Comparative Sustainable Development in Sub-Saharan Africa

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Abstract

Motivated by sustainable development challenges in Sub-Saharan Africa, this study assesses the comparative persistence of environmental unsustainability in a sample of 44 countries in the sub-region for the period 2000 to 2012. The empirical evidence is based on Generalised Method of Moments. Of the six hypotheses tested, it is not feasible to assess the hypothesis on resource-wealth because of issues in degrees of freedom. As for the remaining hypotheses, the following findings are established. (i) *Hypothesis* 1 postulating that middle income countries have a lower level of persistence in carbon dioxide (CO_2) emissions is valid for CO_2 per capita emissions, CO_2 emissions from electricity and heat production and CO_2 emissions from liquid fuel consumption. (ii) *Hypothesis* 2 on the edge of French civil law countries is valid for CO_2 emissions from liquid fuel consumption and CO_2 intensity, but not for CO_2 per capita emissions. (iii) *Hypothesis* 3 on the postulation that politically-unstable countries reflect more persistence is valid for CO_2 per capita emissions. (iv) *Hypothesis* 5 on the propensity for landlocked countries to be associated with more persistence in CO_2 emissions is valid for CO_2 per capita emissions but not for CO_2 emissions from liquid fuel consumption. (v) *Hypothesis* 6 maintaining that Christianity-dominated countries are more environmentally friendly with regard to CO_2 emissions is valid for CO_2 per capita emissions but not for CO_2 emissions from liquid fuel consumption and CO_2 intensity. Implications for policy and theory are discussed.

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

Keywords: CO2 emissions; Sustainable development; Environment; Africa

1. Introduction

Two main factors motivate this study, namely: (i) growing challenges of climate change and emissions of green house gases and (ii) gaps in the literature. These points are substantiated in chronological order. First, environmental sustainability has become a key policy agenda in the post-2015 development era (Asongu et al., 2016a). The particularity of sub-Saharan Africa (SSA) within this framework can be substantiated with four main points, namely: the sub-region's comparatively impressive recent growth record; growing energy crisis; the sub-region's poor management of energy crises and consequences of climate change. We substantiate the highlighted points in chronological order.

(i) Over the past two decades, SSA has experienced a period of growth resurgence (see Fosu, 2015), after lost decades that were the result, in part to the ineffective Structural Adjustment Programmes (SAP). Moreover, some narratives posit that the sub-region has recently hosted seven of the ten fastest growing economies in the world (see Asongu & Rangan, 2016). (ii) In the post-2015 sustainable development era, energy crisis is one of the most challenging policy syndromes in the sub-region[1]. The need for energy is most apparent in SSA because: only 5% of the population have access to energy in the sub-region; the total energy consumed in SSA is about the same as that consumed by a single state such as New York in the United States of America (USA) and the consumption of energy in the sub region is below 17% of the global average (see Shurig, 2015). (iii) As recently documented by Anyangwe (2014) and Asongu et al. (2017), inefficiency has been a dominant characteristic in the management of energy in most African countries. As a case in point, Nigeria which is the most populated country resorts to petroleum subsidized fossil fuel as a means of addressing concerns related to electricity outage and shortage. Accordingly, a sustainable development policy should instead place more emphasis on renewable sources of energy as opposed to government-subsidized petroleum fuel[2]. (iv) The consumption of fossil fuels has a direct consequence on global warming (Huxster et al., 2015), largely because the emissions of carbon dioxide (CO_2) associated with the consumption of such fuels, account for about seventy-five percent of global greenhouse gas emissions. According to Kifle (2008), Africa is the continent projected to be associated with the most negative consequences of global warming.

[1] Fosu (2013) defines policy syndromes as situations that are detrimental to growth: 'administered redistribution', 'state breakdown', 'state controls', and 'suboptimal inter temporal resource allocation'. Within the framework of this study, policy syndromes are considered as issues that merit policy action in order to achieve environmental sustainable development.

[2] The definition of sustainable development is consistent with that provided by the Brundtland Commission: '. . . development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland Commission, 1987). This definition is related to the context of this study because environmental unsustainability by means of CO_2 emissions can compromise the needs of future generations.

Second, to the best of our knowledge, in spite of the abundant supply of literature (notably on connections between energy consumption, CO_2 emissions and economic growth), we know very little about the persistence of CO_2 emissions, especially in countries projected to be the most affected by global warming. Accordingly, the positioning of this study deviates from mainstream literature which has largely articulated connections between energy consumption, CO_2 emissions and economic growth. This mainstream literature has been established in two main strands. The first provides insights into the relationships between the pollution of the environment and economic prosperity, with particular emphasis on the Environmental Kuznets Curve (EKC) assumption (see Akbostanci et al., 2009; Diao et al., 2009; He & Richard, 2010)[3]. The second strand has been concerned with: (i) linkages between environmental pollution, energy consumption and economic growth (Jumbe, 2004; Ang, 2007; Apergis & Payne, 2009; Odhiambo, 2009a, 2009b; Ozturk & Acaravci, 2010; Menyah & Wolde-Rufael, 2010; Begum et al., 2015; Bölük & Mehmet, 2015) and the relationship between economic prosperity and the consumption of energy (Mehrara, 2007; Esso, 2010).

A common denominator in the highlighted studies is the failure to engage the concept of persistence in environmental pollution. Moreover, the estimated techniques (such Granger Causality, Vector Error Correction Models and Autoregressive Distributed Lag) employed by the highlighted studies fall short of critically engaging the lagged dependent variable. In essence, models employing the lagged dependent variable may not be consistently estimated given that by construction the error term is correlated with the lagged outcome indicator via fixed effects. We address above shortcomings by focusing on CO_2 persistence and employing a Generalised Method of Moments (GMM) estimation approach which thoroughly addresses the concern of the correlation between the lagged dependent variable and the error term.

In order to increase the policy relevance of this study, the dataset is decomposed into fundamental characteristics of environmental degradation based on income levels (low income versus (vs.) middle income countries); legal origins (English Common law vs. French Civil law countries); religious domination (Christianity- vs. Islam-dominated countries); openness to sea (landlocked vs. coastal countries); resource-wealth (oil-rich vs. oil-poor countries) and political stability (stable vs. unstable countries). Motivations for the choice of fundamental features are critically engaged in Section 2.

In the light of the underlying theoretical insights, this study examines the persistence of environmental unsustainability. The concept of persistence in the study should be understood as

[3] According to the EKC hypothesis, in the long term, there is an inverted U-shaped relationship between per capita income and environmental degradation.

the connection between how past observations in environmental unsustainability influence future observations in environmental unsustainability. From an empirical standpoint, a hypothesis on persistence can be examined using a dynamic estimation technique. An example of such an estimation strategy is the Generalized Method of Moments that has been employed in recent literature to investigate persistence in economic phenomena (Asongu & Nwachukwu, 2018; Asongu et al., 2018a).

The positioning of this study depart from recent environmental sustainability literature which has focused on *inter alia*: sustainable economic planning (Radovanovic & Lior, 2017); the role of normative beliefs on environmental behaviour (Wang & Lin, 2017); nexuses between conflict, development and environmental sustainability (Fisher & Rucki, 2017) and the promotion of work place environmental sustainability (Saifulina & Carballo-Penela, 2017).

The rest of the study is structured as follows. The theoretical underpinnings and motivations for fundamental characteristics are discussed in Section 2 while Section 3 engages the data and methodology. The empirical results are presented in Section 4 whereas Section 5 concludes with implications and future research directions.

2. Theoretical underpinnings and motivations for fundamental characteristics

The theoretical underpinnings for persistence in CO_2 emissions (e.g. per capita CO_2 emissions) is consistent with recent literature on persistence in inclusive development (see Asongu & Nwachukwu, 2017a). The theoretical background is in accordance with the literature on per capita income convergence which has been considerably established within the framework of neoclassical growth estimations (see Barro, 1991; Barro & Sala-i-Martin, 1992, 1995; Mankiw et al., 1992; Baumol, 1986) and recently extended to other fields of economic development, *inter alia*: financial market performance (Narayan et al., 2011; Bruno et al., 2012) and inclusive human development (Mayer-Foulkes, 2010; Asongu & Nwachukwu, 2017a)[4].

In the post-Kenynesian period, seminal growth theories which gained prominence with the birth of the neoclassical revolution have eased convergence across countries. Under this

[4] It is important to note that the connection between inclusive development and CO_2 emissions should be seen in the light of the fact that the theoretical underpinnings of income convergence are being extended to other development fields. Accordingly, if such underpinnings have been employed for inclusive development and other macroeconomic variables, they can also be extended to environmental degradation by means of CO_2 emissions. Moreover, the fundamental characteristics in the concept of inclusive development (used by Asongu & Nwachukwu, 2017b) are much related to the concept of sustainable development (used in this paper) from a conceptual point of view. In essence, such concepts are connected in the perspective that in order for inclusive development to be sustainable, it must be sustained and in order to sustained development to be sustainable, it should be inclusive (see Amavilah et al., 2017).

framework, concepts for market equilibrium have been broadened to articulate some background for theories of economic growth that predict absolute convergence. Within this context, cross-country catch-up is the outcome of policies that are conducive to ‘free-market competition’ (Mayer-Foulkes, 2010). Seminal studies on catch-up concluded on the absence of convergence (see Barro, 1991; Pritchett, 1997). Reasons for the absence of convergence include: differences in initial endowments and the presence of multiple equilibria. Conversely, a contending strand which articulates the exogenous growth theory argues that regardless of initial endowments, convergence is feasible in each country’s common steady state or long run equilibrium.

In the light of the above, the theoretical and empirical underpinnings employed by both schools of thought to establish their positions (on evidence or not of convergence) are what matter to us for this study. In other words, both proponents for and against the presence of convergence have largely based their conclusions using the same theoretical and empirical frameworks. Therefore, we aim within the context of this inquiry to employ the same theoretical and empirical underpinnings to assess the persistence of CO_2 emissions. Our results, depending on fundamental characteristics and sub-panels may consolidate the positions of either school of the thought.

We discuss the testable hypotheses for comparative CO_2 emissions in terms of income levels, legal origins, religious domination, openness to sea, natural resources and political stability. Recent literature has employed the underlying fundamental characteristics (see Narayan et al., 2011; Mlachila et al., 2016; Asongu & Le Roux, 2017). Hence, in the narratives that follow, we articulate how environmental degradation can be associated with these fundamental characteristics.

First, from the perspective of income levels, compared to middle income countries, their low income counterparts are less likely to be connected with more effective mechanisms of managing CO_2 emissions. This builds on the motivation that, developed countries have more resources at their disposal with which to deal with issues connected to environmental degradation. Moreover, given that institutions have been established to be positively connected to economic development, one may analogically infer that these institutions offer genuine mechanisms for resource and environmental management (see Fosu, 2013a, 2013b; Anyanwu & Erhijakpor, 2014) and the consolidation of societal change (Efobi, 2015). It is also important to note that low income nations are less industrialised and therefore associated with lower CO_2 emissions, which require less mechanisms of CO_2 management. Moreover, these nations are likely to attract corporations that exploit its weak environmental regulations/legislations to set up factories that employ dirty technologies, and therefore emissions may be higher than in higher income countries.

Hypothesis 1: Compared to low income countries, middle income countries have lower persistence in CO_2 emissions.

Second, the relevance of legal origins in contemporary development has been substantially documented in the literature using African (Agbor, 2015; Asongu, 2012) and broader (see La Porta et al., 1998, 1999) samples. According to the consensus, compared to French Civil law countries, their English Common law counterparts have institutions that are more likely to address concerns about climate change because of political and adaptability mechanisms (see Beck et al., 2003). According to the adaptability mechanism, institutions in English common law countries are more likely to adapt to environmental challenges. In essence, the institutional web of formal rules, informal norms and characteristics of enforcement affect the vulnerability of the population to climate change and global warming.

Hypothesis 2: English Common Law countries have lower persistence in CO_2 emissions compared to their French Civil Law counterparts.

Third, from intuition, nations that are politically-stable are more likely to create conditions for better environmental management compared to their counterparts that are politically-unstable. This intuition is in accordance with Beegle et al. (2016, p.10) who have argued that fragility is linked with significantly less development[5]. By extension, poor environmental management is a product of less effective economic development. Accordingly, rules and regulations governing environmental protection are more likely to be respected in politically-stable than in politically-unstable countries. In the latter set of countries, the respect

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[5] The classification of politically-stable countries is consistent with Asongu (2014). According to the author, categorising a country as affected by conflict presents both practical and analytical hurdles. Hence, since few countries in the world are absolutely free from conflict, the distinctions are made in terms of degree of political strife and internal violence. Few researchers would object to the inclusion of Burundi, the Democratic Republic of Congo, Chad, the Central African Republic, Somalia and Nigeria. In spite of the absence of formal features of civil war, Zimbabwe can be included owing to the severity of its internal strife while Liberia which has not fully recovered from decades of civil war and political unrest can also be considered as a conflict-affected country. Given the 26 year period of Angolan civil war, at least half of the sampled periodicity should reflect a conflict-affected country, despite calm returning to the country in 2002. The Darfur crisis in Sudan which has lasted for more than 14 years has not officially ended. In the light of classification, aspects of seasonality in the occurrence of conflicts are taken into account.

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of the State and citizens of environmental-protecting institutions that govern their interactions between them is weak.

Hypothesis 3: Politically-stable countries are linked with less persistence in CO_2 emissions, relative to politically-unstable countries.

Fourth, contrary to the motivation on the relevance of income-levels in managing environmental degradation, we posit that resource-rich countries are associated with more characteristics of environmental degradation because they are often linked with low quality institutions (Mehlum et al., 2016a, 2016b). Moreover, petroleum-rich countries (e.g. Nigeria) are very likely to subsidize non-renewable sources of energy. The underlying motivation is consistent with the narrative that nations which have acknowledged scarcity in natural resources have focused more on achieving sustainable development (America, 2013; Fosu, 2013b; Amavilah, 2015). Rwanda is such an example in Africa.

Hypothesis 4: Resource-poor countries are associated with lower levels of persistence in CO_2 emissions, compared to their resource-wealthy counterparts.

Fifth, with the same motivation that there are economic and institutional costs associated with landlockedness (see Arvis et al., 2007), it is also assumed that environmental costs are linked to the underlying institutional and economic costs. This is essentially because: (i) institutions provide more conducive conditions for the management of the environment and (ii) landlocked countries in Africa rely more on road traffic which intuitively could be more responsible for CO_2 emissions. Hence, an example of a corresponding institutional cost can be the additional time required to transport equipments needed to promote environmental sustainability. Time wasted by land transport through another neighbouring country could (in cases of emergency for instance), seriously affect the successful implementation of some environmental operations if the transportation of heavy equipments associated with the underlying operations cannot be transported by air transport because of financial, technical and logistical reasons. Moreover, given that oceans absorb CO_2 emissions (Cole et al., 1993; Fletcher, 2017), it is reasonable to infer that countries that are open to the sea enjoy a comparative advantage of less persistence in CO_2 emissions.

Hypothesis 5: Landlocked countries are associated with more persistence in CO_2 emissions compared to countries that are opened to the sea.

In this study, religious domination is also employed as a fundamental characteristic of comparative sustainable development. The motivation for this distinction is that religious considerations build on some form of solidarity to inclusive and sustainable development (see Asongu & Nwachukwu, 2017b). Moreover, neoliberal societies comparatively have better institutions than their conservative counterparts. According to the narrative, Islam-oriented countries are traditionally more conservative and associated with institutions of less quality than their Christianity-dominated counterparts. Such underpinnings influence the choice of institutions and neoliberal policies for sustainable development (Roudometof, 2014).

Hypothesis 6: Christianity-dominated countries are associated with lower levels of persistence in CO_2 emissions, compared to their Islam-oriented counterparts.

3.1 Data and methodology

3.1 Data

This study is based on a sample of forty-four African countries with data from World Development Indicators and World Governance Indicators of the World Bank for the period 2000-2012[6]. Whereas the choice of the periodicity is motivated by constraints in data availability at the time of the study, the scope of the inquiry builds on the strands engaged in the introduction. Four main outcome variables are used, namely: CO_2 emissions per capita; CO_2 emissions from electricity and heat production; CO_2 emissions from liquid fuel consumption and CO_2 intensity. While we cannot select all the CO_2 emissions variables from all categories in World Bank database, the four variables are selected based on constraints in missing observations. Moreover, the modelling of persistence is contingent on the variables employed in the model. This caveat is further discussed in the concluding section.

Consistent with recent literature (see Asongu & Nwachukwu, 2017a), the independent variable of interest with which persistence is established is the estimated lagged dependent variable. Four main control variables are adopted in order to control for variable omission bias, namely: Gross Domestic Product (GDP) growth, population growth, educational quality and regulation quality. The choice of the control variables is consistent with recent literature on environmental sustainability (Asongu et al., 2018b).

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

While the first-two variables are logically expected to positively influence CO_2 emissions, the last-two should have the opposite impact. However, it is also important to balance the narrative by noting that when growth is not broad-based, but limited to few extractive industries, unexpected effects may be apparent. Furthermore, the expected impacts could be contingent on the weight of country-specific features that are not considered in the specification of the Generalised Method of Moments (GMM). The full definitions of variables, corresponding summary statistics and correlation matrix are disclosed in Appendix 1, Appendix 2 and Appendix 3 respectively.

The motivations for the choice of the fundamental features of comparative development have been covered in Section 2[7]. These fundamental characteristics have been used in recent comparative development literature (see Mlachila et al., 2016; Asongu & Nwachukwu, 2017b). The categorisation of countries by legal stratification is borrowed from La Porta et al. (2008, p. 289) whereas decomposition by income levels is in accordance with the World Bank's classification[8]. The classification of resource-wealth is exclusively oriented by the availability of petroleum resources which account for about 30% of the country's GDP for at least one decade of sampled periodicity. The Central Intelligence Agency (CIA) World Fact Book (CIA, 2011) provides the classification of religious-domination whereas Landlocked versus Coastal nations are apparent from an Africa map. Countries that are politically-unstable represent those that have witnessed political violence and/or instability for at least half of the periodicity being investigated. Appendix 4 provides the categorisation of countries.

3.2 Estimation technique

3.2.1 Specification

We adopt a *two-step* GMM for five main reasons. First, the number of countries is substantially more than the number of years in each cross-section. Second, the outcome variables are persistent given that the coefficient of correlation between the outcome variables and their first lags is higher than 0.800 which is the rule of thumb for establishing persistence in a dependent variable. Third, since the GMM technique is in accordance with a panel data structure, cross-country differences are considered in the regressions. Fourth, the estimation approach further takes account of endogeneity by controlling for simultaneity in the exploratory

[7] While the motivations for the choice of fundamental features are the testable hypotheses that have been postulated in Section 2, in Section 3 we discuss the selection criteria for the fundamental characteristics.

[8] There are four main World Bank income groups: (i) high income, $12,276 or more; (ii) upper middle income, $3,976-$12,275; (iii) lower middle income, $1,006-$3,975 and (iv) low income, $1,005 or less.

variables by means of a process of instrumentation as well as controlling for the unobserved heterogeneity through time-invariant variables. Fifth, inherent biases in the *difference* estimator are corrected with the *system* estimator.

Within the framework of this study, the Roodman (2009a, 2009b) extension of Arellano and Bover (1995) is adopted because, compared to traditional GMM techniques (*systems* and *difference* GMM approaches), it mitigates the proliferation of instruments (or restricts over-identification) and controls for cross-sectional dependence (Love & Zicchino, 2006; Baltagi, 2008; Boateng et al., 2018; Tchamyou, 2018).

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

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

$$CO_{i,t} - CO_{i,t-\tau} = \sigma_1 (CO_{i,t-\tau} - CO_{i,t-2\tau}) + \sum_{h=1}^{4} \delta_h (W_{h,i,t-\tau} - W_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + \varepsilon_{i,t-\tau} \quad , (2)$$

where, $CO_{i,t}$ is a CO_2 emissions indicator of country i at period t, σ_0 is a constant, W is the vector of control variables (GDP growth, population growth, education and regulation quality), τ represents the coefficient of auto-regression which is one for the specification, ξ_t is the time-specific constant, η_i is the country-specific effect and $\varepsilon_{i,t}$ the error term.

3.2.2 Identification and exclusion restrictions

It is relevant to engage identification properties and exclusion restrictions that are essential for a good GMM specification. All explanatory indicators are acknowledged to be suspected endogeneous or predetermined variables and only time invariant indicators are considered to exhibit strict exogeneity. This process of identification is in accordance with recent empirical literature (see Boateng et al., 2018; Asongu & Nwachukwu, 2016b). It is imperative to note that is not very likely for time invariant variables to be endogenous after first difference (see Roodman, 2009b; Tchamyou & Asongu, 2017)[9].

As concerns exclusion restrictions, given the identification process above, the years or variables that are time-invariant affect the outcome variable (or CO_2 emissions) exclusively via the suspected endogenous variables. Furthermore, in order for the underlying exclusion restriction assumption to be valid, the null hypothesis of the Difference in Hansen Test (DHT)

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

for the exogeneity of instruments should not be accepted. Failure to reject the null hypothesis of the DHT is an implication that time invariant variables influence the CO_2 indicators exclusively through the predetermined variables.

In the light of the above, in the findings that are reported in the empirical results section, the assumption of exclusion restriction is confirmed if the null hypothesis of the DHT related to instrumental variables (IV) (year, eq(diff)) is not rejected. This process of assessing the validity of exclusion restriction is not different from the standard IV procedure where-by, the failure to reject the null hypothesis of the Sargan Overidentifying Restrictions (OIR) test is an indication that strictly exogenous variables affect CO_2 emissions exclusively via the suspected endogenous variable mechanisms (see Beck et al., 2003; Asongu & Nwachukwu, 2016c).

4. Empirical results

Table 1, Table 2, Table 3 and Table 4 respectively present results corresponding to CO_2 emissions per capita, CO_2 emissions from electricity and heat production, CO_2 emissions from liquid fuel consumption and CO_2 intensity. The basis for assessing persistence is established with the estimated lagged dependent variable. A higher magnitude of this estimated coefficient translates a higher degree of persistence because past values of the outcome variable have a more proportionate impact of future values. It is also important to note that for persistence to be established, the estimated lagged dependent variable should be within the convergence range.

The convergence criterion is that the absolute value of the lagged estimated endogenous variable should be within the interval of zero and one. The interested reader can find more information on this criterion in recent catch-up literature (see Fung, 2009, p. 58; Asongu, 2013, p. 192). Accordingly, in the standard GMM approach, the estimated coefficient can be reported and one subtracted from it to obtain β (β= a-1). Within this alternative framework, the information criterion for catch-up is established if β<0. Otherwise, the estimated lagged dependent variable could also be reported and the alternative criterion ('0< lagged value <1') used to assess catch-up (see Prochniak & Witkowski, 2012a, p. 20; Prochniak & Witkowski, 2012b, p. 23).

We have clarified the concepts and criteria for persistence and convergence. However, a precondition for these to be established is the validity of overall estimated models. Four principal information criteria are used to investigate if the GMM models are valid[10]. In addition to the information criteria, it is important to note that the second-order Arellano and Bond autocorrelation test (AR(2)) is more relevant as information criterion than the first-order. This is essentially because some studies have exclusively reported the higher order with no disclosure of the first order (e.g. see Narayan et al., 2011; Asongu & Nwachukwu, 2016d). Based on these information criteria, for overall validity of estimated models, the models are overwhelmingly valid. In Tables 1-4, estimates are omitted for some fundamental characteristics because of issues in degree of freedom. Hence, in scenarios where the two sub-panels within a fundamental characteristic cannot be estimated, the corresponding hypothesis cannot be tested. This exception applies to: (i) resources in Table 1; (ii) resources, religious-domination and landlockedness in Table 2; (iii) resources and political stability in Table 3 and (iv) resources, income levels, landlockedness and political stability in Table 4. It is apparent after cross-examining the tables that *Hypothesis* 4 on resource-wealth cannot be feasibly examined.

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

Table 1: Environmental Unsustainability with CO_2 emissions per capita

	Dependent variable: CO_2 emission per capita											
	Income Levels		Legal Origins		Resources		Religion		Openness to Sea		Political Stability	
	L.I	M.I	Eng.	Frch.	Oil-rich	Oil-poor	Christi	Islam	Land locked	Unland locked	Stable	Unstable
Constant	**0.146****	-0.668	-0.227	**0.968*****	na	**0.626*****	**0.144*****	0.561	-1.868	**0.766*****	**0.616*****	omitted
	(0.034)	(0.775)	(0.449)	**(0.000)**		**(0.000)**	**(0.009)**	(0.319)	(0.346)	**(0.000)**	**(0.000)**	
CO_2 per capita (-1)	**0.971*****	**1.255*****	**0.966*****	**0.810*****		**0.870*****	**0.904*****	**0.935*****	**0.955*****	**0.860*****	**0.863*****	**0.900*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**		**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.001)**
GDP growth	-0.0004	-0.044	0.002	**-0.005****		-0.001	**0.002****	-0.039	-0.006	**-0.010*****	-0.004	-0.010
	(0.548)	(0.389)	(0.668)	**(0.049)**		(0.548)	**(0.018)**	(0.328)	(0.441)	**(0.005)**	(0.121)	(0.505)
Population growth	0.001	0.308	0.017	**-0.250*****		**-0.106*****	-0.009	0.162	0.158	**-0.187*****	**-0.105*****	0.029
	(0.950)	(0.461)	(0.623)	**(0.000)**		**(0.000)**	(0.219)	(0.525)	(0.356)	**(0.000)**	**(0.000)**	(0.900)
Education	-0.001	0.012	0.004	**-0.005****		**-0.003****	-0.0009	-0.010	0.031	**-0.003****	**-0.005****	0.006
	(0.153)	(0.701)	(0.407)	**(0.047)**		**(0.020)**	(0.225)	(0.607)	(0.352)	**(0.019)**	**(0.023)**	(0.753)
Regulation Quality	**0.083****	-0.411	-0.026	-0.122		**0.201****	**0.086*****	-0.129	0.217	-0.005	0.049	omitted
	(0.011)	(0.622)	(0.821)	(0.365)		**(0.021)**	**(0.003)**	(0.795)	(0.436)	(0.893)	(0.555)	
AR(1)	**(0.211)**	**(0.282)**	**(0.298)**	**(0.247)**		**(0.128)**	**(0.033)**	**(0.306)**	**(0.303)**	**(0.117)**	**(0.223)**	**(0.432)**
AR(2)	**(0.330)**	**(0.905)**	**(0.185)**	**(0.311)**		**(0.195)**	**(0.230)**	**(0.547)**	**(0.094)**	**(0.178)**	**(0.302)**	**(0.182)**
Sargan OIR	(0.013)	(0.005)	**(0.198)**	(0.000)		(0.000)	**(0.280)**	(0.008)	(0.001)	(0.000)	(0.000)	**(1.000)**
Hansen OIR	**(0.830)**	**(1.000)**	**(1.000)**	**(0.675)**		**(0.885)**	**(0.282)**	**(1.000)**	**(1.000)**	**(0.658)**	**(0.648)**	**(1.000)**
DHT for instruments												
(a)Instruments in levels												
H excluding group	**(0.267)**	**(1.000)**	**(0.721)**	**(0.678)**		**(0.550)**	**(0.155)**	**(1.000)**	**(1.000)**	**(0.249)**	**(0.796)**	**(1.000)**
Dif(null, H=exogenous)	**(0.964)**	**(1.000)**	**(1.000)**	**(0.543)**		**(0.892)**	**(0.459)**	**(1.000)**	**(1.000)**	**(0.831)**	**(0.448)**	**(1.000)**
(b) IV (years, eq(diff))												
H excluding group	**(0.687)**	**(1.000)**	**(0.877)**	**(0.216)**		**(0.869)**	**(0.310)**	**(1.000)**	**(1.000)**	**(0.498)**	**(0.746)**	**(1.000)**
Dif(null, H=exogenous)	**(0.747)**	**(1.000)**	**(1.000)**	**(0.880)**		**(0.733)**	**(0.301)**	**(1.000)**	**(1.000)**	**(0.630)**	**(0.474)**	**(1.000)**
Fisher	**62979*****	**550*****	**2571*****	**6054*****		**3608*****	**14706*****	**1941*****	**9972*****	**11443*****	**6199*****	**11732*****
Instruments	28	28	28	28		28	28	28	28	28	28	28
Countries	29	15	17	27		37	30	14	14	30	34	10
Observations	227	115	139	203		286	231	111	112	230	166	76

LI: Low Income countries. MI: Middle Income countries. Eng: English Common law countries. Frch: French Civil law countries. Oil-rich: Oil exporting countries. Oil-poor: Nonoil exporting countries. Christ: Christian-dominated countries. Islam: Islam-dominated countries. Landlocked: Landlocked countries. Unlandlocked: Unlandlocked countries. Stable: Politically stable countries. Unstable: Politically unstable countries. *,**,***: significance levels of 10%, 5% and 1% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments' Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) and AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests.

The following can be established for the remaining five hypotheses. (i) *Hypothesis* 1 postulating that middle income countries have a lower level of persistence in CO_2 emissions is valid in Tables 1 (CO_2 per capita emissions), Table 2 (CO_2 emissions from electricity and heat production) and Table 3 (CO_2 emissions from liquid fuel consumption). (ii) *Hypothesis* 2 on the edge of French civil law countries is valid in Table 3 (CO_2 emissions from liquid fuel consumption) and Table 4 (CO_2 intensity), but not in Table 1 (CO_2 per capita emissions). (iii) *Hypothesis* 3 on the postulation that politically-unstable countries reflect more persistence is valid in Table 1 (CO_2 per capita emissions). (iv) *Hypothesis* 5 on the propensity for landlocked countries to be associated with more persistence in CO_2 emissions is valid in Table 1 (CO_2 per capita emissions) but not in Table 3 (CO_2 emissions from liquid fuel consumption). (v) *Hypothesis* 6 maintaining that Christianity-dominated countries are more environmentally friendly with regard to CO_2 emissions is valid in Table 1 (CO_2 per capita emissions) but not in Tables 3-4 (CO_2 emissions from liquid fuel consumption and CO_2 intensity).

Table 2: Environmental Unsustainability CO_2 emissions from electricity and heat production

	Dependent variable: CO_2 emissions from electricity and heat production											
	Income Levels		Legal Origins		Resources		Religion		Openness to Sea		Political Stability	
	L.I	M.I	Eng.	Frch.	Oil-rich	Oil-poor	Christi	Islam	Land locked	Unland locked	Stable	Unstable
Constant	-11.209	omitted	omitted	3.473	na	7.095	3.101	na	na	-7.242	-7.519	na
	(0.457)			(0.768)		(0.637)	(0.745)			(0.557)	(0.627)	
CO_2 emissions (-1)	**0.985*** **	**1.130*** **	**1.132*** **	**1.008*** **		**0.892*** **	**1.079*** **			**1.033*** **	**1.018*** **	
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**		**(0.000)**	**(0.000)**			**(0.000)**	**(0.000)**	
GDP growth	0.434	-0.150	0.144	0.067		0.259	0.212			0.129	0.032	
	(0.227)	(0.579)	(0.522)	(0.503)		(0.255)	(0.436)			(0.311)	(0.869)	
Population growth	-2.287	-3.122	-0.576	2.430		-0.441	-1.127			-0.278	0.630	
	(0.288)	(0.768)	(0.861)	(0.764)		(0.886)	(0.607)			(0.959)	(0.755)	
Education	0.282	0.112	-0.135	-0.156		0.010	-0.034			0.057	0.028	
	(0.322)	(0.827)	(0.309)	(0.327)		(0.971)	(0.860)			(0.665)	(0.901)	
Regulation Quality	omitted	omitted	-3.791	-1.438		11.175	-0.248			-6.119	-1.925	
			(0.499)	(0.789)		(0.327)	(0.955)			(0.191)	(0.850)	
AR(1)	(0.082)	(0.499)	(0.192)	(0.240)		(0.103)	(0.240)			(0.003)	(0.109)	
AR(2)	**(0.147)**	**(0.386)**	**(0.348)**	**(0.662)**		**(0.154)**	**(0.462)**			**(0.265)**	**(0.125)**	
Sargan OIR	**(0.985)**	**(0.322)**	**(1.000)**	**(0.885)**		**(0.919)**	**(0.968)**			**(0.950)**	**(0.981)**	
Hansen OIR	**(1.000)**	**(1.000)**	**(0.763)**	**(1.000)**		**(1.000)**	**(1.000)**			**(1.000)**	**(1.000)**	
DHT for instruments												
(a)Instruments in levels												
H excluding group	**(1.000)**	**(1.000)**	**(1.000)**	**(1.000)**		**(0.103)**	**(0.943)**			**(0.772)**	**(0.844)**	
Dif(null, H=exogenous)	**(1.000)**	**(1.000)**	**(1.000)**	**(1.000)**		**(0.154)**	**(1.000)**			**(1.000)**	**(1.000)**	
(b) IV (years, eq(diff))												
H excluding group	**(1.000)**	**(1.000)**	**(1.000)**	**(1.000)**		**(0.919)**	**(1.000)**			**(0.358)**	**(0.834)**	
Dif(null, H=exogenous)	**(1.000)**	**(1.000)**	**(1.000)**	**(1.000)**		**(1.000)**	**(1.000)**			**(1.000)**	**(1.000)**	
Fisher	**177.20*** **	**1666*** **	**284*** **	**8908*** **		**107.10*** **	**47844*** **			**345.50*** **	**52.89*** **	
Instruments	28	28	28	28		28	28			28	28	
Countries	14	8	8	14		18	16			18	17	
Observations	106	63	69	100		142	120			144	139	

LI: Low Income countries. MI: Middle Income countries. Eng: English Common law countries. Frch: French Civil law countries. Oil-rich: Oil exporting countries. Oil-poor: Nonoil exporting countries. Christ: Christian-dominated countries. Islam: Islam-dominated countries. Landlocked: Landlocked countries. Unlandlocked: Unlandlocked countries. Stable: Politically stable countries. Unstable: Politically unstable countries. *,**,***: significance levels of 10%, 5% and 1% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments' Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) and AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests.

Table 3: Environmental Unsustainability with CO_2 emissions from liquid fuel consumption

	Dependent variable: CO_2 emissions from liquid fuel consumption											
	Income Levels		Legal Origins		Resources		Religion		Openness to Sea		Political Stability	
	L.I	M.I	Eng.	Frch.	Oil-rich	Oil-poor	Christi	Islam	Land locked	Unland locked	Stable	Unstable
Constant	0.494	-121.84	-1.140	**7.817*** **	na	0.856	1.476	omitted	**197.928***	0.447	0.011	n.a
	(0.848)	(0.326)	(0.861)	**(0.006)**		(0.809)	(0.622)		**(0.068)**	(0.871)	(0.998)	
CO_2 emissions (-1)	**0.873*** **	2.249	**1.125*** **	**0.902*** **		**0.964*** **	**0.907*** **	**1.430** **	-2.658	**0.970*** **	**0.956*** **	
	(0.000)	(0.100)	**(0.000)**	**(0.000)**		**(0.000)**	**(0.000)**	**(0.029)**	(0.158)	**(0.000)**	**(0.000)**	
GDP growth	**-0.115*** **	-0.189	**-0.381***	-0.014		-0.024	-0.034	2.813	**-1.743** **	-0.028	-0.019	
	(0.004)	(0.222)	**(0.073)**	(0.558)		(0.661)	(0.477)	(0.505)	**(0.040)**	(0.556)	(0.716)	
Population growth	**3.223*** **	7.800	1.284	0.337		**0.892** **	0.843	-4.907	**17.049** **	**0.393***	**0.439** **	
	(0.000)	(0.294)	(0.286)	(0.149)		**(0.013)**	(0.140)	(0.541)	**(0.031)**	**(0.070)**	**(0.048)**	
Education	0.020	0.734	-0.054	0.019		0.032	**0.112*** **	-0.785	**1.501** **	0.010	0.054	
	(0.519)	(0.286)	(0.839)	(0.297)		(0.428)	**(0.002)**	(0.450)	**(0.045)**	(0.731)	(0.172)	
Regulation Quality	-1.125	13.870	2.169	1.715		1.662	0.866	-36.182	0.648	**1.639***	0.060	
	(0.460)	(0.528)	(0.784)	(0.248)		(0.323)	(0.543)	(0.435)	(0.833)	**(0.095)**	(0.972)	
AR(1)	(0.012)	**(0.656)**	**(0.133)**	(0.051)		(0.005)	(0.007)	**(0.548)**	**(0.207)**	(0.010)	(0.006)	
AR(2)	(0.049)	**(0.984)**	**(0.218)**	**(0.192)**		(0.027)	(0.029)	**(0.590)**	**(0.165)**	(0.032)	(0.034)	
Sargan OIR	**(0.925)**	**(0.306)**	**(0.968)**	**(0.898)**		**(0.694)**	**(0.864)**	**(0.122)**	**(0.317)**	**(0.949)**	**(0.753)**	
Hansen OIR	**(0.822)**	**(1.000)**	**(0.997)**	**(0.743)**		**(0.771)**	**(0.890)**	**(1.000)**	**(1.000)**	**(0.882)**	**(0.305)**	
DHT for instruments												
(a)Instruments in levels												
H excluding group	**(0.369)**	**(1.000)**	**(0.785)**	**(0.608)**		**(0.640)**	**(0.879)**	**(1.000)**	**(1.000)**	**(0.410)**	**(0.551)**	
Dif(null, H=exogenous)	**(0.909)**	**(1.000)**	**(0.997)**	**(0.670)**		**(0.689)**	**(0.736)**	**(1.000)**	**(1.000)**	**(0.947)**	**(0.213)**	
(b) IV (years, eq(diff))												
H excluding group	**(0.922)**	**(1.000)**	**(0.918)**	**(0.931)**		**(0.641)**	**(0.464)**	**(1.000)**	**(1.000)**	**(0.837)**	**(0.163)**	
Dif(null, H=exogenous)	**(0.596)**	**(1.000)**	**(0.985)**	**(0.481)**		**(0.688)**	**(0.933)**	**(1.000)**	**(1.000)**	**(0.747)**	**(0.483)**	
Fisher	**714.16*** **	**45.32*** **	**192.11*** **	**412.22*** **		**270.10*** **	**1324*** **	**481468*** **	**137.26*** **	**1129*** **	**197.08*** **	
Instruments	28	28	28	28		28	28	28	28	28	28	
Countries	29	15	17	27		37	30	14	14	30	34	
Observations	227	115	139	203		286	231	11	112	230	266	

LI: Low Income countries. MI: Middle Income countries. Eng: English Common law countries. Frch: French Civil law countries. Oil-rich: Oil exporting countries. Oil-poor: Nonoil exporting countries. Christ: Christian-dominated countries. Islam: Islam-dominated countries. Landlocked: Landlocked countries. Unlandlocked: Unlandlocked countries. Stable: Politically stable countries. Unstable: Politically unstable countries. *,**,***: significance levels of 10%, 5% and 1% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments' Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) and AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests.

Table 4: Environmental Unsustainability with CO_2 intensity (kg of oil equivalent energy use)

	Dependent variable: CO_2 intensity											
	Income Levels		Legal Origins		Resources		Religion		Openness to Sea		Political Stability	
	L.I	M.I	Eng.	Frch.	Oil-rich	Oil-poor	Christi	Islam	Land locked	Unland locked	Stable	Unstable
Constant	0.530	na	omitted	0.276		0.117	0.097	omitted	na	-0.151	0.416	na
	(0.899)			(0.535)		(0.893)	(0.924)			(0.900)	(0.644)	
CO_2 emissions (-1)	**0.926*** **		0.123	**0.900*** **		**0.978*** **	**0.975*** **	**1.186*** **		**0.975*** **	**0.974*** **	
	(0.001)		(0.890)	**(0.000)**		**(0.000)**	**(0.000)**	**(0.000)**		**(0.000)**	**(0.000)**	
GDP growth	0.017		0.369	0.006		0.002	-0.005	-0.004		-0.005	-0.001	
	(0.849)		(0.352)	(0.519)		(0.909)	(0.862)	(0.658)		(0.866)	(0.909)	
Population growth	-0.231		-6.323	**-0.144** **		0.034	-0.171	-0.945		-0.062	-0.196	
	(0.902)		(0.378)	**(0.035)**		(0.976)	(0.790)	(0.284)		(0.934)	(0.707)	
Education	-0.003		0.370	0.002		-0.004	0.009	0.032		0.011	0.003	
	(0.941)		(0.372)	(0.617)		(0.945)	(0.748)	(0.300)		(0.738)	(0.899)	
Regulation Quality	-0.442		9.421	-0.111		0.119	-0.044	-1.140		0.145	0.142	
	(0.850)		(0.353)	(0.504)		(0.892)	(0.953)	(0.312)		(0.838)	(0.830)	
AR(1)	**(0.822)**		**(0.246)**	**(0.106)**		**(0.593)**	**(0.844)**	**(0.280)**		**(0.453)**	**(0.331)**	
AR(2)	**(0.823)**		**(0.289)**	**(0.410)**		**(0.971)**	**(0.897)**	**(0.762)**		**(0.844)**	**(0.550)**	
Sargan OIR	(0.000)		(0.000)	(0.364)		(0.000)	(0.000)	(0.223)		(0.000)	(0.000)	
Hansen OIR	**(1.000)**		**(1.000)**	**(0.993)**		**(1.000)**	**(1.000)**	**(1.000)**		**(1.000)**	**(1.000)**	
DHT for instruments												
(a)Instruments in levels												
H excluding group	**(0.990)**		**(1.000)**	**(0.544)**		**(0.966)**	**(0.977)**	**(1.000)**		**(0.999)**	**(0.993)**	
Dif(null, H=exogenous)	**(1.000)**		**(1.000)**	**(1.000)**		**(1.000)**	**(1.000)**	**(1.000)**		**(0.996)**	**(0.997)**	
(b) IV (years, eq(diff))												
H excluding group	**(0.872)**		**(1.000)**	**(0.060)**		**(0.880)**	**(0.881)**	**(1.000)**		**(0.878)**	**(0.873)**	
Dif(null, H=exogenous)	**(1.000)**		**(1.000)**	**(1.000)**		**(1.000)**	**(1.000)**	**(1.000)**		**(1.000)**	**(1.000)**	
Fisher	**69.46*** **		**161.99*** **	**246.46*** **		**30174*** **	**82521*** **	**862582*** **		**12474*** **	**18901*** **	
Instruments	28		28	28		28	28	28		28	28	
Countries	19		10	21		26	21	10		25	26	
Observations	115		74	115		159	133	56		159	159	

LI: Low Income countries. MI: Middle Income countries. Eng: English Common law countries. Frch: French Civil law countries. Oil-rich: Oil exporting countries. Oil-poor: Nonoil exporting countries. Christ: Christian-dominated countries. Islam: Islam-dominated countries. Landlocked: Landlocked countries. Unlandlocked: Unlandlocked countries. Stable: Politically stable countries. Unstable: Politically unstable countries. *,**,***: significance levels of 10%, 5% and 1% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments' Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) and AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests.

5. Concluding implications, caveats and future research directions

Motivated by sustainable development challenges in Sub-Saharan Africa, this study has assessed the comparative persistence in environmental unsustainability in a sample of 44 countries in the sub-region for the period 2000 to 2012. The empirical evidence is based on Generalised Method of Moments. The dataset is decomposed into fundamental characteristics of environmental degradation based on income levels (low income versus (vs.) middle income countries); legal origins (English Common law vs. French Civil law countries); religious domination (Christianity- vs. Islam-dominated countries); openness to sea (landlocked vs. coastal countries); resource-wealth (oil-rich vs. oil-poor countries) and political stability (stable vs. unstable countries).

Of the six hypotheses tested, it is not feasible to assess the hypothesis on resource-wealth because of issues in degrees of freedom. As for the remaining hypotheses, the following findings have been established. (i) *Hypothesis* 1 postulating that middle income countries have a lower level of persistence in CO_2 emissions is valid for CO_2 per capita emissions, CO_2 emissions from electricity and heat production and CO_2 emissions from liquid fuel consumption. (ii) *Hypothesis* 2 on the edge of French Civil law countries is valid for CO_2 emissions from liquid fuel consumption and CO_2 intensity, but not for CO_2 per capita emissions. (iii) *Hypothesis* 3 on the postulation that politically-unstable countries reflect more persistence is valid for CO_2 per capita emissions. (iv) *Hypothesis* 5 on the propensity for landlocked countries to be associated with more persistence in CO_2 emissions is valid for CO_2 per capita emissions but not for CO_2 emissions from liquid fuel consumption. (v) *Hypothesis* 6 maintaining that Christian-dominated countries are more environmentally friendly with regard to CO_2 emissions is valid for CO_2 per capita emissions but not for CO_2 emissions from liquid fuel consumption and CO_2 intensity. Before discussing policy and theoretical implications, we clarify *Hypothesis 6* for which corresponding findings on its invalidity outweigh results for its validity.

We have postulated that since Christianity-dominated countries are more open to the neoliberal culture, it is more likely that they have better institutions that manage the environment more sustainably than their Islam-oriented counterparts. Unfortunately, this hypothesis has been rejected by a substantial margin (two of the three CO_2 emissions variables). Upon more intuition, what we have overlooked in the establishment of the testable hypotheses is the fact that nations which are more liberal are also more likely to adopt capitalistic tendencies that are not friendly to sustainable development (Roudometof, 2014). This interpretation and clarification are broadly consistent with Obeng-Odoom (2015). The author, in a critique of the 'Africa rising' narrative has argued that neoliberal policies imposed on Africa are more focused on increasing the relevance of capital accumulation, with less concern on more fundamental ethnical issues like environmental degradation and inequality. Moreover, liberal economies are generally more opened and there is an established relationship between openness and the carbon footprint of countries (Peters & Hertwich, 2008; Hertwich & Peters, 2009).

The main policy implication is that, contingent on comparative persistence in CO_2 emissions, more resources can be devoted to addressing the policy syndrome within a fundamental characteristic. It is important to note that persistence in a negative aspect of environmental quality represents a policy syndrome. Such persistence implies that past CO_2 emissions positively affect future CO_2 emissions. Furthermore, more persistence in one sub-panel compared to another within the same fundamental characteristic implies that past CO_2

emissions have a more proportionate impact on future CO_2 emissions in the sub-panel exhibiting more persistence.

The theoretical contribution of this study builds on the established persistence in negative economic signals. By deviating from mainstream convergence literature which is based on catch-up in per capita income (or positive economic signals), we have shown in this study that the theoretical underpinnings of the convergence literature can be extended to negative signals. This theoretical extension is consistent with a recent stream of literature on policy harmonization based on catch-up in policy syndromes, namely: the prediction of the Arab Spring based on negative governance and macroeconomic signals (Asongu & Nwachukwu, 2016d) and the fight against capital flight (Asongu, 2014). Therefore, these findings should also be viewed through the lens of a theory-building exercise because applied econometrics should not be exclusively based on the acceptance or rejection of existing theoretical underpinnings. Accordingly, the underpinnings of an existing theory can be employed in other development fields. In essence, we have built on the theoretical underpinnings of income convergence literature (Barro, 1991; Barro & Sala-i-Martin, 1992, 1995; Mankiw et al., 1992; Baumol, 1986) to assess persistence in environmental degradation. This improves recent theoretical literature on the need to extend the theoretical underpinnings of income convergence to other development fields, notably: financial market development (Narayan et al., 2011; Bruno et al., 2012) and inclusive human development (Mayer-Foulkes, 2010; Asongu & Nwachukwu, 2017a). Moreover, the attendant literature has fundamentally been based on positive macroeconomic signals. In this study, the variables used on environmental degradation are negative macroeconomic signals because the persistence in negative macroeconomic signals may even require more policy intervention, compared to the persistence of positive macroeconomic signals.

Two main caveats are worth discussing, notably: the contingency of the analysis on the choice of variables employed and assumptions underlying the testable hypotheses. The points are expanded chronological order. First, as highlighted in the data section, it is impossible to use all the CO_2 emission variables from the World Bank Development database. Hence, we have been limited to a selected few based on constraints in missing observations in the other variables. It follows that the established evidence of persistence is contingent on the outcome variables as well as the variables used in the conditioning information set. This contingency of results in the variables employed in the model is a fundamental shortcoming of conditional (or contingent) convergence and/or persistence modelling by means of the Generalised of the Method of Moments.

Second, some of the motivations underpinnings the postulated hypotheses may be problematic. For instance, critics of the assumption underpinning the legal origin hypothesis maintain that the strength of British Common law vis-à-vis French Civil law may not hold for a plethora of reasons (Deakin & Siems 2010; Fowowe, 2014; Asongu, 2015). (i) It is doubted in some scholarly circles whether the distinction between Civil law and Common law is justifiable from a historical standpoint. (ii) With internationalization in the contemporary era, the distinction between Civil law and Common law is less persuasive. (iii) The categorization of countries in terms of Civil law and Common law does not take into account the following factors, *inter alia*: modifications and mixtures at the moment foreign laws were copied by former colonies, the influence of transplant law and the post-transplant period during which the law transplanted could still be altered or applied differently. Notwithstanding these caveats, we do not expect the hypotheses to be 100% accurate, which is the reason an empirical exercise is needed to either validate or reject them.

Future research can improve the extant literature by investigating whether the established linkages withstand empirical scrutiny when other regions of the world are investigated. It would also be interesting to assess the probability of occurrence of established patterns in the future with alternative estimation techniques.

Appendices

Appendix 1: Variable Definitions

Variables	Signs	Variable Definitions (Measurement)	Sources
CO_2 per capita	CO2mtpc	CO_2 emissions (metric tons per capita)	World Bank (WDI)
CO_2 from electricity and heat	CO2elehepro	CO_2 emissions from electricity and heat production, total (% of total fuel combustion)	World Bank (WDI)
CO_2 from liquid fuel	CO2lfcon	CO_2 emissions from liquid fuel consumption (% of total)	World Bank (WDI)
CO_2 intensity	CO2inten	CO_2 intensity (kg per kg of oil equivalent energy use)	World Bank (WDI)
Educational Quality	Educ	Pupil teacher ratio in Primary Education	World Bank (WDI)
GDP growth	GDPg	Gross Domestic Product (GDP) growth (annual %)	World Bank (WDI)
Population growth	Popg	Population growth rate (annual %)	World Bank (WDI)
Regulation Quality	RQ	"Regulation quality (estimate): measured as the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development"	World Bank (WDI)

WDI: World Bank Development Indicators.

Appendix 2: Summary statistics (2000-2012)

	Mean	SD	Minimum	Maximum	Observations
CO_2 per capita	0.901	1.820	0.016	10.093	567
CO_2 from electricity and heat	23.730	18.870	0.000	71.829	286
CO_2 from liquid fuel	78.880	23.092	0.000	100	567
CO_2 intensity	2.044	6.449	0.058	77.586	321
Educational Quality	43.784	14.731	12.466	100.236	425
GDP growth	4.851	5.000	-32.832	33.735	567
Population growth	2.334	0.866	-1.081	6.576	529
Regulation Quality	-0.607	0.544	-2.238	0.983	530

S.D: Standard Deviation.

Appendix 3: Correlation matrix (uniform sample size: 155)

CO2mtpc	CO2elehepro	CO2lfcon	CO2inten	Educ	GDPg	Popg	RQ	
1.000	0.690	-0.721	0.805	-0.369	-0.057	-0.611	0.593	CO2mtpc
	1.000	-0.695	0.703	-0.502	-0.052	-0.524	0.505	CO2elehepro
		1.000	-0.551	0.246	0.020	0.364	-0.366	CO2lfcon
			1.000	-0.509	-0.055	-0.698	0.676	CO2inten
				1.000	0.104	0.515	-0.515	Educ
					1.000	0.074	-0.140	GDPg
						1.000	-0.624	Popg
							1.000	RQ

CO2mtpc: CO_2 emissions (metric tons per capita). CO2elehepro: CO_2 emissions from electricity and heat production, total (% of total fuel combustion). CO2lfcon: CO_2 emissions from liquid fuel consumption (% of total). CO2inten: CO_2 intensity (kg per kg of oil equivalent energy use). Educ: Quality of primary education. GDPg: GDP growth. Popg: Population growth. RQ: Regulation Quality.

Appendix 4: Categorization of Countries

Categories	Panels	Countries	Num
Income levels	Middle Income	Algeria, Angola, Botswana, Cameroon, Cape Verde, Côte d'Ivoire, Egypt, Equatorial Guinea, Gabon, Lesotho, Libya, Mauritius, Morocco, Namibia, Nigeria, , Senegal, Seychelles, South Africa, Sudan, Swaziland, Tunisia.	21
	Low Income	Benin, Burkina Faso, Burundi, Central African Republic, Chad, Comoros, Congo Democratic Republic, Congo Republic, Djibouti, Eritrea, Ethiopia, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Rwanda, Sierra Leone, Somalia, Togo, Uganda, Zambia, Zimbabwe.	30
Legal Origins	English Common-law	Botswana, The Gambia, Ghana, Kenya, Lesotho, Liberia, Malawi, Mauritius, Namibia, Nigeria, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Uganda, Zambia, Zimbabwe.	19
	French Civil-law	Algeria, Angola, Benin, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo Democratic Republic, Congo Republic, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Guinea, Guinea-Bissau, Libya, Madagascar, Mali, Mauritania, Morocco, Mozambique, Niger, Rwanda, Senegal, Togo, Tunisia.	32
Religion	Christianity	Angola, Benin, Botswana, Burundi, Cameroon, Cape Verde, Central African Republic, Congo Democratic Republic, Congo Republic, Côte d'Ivoire, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Rwanda, Seychelles, South Africa, South Africa, Togo, Uganda, Zambia, Zimbabwe.	31
	Islam	Algeria, Burkina Faso, Chad, Comoros, Djibouti, Egypt, The Gambia, Guinea, Guinea Bissau, Libya , Mali, Mauritania, Morocco, Niger, Nigeria, Senegal, Sierra Leone, Somalia, Sudan, Tunisia,	20
Resources	Petroleum Exporting	Algeria, Angola, Cameroon, Chad, Congo Republic, Equatorial Guinea, Gabon, Libya, Nigeria, Sudan.	10
	Non-Petroleum Exporting	Benin, Botswana, Burkina Faso, Burundi, Cape Verde, Central African Republic, Comoros, Congo Democratic Republic, Côte d'Ivoire, Djibouti, Eritrea, Ethiopia, Egypt, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Senegal, Sierra Leone, Somalia, Rwanda, Seychelles, South Africa, Swaziland, Togo, Tunisia, Uganda, Zambia, Zimbabwe.	41
Stability	Conflict	Angola, Burundi, Chad, Central African Republic, Congo Democratic Republic, Côte d'Ivoire, Liberia, Nigeria, Sierra Leone, Somalia, Sudan, Zimbabwe.	12
	Non-Conflict	Algeria, Benin, Botswana, Burkina Faso, Cameroon, Cape Verde, Comoros, Congo Republic, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Senegal, Rwanda, Seychelles, South Africa, Swaziland, Togo, Tunisia, Uganda, Zambia.	39
Openness to Sea	Landlocked	Botswana, Burkina Faso, Burundi, Chad, Central African Republic, Ethiopia, Lesotho, Malawi, Mali, Niger, Rwanda, Swaziland, Uganda, Zambia, Zimbabwe	15
	Not landlocked	Algeria, Angola, Benin, Cameroon, Cape Verde, Comoros, Congo Democratic Republic, Congo Republic, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Libya, Madagascar, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Nigeria, Senegal, Sierra Leone, Somalia, Sudan, Seychelles, South Africa, Togo, Tunisia.	36

Num: Number of cross sections (countries)

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