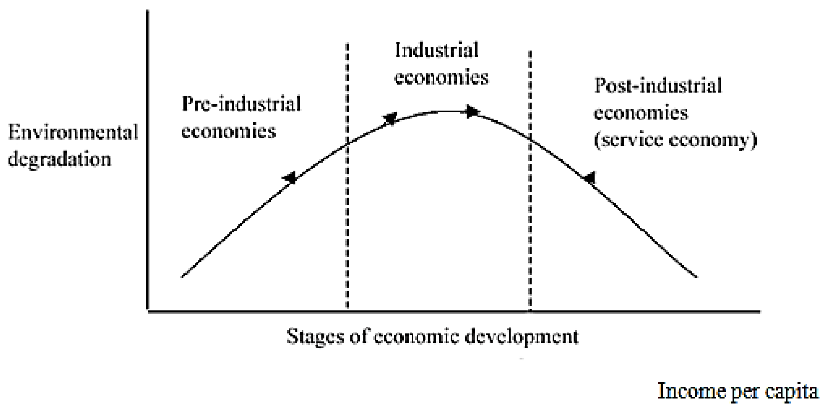

Figure 1. The Shape of the EKC
Source: Panayotou (2003:46).

$$E = \beta_0 + \beta_1 Y + \beta_2 Y^2 + \varepsilon \qquad (2.1)$$

The traditional model for the shape of the EKC presented in Figure 1 is expressed in equation 2.1. Where E is an environmental indicator, Y is the income per capita, Y^2 is the squared income per capita, β_0, β_1, β_2 are coefficients and ε is the error term. Where β_1 is a priori expected to be positive and β_2 is a priori expected to be negative. Equation 2.1 is expected to convey a long-run relationship between environmental quality and economic growth (Stern, 2004).

The EKC's behavior has an income effect resulting from a cleaner environment being a luxury good (Moomaw and Unruh, 1997). That is, a cleaner CO_2 environment is a commodity with an income elasticity that is greater than one. In a political system that is responsive to the preferences of its people, as income grows environmental concern rises more than proportionally. The reason for this is that rich countries are likely to have the advanced social, legal and fiscal infrastructure that is essential for enforcing environmental regulations and promoting 'green awareness' (see, Neumayer 1998). Earlier studies (for example, Grossman and Krueger, 1991; Shafik and Bandopadhyay, 1992) concluded that the connection between some environmental indicators and income per capita is the EKC.

The relation between economic growth and environmental damage seems more complex than portrayed by the EKC. Numerous critics have challenged the EKC, both as a representation of what happens in the development process and as a policy prescription. In developing countries, some policymakers have interpreted the EKC as conveying a message that prioritises the logic of 'grow first, clean up later (Dasgupta et al., 2002). However, the supposition that the rich care more about the environment than the poor is far from conclusive (Kriström and Riera, 1996). This implies that policymakers might be able to prevent environmental degradation at any stage of development (Neumayer, 1998). This is given that income is a significant factor in CO_2 emissions but not the only viable solution for environmental problems (Onanuga, 2017).

Empirical Review

Economic Development

Empirical evidence on the pattern of EKC in SSA is diverse. Al-Mulali et al. (2015) find that the EKC is invalid in low and lower-middle-income countries (LIC and LMIC) while it is valid for upper-middle and high-income countries (UMIC and HIC). This supports the fact that LIC and LMIC are in the early stages of economic development. Casey and Galor (2017) find that a linear relationship exists for both poor and rich countries. Muftau et al. (2014) indicate that the N shape exists between CO_2 emissions and GDP for West Africa while Ojewumi (2015) supports that the U-shape exists for SSA and not the EKC. To resolve this finding of no EKC for SSA (and LIC and LMIC), this study applies the structural change.

Dissimilar from this study, Mensah (2014) employs energy use to proxy structural change in six emerging economies and finds that it has environmental effects. Instead of the industrialization effect, Marsiglio et al. (2016) explore the tertiarisation effect of structural change and find that it is not sufficient to delink income from emissions in developed countries. Yassin and Aralas (2017) conduct both the industrialization and tertiarisation effect and finds that industrialization induces emissions while tertiarisation lowers emissions in Asian countries. However, Yassin and Aralas's model can be criticized for multicollinearity. Unlike Yassin and Aralas, the difference between the share of agriculture and the share of industry in GDP is employed with the share of agriculture and industry in GDP to specify nexus models in this paper.

Studies have also considered industry activity to investigate the link between CO_2 emissions and economic development on the premise that fossil fuels led to the start of the industrial revolution in the 18th century. They found that industry activity captures the composition effect as to whether per capita emissions decrease due to a movement from pollution-intensive industries to less-polluting industries (see, He and Richard (2010); Tamazian et al. (2009); Grunewald and Martinez-Zarzoso (2011)). Since continuous industrialization requires a sustained energy source, industrial production is assumed to be more polluting than agricultural production in the early stages of development in structural change (He and Richard, 2010). Therefore, agricultural activity is under-researched because it is assumed that developing countries are gradually industrializing. Meanwhile, activities like soil tillage and conversion of land not previously used for the cultivation of crops release organic carbon into the atmosphere. This is severe in East Africa, Namibia, Botswana, and Mauritania. The increase in livestock production due to the globally growing human population has led to tens of billions more livestock exhaling more CO_2 than the pre-industrial era. As more livestock are kept for consumption, forests are simultaneously cleared to grow feeds, more pastures get degraded through livestock grazing, and the earth's carbon sink potential declines sharply (Goodland and Anhang, 2009).

Based on Heckscher-Ohlin trade theory, developing countries specialize in the production of commodities that are labor and natural resources abundant (which are usually pollution-intensive) for exportation. Developing countries also serve as a dumping ground for outdated technology through importation from developed countries. The use of such old model technology in industries in SSA would stimulate an increase in emissions into the atmosphere. This is referred to as the 'pollution haven effect' (Begun and Eicher, 2008). Alternatively, trade openness may lead to more investment in efficient and cleaner technologies that meet climate change mitigation actions (Shafik and Bandyopadhyay, 1992). The disparity in findings between Charfeddine and Khediri (2016) and these studies -Tamazian and Rao (2010), Alege and Ogundipe (2013), and Onafowora and Owoye (2013)- concludes that the pollution haven effect does not apply to all developing countries.

Although fossil fuels top the list when CO_2 emissions are discussed because it guarantees a continuous energy source for domestic and industrial consumption (Goodland and Anhang, 2009), energy consumption includes fossil fuels, nuclear, renewable electricity and net electricity imports. Despite this, studies in the literature (for example, Tamazian and Rao, 2010; Shahbaz, 2013) have found that energy consumption increases CO_2 emissions. This finding is in line with the popular view that energy consumption is the main source of CO_2 emissions. Neumayer (2004) suggests that if there is a negative relationship between energy consumption and CO_2 emissions then more renewable energy sources may have been substituted for fossil fuels. Onanuga (2017) provides evidence that establishes this.

Environmental pressures intensify not only because of rising affluence and structural transformation but also because of a growing population and increasing urbanization (UNCTAD, 2012). Selden and Song (1994) (empirically supported by Carvalho and Almeida (2010)) argue that higher population density may lead to a decline in per capita pollution emissions because high population density results in greater social conscience about environmental problems. Meanwhile, Panayotou (2000) (empirically supported by Onafowora and Owoye (2013)) observes that, as an economy transforms from agricultural-based to industrial-based, higher population density may reduce the cost of transportation and electrification but increases emissions level through higher demand in fuel.

As an economy industrializes, more of its population leave the rural areas for urban centers in search of white-collar jobs (Cole and Neumayer, 2004). Due to the rapid increase in urbanization in SSA (Muggah and Kilculien, 2016), measuring the effect of structural change becomes imperative.

Financial Development

The deterministic role of financial development, to facilitate more finance at lower costs for investment in eco-friendly projects to reduce CO_2 emissions in developing countries, is empirically supported by Salahuddin et al. (2015), and Ozatac et al. (2017). Muftau et al. (2014), Charfeddine and Khediri (2016) and Javid and Sharif (2016) empirically support the influential role of financial development. The literature recognizes the importance of financial openness on environmental performance (Tamazian et al., 2009). Due to data deficiency on de jure measures of financial openness, de facto measures of financial openness are popular. Tamazian et al. (2009) applied the de facto measure of the Lane and Milesi-Ferreti index. However, the United Nations Commission on Trade and Development's (UNCTAD) *de facto* measure of the inward flow of Foreign Direct Investment (FDI) to GDP is applied for this study because of its long-term nature and less volatility (Estrada et al., 2015).

Frankel and Romer (1999) believe that policies directed at financial openness to attract research and development-related FDI can improve economic activities that would reduce CO_2 emissions. Instead of the inflow of FDI to GDP, studies have applied FDI inflows stock. The impact of FDI on CO_2 emissions is controversial. Tamazian et al. (2009) and Tamazian and Rao (2010) support the premise that FDI (or multinational plants) in developing countries are more likely to act as a conditional factor that motivates the procurement and use of energy-efficient and cleaner technologies. On the contrary, Alege and Ogundipe (2013) and Baek (2016) find that increasing FDI leads to an increase in CO_2 on the premise that multinationals would invest in energy inefficient and material intensive technologies in developing countries with weak environmental regulations. Hence, the pollution haven effect can occur in developing countries through financial openness. To the best of our knowledge, the literature is terse on how both structural change and financial development advance the EKC hypothesis in SSA. This is the gap this study is filling.

Methodology

Empirical Model

Considering the debate on additional explanatory variables and the Cobb-Douglas feature identified by Andreoni and Levinson (2001), this study adopts equation 3.1 (in the natural log) in the form:

$$lnE = \beta_0 + \beta_2 lnY + \beta_3 lnY^2 + \beta_k lnZ + \varepsilon \tag{3.1}$$

where *lnE* is the logarithm of environmental degradation, β_0 is the constant while β_2, β_3 β_4 and β_k are coefficients of respective explanatory variables, lnY is the logarithm of income, lnY^2 is the logarithm of squared income, lnZ is the vector of other variables and ε is the error term. Using equation 3.1, three models (equations 3.2 to 3.4) are specified to investigate the relationship that per capita emissions of CO_2 have with per capita income and other variables that may possess the characteristics of cleanup or increase in emissions in SSA.

$$lnCO_{2it} = \beta_0 + \beta_1 lnY_{it} + \beta_2 lnY_{it}^2 + \beta_4 A_{it} + \beta_6 EO_{it} + \beta_7 lnEc_{it} + \beta_8 FD_{it} + \beta_9 FO_{it} + \beta_{10} Pd_{it} + \beta_{11} Up_{it} + \varepsilon_{it} \tag{3.2}$$

$$lnCO_{2it} = \beta_0 + \beta_1 lnY_{it} + \beta_2 lnY_{it}^2 + \beta_5 I_{it} + \beta_6 EO_{it} + \beta_7 lnEc_{it} + \beta_8 FD_{it} + \beta_9 FO_{it} + \beta_{10} Pd_{it} + \beta_{11} Up_{it} + \varepsilon_{it} \tag{3.3}$$

$$lnCO_{2it} = \beta_0 + \beta_1 lnY_{it} + \beta_2 lnY_{it}^2 + \beta_3 STRCH_{it} + \beta_4 A_{it} + \beta_6 EO_{it} + \beta_7 lnEc_{it} + \beta_8 FD_{it} + \beta_9 FO_{it} + \beta_{10} Pd_{it} + \beta_{11} Up_{it} + \varepsilon_{it} \quad (3.4)$$

where $lnCO_2$ is per capita emissions of CO_2; income (lnY and lnY^2) is represented with GDP per capita. Other variables (lnZ) in rates or percentages are not in logarithmic form. These are the share of agriculture as a percentage of GDP (A); the share of industry in GDP (I); the difference between I and A which is to measure structural transformation ($STRCH$); total trade as a percentage of GDP is the proxy for trade openness (EO); total primary energy consumption ($lnEc$); the ratio of bank credit to bank deposit is the proxy for financial development (FD); the ratio of net inflow of foreign direct investments to GDP is the proxy for financial openness (FO); population density (Pd); and urban population as a percentage of total population (Up). The acronyms defined above are expressed at country i, time t and ε_{it} is the error term, which is assumed to be white noise. The Turning point is obtained by applying $e^{-\beta_1/2\beta_2}$ to the specified coefficients.

To examine the structural change in SSA, the share of agriculture to GDP, industry share as a percentage of GDP, and the measure of structural transformation are alternately treated as control variables in the specified panel models. Data for all the variables, except CO_2 emissions per capita, total primary energy consumption, and bank credit to bank deposit, are obtained from the World Development Indicators. CO_2 emissions per capita are from Boden *et al.* (2017); total primary energy consumption is from the United States Energy Information Administration, and bank credit to bank deposit is from the Global Financial Development Database. The data are for the period 1990 to 2017 for 31 SSA countries.

Estimation Procedure

The descriptive statistics of the data are obtained (Table 2). The data's respective unit root test is conducted using Levin, Lin, and Chu's (LLC) unit root test which assumes that all panels share a common autoregressive parameter. Based on the dynamic nature of the specified models and the level and first difference levels of integration among the study variables, the pooled mean group / autoregressive distributed lag estimation method (PMG/ARDL) is the non-stationary estimation method employed. The method adapts the cointegration form of the ARDL model to a panel set by allowing the intercepts, coefficients, and the cointegrating term to differ across cross-sections (Pesaran et al., 1999). Since the EKC is expected to convey a long-run relationship, the PMG/ARDL is suited for the task.

The PMG/ARDL estimator as developed by Pesaran et al., 1999 is adopted due to its superiority to the mean group (MG) estimator introduced by Pesaran and Smith (1995). Unlike the MG, the PMG/ARDL is an intermediate estimator that allows its short-run coefficients to differ across groups and constrains the long-run coefficients to be equal across groups.

Before the PMG/ARDL, the conduct of the cointegration test is necessary for the (EKC) regressions to confirm that there is an equilibrium relationship between CO_2 and its determinants.[1] Due to its ease to conduct and interpret, compared to other cointegration tests, the Kao Residual cointegration test is conducted. Unlike Ojewunmi (2015) whose study is on West Africa, this procedure is applied to the entire sample of SSA countries (itemized in Table 1) and three income groups.

Discussion of Findings

[1]. Simultaneity bias becomes less serious in models that exhibit cointegration (Stern 2004).

The results of the panel unit root tests in Table 3 conform to the condition to apply the

Table 1. List of Countries

Sub-samples	Countries
LIC(18)	Benin, Burkina Faso, Burundi, Chad, Central Africa Republic, Guinea, Guinea Bissau, Madagascar, Malawi, Mali, Mozambique, Niger, Rwanda, Senegal, Sierra Leone, Tanzania, Togo, and Uganda
LMIC(8)	Cameroon, Congo Republic, Ghana, Kenya, Lesotho, Nigeria, Sudan, and Zambia
UMIC&HIC(5)	Botswana, Mauritius, Namibia, Seychelles, and South Africa

Source: Research finding.

Table 2. Descriptive Statistics

	Entire sample			LIC			LMIC			UMIC & HIC		
	Mean	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**
CO_2	0.824	0.01	10.0	0.137	0.011	0.629	0.423	0.092	1.15	3.954	0.02	10.0
Y	3402	354	25218	1236	354	2491	2939	1380	5671	12046	5719	25524
A	28.2	2.03	62.4	36.64	13.8	62.4	23.42	3.38	48.5	5.427	2.03	12.8
I	24.9	2.59	77.4	19.6	4.62	47.1	32.58	2.59	77.4	31.92	14.3	61.0
STRCH (I-A)	-3.22	-56.8	73.7	-17.0	-56.8	23.7	6.36	-38.3	73.7	26.29	10.0	56.1
EO	67.99	11.1	225	54.58	19.7	126	77.22	11.1	209	101.3	37.4	225
EC	0.234	0.002	5.71	0.031	0.002	0.27	0.2101	0.003	1.35	0.9918	0.006	5.71
FD	75.86	16.9	192	78.92	20.9	192	66.2	22.2	160	80.44	16.8	137
FO	3.482	-6.89	54.1	4.70	-4.85	46.4	4.349	-4.84	38.8	4.215	-6.89	54.0
Pd	88.22	1.72	621	81.33	4.72	471	54.61	7.14	198	167.2	1.71	621
Up	33.01	5.42	65.4	26.76	5.41	47.7	37.72	13.9	65.3	47.86	27.6	64.8

Source: Research finding.

PMG/ARDL. All the variables are either integrated at level (I(0)) or first difference (I(1)) and none of them are integrated at the second difference (Baek, 2016). The panel cointegration tests presented in Table 4 also conform to the condition to apply the PMG/ARDL. There is a cointegrating relationship in the specified models at one percent. Based on the theory, only the long-run relationship of the specified models and their respective error correction terms (ECT) are presented in Table 5. The ECT is expected to be negative, less than unity, and statistically significant to provide evidence that a unique cointegrating vector exists between CO_2 and the explanatory variables. This exists for all the equations estimated for the entire sample, LIC, LMIC, and UMIC & HIC.

Table 3. Panel Unit Root Tests

Entire Sample		**lnCO_2**	**lnY**	**A**	**I**	**STRCH**	**EO**	**lnEC**	**FD**	**FO**	**Pd**	**Up**
LLC:	Statistic	-10.5	-14.5	-3.63	-3.47	-5.14	-2.48	-4.93	-7.28	-8.43	-5.34	-5.43
	Diagnostic	I(0)*	I(1)*	I(0)*	I(0)*	I(0)*	I(0)*	I(0)*	I(1)*	I(0)*	I(1)*	I(1)*
LIC (low-income countries)												
LLC:	Statistic	-14.4	-12.7	-4.28	-3.48	-3.97	-18	-6.95	-5.64	-3.1	-6.01	-5.13
	Diagnostic	I(1)*	I(1)*	I(0)*	I(0)*	I(0)*	I(1)*	I(0)*	I(0)*	I(0)*	I(1)*	I(1)*
LMIC (lower-middle-income countries)												
LLC:	Statistic	-9.89	-7.68	-2.86	-2.18	-2.86	-11.5	-2.53	-2.06	-3.57	-1.78	-9.55
	Diagnostic	I(1)*	I(1)*	I(0)*	I(0)**	I(0)*	I(1)*	I(0)*	I(0)*	I(0)*	I(1)*	I(0)*
UMIC & HIC (upper-middle and high-income countries)												
LLC:	Statistic	-14.4	-7.06	-3.28	-5.16	-6.71	-5.87	-10.6	-2.45	-6.6	-2.64	-4.18
	Diagnostic	I(0)*	I(1)*	I(0)*	I(1)*	I(1)*	I(1)*	I(1)*	I(0)*	I(0)*	I(1)*	I(1)*

Note: * means 0.01 level of significance, ** means 0.05 level of significance and *** means 0.1 level of significance

Source: Research finding.

Table 4. Panel Cointegration Tests

t-statistic for each specified model			
	Equation 3.2	**Equation 3.3**	**Equation 3.4**
Entire	-13.8*	-13.5*	-13.6*
LIC	-3.68*	-3.65*	-3.63*
LMIC	-2.68*	-2.87*	-2.67*
UMIC & HIC	-15.6*	-16.2*	-16.4*

Note: * means 0.01 level of significance, ** means 0.05 level of significance and *** means 0.1 level of significance
Source: Research finding.

The EKC is not found for the entire sample for SSA. There is a linear relationship between CO_2 and income in SSA based on the premise that SSA is still over-dependent on the agricultural sector [equation 3.2]. That is CO_2 emission increases as income increases in SSA. These findings support Alege and Ogundipe (2013), Casey and Galor (2017), and conform to the EKC theory that moving from a pre-industrial economy to an industrial economy would lead to a deterioration of environmental quality. However, it contradicts the strong evidence that there is EKC amongst LIC, LMIC, and UMIC & HIC in SSA when the economies are agricultural-based. This result agrees with Al-Mulali et al. (2015) on UMIC & HIC but not on LIC and LMIC. This shows that, given awareness of the need for environmental protection, developing countries can demand environmental quality even at a low-income level. Although the EKC may exist amongst income groups as their level of income increases, agricultural activities lead to higher emissions in LIC and there is an insignificant effect of agricultural activities on emissions in LMIC and UMIC & HIC. Generally, in the region, agricultural activities limit CO_2 emissions. This might be due to the multilateral incentives enjoyed by SSA to reduce their emissions through agro-based and reforestation projects.

Table 5. PMG/ARDL Long-run Elasticities

	Entire Sample			**LIC**		
Equations	3.2	3.3	3.4	3.2	3.3	3.4
lnY	1.408**	0.571	0.86	17.8*	5.546***	9.454**
lnY^2	0.055	0.007	-0.02	-1.204*	-0.328	-0.618*
A	-0.004**	---	---	0.004***	---	---
I	---	0.007*	---	---	-0.002	---
STRCH	---	---	0.003*	---	---	-0.003*
EO	0.004*	0.003*	0.004*	0.001	0.001	0.001
lnEC	0.081	0.101**	0.127*	-0.474*	-0.313*	-0.524*
FD	0.000	-0.000	0.000	-0.001**	-0.002*	-0.003*
FO	-0.008*	-0.006*	-0.007*	-0.008*	-0.004**	-0.006*
Pd	0.007*	0.002***	0.004*	0.001	0.001	0.004**
Up	-0.016*	-0.017*	-0.019*	0.068*	-0.018**	-0.028*
ECT	-0.411*	-0.455*	-0.434*	-0.446*	-0.423*	-0.381*
The turning point for EKC	---	---	---	$1,623	---	$2,098
	LMIC			**UMIC & HIC**		
Equations	3.2	3.3	3.4	3.2	3.3	3.4
lnY	37.3**	-18.5**	21.2**	10.4**	33.3*	3.225
lnY^2	-2.515**	1.141**	-1.295**	-0.528*	-1.792*	-0.136
A	-0.008	---	---	-0.021	---	---
I	---	0.009**	---	---	-0.008	---
STRCH	---	---	0.001	---	---	0.008***
EO	0.010*	0.001	0.003	0.002**	0.016*	0.004*

lnEC	-0.326	0.184	-0.266	0.372*	0.534*	0.239**
	LMIC			**UMIC & HIC**		
FD	-0.010*	-0.004*	-0.006*	0.001	0.004**	0.003**
FO	0.001	-0.01***	0.008	-0.015*	-0.03*	-0.029*
Pd	-0.081*	-0.001	-0.002	-0.000	0.000	0.001
Up	0.213*	0.092*	0.114*	-0.025*	-0.037*	-0.018*
ECT	-0.382***	-0.526*	-0.489*	-0.584*	-0.342***	-0.607*
Turning point for EKC	$1,662	$3,317	$3,588	$18,930	$10,843	---

Note: * means 0.01 level of significance, ** means 0.05 level of significance and *** means 0.1 level of significance
Source: Research finding.

As industrial-based economies, there is evidence that suggests that there may be the delinking of CO_2 emissions from income while the industry influences emissions in SSA [equation 3.3]. [1] This may happen if SSA countries leapfrog to clean infrastructural investments (AfDB, 2012). The EKC exists for UMIC & HIC only. This corroborates Baek (2016) that there is the EKC for high-income countries. This suggests that as UMIC & HIC economies in SSA get richer and industrialize, they demand a cleaner CO_2 environment. Effort in LIC to industrialize does not significantly influence emissions but shows that emissions monotonically increase with income. The U shape relationship found between CO_2 and income for LMIC indicates that as LMIC industrialized, economic activities like the oil price shock of 1990 might have initially shrunk emissions while economic activities like the increase in commodity prices during 2000-2007 might have increased emissions as income rises (UNCTAD, 2012). Generally, industrial activities influence emissions in SSA, specifically, in LMIC but not significantly in LIC and UMIC & HIC. This implies that efforts in LIC and LMIC to industrialize do not utilize clean technology and so LIC and LMIC might not be leapfrogging as their income rises like UMIC & HIC. The results support He and Richard (2010) that industrial production is more polluting than agricultural production.

Considering the structural transformation measure (i.e. STRCH), there is also evidence that there may be the delinking of CO_2 emissions from income in SSA as the region structurally transforms from agricultural-based to industrial-based [equation 3.14]. Generally, our findings reveal that the more the region transforms, the higher the level of its emissions. The EKC is found for LIC and LMIC as they transform from a pre-industrial stage to an industrial stage while the delinking of CO_2 emissions from income is found for UMIC & HIC. As LIC structurally transforms, the less it contributes to CO_2 emissions. Structural change does not significantly affect CO_2 emissions in LMIC and as the transformation occurs income generated in LMIC may be used to demand a cleaner CO_2 environment, hence the EKC. The EKC may, however, change to linear and U relation shape (respectively) once LIC and LMIC become industrial-based if the economies do not protect the environment from the industrial sector. The delinking of CO_2 emissions from income may be temporal for UMIC & HIC as the EKC might return once UMIC & HIC become industrialized.

The observed turning points for the income groups fall within the range of minimum and maximum of real GDP of the estimated samples of the income groups. The turning points increase with income level in SSA. That is, the turning point for UMIC & HIC is higher than that of LMIC while that of LMIC is higher than the turning point for LIC. Due to this, this study opposes the suggestion of Stern (2004) that including more low-income countries in a cross-country study might yield a higher turning point. It, however, supports the proposition of Al Sayed and Sek (2013) that high-income countries have higher turning points than low-

1. Delinking is when economic growth is not linked to pollution due to environmentally non-damaging practices (WDR, 1992).

income countries.

Although the literature depicts that the pollution haven effect does not apply to all developing countries, the pollution haven effect exists in SSA among LMIC and UMIC & HIC. The consumption of energy increases emissions in UMIC & HIC while it limits emissions in LIC. This supports Onanuga (2017) that energy consumption can limit CO_2 emissions in developing countries if increasing low-carbon energy is used. Both sides of the literature on financial development are found for SSA. The financial sector influences CO_2 emissions in UMIC & HIC on one hand and it limits emissions in LIC and LMIC on the other hand in SSA. This study empirically found that the pollution haven effect does not occur through financial openness in SSA. Irrespective of the income level, financial openness limits emissions.

In support of Panayotou (1997) and (2000), it is observed that as SSA transforms from agricultural-based to industrial-based, higher population density places pressure on carbon-oriented natural resources which increases emissions generally. Being the fastest urbanizing continent (Africa) in the world, SSA's urbanization process may be environmentally efficient, except amongst the LMICs.

Considering the contribution of this paper on how structural change affects emissions in SSA, the EKC would exist sooner for all the income groups in SSA if they remain agricultural-based as their level of income increases. As they transform from pre-industrial to the industrial stage, SSA may experience higher levels of emissions as industrial production is more polluting than agricultural production. However, the EKC would still exist as income increases and a likely delinking of CO_2 emissions from income can be experienced as the region leapfrog to clean industrial technologies and practices.

Conclusion and Recommendation

This study investigates the plausibility of the EKC for sub-Sahara Africa (SSA) considering the impact of structural change and financial development on CO_2 emissions. The EKC was found for low-income countries (LIC), lower-middle-income countries (LMIC), and upper-middle and high-income countries (UMIC & HIC). The observed turning points for the income groups speak to the validity of the findings as they fall within the range of minimum and maximum of the real GDP of the estimated samples of the income groups. Also, financial openness does not cause the pollution haven effect in SSA and the region's urbanization process may be environmentally efficient, except in LMIC.

However, the abovementioned optimistic results should be accepted with caution as structural changes in the region reveals that: agricultural activities may lead to higher emissions in LIC if organic agriculture is neglected for conventional practices; industrialization leads to higher emissions in LMIC which indicates that the use of clean industrial technologies and practices are on the low, and the process of moving from agricultural-based to industrial-based activities may lead to higher emissions in UMIC & HIC till the countries start adopting clean industrial technologies and practices. This implies that even though there is EKC, it would only be sustainable if clean agricultural and industrial practices are continuously adopted.

There is a pollution haven effect through trade openness in LMIC and UMIC & HIC. The financial sector influences CO_2 emissions in UMIC & HIC on one hand and it limits emissions in LIC and LMIC on the other hand in SSA. Increasing population density places pressure on carbon-oriented natural resources in SSA as the structural change takes place. Based on these findings, this paper concludes that economic growth monotonically increases CO_2 emissions in SSA. This is under the linear relationship found between CO_2 and income in SSA.

The study recommends that the region should not relent on its green sector improvements by ensuring strict adoption and implementation of low-carbon development strategies. The areas for consideration in the agriculture sector include organic farming, perennial farming, grazing land management, and restoration of cultivated peaty soils and degraded soils that would increase soil carbon sequestration capacity. As SSA nations move from agricultural-based activities to industrialization, they should improve on fiscal policies for climate change mitigation, like the introduction of feebate and rebate for the promotion of low-carbon technologies and practices in both the agricultural and industrial sectors. Leapfrogging in the area of renewable energy and energy efficiency should be continuously and adequately adapted to reduce pressure on natural resources through increasing population density and energy consumption. Trade actions like lower tariffs for eco-friendly technologies that would promote low-carbon development and higher tariffs for technologies that contribute to a dirtier CO_2 environment should be implemented to reduce, if not, eradicate the pollution haven effect in SSA. This paper can be extended to test whether the 'race to bottom' scenario exists in SSA in further studies.

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