IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY
EJ EconJournals
ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2021, 11(6), 479-488.

EJ EconJournals

Structural Transformation versus Environmental Quality: The Experience of the Low-income Countries in Sub Saharan Africa

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Received: 16 May 2021 **Accepted:** 25 September 2021 **DOI:** https://doi.org/10.32479/ijeep.11516

ABSTRACT

Structural transformation has been recognized as a critical mechanism for improving living standards for developing countries in Africa. However, the growing evidence indicates that such change is associated with considerable damage to the environment quality and, hence, challenging sustainable development. The present study investigates industrialization's influence on the environment quality for 20 low-income countries in Sub-Saharan Africa during 1980-2018. We employed two measurements for environmental quality, which are CO2 and nitrous dioxide emissions. Likewise, the study applied the Fully modified OLS and the Dynamic OLS as the most modern and suitable techniques related to the panel data analysis. Overall, the FMOL and DOLS results show that industrialization has an insignificant influence on environmental quality. The results also show that these countries' population size is the main driver for environmental quality changes. This finding implies that these countries should continue in their current efforts regarding promoting the industrial sector without wondering about sustainable development.

Keywords: EKC, Industrialization, Low-income Countries, FMOL, DOLS
JEL Classifications: Q560, Q580, O140, O550

1. INTRODUCTION

Since the beginning of the new millennium, the figures show that African economies have been growing at a somewhat speedy rate (UNCTAD, 2012). The achieved growth was reflected in an improvement on several factors such as trade, FDI, and progress in the physical infrastructure (African Union's Agenda 2063, 2015; African Development Bank, 2015; African Transformation Report, 2014; UNCTAD, 2012; IMF, 2013). Unfortunately, evidence suggests that the present trend of growth is neither inclusive nor sustainable. Several interrelated factors have been identified as primary sources for this failure. However, bypassing industrialization, a major stage in the structural change and development process, is recognized as a critical explanation(UNCTAD, 2012; Opokua and Boachieb, 2020). Theoretically, structural change is said to occur, as described by Kuzents(1966) and others, through the gradual movement and shift of an economy via two stages. In the first stage, from agriculture to the industrial sector, the second stage is industrial to the services sector. However, unlike other regions' experiences, in Africa, the economy jumps directly from agriculture to informal economic activities in the service sector(UNCTAD, 2012; Opokua and Boachieb, 2020). The industrial and manufacturing sector is recognized as the sector able to create new and sustainable job opportunities. Thus, with the absence of manufacturing, sustainable and inclusive growth will be unattainable in Africa (Zamfir, 2016; Page, 2011; Gui-Diby and Renard, 2015;World Bank, 2014; Africa Growth Initiative, 2016; Opokua and Boachieb, 2020). Recently, African policymakers have responded to the growth-exclusiveness outcomes by establishing structural transformation basics. Thus, today we can see several initiatives have been emerged to support the importance of creating a fundamental change in the structure of the Africa economy (UNCTAD and UNIDO, 2011).

Nonetheless, by shifting the economy's structure toward the industrial sector, structural transformation is a double-edged sword. It is well recognized that structural change is essential and pre-conditions for improving living standards and generating sustained growth. However, it is not sufficient to achieve sustainable development because such change is more likely to reflect high costs on ecological systems. The other countries' experience shows that the transformation from an agriculture-based economy to an industrial one is associated with considerable destruction to the environment (Fischer-Kowalski and Haberl, 2007). That is to say, despite the importance of structural change and industrialization for job creation and poverty alleviation; however, it also might create undesirable consequences on the quality of the environment and hence sustainable development. In this respect, Stern (2009) argued that due to climate change disasters and rising temperatures, achieving sustainable development is challenging.

Given the significance of industrialization in accomplishing sustainable development goals, on the one hand, and the potential negative impact of automation on such goals, on the other hand, it is imperative to explore the consequence of industrialization on the environmental quality of developing countries in Africa. Although numerous empirical studies tried to explain the critical factors determining a group of African countries' ecological systems, industrialization's potential and explicit role in explaining this phenomenon has been ignored(will be discussed in the next section). To the best of our knowledge, only two studies by Lin et al. (2016) and Opokua and Boachieb (2020) addressed this matter straightforwardly for a group of African economies. The present study utilized the panel cointegration technique for 20 low-income economies in Sub Sharhan Africa (SSA) over the period 1980-2018 to explore the industrialization process's influence on the environment quality. More specifically, this study's main objectives are first; to analyze the EKC's validity in low-income countries in Sub Sharah Africa using an extended version of the IPAT version. The secondary objectives comprise identifying the key factors that affect the quality of the environment in Africa by utilizing appropriate techniques such as panel cointegration, Fully Modified OLS(FMOLS), and Dynamic OLS (DOLS) techniques.

This article aims to discover the experience of low-income countries in SSA with this matter, and it adds to the present works in three significant ways. Firstly, as we said, since so far, only two studies accounted for the role of industrialization in explaining environmental quality in Africa, the present study will add a new contribution to the field and open the door for further studies. Second, instead of dealing with African countries as a homogenous group, as Lin et al. (2016) and Opokua and and Boachieb (2020), the present study will limit the analysis to the low-income countries the continent. As per the World Bank (2020) classification, the 53 economies in the continent are classified into 23 low income,21 Lower middle income,6 Upper median income, and the remaining three as high income. It is well recognized that the structure of the economy and the level of development vary across countries. Thus, as UNCTAD (2012) suggested, the challenge of attaining sustainable development is different in economies at varying stages of development. Thirdly, the current study applies the most modern and suitable long-run panel techniques in the field of panel cointegration procedures offered by Pedroni (1999). For robustness checking, the current study utilized two indicators for the degree of environmental quality, namely, CO2 and nitrous dioxide emissions, and two analysis techniques, which are FMOLS besides DOLS. Besides, we also consider the influence of trade and FDI within the environmental quality -industrialization nexus. This study's outcomes are essential for these countries' policymakers in their current efforts to achieve, in a simultaneous way, structure transformation and social and environmental sustainability. In the subsequent section, related empirical literature will be summarized. The data, estimation technique, and methodology procedures are displayed in Section 3. The obtained results will be highlighted and discussed in Section 4. The final section includes the conclusion of the study in addition to policy implications and recommendations.

2. LITERATURE REVIEW

Following the influential work of Grossman and Krueger (1991), empirical analyses on the influence of various human actions and behavior on the environment's quality are growing extensively. However, most of these studies focused on developed counties' experiences and ignored that of emerging economies. Despite these growing studies, the relationship between growth in per capita GDP and environmental pollution remains complicated. Indeed, the EKC suggests some demonstrative instruments for shedding light on the interrelationship between economic activities and their environmental quality consequence. The EKC indicates that in the first stage of development, the per capita income increases will be associated with deterioration in the environment at an increasing rate. However, over time and once the economy moves to a relatively high development level, there will be a gradual improvement in the environment. Grossman (1995) interpreted the inverted 'U-shaped' form in the EKC hypothesis through the three effects, which are scale, composition, and technology influences. The scale consequence denotes that there will be a massive demand for all resources in general and natural resources, particularly at the beginning of the development process journey. The direct and indirect utilization of natural resources will be converted into the production of various manufactured products. At this stage, the economy is expected to witness a considerable amount of industrial waste that creates significant damage to the environment. Second, to sustain and boost per capita GDP growth, policymakers neglect the deterioration in environmental quality. The whole ecological degradation begins to spread with a rise in the production process (per capita GDP growth). However, with continuous increases in the per capita income, the industrial component of an economy starts experiencing a transformation, and thus, the composition of an economy begins altering. However, once the economy reaches a specific level of per capita income during this stage, the public and policymakers' attention will shift towards a clean environment. Therefore, the emerging industrial sector has to adopt more friendly-environment tools and equipment in the production process. This is once the industries sectors begin to integrate technologies for expanding energy efficiency, and thus less and less damage to the environment will occur.

The growing empirical results regarding the growth-environment nexus have yielded mixed results. Besides, most of these studies are focused on advanced economies; thus, their outcomes are not consistent and untrustworthy with poor developing countries (Carson, 2010; Stern, 2003). Likewise, even the few empirical studies related to Africa derived mixed outcomes, which creates a challenge for leaders since it will manifest dissimilar policy consequences. The inconsistency of the findings was attributed to various factors including, model specifications(linear, quadratic, and Cubic), environment measurement, the additional explanatory variables that included, and the method of estimation employed, which depends on the structure of the data (time series/panel, cross-section). Likewise, the mixed outcomes were attributed to geographic location and the chosen period of the study. According to Wagner (2008), numerous critical econometric drawbacks have been neglected in previous studies related to the environmental Kuznets curve. Recently, Katz (2015) analyzed the correlation between freshwater use and income growth, and he discovered that the finding is substantially dependent on selecting datasets and employed econometric methods. This is why, even for similar economies or panels of economies, the obtained results are mixed (Shahbaz and Sinha, 2020).

In the present study, since previous empirical work in this matter is significantly tremendous, we will limit the review on the empirical studies on EKC that focused on the Africa continent only[1]. More specifically, in reviewing previous studies in Africa, we divided these studies into two groups, a single country-oriented analysis and a group of countries-oriented research. Second, we will review empirical studies, regardless of the location of the country/countries covered, that incorporated, in an implicit way, industrialization as one of the critical explanations for environmental quality. This work will be classified into two groups; the first group comprises studies using several versions from the decomposition techniques. The second group contains studies that incorporated a proxy for industrialization variables in a linear, quadratic, or cubic form.

Due to the unavailability of sufficient time-series data for most African countries, most of the studies, as mentioned earlier, are cross-section or panel data. However, recently and with the relative improvement in the data collection, some singles based studies started to emerge. For instance, Kohler (2013) analyzes EKC's validity for South Africa during 1960-2009 using the ARDL technique. The results of the quadratic specification detected the existence of inverted U- Shaped. Moreover, Shahbaz et al. (2013) examine the validity of EKC hypotheses for South Africa during 1960-2008 using the ARDL technique. The author implemented two specifications, linear and quadratic. While the linear specification results show monotonically increasing, the results detected the exitance of an inverted U-shaped quadratic one. Besides, Nasr et al. (2015) examine the validity of EKC hypotheses for South Africa (1911-2010) by utilizing the ECK's Cubic form. The results of the Co-summability technique show inverted N-shaped. Likewise, Farhani et al. (2014a) inspected the strength of EKC hypotheses for Tunisia during 1971-2008) using the ECK's quadratic form. The results of the ARDL method show existence of inverted U-shaped.

1 For comprehensive and recent literature survey in this matter, see Shahbaz and Sinha, 2020).

Similarly, Kivyiro and Arminen (2014) examine the validity of EKC hypotheses for 6 Sub-Saharan countries during 1971-2010 using the quadratic specification. The findings show that while inverted U-shaped is verified in three economies, no evidence of EKC hypotheses is revealed in the remaining three countries. Moreover, Shahbaz et al. (2015) explore the validity of EKC hypotheses for 13 African countries (1980-2012) by applying the ECK's quadratic specification. The results of the Johansen Cointegration method show mixed findings across these countries. Namely, the EKC shape is confirmed as inverted U, U-shaped, monotonically increasing, and no EKC in some countries.

Regarding cross-countries studies, Farhani and Shahbaz (2014) inspect the validity of the EKC hypotheses for 10 MENA economies during 1980-2009 using the quadratic specification. The results of both FMOLS, as well as DOLS detected the existence of inverted U-shaped. Farhani et al. (2014b) reinvestigated the EKC hypotheses for 10 MENA economies during 1990-2010 by implementing a quadratic form. The results of both FMOLS and Panel DOLS confirm the presence of inverted U-shaped. Besides, Osabuohien et al. (2014) analyze the validity of EKC hypotheses for 50 African economies (1995-2010) through applying PDOLS on quadratic specification. The results show the presence of an inverted U-shaped. Likewise, Oshin and Ogundipe (2014) examine the strength of the EKC hypotheses for 15 West African countries (1980-2012) using the quadratic specification. The author applies three methods of estimations, pooled OLS, Random effect, and fixed effect. Interestingly, the study revealed that the EKC hypotheses' validity depends mainly on the estimates' technique.

Similarly, Jebli et al. (2015) examine EKC postulations' strength for 24 Sub-Saharan Africa economies during the 1980-2010 period by applying EKC's quadratic form. The results of both OLS and FMOLS confirm the existence of U shape. Besides, Zoundi (2017) inspects EKC's validity for 25 African economies during 1980-2012 via EKC's quadratic form. The author implements five different estimation methods: DOLS, System GMM, Dynamic Fixed Effect, MG, and PMG. While the results of GMM confirm the presence of U-shaped, the remaining methods fail to detect any form of EKC. Using the STIRPAT framework, Awad and Abougamos (2017a) examine the validity of EKC hypotheses of 54 economies in Africa during 1980–2014. The results show evidence that supports the presence of an inverted-U shaped. Within the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) framework, Awad and Abougamos (2017b) examine the validity of EKC hypotheses in 20 countries in the MENA region during 1980–2014. Using panel data and a semi-parametric panel fixed effects regression, the results show evidence supports an inverted-U-shaped presence. Likewise, Awad and Warsame (2017) inspect the validity of EKC hypotheses for 54 economies in Africa during 1990-2014. The study fails to find any evidence that supports the EKC hypothesis.

Concerning preceding empirical studies that addressed industrialization's influence on the environment quality, as we mentioned previously, we classified these studies into two groups. The first group comprises studies that used several versions of the decomposition techniques. The second group contains studies that incorporated a proxy for industrialization variables in a linear, quadratic, or cubic specification of the EKC. Several version forms of the decomposition technique were employed in most of these studies. For instance, AkbostancI et al. (2008) tried to identify the source of the CO2 emissions of the Turkish manufacturing sector during 1995–2001. The Log Mean Divisia Index (LMDI) method was utilized to decompose the variations in the CO2 emissions of the manufacturing industry into five elements; changes in activity, activity structure, sectoral energy intensity, sectoral energy mix, and emission factors. The results demonstrated that the chief sources of the variation in CO2 emissions were total industrial activity and energy intensity. Likewise, Tunc et al. (2009) tried to recognize the factors contributing to changes in CO2 emissions for the Turkish economy during 1970–2006 via utilizing the LMDI method. The result shows that the primary sources of CO2 emissions are economic activity. Roinioti and Koroneos (2017) and Khan et al. (2019) arrive at a similar finding for the case of Greece and Pakistan economy, respectively. Likewise, Cherniwchan (2012) examines the role of observed industrialization on the environmental quality for 157 economies over 1970–2000. The results demonstrate that the process of manufacturing is a substantial determinant of observed changes in emissions. Lu et al. (2015) arrive at a similar finding for the case of Jiangsu, the Chinese province. Likewise, ChunXu et al. (2016) analyzes carbon emissions due to energy consumption based on China's sectors from 1996 to 2014 by utilizing the LMDI method. One more time, the carbon emissions were decomposed into four categories: energy structure, energy intensity, economic structure, and economic output effect. The results detected that the chief factor driving carbon emissions was the economic output, and the industry sector was the top contributor to carbon emissions.

Concerning the second group of the studies, few studies incorporated a proxy for industrialization in linear, quadratic, or cubic specification. For instance, Xu and Lin (2015) examine automation and urbanization's role in explaining CO2 emissions for provincial panel data in China from 1990 to 2011. An inverted U-shaped nonlinear relationship has been confirmed between industrialization and CO2 emissions. Besides, Lin et al. (2016) utilize the STIRPAT framework and panel cointegration for five African economies from 1980 to 2011. The authors decompose growth into agricultural-based growth and industrial-based growth. The FMOLS technique's results failed to identify any significant relationship between CO2 emissions and agricultural-based development or industrial-based growth. Also, Dogan and Inglesi-Lotz (2020) tried to inspect the economic structure's impact on seven European countries' environmental quality from 1980 to 2014. The FMOLS results show the U-shaped relationship between industrialization and growth in these countries. Likewise, Ha Le (2020) examined the impact of several factors on greenhouse gas emissions for a sample of 16 economies in South and East Asia during 1995-2012. The author employs four types of emission: GHG, CO2, CH4, and N2O, and utilizes two estimations; Prais-Winsten regression with Panel corrected standard error (PCSE) and Feasible General OLS (FGOLS). The results show that the influence of industrialization on the environment depends on environmental measurement. More specifically, while industrialization activities tend to harm the CO2, its effect on the remaining three environmental measures is favorable.

Likewise, Opokua and Boachieb (2020) examined industrialization's environmental impact in 36 selected African economies during 1980–2014. Using various measures for the environment quality, the Pooled Mean Group (PMG) technique indicates the insignificant impact of industrialization on the environment depend on utilized measurement for the environment. Namely, the results show that manufacturing has a statistically negligible consequence on all pollution measurements except for nitrous oxide emissions that appear adversely affected by industrialization. From the reviewed literature, it is clear that there is a lack of consensus over the relevance of the EKC to the continent in general and the impact of the structural transformation. Most importantly, the previous studies' review confirms the lack of sufficient empirical research that accounted for industrialization's expected role in explaining the critical determinants of the environmental quality for the developing countries in Africa. As we said previously, the challenge of accomplishing sustainable development is different in countries at varying development levels.

3. METHODOLOGY

3.1. Model, Variables, and Data

This section aims to illustrate the model, data, and framework utilized to build the empirical analysis of industrialization's environmental quality impact. To display the theoretical links among manufacturing, income per capita, and environmental quality, we firstly specified the quality of the environmental (EQ) as a function of industrialization (IND) and real per capita GDP (Y)and its square (Y^2) as shown in the general form below:

$$EQ=F(IND, Y, Y^2) \quad (1)$$

Equation 1 demonstrates the fundamental role of economic growth in affecting the environment's status; thus, the EKC was combined into our investigation. It was crucial to select an appropriate measure for the quality of the environment as it was a vital factor in this study's interpretation. The ecological consequence of industrialization could take various types of pollution. In the present study, we employed two environmental quality measures following preceding studies: CO2 and nitrous oxide emissions. The utilization of these two indicators because the first, although data related to the environmental quality, is massive; however, for poor countries in Africa and during the study period, data are available for only these two variables. Second, using more than one indicator provides the sound of robustness for the analysis. Following the recent empirical research on the environmental quality, we added to Equation 1 an additional three explanatory variables that may contribute directly to the ecological quality or indirectly through its impact on industrialization. The variable that contributed directedly is population growth, as hypothesized in the IPAT framework (Rosa and Dietz, 2012; Chertow, 2000). The second two variables that indirectly contribute are a foreign direct investment, as hypothesized in the pollution haven hypothesis and Halo effect hypothesis (Copeland, 2005; Eskeland and Harrison, 2003; Temurshoev, 2006), and trade as postulated in the Porter hypothesis (Porter and Van Der Linde, 1995; Ren et al., 2014; Seker et al., 2015; Zhang and Zhou, 2016; Sapkota and Bastola, 2017). After adding these variables, Equation 1 can be shown as follows

$$EQ=f(IND, Y, Y^2, P, T, FDI) \quad (2)$$

Where *P* refers to population, *T* for trade, and FDI for foreign direct investment. The log liner specification for EQ 2 can be write down as follows: -

$$logEQ_{it} = \alpha_1 + \alpha_2 logIND_{it} + \alpha_3 logY_{it} + \alpha_4 logY_{it}^2 + \alpha_5 logP_{it} + \alpha_6 T_{it} + \alpha_7 FDI_{it} + \delta_i t \quad (3)$$

Here, EQ signifies the CO2 emissions (kt), i denotes the country (19 economies), and t signifies time (1980-2018). For robustness, as we said previously, Equation 3 was re-estimated employing an alternative air pollution measure, which is nitrous dioxide emissions; IND is Industry, value added (2010 US$). GDP (Y) is the GDP per capita (US$ 2010). P is the total population, and T is the trade-in terms of exports plus imports scaled by the GDP. FDI is the foreign direct investment as a percentage of GDP. Except for trade and FDI variables, all the remaining variables have been converted into the natural logarithmic form (Shahbaz et al., 2013a). Statistical features for the data are presented in Table 1. Data related to entire variables are gathered from the World Development Indicators. The data covered 20 African economies (see the list of these economies in Appendix A1) for 1980-2018. Variables measurement and definition are displayed in Table A2 in the appendix.

The results of the correlation matrix, as shown in Table 1, reflect a relatively high correlation between the variable of interest, which is the industry, with each pollution measurement (LCO2 and LNIT). However, this outcome is not robust because, as we know, the correlation is different from causation.

Table 1: Correlation matrix

	LCO2	LNIT	LP	LY	T	FDI	LIND
LCO2	1	0.62	0.68	0.38	0.28	0.28	0.71
LNIT	0.62	1	0.75	0.15	0.12	0.13	0.78
LP	0.68	0.75	1	–0.16	–0.03	0.23	0.83
LYY	0.38	0.15	–0.16	1	0.32	0.06	0.27
T	0.28	0.12	–0.03	0.32	1	0.38	0.05
FDI	0.28	0.13	0.23	0.06	0.38	1	0.22
LIND	0.71	0.78	0.83	0.27	0.05	0.22	1

Source: Author calculation

Table 2: Cross-sectional dependence result

Factors	BP	PS	BCS	CD
LCO2	2999.81[a]	144.14[a]	143.85[a]	46.57[a]
LNIT	11051.58[a]	220.16	219.35a	81.70[a]
LIND	2401.35[a]	113.54[a]	113.13[a]	28.81[a]
LY	2785.65[a]	133.65[a]	132.85[a]	14.28[a]
T	960.07[a]	39.56[a]	39.24[a]	15.39[a]
LP	7232.45[a]	361.64[a]	360.64[a]	85.03[a]
FDI	1158.212[a]	49.66[a]	49.41[a]	27.85[a]

Source: Author calculation. A signifies significance at the 1% level

3.2. Estimation Approaches

This section seeks to explain the stages that will be implemented toward the study's objective. As per previous empirical works that deal with panel data, we have to test the data's statistical features to construct the cross-sectional dependence test. In the second step, which depends on the first step's outcomes, we perform the unit root test, followed by specific panel cointegration testing. In the final step, if we identify a long relationship between the variables, we completed the long-run analysis by utilizing the FOMOLS and the DOLS. According to Shahbaz et al. (2017), unobserved frequent shocks that become an essential component of the error terms(ET) will lead to the presence of cross-sectional dependence in cross-countries data. Ignoring this test and procedure in the examination may lead to unreliable ET of the estimated coefficients (Driscoll and Kraay, 2001). In the present study and following previous work in this field and for robustness purposes, we will implement four different types of cross-sectional dependence tests. Once we perform the cross-sectional dependence tests, the next step is to examine the integration between the variables via panel unit root tests. Since several unit root test is available, selecting the specific unit root test depends mainly on the first step(i.e., cross-sectional dependence). If the unit root results show the nonexistence of integration at order two *I*(2), we have to move to the third step, the panel cointegration tests. If the test results show cointegration evidence between the selected variables, we move to the final step to perform our principal analysis and get our key objectives. The common and traditional estimation technique of panel data such as random effects, fixed effects, and GMM may manifest ambiguous and untrustworthy coefficients if employed on cointegrated panel data (Awad, 2019; Shahbaz et al., 2017). Besides, there is a possibility of an endogeneity problem in our EQ2 that might due to either omitted variables and reverse causality. On the one hand, some of the control variables may have been overlooked in EQ2. Therefore, our findings are most likely to be biased if the omitted variables are associated with the industrialization variable.

On the other hand, it is also possible that the environment quality will influence industrialization, reflecting reverse causality. EQ2 has been estimated to overcome these problems using two techniques: Fully Modified Ordinary Least Squares (FMOLS) Dynamic Ordinary Least Squares. (DOLS). Pedroni has developed these two techniques (2000, 2001) that are commonly used in the literature. It is well recognized that panel DOLS and FMOLS techniques reduce the endogeneity and autocorrelation between independent variables and ET, thus producing efficient results. For this reason, we follow the panel FMOLS and DOLS methods whose basic procedures are given in Eqs. (4) and (5), where A/EQ refer to explanatory/dependent variable in Eq. (3).

$$\hat{\beta}_{fmols} = \left[\frac{1}{N}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}(A_{it}-\bar{A}_i)^2\right)\right]\times \left[\left(\sum_{t=1}^{T}(A_{it}-\bar{A}_i)\widehat{EQ}_{it}-T\hat{\Delta}_{it}\right)\right] \quad (4)$$

$$\hat{\beta}_{dols} = \left[\frac{1}{N}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}A_{it}\tilde{A_{it}}\right)\left(\sum_{t=1}^{T}A_{it}EQ_{it}\right)\right] \quad (5)$$

Whether the FMOLS or DOLS method is favored, the empirical evidence is conflicting (Harris and Sollis, 2003). On the one hand,

Table 3: The results of the panel root test

Variables	Levin, Lin and Chu				CADF-Fisher Chi-square test			
	level		Difference		level		Difference	
	C	C + T	C	C + T	C	C + T	C	C + T
LCO2	5.21 (0.000)	1.50 (0.93)	–7.95 (0.000)	–7.30 (0.000)	7.33 (1.000)	2.72 (0.99)	–10.94 (0.000)	–10.08 (0.000)
LNIT	1.37 (0.93)	0.48 (0.68)	–10.11 (0.000)	–7.42 (0.000)	2.00 (0.79)	–0.65 (0.48)	–16.21 (0.000)	–14.56 (0.000)
LIND	1.65 (0.96)	–0.07 (0.48)	–8.18 (0.000)	–7.81 (0.000)	5.16 (1.000)	0.85 (0.81)	–8.50 (0.000)	–6.03 (0.000)
LY	2.04 (0.97)	–1.98 (0.023)	–17.85 (0.000)	–17.22 (0.000)	3.46 (1.000)	–0.15 (0.84)	–19.95 (0.000)	–18.20 (0.000)
T	–2.75 (0.002)	–4.07 (0.000)	–22.37 (0.000)	–20.87 (0.000)	–2.77 (0.003)	–3.56 (0.000)	–21.91 (0.000)	–16.98 (0.000)
LP	–1.84 (0.03)	6.41 (1.000)	1.24 (0.89)	8.70 (1.000)	4.82 (1.000)	–3.24 (0.002)	–4.90 (0.000)	–5.80 (0.000)
FDI	–3.81 (0.000)	–6.31 (0.000)	–27.36 (0.000)	–23.64 (0.000)	–3.90 (0.000)	–6.99 (0.000)	–28.63 (0.000)	–26.35 (0.000)

Source: Author calculation. * **indicates significance at the 1%.

the FMOLS method and by default overcome the autocorrelation issue, but it is non-parametric. On the other hand, although the DOLS method remains a parametric test, its powerlessness rests in the degree of freedom matter due to leads and lags (Maeso-Fernandez et al., 2006).

4. RESULTS AND DISCUSSION

Table 2 represents the results of the cross-sectional independence tests. The products detect the existence of cross-sectional dependency for each selected variable.

We carry on by carrying out panel unit root tests that take into account the dependency in our cross-sectional. The LLC statistic of Levin et al. (2002) and the CADF statistic of Pesaran (2007) are the two tests that consider such dependency (Awad, 2019). The results of these tests are reported in Table 3. The results indicate that all the variables are $I(1)$. This finding implies that emissions measurement, industrialization, economic growth, population, trade, and FDI have a unique integration order for each panel.

CADF-Fisher Chi-square test

Therefore, and for each panel, we inspected the cointegration relationship between the variables. The Pedroni (1999, 2004) panel cointegration tests are displayed in Table 4. The results suggest that out of the seven Pedroni tests, five statistics confirmed the existence of cointegration in each specification. However, as Pedroni (1999) proposed, Panel ADF and Group ADF are the leading statistics for small samples. In other words, if the results are controversial, as in our case, the Panel ADF and Group ADF statistics could be the benchmark. Consequently, based on the ADF and group ADF results, we can conclude that the long relationship is confirmed for each specification.

Table 5 reports the estimated long-run coefficients from the FMOLS and the DOLS approach. Prior to discussing the findings, we verified the possible multicollinearity problem between the variables in each model. Tables A3 and A4 in the appendix show the Variance Inflation Factors (VIF) test implemented in each description. The results show that of such a problem in our analysis[2]. Now is the time to move forward and to look for the FMOLS and DOLS outcomes.

2 We tested the potential collinearity problems amongst the regressors by using the Coefficient Variance Decomposition (CVD) test. The results, which are not reported here, show the nonexistenceof any collinearity problem in our reults.

Table 4: Pedroni residual cointegration test

Dependent variable	LCO2		LNIT	
	Value	Value	Value	Value
Alternative hypothesis: common AR coefs. (within-dimension)				
Panel v-Statistic	0.55	–2.54***	–1.84	–3.88***
Panel rho-Statistic	0.53	1.40	1.01	–0.86
Panel PP-Statistic	–2.05**	–2.89***	–4.25***	–10.73***
Panel ADF-Statistic	–2.88***	–3.99***	–4.25***	–9.88***
	Statistic		Statistic	
Alternative hypothesis: individual AR coefs. (between-dimension)				
Group rho-Statistic	2.38		1.56	
Group PP-Statistic	–3.01***		–10.69***	
Group ADF-Statistic	–3.38***		–7.05***	

Source: Author calculation. ***, ** indicates rejection of the null hypothesis of no cointegration at the 1% and 5%, respectively

The results of both FMOLS and DOLS are identical, which indicates the robustness of our analysis. The results tell us that our primary variable of interest, which is the industry, has a statistically insignificant impact on the two emitted pollutants' two measures.

The negligible effect of industrialization on the environment could be due to the region's low industrial activity level. Indeed, aggregate data on the industry value add in Sub-Saharan Africa show a decreasing trend over time. For instance, while both Sub Saharan Africa (SSA)and South Asia (SA) have the same rate of growth in the industry value added as per 2000(10%), by 2017, SA registered a growth rate of 24% and for SSA remain below 10%. As we mentioned previously, unlike the experience of other regions, in Africa, the economy jumps directly from agriculture to informal economic activities in the service sector. According to Opoku and Yan (2019), the industrial sector's contribution to Africa's growth is either low or non-existent. Likewise, according to Gui-Diby and Renard (2015), industrialization has not yet occurred in Africa.

Similarly, the Africa Growth Initiative (2016) has explained that Africa's industrial improvement and drive have been lagged for more than 40 years. According to Zamfir (2016), Africa's share in global manufacturing is tiny. This study's outcome seems, and to some extent, consistent with previous studies that addressed this matter in Africa, namely the work by Lin et al. (2016) and Opokua and Boachieb (2020). Lin et al. (2016) use the exact estimation

Table 5: FMOLS and DOLS technique

Explanatory variables	LCO2		LINT	
	FMOLS	DOLS	FMOLS	DOLS
LIND	0.012 (0.84)	0.13 (0.27)	0.001 (0.99)	0.094 (0.94)
LY	–5.98** (0.014)	–7.53** (0.05)	–7.67** (0.02)	–6.25** (0.03)
LY2	0.56*** (0.005)	0.72** (0.04)	0.64** (0.02)	0.53** (0.03)
LP	1.11*** (0.000)	0.97*** (0.000)	0.57*** (0.000)	0.57*** (0.000)
T	0.001 (0.50)	0.0007 (0.80)	0.003 (0.15)	0.002 (0.17)
FDI	0.002 (0.72)	0.003 (0.83)	0.01 (0.11)	0.009 (0.94)

Source: Author calculation. The *P* values are in ( ) ** and ***denotes significance at the 5% and 1% level of significance, respectively.

Table 6: Descriptive statistic

	LCO2	LNIT	LP	LYY	T	FDI	LIND
Mean	6.776232	8.199746	16.05668	6.132878	50.28451	1.978924	20.35469
Median	6.743951	8.154916	15.99539	6.160502	47.96138	0.815095	20.38805
Maximum	9.163794	11.91689	18.34517	6.963822	108.8148	34.46370	23.07601
Minimum	4.988253	5.880378	13.99892	5.299806	19.68416	–28.62426	17.91588
Std. Dev.	0.818717	1.242315	0.807418	0.360884	17.52620	3.981784	1.088331
NO of Obs	456	456	456	456	456	456	456

Source: Author calculation

(FMOLS) and arrive at the same conclusion on the insignificant impact of industrialization on environment quality for five African countries. Our finding is also consistent with the outcome of Opokua and Boachieb's (2020) result when CO2 is utilized but differs when environmental quality is proxied by nitrous dioxide emissions.

Concerning the impact of per capita GDP, and it is a quadratic term, the results show that while per capita GDP is negative and statistically significant, its quadratic term appears positive and statistically significant. This suggests the presence of a "U"-shaped relationship between the two environmental measurements and income in the low-income economies in Africa. Following Hasanov et al. (2019), to confirm that the results are consistent with reality, we calculated the turning point using both estimation methods' average results. The estimated turning point value is approximately equal to 5.5. This turning point value is lower than the whole countries' average income in our study (Table 6). This finding implies that for poor countries in Africa, it is expected that the growth process will continue to generate more damage to the environment as long as per capita income below the computed turning point. However, once this group of countries moves beyond that average, the growth process will generate minor damage to the environment. Our findings are consistent and contradict studies that were reviewed previously within the Africa context.

The results indicate that the population is a leading and significant driver for the selected countries' emissions. As proposed by the STIRPAT framework, population growth is a considerable factor driving environmental problems comprising climate change. The increase in the population can cause damage to the environment in several ways. The pressure on the limited land resources will force the society to either destroy imperative forest resources or overexploitation arable land. Likewise, natural resources and climate are expected to be affected negatively due to population growth that will reflect more production and consumption. Numerous analyses have been conducted on the potential influences of the population on the environment (Lin et al., 2015; Ray and Ray, 2011). Finally, both specifications indicate that neither the pollution haven hypothesis and the Halo effect hypothesis nor Porter hypothesis is valid for developing countries in Africa.

5. CONCLUSION AND POLICY IMPLICATIONS

The leaders in Africa have implemented several types of strategies to improve living standards and achieve sustainable growth. Although most of these countries witnessed and, to some extent, positive growth in per capita GDP, the poverty rate and the unemployment rate started to increase and expand. This led to a significant shift in the policymakers' mindset in the continent to implement a new strategy to allocate resources toward a more inclusive growth pattern. The structural transformation of the economy from agriculture, a and raw material-based economy, to a more industrialized economy, has been recognized as an essential tool in this strategy. However, evidence and the experience of the other countries show that industrialization is associated with environmental damage. Thus, it seems that there is a trade-off between automation and ecological quality.

The present study employed panel data techniques to investigate the potential impact of industrialization on the environment quality for 19 developing countries in Sub-Saharan Africa during 1980-2018. The present study employed two indicators of environmental quality as well as the method of estimation. More specifically, for environmental quality, the current studies used CO2 and nitrous dioxide emissions. Besides, the FMOLS, as well as the DOLS, was utilized in the analysis. The results seem to bring good news for the developing countries in Africa since no significant impact for the industrialization of the environment quality has been detected. This finding implies that current observed efforts in the industrialization process should continue without considering it has a potentially adverse impact on these countries' environment. The environmental issue should be handled through topics related to population behavior.

This study's results are considerable and provide imperative policy implications for the countries inspected in the panels and regional economic blocks, and environmental organizations. Our results also crucial for future studies, as it is expected that our research may open additional research directions. Other studies are still required for in-depth analysis and investigation for this matter. Future studies may, for example, with the Africa context, compare the outcome of the industrialization on the environment between this group of countries (low income) and other groups such as the middle-income group. Likewise, future studies may address the same issue by looking for low-income countries' experiences in different regions. Similarly, further studies may employ an alternative proxy for industrialization or add more explanatory variables or another specification.

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APPENDIXES

Table A1: List of the low-income Countries in Africa

Benin	Madagascar
Burundi	Malawi
Burkina Faso	Mali
Chad	Mozambique
Central African Republic	Niger
Congo, Dem. Rep.	Rwanda
Ethiopia	Sierra Leone
Gambia, The	Tanzania
Guinea	Togo
Guinea-Bissau	Uganda

Table A2: Variables Definition and measurement

Variable	Definition and measurement
CO_2 emission	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring
Nitrous oxide emissions (thousand metric tons of CO_2 equivalent)	Nitrous oxide emissions are emissions from agricultural biomass burning, industrial activities, and livestock management
Industry, value added (constant 2010 US$)	Industry corresponds to ISIC divisions 10-45 and includes manufacturing (ISIC divisions 15-37). It comprises value added in mining, manufacturing (also reported as a separate subgroup), construction, electricity, water, and gas. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Data are in constant 2010 U.S. dollars
Population, total	The total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship
GDP per capita (constant 2010 US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.
Foreign direct investment, net inflows (% of GDP)	Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital, as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors and is divided by GDP
Trade (% of GDP)	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product

Table A3: Variance inflation Factors, Dependent variable L CO2

Variable	Coefficient Variance	Uncentered VIF
LP	0.020654	4.241493
LYY	5.881338	695.0213
T	3.06E-06	1.551459
LY^2	0.039730	690.1430
FDI	2.69E-05	1.610652
LIND	0.008011	7.190250

Source: Author calculation

Table A4: Variance inflation Factors, Dependent variable LNIT

Variable	Coefficient Variance	Uncentered VIF
LP	0.040738	4.195345
LYY	11.42899	671.9985
T	5.42E-06	1.388022
LY^2	0.077741	664.8192
FDI	5.57E-05	1.571421
LIND	0.016573	7.115771

Source: Author calculation