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A MODIFIED EKC FOR SUSTAINABILITY ASSESSMENT IN SUB-SAHARAN AFRICA: A PANEL DATA ANALYSIS

A modified Environmental Kuznets Curve is proposed, where, by substituting the traditional measure of pollution with the level of natural resource depletion and degradation, a more sustainability-oriented EKC model is presented. The focus is placed on a panel data set of 30 Sub-Saharan African (SSA) countries, over a period of thirty-five years (1980-2014). SSA is chosen as the subject of this research, as it is a resource-rich region and is currently one of the world's fastest-growing regions in terms of foreign direct investment (FDI), especially natural resource seeking, but SSA is also plagued with poor institutional quality and widespread poverty and income inequality. Several studies also associate SSA with a resource curse. The EKC hypothesis is tested for natural resource depletion after controlling several variables pertinent to the SSA region. One of the major findings is that no EKC or inverted U-shape relationship is found between natural resource depletion and the level of economic development. In other words, natural resource depletion does not seem to subside after a given per capita income level is reached for the sampled countries. In addition, the results show that globalisation, which is measured through trade openness, and industrialisation both contribute towards a greater depletion of natural resources and hence have an adverse impact on environmental sustainability for this sample of countries.

JEL: QO1; Q56; C23

Keywords: natural resource depletion; EKC; Sub-Saharan Africa; panel data

With global warming and other environmental problems becoming acute worldwide, environmental concerns are receiving more attention than ever. One of the most widely used environmental models in the economics literature is the Environmental Kuznets Curve (EKC). The theory suggests that the EKC, which shows the relationship between the per capita income of a country and the level of environmental degradation, has an inverted U-shape. This can be explained by the fact that, at initial stages of development, people, households and even governments are more interested in the creation of jobs and the production of goods and services rather than in environmental quality, thus leading to more pressure on environmental resources. However, at higher stages of development, as the population starts to enjoy higher levels of affluence, stronger institutions are established and modern industrial processes are developed which tend to be more environment-friendly. Furthermore, as societies progress, governments can pass new environmental laws and regulations while dedicating more resources towards improving the quality of the environment (Dasgupta et al., 2002).

However, the traditional EKC has been criticised for incompleteness in the sustainable development context as most EKC studies focus on flow pollutants such as air and water pollution but rarely consider natural resources. For example Sobhee

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(2004) has questioned the quadratic relationship and has argued that the EKC may follow a cubic functional relationship.

Therefore, one of the major challenges facing developing countries in particular is how to progress to higher levels of economic development without irreversibly damaging their environment. Most EKC studies have investigated flow pollutants such as air and water pollution but have rarely considered stock pollutants or natural resources except for specific issues such as deforestation and endangered species like marine life for instance. Furthermore, despite the huge diffusion of EKC studies, the traditional EKC has been criticised for incompleteness in a sustainable development context. Some recent contributions (Costantini and Monni, 2006; Costantini and Martini, 2008) have attempted to investigate sustainability implications in an empirical EKC formulation.

Costantini and Monni (2008) include the negative Genuine Savings (GS) as a measure of unsustainability in their modified EKC formulation and argue that the GS takes into account the depletion of natural capital. A measure of stronger sustainability, namely the depletion and degradation of natural capital itself, is used as the dependent variable for a sustainability-oriented EKC model in this paper. Thus, this study proposes to extend the current literature by modifying the typical testing of EKC by substituting the dependent variable with a wider measure of environmental pressure, proxied by the level of natural resource degradation and depletion, which is more relevant for Sub-Saharan African (SSA) countries as a resource-rich region. The choice of SSA for this study on sustainability has been motivated by several reasons. Many countries in Sub-Saharan Africa have now sustained 5-6 % growth rates for more than a decade (IMF, 2014), which is a much higher rate than that in other parts of the world, including East Asian countries, and this trend is projected to accelerate in future years. Part of the African success is based on the fact that it has become one of the world's fastest-growing regions in terms of foreign direct investment (FDI). Foreign investments that are resource-seeking in nature, such as oil and gas investments, represent approximately one third of the total. Hence, it is important to investigate whether the thriving economic performance of the continent is in fact at the expense of the environment.

The focus of the study is placed on the EKC models that address the issues of natural resource degradation and depletion, which are linked to the development process, the concept of strong sustainability and the necessary measures for achieving it are discussed, and an overview of the empirical studies linking sustainability and the EKC are provided. Next, the empirical strategy along with the data and model specification are presented, followed by a presentation of the empirical findings, analysis and discussion; and finally, a summary of the key findings and the conclusion reached is made.

Overview of the literature

On the one hand, early stages of economic growth are often characterised by heavy exploitation of natural resources as well as high reliance on the agricultural sector, which leads to a reduction in the stock of natural capital. After a certain level of development has been attained, efficiency in the utilisation of natural resources increases. In addition, markets for environmental resources start to develop and prices start to reflect the value of natural resources. The consequent increase in the price of natural resources reduces their exploitation at later stages of development. Furthermore, the higher prices of natural resources also contribute to speeding up the shift towards less resource-intensive technologies (Torras and Boyce, 1998), therefore lower levels of natural resource exploitation and lower levels of environmental degradation are associated with higher levels of development, eventually leading to an inverted U-shaped curve.

On the other hand, two divergent paradigms can be distinguished in terms of sustainable development, namely weak sustainability and strong sustainability. Weak sustainability is based on the belief that what matters for future generations is the total aggregate stock of different forms of capital and not only natural capital per se, for instance, it does not matter whether the current generation uses up non-renewable resources or pollutes the environment, as long as enough machines or roads are constructed in compensation. However, a progression down the weak sustainability path, where natural capital is decreasing over time, can result in a (strongly) unsustainable development (Barr, 2008).

In opposition, the essence of strong sustainability is that natural capital is regarded as being non-substitutable. However, it is more difficult to define strong sustainability (Neumayer, 2003). Two different interpretations of strong sustainability prevail. One is about preserving natural capital in value terms and the other is about preserving physical stocks of certain forms of natural capital that are non-renewable or critical, such as the ozone layer. Strong sustainability does not however call for keeping nature totally intact, as this is impossible, but rather calls for maintaining its functions intact. Natural capital can thus be used but its regenerative functions should not be exceeded so that the environmental function remains unharmed. For instance, Hueting and Reijnders (1998, p. 145) illustrate this concept with an example: “the rate of erosion of topsoil may not exceed the rate of formation of such soil due to weathering.”

According to Daly (1993), preserving critical natural capital involves the use of renewable natural resources, utilised at a sustainable rate that is, depending on its regenerative capacity and the use of the environmental sink function, only to the extent that the natural absorptive capacity does not decline over time. Proponents of strong sustainability are therefore concerned about the utilisation and sustainability of non-renewable resources, for example fossil fuel, as well as the environmental consequences of growth (Daly, 1993). The depreciation of natural capital, ecosystem degradation and biodiversity loss carry the risk of being potentially irreversible in some cases (Barbier, 2010). Natural capital is also often subject to threshold levels beyond which the asset can cease to provide certain services. Although these thresholds might not be known with precision, the basic idea is that reducing the stocks of natural capital can damage the resilience of that asset, which can in turn affect the sustainability of economic growth or development, if not the survival of mankind itself. Strong sustainability thus represents the greater challenge (Neumayer, 2003).

According to Davies (2013), the developed world seems to be leaning towards the stronger end of the sustainability spectrum with its increasing and explicit recognition of the need to preserve natural resources and the environment. Nevertheless, in the developing world, damages to natural capital, especially those linked to the operation of multinational enterprises (MNEs), are very often documented and, in many cases, the damage is irreversible (Osaghae, 1995). Some researchers such as Cole (2004) also view the concepts of weak and strong sustainability as having temporal dimensions. They support their arguments with the EKC 'turning point' that occurs at a certain stage where environmental consciousness starts to prevail, causing environmental damage to subsequently decrease.

Contrary to the weak sustainability measure – the Genuine Savings (GS) – there are no widely agreed upon indicators of strong sustainability (Neumayer, 2003). Strong sustainability indicators can basically be divided into three groups: indicators using monetary values, such as the Index of Sustainable Economic Welfare (ISEW) or the Genuine Progress Indicator (GPI); indicators using physical values, such as the Ecological Footprint (EF) or the material flows; and finally, indicators using hybrid approaches that combine physical indicators and monetary valuation, such as the so-called sustainability gaps, the Greened National Statistical and Modelling Procedures (GREENSTAMP) and Hueting's 'sustainable national income' (SNI). A detailed and technical discussion about various strong sustainability indicators is however beyond the scope of this study (see Neumayer, 2003; Getzner, 1999; Pearce, 1996). Many of these indicators are still in their infancy, requiring further fine-tuning (Neumayer, 2005) and are also not available for empirical analysis of large samples of countries and for panel data analysis in particular.

In this context, the choice of meaningful indicators raises several issues. The shape of the EKC, including the location of the peak differs considerably for different indicators like air pollution, water quality and soil erosion. In addition, seeking to combine different measures of environmental degradation will not yield meaningful results. Costantini and Martini (2008) argue that the various critiques of the initial EKC formulation have stimulated a debate around alternative representations of the relationship between economic growth and the environment. A sustainability-oriented EKC is a new line of research which could allow new theoretical formulations in relation to sustainable development for a more accurate specification of the growth-environment relationship.

Hill and Magnani (2002) recommend replacing the GDP in the EKC with more inclusive measures of well-being, such as the Genuine Progress Indicator (GPI), or the Index of Sustainable Economic Welfare (ISEW) and the Human Development Index (HDI), which might better capture the concept of sustainable development. Munasinghe (1999) uses the Environmentally Adjusted Net Domestic Product (EDP), which is calculated by subtracting the economic value of the net loss of natural capital from the Net Domestic Product. The resulting EKC shows a steeper upwards sloping curve than would have been the case with the usual measure.

Jha and Murthy (2003) examine the EKC hypothesis using the HDI as a broader measure of economic development instead of the GDP and the Environmental Degradation Index (EDI) as a global indicator of environmental quality. They find a positive correlation between the EDI and the HDI for countries with a high HDI, a negative relationship for countries with a low HDI and a weakly negative relationship for countries found in the intermediate class. Their results confirm an inverted U-shaped relationship where the level of environmental degradation is dependent on the development stage of the country, while Gürlük (2009) models the EKC as a relationship between biological oxygen demand as a type of industrial pollution and per capital income along with a modified human development indicator (MHDI) as indicators of development.

Costantini and Monni (2008) also examine the EKC hypothesis using the HDI as a development indicator, but they use the Genuine Saving (GS) as a measure of weak sustainability, based on the assumption of perfect resource substitutability. They use a modified HDI as well to cater for the correlation between the income factor included in the HDI and the GS. The GS is seen to increase as long as the HDI rises but countries with low and medium-low levels of the HDI do not see any significant changes in the GS level. The threshold level of un-sustainability is associated with a low-medium level of the HDI of approximately 0.60, while for classical EKC formulations, the threshold levels tend to be significantly higher than this value, therefore corroborating the so-called “tunnelling through the curve” effect suggested by Munasinghe (1999). Costantini and Martini (2008) on the other hand, adopt a stronger sustainability criterion, taking into account only the components of the GS related to the depletion and degradation of natural capital in order to construct an adjusted GS (AGS) by excluding the manufactured capital accumulation. By considering the depletion and degradation value of natural resources contained in the AGS index, as compared with only the pollutant emissions considered in a standard EKC model, their analysis is more sustainability-oriented and also caters for the non-substitutability of the different types of capital in line with the strong sustainability paradigm. Building on Costantini’s work, Farhani et al. (2014) find the existence of an inverted U-shape relationship between sustainability and human development (HD) in 10 Middle East and Northern African (MENA) countries over the period 1990–2010 using panel data. Their model includes other factors such as energy, trade, manufacturing added value and the role of law.

Babu and Dutta (2013) substitute a pure measure of environmental stress as a dependent variable in the standard EKC with a wider assessment of environmental pressure defined by the environmental degradation index (EDI). They include the gross domestic product (GDP) as the explanatory variable in one model and the development balance index (DBI) in another model. They find an N-shaped pattern for most of the countries.

There is a lack of strong sustainability indicators or data on environmental degradation for a large number of countries over an adequately long period of time.

Sub-Saharan African countries are particularly affected by this paucity of indicators. Studies by Farhani et al. (2014) and Babu and Datta (2013) use composite environmental degradation measures such as the environmental degradation index (EDI) in EKC studies but no study focuses exclusively on Sub-Saharan African countries due to data unavailability.

Model specification and data

Typically, most studies on the EKC use reduced-form models in which the environment-income relationship is a quadratic function of income linking the levels of income and a measure of environmental degradation directly (such as Grossman and Krueger, 1995) instead of structural form equations identifying the underpinning mechanisms, for instance, the level of technology, governmental regulations, or trade that connect the development process with environmental outcomes.

In this study, the quadratic relationship is postulated, i.e. that of the inverted U-shape hypothesis, in order to investigate the existence of a sustainability-oriented EKC in terms of natural resource depletion. Besides the income per capita variable and its squared term proxied by the GDP per capita as in the classic EKC formulation, based on the body of literature, some conditioning/control variables are added to the model in order to better explain the relationship between economic development and the environment. The equation is given below:

Specified Theoretical Equation

Natural Resource Depletion = β_0 + β_1 *(Income)* + β_2 *(Income)* ^{2} + β_3 *(Trade Openness)* + β_4 *(FDI Stock)* +β_5 (*Population Density)* +β_6 (*Human Capital*) +β_7 *(Technology)* +β_8 *(Share of Industry)* +β_9 *(Institutional Quality)* + β_{10} (*Income Inequality*) +e_i

The values for the depletion of different types of natural resources such as energy, mineral resources and forests exploited at country level are calculated by the World Bank[1] to be subtracted from the total manufactured and human capital produced for the computation of the GS rate, which is a measure of weak sustainability based on the assumption of the substitutability of natural and man-made capital. The data on the depletion and degradation of natural capital itself is used as the dependent variable for our sustainability-oriented EKC model as a measure of strong/ environmental sustainability. This study uses a panel data set of 30 Sub-Saharan African countries, over a period of thirty-five years (1980-2014). Data availability dictated the number of countries used in the analysis. All data is taken from World Bank (2014), unless specified otherwise.

Conditioning Variables

- *Economic Globalisation.* In order to obtain robust results from the econometric specification of the EKC, several studies have introduced economic globalisation into

[1] The energy and mineral resources include oil, natural gas, coal, bauxite, copper, lead, iron, nickel, phosphates, tin, zinc, gold, and silver.

the model (Cole, 2004; Hettige et al., 2000; Tisdell, 2001). Economic globalisation is represented here by two aspects, namely trade openness and FDI stocks, which capture the presence of Multinationals (MNEs) better than FDI flows alone (Neumayer et al., 2005). In terms of a sustainability-oriented EKC with natural resource depletion rate as the dependent variable, trade openness, calculated as the sum of exports and imports as a percentage of GDP, is expected to have a positive sign for the developing countries, that is, higher trade openness is likely to lead to a higher natural depletion and degradation rate as developing countries tend to be highly dependent on commodity exports while developed countries tend to import goods whose production is not only polluting but also resource intensive (Van Alstine and Neumayer, 2010). The presence of MNEs, proxied by FDI stock as a percentage of GDP, will provide indications about whether the MNEs promote ecological sustainability while locating themselves in those countries.

• *Population density.* Several EKC studies have included population density as an important determinant, however, no consensus exists (Grossman and Krueger, 1995; Panayotou, 1993, 1997). Panayotou (1997) for instance, found that the turning point of the EKC is delayed by a higher population density when studying air pollution. Sub-Saharan Africa is characterised in general by rapid population growth rates. Population density is included in the model here in order to investigate its impact on the level of natural resource depletion and environmental degradation.

• *Human capital.* The level of human capital is represented by the school enrolment rate, which is the usual measure used in the context of Africa (Sala-i-Martin and Subramanian, 2003). A higher level of human capital is expected to be associated with higher levels of awareness and concern towards the environment. A more educated population is also more likely to pressurise policy makers and institutions for better protection of the environment (Farzin and Bond, 2006).

• *Technology.* Technological progress is an important factor in determining the EKC's inverted U-shaped relationship whose role has recently been highlighted in the theoretical literature. In general, technological progress and innovation lead to greater efficiency in terms of energy and materials usage and contribute to abate pollution. Therefore, a given amount of output can be produced with decreased burdens on natural resources and the environment. Improved technology not only increases productivity in the manufacture of existing products but also leads to the development of new products which are more environmentally friendly. On the empirical side, technological progress has been depicted as a time trend in the individual countries (Shafik, 1994; Holtz-Eakin and Selden, 1995) or as a global common effect to illustrate shared technological progress (Stern et al., 2002). Technological progress is also an important structural determinant of the heterogeneity between countries. Archibugi and Coco (2004) develop an index of "technological capabilities", encompassing four different aspects of technical progress, namely: (i) the development of technology; (ii) technological infrastructures; (iii) the development of human skills; and (iv) imported technology. Since the presence of MNEs is represented in the equation, this already proxies for import technology while the development of human skills is captured by the school enrolment rate. The number of patents has previously been used in the literature as a proxy for the creation of technology; however, due to data paucity for the majority of SSA countries, this variable was eliminated. Hence, the technology variable will be represented by technological infrastructures proxied by internet penetration (Archibugi and Coco, 2004), as is common practice in the literature.

• *Share of Industry.* The share of value added from the manufacturing sector represents the role of the industrialisation process or the composition effect (Panayotou, 1997). Shifts in the structure of the economy can be represented by the industry's share of GDP (Dinda, 2004). While Hettige et al. (2000) argue that an economy based on heavy industries should have higher levels of polluting emissions, as compared to economies heavily based on agriculture or services in a classic EKC formulation, the inclusion of the share of the industry in the model here will allow assessing whether industrialisation leads to an increased depletion or a reduced reliance on natural resources for this sample of SSA countries.

• *Institutional Quality.* As populations become more concerned about the depletion of natural resources and the degradation of the environment, more pressure is exerted on policy makers to introduce environmental regulations. In particular, the existence of a democratic government and the rule of law are instrumental to translate public pressure into policies (Munasinghe, 1995). Policy choices are also a key source of heterogeneity when studying cross-country differences. The institutional quality indices provided by Kaufman et al. (2014), namely: Rule of Law, Political Instability, Government Effectiveness, Control of Corruption, Regulatory Quality and Voice and Accountability are used in this study. The indicators take values ranging from -2.5 to 2.5 inclusive, with an increase consistently implying better quality of institutions. A single composite measure comprising of the mean of these six variables is computed in order to generate an overall institutional quality index (Faria and Mauro, 2004; Lagon and Arend, 2014). Although, there are alternative governance indicators from international agencies, most of these indicators do not cover a wide sample of countries, for instance the Corruption Perspectives Index (CPI) by Transparency International which is used by Dasgupta et al. (2006) in an EKC context. Institutions are included here as an exogenous variable in the sustainability-oriented EKC model.

• *Income Inequality.* Sub-Saharan Africa is the second most inequitable region in the world (World Bank, 2014). Several researchers such as Gawande et al. (2001) and Bimonte (2002) argue that a higher income inequality level worsens environmental degradation. The poor are more likely to be highly dependent on natural resources for earning their livelihoods as well as for their household activities such as burning fuel and often make use of environmentally unfriendly tools and techniques. The level of income inequality is represented by the Gini coefficient. It is expected that the higher the Gini coefficient, the more degraded the environment becomes.

Analysis, findings and discussion

The first empirical studies on the EKC hypothesis have in general used cross-sectional data representing a sample of countries at different stages of economic development at a specific point in time or within a narrow time frame. The detected GDP-environmental relationship across space is then assumed to emerge through time, while more recently, the majority of EKC studies make use of panel data. A cross-sectional regression formulation presumes constant coefficients across countries, suggesting that every country follows the same EKC path whereas with panel data analysis, this constraint can be lifted to allow the regression intercept to differ across the countries.

Two approaches to using panel data models are customary; namely, the Fixed Effects (FE) and the Random Effects (RE) models. The two approaches essentially differ in their treatment of the error term. If the unobserved country-level effects are correlated with the vector of explanatory variables, then the Fixed Effects model is deemed to be the appropriate estimation method, otherwise the Random Effects model is sufficient (Greene, 2008 and Wooldridge, 2009). The underpinning logic being that whatever impact the omitted variables might have on the subject at one point in time, it will also have the same effect later; hence their effects are constant or fixed. Fixed Effects models thus do not estimate the impact of variables whose values do not change over time. Substantively, Fixed Effects models are used to study the causes of changes within an entity and permit each cross-sectional unit to have its own constant term as the time invariant variables are absorbed by the intercept. In this particular context, some Fixed Effects might include the geography or the colonial heritage of the sampled countries. The FE method thus considers individual country differences.

When using the Fixed Effects approach, the assumption is that the environment-GDP relationship varies across countries in a limited way: countries can have differing intercepts but they have the same turning point where environmental degradation starts to decrease, that is, the threshold income per capita level is the same for all the countries, while the amount of environmental degradation can vary among countries at this point. However, this assumption of a low degree of heterogeneity can be criticised as not being sufficient given the diversity of social, economic, political and bio-physical factors impacting on environmental quality in the different countries of the sample.

On the other hand, some studies make use of the Random Effects model which is based on the assumption of commonalities within a country over time rather than that of commonalities across countries, in order to allow for more cross-country heterogeneity in the environment-GDP relationship since a country's physical and social characteristics, which determine its distinctive growth-environmental outcomes, do not change drastically over time (Koop and Tole, 1999). RE regression models assume that the unobserved country level effects are uncorrelated with the regressors and the overall disturbance term, such that the individual level effects are parameterised as additional random disturbances to form a composite error term.

Table

Panel regression estimates (dependent variable: natural resource depletion and degradation)

	1	2
	RE (1)	FE (2)
Income	0.005	0.005
	(0.212)	(0.268)
Income^2	-2.43e-06	-2.23e-06
	(0.370)	(0.418)
Trade Openness	16.794	17.048
	(0.000)***	(0.000)***
FDI Stock	-5.78e-06	-8.12e-06
	(0.674)	(0.557)
Population Density	3.120	4.172
	(0.016)**	(0.010)***
Human Capital	0.055	0.054
	(0.000)***	(0.000)***
Technology	0.693	0.672
	(0.000)***	(0.000)***
Share of Industry	10.361	9.947
	(0.000)***	(0.000)***
Institutional Quality	-5.143	-4.065
	(0.000)***	(0.000)***
Income Inequality	0.050	0.060
	(0.190)	(0.119)
Constant	-24.376	-25.201
	(0.000)***	(0.000)***
Overall R^2	0.2652	0.2020
Wald Test	228.20	-
F- statistic	-	25.89
P-value	(0.0000)	(0.0000)
No. Countries	30	30
No. Observations	1050	1050

Notes: The P-values are below the coefficients in parentheses. *, **, and *** denote significance at 10%, 5%, and 1%, respectively.

(1) All regressions have a constant term.

(2)The Hausman test: accept $H_{1,}$ rejecting the RE as the preferred model ($\chi 2$ = 16.20 and the P-value of 0.0396 is significant).

(3) Wooldridge test for serial correlation and the modified Wald test for heteroscedasticity were performed for equation 2. The null-hypothesis of no autocorrelation cannot be accepted F(1,29) = 372.1, whereas the null-hypothesis of homoscedastic errors was rejected given that $\chi 2$ = 686.14.

Source. Author’s computation.

Column 1 of the Table reports the results of the RE model while Column 2 depicts the FE model. The choice between the FE and the RE model can be made by using the Hausman test. However, the non-rejection of the RE model implies that both the FE and the RE models approximate each other and either one can be applied (Wooldridge, 2006).

The Hausman test suggests using the FE model instead of the RE model. As the FE model is the preferred model between the two, the focus is on the results in Column 2. In terms of the signs of the coefficients, that of the income per capita is positive while that of its squared term is negative. However, the coefficients are not statistically significant at the customary levels. Hence, it can be said that there is weak evidence of the EKC in the FE model. This result is obtained after controlling for other economic aggregates.

As for the economic globalisation variables, trade openness has a positive sign and is highly statistically significant, confirming that higher trade openness is leading to a higher depletion of natural resources in the sample of countries under consideration. The coefficient of the FDI stock is negative but not statistically significant in our model.

In terms of the other control variables, the coefficient of population density is positive and highly significant, providing support for Malthusian concerns about population as countries with higher population density have a higher natural resources depletion rate.

Surprisingly, the results show that a more educated population, represented by the school enrolment rate, and better technology, proxied by internet penetration, have a significantly "positive" effect on the natural depletion and degradation rate, meaning that they lead to higher depletion of natural resources. This is contrary to what is expected in terms of composition and/or technique and diffusion of technology effects (Dinda, 2004), whereby technological progress leads to greater efficiency in energy and materials usage, thus decreasing the burden on natural resources and the environment. It is also found that as the countries in the sample become more industrialised (indicated by the share of manufacturing output to GDP), the natural depletion rate increases. Thus, higher levels of industrialisation and technological progress seem to in fact lead to a more intensive use of natural resources, illustrating these countries' high level of dependence on the extractive sector and related value chain industries. These results are in conformity with the findings on trade openness.

Very interestingly, institutions do matter. The countries with higher institutional quality in the sample of countries tend to have lower natural resource depletion. Good institutions and democracy are beneficial for environmental protection because they provide channels through which governments can be influenced by civil society (Frankel, 2003). Baliamoune-Lutz (2012) also finds that political institutions influence the relationship between trade and environmental quality in the case of CO_2 in Africa over the period 1980-2012. Therefore, promoting better institutional quality may lead to improved environmental sustainability for this sample of countries. Finally, no evidence was found that income inequality damages the environmental sustainability of the economies in the sample. The coefficient of the Gini coefficient is insignificant.

Conclusion

This paper investigates whether the EKC hypothesis holds in the case of a strong sustainability model in the case of the depletion and degradation of natural resources. The model is tested after controlling for key aggregates pertinent in the context of Sub-Saharan Africa, such as globalisation, population density, institutional quality, industrialisation and technological advancement.

Regression results pertaining to the FE model reject the hypothesis of EKC for natural resource depletion for this sample of countries, given that the per capita income and its squared term were both found to be insignificant. However, the quest for developing better sustainability indicators is far from being over and more research is warranted in this direction in order to develop more valid and reliable indicators of sustainability as the existing measures are criticised for being fraught with methodological and data problems. Nevertheless, trade openness is found to have a significant negative impact on the environmental sustainability indicator used. In particular, it is vital for these economies to diversify their economies and avoid over-reliance on the exports of primary goods. Population density is also found to be highly significant, justifying Malthusian concerns about the impact of the population on the depletion of natural resources. Finally, institutions matter in promoting environmental sustainability especially in terms of lower natural resource depletion and degradation for this sample of countries.

It is important to ensure that, in the pursuit of development, countries do not end up damaging their environmental assets irreversibly. Thus, it is crucial to put in place environmental policies and institutions in the early stages of development itself, in order to restrain ecological damage within acceptable levels.

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Appendix

List of Countries

1. Angola
2. Benin
3. Botswana
4. Burkina Faso
5. Burundi
6. Cameroon
7. Côte d'Ivoire
8. Ethiopia
9. Gabon
10. Gambia, The
11. Ghana
12. Guinea
13. Kenya
14. Madagascar
15. Malawi
16. Mali
17. Mauritania
18. Mauritius
19. Mozambique
20. Namibia
21. Niger
22. Nigeria
23. Rwanda
24. Senegal
25. South Africa
26. Sudan
27. Tanzania
28. Togo
29. Uganda
30. Zambia

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