European Xtramile Centre of African Studies (EXCAS)

EXCAS Working Paper

WP/20/022

Energy Consumption, Capital Investment and Environmental Degradation: The African Experience [1]

Forthcoming in: Forum Scientiae Oeconomia

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Energy Consumption, Capital Investment and Environmental Degradation: The African Experience

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January 2020

Abstract

This study investigates the effects of energy consumption and capital investment on environmental degradation in selected African countries between 1981 and 2017 using panel cointegration approaches. The Fully Modified and the Dynamic Ordinary Least Squares results affirm that energy consumption positively affects carbon emissions in Algeria, Nigeria, Morocco, and in the panel. At the same time, both also confirm that capital investment positively and significantly impacts carbon emissions in the region. Again, results show that capital investment augments energy use to reduce carbon emissions in Africa significantly. This implies that capital investment can provide needed impetus to reduce environmental degradation in the continent. The study, therefore, recommends that African countries should focus on energy conservation policies to reduce the adverse effect of energy use on carbon emissions.

Keywords: Electricity Consumption, Capital investment, Environmental Degradation, Africa.
JEL Classification: Q40; Q42; Q43; Q54; Q57.

1. Introduction

With the increased concern over the ability of energy supply to keep up with demand, combined with worries over global warming, studies focusing on the relationship between energy consumption, economic growth, and greenhouse gas (GHGs) emissions has gained increasing attention (see, Menyah and Wolde-Rufael 2010; Farhani and Rejeb, 2012; Omri, 2013; Mesagan, Omojolaibi, & Umar, 2018; Popp, Kot, Lakner, & Oláh, 2018). In 2007, the intergovernmental panel on climate change reported that the average global temperature was estimated to rise between 1.1^0C and 6.4^0C in the next 100 years (IPCC, 2007). It is also predicted that a mere 2^0C increase in temperature would generate a substantial change to numerous natural ecosystems and a rise in the sea-level with attendant implications on the human lives in the coastal zones (Farhani and Shahbaz, 2014; Eregha and Mesagan, 2017). High pollution level is often traced to the pace of growth, especially during production activities. Moreover, increases in environmental pollution can result from the fast growth of the population, which has necessitated the decking of trees and overall biodiversity depletion (Asafu-Adjaye, 2003; Mesagan, 2015; Isola *et al.*, 2017; Popp, Oláh, Farkas Fekete, Lakner, & Máté,2018; Sarkodie and Strezov, 2019). Again, when investment in capital projects and productivity increase in a country, the environment can be affected positively or negatively depending on both the output composition and the technique effect generated. For instance, the Environmental Kuznets Curve (EKC) suggested that an inverted U-shaped curve exists between growth and pollution as both grow together at the early stage while pollution falls after that at the latter stage of growth expansion (Andreoni and Levinson, 2001; Stern, 2004). However, despite that the shape of the EKC has been tested and refuted in several studies; it is still a vital policy derivative for developing countries when modelling growth and environmental pollution.

Capital investment via foreign direct investment into countries with weak regulatory policies has environmental implications. For instance, frontier African nations with huge production capacities are the worst hit by emissions of carbon (Isola & Mesagan, 2017). For example, countries like Nigeria, Algeria, and Egypt are among the top 15 highest flaring nations in the world, implying that valuable energy resources that could be used to support economic growth and progress in Africa are emitted to the air as wastes. Importantly, countries across the globe like Russia, Venezuela and Mexico are working assiduously to lower gas flaring and convert it to revenue generation hub for the government (Eregha & Mesagan, 2019; World Bank, 2019). Hence, such potentials can be tapped into by African nations too. In addition to the fact that gas flaring leads to revenue loss for a nation, the CO_2 emissions it generates are also major concerns in Africa. This is more pronounced in big African countries with massive usage of fossil fuel energy. Furthermore, inappropriate investment inflow and fossil fuel energy usage is a source of worry to most African leaders as they tend to increase air pollution and further deepen the CO_2 emissions problems. As noted for China by Zhang and Cheng (2009),a unidirectional causal relationship runs from energy use toCO_2 emissions, while for ASEAN nations, Lean and Smyth (2010)confirmed a positive association between energy use and CO_2 emissions. Recently for BRICS for countries, Mesagan *et al.* (2018) confirmed that investment inflow significantly determined the volume of CO_2 emissions.

Consequently, this means that the nature of investment inflow shapes the link between energy and carbon emissions in a country. As prescribed in Sims *et al.* (2003) and Tang and Tan (2015), an investment can help to neutralize the threat of CO_2 emissions. Thus, the attraction of environmentally-unfriendly multinational firms from developed to developing nations can give rise to the pollution haven concept. For instance, the pollution haven hypothesis states that dirty industries usually relocate from the North to the South to take advantage of the lax environmental regulations and produce cheaply. Furthermore, countries with stringent environmental regulations determine the volume of capital investment and consequently alter the narratives of the environment (Letchumanan and Kodama, 2000; Blomquist and Cave, 2008; Saibu and Mesagan, 2016; Ilesanmi, & Tewari, 2017; Sarkodie and Strezov, 2019).This follows that energy use and pollution level are strongly linked, and the quality of capital investment domiciled in such countries is very crucial in shaping the link. This forms the main focus of this study. In other words, capital investment is vital in the energy-carbon emissions model for Africa because it is often omitted by previous studies in the literature. Hence, the novelty of this study is that it controls for capital investment in the energy-pollution abatement model. Specific objectives include; (i) analyzing the effect of energy consumption on environmental degradation in Africa, (ii) examining the impact of capital investment on the environment, (iii) determining the interaction effect of energy and investment on the environment, and (iv) testing the EKC proposition on Africa's environment. The rest of the study is structured as follows: section two presents the literature review; section three presents the research methodology; section four presents the empirical findings, and section five presents the conclusion.

2. Literature Review

In the literature, efforts have been made to examine the factors and efforts to control environmental pollution. In several studies, the pollution-income relationship was examined. For instance, Aldy (2007) examined the divergence in State-Level Per Capita Carbon Dioxide Emission in the United States for the period 1960 to 1999, by undertaking a variety of cross-sectional and stochastic convergence tests. The result showed that there is a divergence in the production of carbon emission. In the same vein, Ezcurra (2007) analyzed the spatial distribution of CO_2 emissions between 1960 and 1999 in 87 countries using a non-parametric method. Results confirmed the existence of emissions convergence as cross-country CO_2 emissions disparities declined over the period. Concentrating on 93 countries between 1960 and 2008 and employing dynamic panel, Stolyarova (2009) found the only short-run relationship between energy and CO_2 emissions while output growth and energy mix were reported to exert positive and negative impact respectively on CO_2 emissions. Again, Halicioglu (2009) examined the scenario in Turkey by including foreign trade in the model covering 1960to2005. Findings revealed the existence of two types of long-run nexus among the regressors. Regarding the first, trade, income and energy use determined CO_2 emissions while only foreign trade and energy consumption determined CO_2 emissions in the second type.

Similarly, Shahbaz *et al.* (2013) investigated the impact of financial development, energy use, income and trade on carbon emission between 1975Q1 and2011Q4 in Indonesia. Findings revealed that energy use and income increased CO_2emissions, while trade and financial development lowered CO_2 emissions. More so, Bento and Moutinho (2016) analyzed a similar situation in Italy between 1960 and 2011 and confirmed that foreign trade increased long-run pollution while renewable electricity generation reduced pollution in both long- and short-run. Similarly, Dogan and Seker (2016) focused on the major renewable energy nations by disaggregating energy use into non-renewable and renewable. They found that non-renewable energy increased emissions, while renewable energy reducedCO_2emissions. Mesagan and Nwachukwu (2018) controlled for financial development in Nigeria between 1981 and 2016. The result showed that energy use, output, trade, and financial development significantly determined environmental pollution, while urbanization and investment were less crucial.

Regarding studies on causality, Halicioglu (2009), for instance, found bidirectional causality between CO2 emissions and income both in the short run and long run. Examining the Chinese case from 1960 to 2007, Zhang and Cheng (2009) analyzed China between 1960 and 2007. They found unidirectional causality running from energy use to CO_2 emissions and from income to long-run energy use. Moreover, the neutrality hypothesis was found between income and CO_2 emissions and between income and energy use. Lean and Smyth (2010) focused on five ASEAN countries between 1980 and 2006 and the findings revealed long-run unidirectional causality from CO_2 and electricity consumption to output growth and short-run unidirectional causality from CO_2 emissions to electricity use. Shahbaz *et al.* (2013) confirmed a bidirectional causal relationship between CO_2 emissions and energy use, and between CO_2 emissions and economic growth while unidirectional causality was found running from financial development CO_2emissions. In the same vein, Cowan *et al.* (2014) focused on BRICS by analyzing panel data covering 1990 to 2010. It was observed that there exists no causality between electricity consumed and growth in China, India, and Brazil. However, bidirectional causality was found for them in Russia while they found unidirectional causality between output and electricity in South Africa. It found the neutrality hypothesis between output and CO_2 emissions in China and India, feedback hypothesis was found in Russia, while bidirectional causality existed in Brazil and South Africa. Li *et al*. (2017) analyzed the Chinese case between 1965 and 2015 and confirmed feedback between coal consumption and income, between gas consumption and income, and between CO_2 emissions and coal consumption. It also found unidirectional causality running from coal usage to oil and gas, and from oil and income to CO_2emissions. Mesagan and Nwachukwu (2018) found a feedback hypothesis between pollution and energy use, while unidirectional causality was found running from output and urbanization to pollution. Also, Gorus and Aslan (2019) found that foreign investment and energy consumption increased pollution in MENA countries. Ssali et al. (2019) affirmed the existence of bidirectional causality between environment pollution and energy consumption in the short-run, but in the long run, unidirectional causality runs from energy consumption to the environment. Also, Destek and

Sarkodie (2019) observed that the U-shaped association exists between growth and ecological footprint, while bidirectional causality was found also reported.

Summarily, several of the previous studies focused on the causal nexus between pollution and its determinants (e.g. Cowan *et al.,* 2014; Dogan and Seker, 2016). This study is different as it examines the effects of energy use and investment on the environment. Also, the inclusion of investment is vital because it can help to reduce the threat of pollution in an economy if well handled. Hence, it cannot be omitted in the energy-pollution model as several studies like Shahbaz *et al.* (2013), Cowan *et al.* (2014), Bento and Moutinho (2016), Li *et al.* (2017), Mesagan and Nwachukwu (2018), and Gorus and Aslan (2019) have done. Also, there is a dearth of related studies in Africa, despite its increasing industrial consciousness, which is currently being championed by the New Partnership for Africa's Development (NEPAD). This present study, therefore, aims to fill this noticeable gap in the literature and extend the frontiers of knowledge.

3. Research Methodology

The theoretical leaning of this study is that of the EKC, which submitted that at the early stages of economic growth, the distribution of income tends to worsen; only at later stages will it improve. This observation is characterized by the Inverted-U shaped relationship between per capita income and pollution level. Hence, following Andreoni and Levinson (2001), Stern (2004), Farhani and Shahbaz (2014), Mesagan (2015), and Li *et al.* (2017), we specify the empirical model as:

$$(CO_2)_{it} = \phi_0 + \phi_1 Y_{it} + \phi_2 Y_{it}^2 + \varepsilon_{it} \qquad (1)$$

Equation (1) is the EKC model CO_2 represents carbon emissions, which proxies environmental degradation. Thus, CO_2 depends on the level of output per capita (*Y*) and Y^2, which captures the quadratic function of the EKC. To confirm the EKC, the coefficient of *Y* will be positive while that ofY^2 will be negative. *'i'* is the number of cross-section, *'t'* is the time period and 'ε' is the residual term. In equation (2), the model for the study is specified as:

$$(CO_2)_{it} = \phi_0 + \phi_1 Y_{it} + \phi_2 Y_{it}^2 + \phi_3 EN_{it} + \phi_4 CI_{it} + \phi_5 ENCI_{it} + \phi_6 FDI_{it} + \phi_7 TO_{it} + \varepsilon_{it} \qquad (2)$$

Where CO_2 represents carbon emission per capita measured in kilo tonnes, Y signifies real GDP per capita, EN represents energy consumption proxied with fossil fuel energy use per capita measured in kilowatts, CI is capital investment which is captured with gross capital formation as a ratio of GDP, while ENCI is the interaction term between energy use and capital investment. Other variables include trade openness (TO), which is measured as the ratio of total trade to the GDP, and foreign direct investment (FDI), measured as net inflows of investment. In addition, in equation (2), ϕ_0 is the intercept term, while ϕ_1, ϕ_2, ϕ_3, ϕ_4, ϕ_5, ϕ_6, ϕ_7 are the coefficients of the various explanatory variables as defined. We expect all explanatory variables to be positive or negative depending on the situation on the continent.

The study used panel co-integration approaches[3] by employing Fully Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS) technique as used in Pedroni (2001). The panel co-integration approaches assist in correcting the endogeneity and serial correlation in long-run relationships associated with the regular pooled OLS. In estimating the long-run model, the panel co-integration test is conducted to determine the long-run relationship among the regressors. Whenever co-integration tests for long-run hypotheses in aggregate panel data are applied, the challenge is constructing the estimators without inhibiting the transitional dynamics among the panel. Bangake & Eggoh (2011) and Eregha & Mesagan (2017) suggest using the panel co-integration approaches by pooling only the information which concerns the long-run hypothesis of interest and permits the short-run changes to be potentially heterogeneous.

The data for the study was sourced from the World Bank's World Development Indicators (WDI, 2019) for the period 1981 to 2017.

4. Results and Discussion

In Table 1, the study presents the panel unit root result for the heterogeneous process (Im *et al.*, 2003) and the homogenous unit root tests (Breitung, 2001 and Levin *et al.*, 2002).

[3]To obtain both the FMOLS and DOLS estimates, the study estimated first the individual country-specific results using E-views 10. Specifically, the DOLS estimates were obtained using lag 1 and lead 1, which is appropriate as suggested by Pedroni (2001), Bangake & Eggoh (2011), and Eregha & Mesagan (2017). Moreover, the next step involves obtaining the panel estimates for the five selected African nations. For further step by step details about the calculations involving both panel cointegration approaches, see Eregha & Mesagan (2017), titled "Energy consumption, oil price and macroeconomic performance in energy-dependent African countries". Published in the Applied Econometrics Journal.

Table 1: Panel Unit Root

Variables	Heterogeneous Unit Root Process						Homogeneous Unit Root Process			
	Level			1st Diff			Level		1st Diff	
	ADF	PP-Fisher	IPS	ADF	PP-Fisher	IPS	Breitung	LLC	Breitung	LLC
CI	23.1**	25.2***	-2.33**	75.6***	249***	-8.49***	-3.71***	-0.41	-4.81***	-7.54***
CO_2	11.3	9.15	-0.20	46.3***	125***	-5.29***	-2.15**	0.93	-6.79***	-5.88***
EN	16.5	15.8	-1.71	58.0***	145***	-5.43***	-0.34	-1.77*	-5.55***	-6.97***
ENCI	23.7***	24.5***	-2.56***	72.3***	230***	-7.17***	-3.56***	-1.22	-9.06***	-6.46***
FDI	17.6**	32.0***	-1.79**	89.2***	534***	-9.81***	0.27	-0.65	-4.27***	-4.19***
TO	10.7	12.5	-0.39	58.1***	134***	-6.92***	-0.91	-0.72	-3.47***	-5.37***
Y	7.49	4.53	0.51	25.8***	75.1***	-3.08***	0.18	-1.34	-2.89***	-1.54**

***** 1% significant, ** 5% significant; IPS=Im, Pesaran & Shin; LLC=Levin, Lin & Chu.**

Table 1 affirms that we accept the null hypothesis of unit root, at level, implying that variables are not stationary at level. To this end, we first differenced the panel data and observed that all the variables are stationary, which means that, at first difference, we can reject the null hypothesis of unit roots in the panel. Having confirmed the stationarity of the regressors, we then proceed to estimate the panel co-integration test to determine the existence of a long-run relationship between the regressors. As provided in Pedroni (1999), four within-group tests and three between-group tests are explored. In Table2, we present the between dimension and the within dimension results.

Table 2: Pedroni Residual Cointegration Test

Between-Dimension		Within-Dimension		
	Statistic		**Statistic**	**Weighted Statistic**
Group rho	1.62	Panel v-Stat.	-4.98***	-2.68***
Group PP	-3.52***	Panel rho-Stat.	3.79**	1.34**
Group ADF	-1.89***	Panel PP-Stat.	-3.46***	-2.69***
		Panel ADF-Stat.	-1.95**	-1.71**

*****, ** indicates1%, 5% significance level.**

The between-dimension presents the computed value of the statistics based on the average individually estimated coefficients for every country in the panel. In contrast, the within-dimension presents the computed value based on the estimates that pooled the autoregressive coefficient across the different countries in the panel on the estimated residuals. In Table 2, the null hypothesis of no co-integration is rejected for both the between-group dimension and within-group dimensions. Only the group Rho is statistically insignificant in the between-dimension, while all the criteria in the within-dimension are statistically significant. Hence, we conclude that there is a long-run relationship between the variables. In Table 3, we present the panel co-integration estimates using the FMOLS, while the DOLS result is presented in Table 4.

Table 3: FMOLS Result of CO_2 emissions in Selected African Countries

Variables	Algeria	Egypt	Nigeria	Morocco	South Africa	Panel
Y	-3.311***	6.930	3.079***	5.299	1.798	-4.681
Y^2	0.172***	-0.404	-2.068***	-0.347	-1.019	0.357
EN	0.034	-0.026	0.024	0.029	-0.076**	0.167***
CI	-0.125	-0.046**	-0.003	0.073	-0.894***	0.038
ENCI	2.629	1.712***	-0.118	-1.791	1.988***	-1.611
FDI	0.217***	0.012	-0.048***	0.009	-0.024	0.017
TO	-0.021***	0.003	0.004	0.005**	0.026	-0.007
C	1.213***	-3.788	-1.134***	-1.555	-8.795	-
R^2	0.687	0.752	0.592	0.995	0.895	0.971
Adj. R^2	0.596	0.840	0.513	0.979	0.769	0.920

Note: *, ** indicate 1%, 5% level of significance**

In table 3, the FMOLS result presented shows that energy consumption positively affects carbon emissions in Algeria, Nigeria, Morocco, and in the panel. Whereas, energy consumption has a negative influence on carbon emissions in both Egypt and South Africa while keeping all the other explanatory variables constant. Concerning statistical significance, energy consumption is only significant at a 5% level in South Africa and a1% level for the panel. At the same time, it is not significant in determining emissions in Algeria, Egypt, Nigeria, and Morocco. For capital investment, the FMOLS result shows that capital investment has a negative effect on emissions in Algeria, Egypt, Nigeria, and South Africa. In contrast, it has a positive effect on carbon emissions in Morocco and the panel of selected countries while keeping the other explanatory variables constant. Regarding statistical significance, capital investment is significant at various levels in Algeria, Egypt, South Africa, and in the panel. Regarding the interaction term, the result shows that capital investment interacts with energy use to lower emissions in Nigeria, Morocco, and in the panel. It, however, interacts with fossil fuel energy use to worsen CO_2 emissions levels in Algeria, Egypt, and South Africa. In terms of its significance, the interaction term is significant at a 1% level in Egypt and South Africa. Although it lowers emission levels in Nigeria and Morocco, it is not significant. Concerning the proposition of the EKC, evidence from Table 3 suggests that the EKC proposition holds in Egypt, Nigeria, Morocco, and South Africa. In contrast, it did not hold in Algeria and the selected panel of African countries.

Table 4: DOLS Estimation Result of CO_2 emission in Selected African Countries

Variables	Algeria	Egypt	Nigeria	Morocco	South Africa	Panel
Y	-1.627	2.043	3.254	5.462	-8.511**	-1.997
Y^2	9.807	-1.458	-2.171	-0.314	4.629**	0.162
EN	1.365	-0.298	0.187**	0.076***	-0.436	0.126***
CI	-0.007	-0.161	-0.368**	0.211	-0.142	0.064***
ENCI	0.275	4.349	-2.952**	-5.832	3.688	-1.069***
FDI	0.191	0.166**	-0.019	0.052	-0.473	0.018
TO	-0.026	0.013	0.016***	0.003	0.212***	-0.001
C	7.841	1.880	-1.297	9.433	3.722**	-
R^2	0.747	0.891	0.979	0.966	0.776	0.989
Adj. R^2	0.696	0.761	0.754	0.893	0.639	0.915

Note: *, ** indicates 1%, 5% level of significance; Lead (1) and Lag (1)**

In table 4, the dynamic OLS result suggests that energy consumption positively affects carbon emissions in Algeria, Nigeria, Morocco, and in the panel. Whereas, energy consumption has a negative impact on carbon emissions in both Egypt and South Africa while keeping all the other explanatory variables constant. This means that both FMOLS and DOLS results are similar. Regarding statistical significance, energy consumption is significant at a 5% level in Nigeria and a 5% level in Morocco. For the panel, it is significant at a 5% level of significance while it is not significant in driving CO_2 emissions in Algeria, Egypt and South Africa. For capital investment, the DOLS result shows that capital investment has a negative impact on carbon emissions in Algeria, Egypt, Nigeria, and South Africa. At the same time, it has a positive effect on carbon emissions in Morocco and the panel like the case in FMOLS also. Concerning statistical significance, capital investment is only significant at a 5% level in Nigeria and a1% level in the panel. At the same time, it is not significant in impacting emissions in the other four countries specifically. Regarding the interaction term, the DOLS result shows that capital investment interacts with energy use to lower emissions in Nigeria, Morocco, and the panel. Still, for Algeria, Egypt, and South Africa, the reverse is the case. In terms of its significance, the interaction term is significant at a 5% level in Nigeria and a1% level in the selected panel. In contrast, it is not significant in Algeria, Egypt, Morocco, and South Africa. Regarding the proposition of the EKC, evidence from Table 4 suggests that the EKC proposition holds in Egypt, Nigeria, and Morocco, while in South Africa, Algeria, and the selected panel, no EKC was found using the DOLS.

Given the two results presented, it is evident that the robustness of the result has been confirmed for both approaches. For the panel of countries in Africa, both methods confirm that energy use positively and significantly contributed to the level of emissions in Africa. This is in line with the earlier findings of Lean and Smyth (2010) and Shahbaz *et al.* (2013) but at variance with Dogan and Seker (2016) that energy consumption lowers carbon emissions. Also, capital investment was found to have a positive and significant impact on emissions in the region, thereby confirming the result of Mesagan *et al.* (2018), which was conducted for BRICS. Moreover, the fact that energy use interacts with capital investment to reduce carbon emissions in the selected countries is also fascinating as it means that capital investment is an essential channel through which energy consumption can be used to improve Africa's environment. Again, it implies that the pollution Hallo theory of Gray (2002) and Copeland and Taylor (2004) is supported in the study. The Pollution Hallo theory opines that capital investment can provide the needed impetus to lower carbon emissions. The result is for the EKC is at variance with several studies like Bento and Moutinho (2016), as well as, Dogan and Seker (2016), as the proposition of the EKC was not found for the African countries. This is because the elasticity of income with respect to emission is negative, while the elasticity of the squared income with respect to emission is positive. The interpretation is that among the selected countries, pollution is much lower at the early developmental stage. Still, emissions continue to rise instead of falling at the latter stages of production, thereby refuting the EKC proposition in Africa.

5. Conclusion

This study focused on determining the effects of energy consumption and capital investment on environmental degradation in Africa between 1981 and 2017. Variables such as the real GDP, fossil fuel energy consumption, capital investment, trade openness, foreign direct investment, and carbon emissions were analyzed using the FMOLS, and DOLS approaches. In the results presented, findings show that for the panel of African countries, energy consumption and capital investment positively and significantly impacted carbon emissions. Again, capital investment interacted with energy use to reduce carbon emissions, whereas the Environmental Kuznets Curve was not found in the panel. The conclusion is that both energy use and investment worsened environmental quality in Africa while investment augmented energy use to significantly lower emissions in the continent. Considering the result of this scientific inquiry, the study recommends that African countries should focus on energy conservation policies to reduce the effect of energy use on emissions. Capital investment inflow to the continent must be adequately regulated and screened to enforce strict adherence to emissions reduction compliance. This empirical study has extended the frontiers of knowledge by controlling for capital investment in the energy-pollution abatement model and found that it is an important channel to lower environmental degradation in Africa. In terms of theoretical contribution, the study contributed to the expanse environmental literature by refuting the EKC proposition in the region. However, while this study has made a significant contribution, it is not oblivion of the fact that only a few African studies are selected. Albeit, the benefit remains that focusing on some of the major polluting nations in the continent is revealing and future studies can then extend this discussion to involve more cross-sections in the region to capture both high- and low-income countries.

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