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REVISITING THE ENVIRONMENTAL KUZNET CURVE IN AFRICA: THE INTERACTIVE ROLE OF FINANCIAL DEVELOPMENT IN SUSTAINABLE ENVIRONMENT

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Abstract: The aim of this study is to revisit the validity of EKC hypothesis in six leading African countries, with interaction effect of financial development and economic growth on the quality of environment over a period of 1970 to 2019. The research used the updated version of Driscoll and Kraay model by Hoechle, which resolved the consequences of heteroscedasticity and cross-sectional dependency. The empirical results of the study reveal that the EKC hypothesis is supported in these leading African economies. Carbon emissions increase due to foreign direct investment (FDI) and energy consumption. Financial development improves the environmental quality in these leading African economies. The interactive role of financial development and economic growth increases CO_2 emissions thereby degrading the quality of environment. The study recommends that environmental policies that minimize emissions should be enforced for the purpose of making the environment cleaner, FDI should be environmentally friendly and relevant incentives are required to redirect private credits towards green projects and renewable energy development.

Keywords: EKC, economic growth, financial development, environment, heterogeneity.

Introduction

The carbon dioxide (CO_2) emissions and other ambient greenhouse gases pose a significant global challenge to the environment. The main contributor to the greenhouse effect, which threatens the atmosphere and adversely affects human lives, is CO_2 emissions (Ehigiamusoe *et al.,* 2020). Global energy-related carbon emissions increased by 1.4% in 2017, as stated by the report of the International Energy Agency (IEA) (2018). This marks an absolute rise of 460 million tonnes (Mt) to a record peak of 32.5 gigatons (Gt) after remaining flat for the last three years. The incessant increase in the amount of CO_2 emissions controvert with the Paris Agreement on Climate Change that has a sole aim of reducing the amount of CO_2 emissions. The report of the IEA (2018) indicates that higher rate of economic growth experienced globally, weak effort for developing renewable energy as well as drastic fall in the price of oil in the world market are the reasons behind the increase in global carbon emission.

Although economic growth plays a significant role in ensuring a healthier as well as qualitative life, it significantly affects the quality of the environment (Shahbaz *et al.,* 2016; Ahmad *et al.,* 2020). An enormous amount of literature investigated the kind of relationship that exists between the quality of environment and economic growth, which is known broadly as the hypothesis of EKC (Environmental Kuznet Curve) developed after the Grossman and Krueger (1991) seminal paper. The EKC hypothesis suggest that several environmental quality indicators that include CO_2 emissions have a tendency of getting worse until an average rate of economic growth stretches to a turning level, then the quality of environment begins to enhance. Studies regarding the hypothesis of EKC revealed a conflicting outcome with a certain number of studies conducted by Al-mulali *et al*. (2015), Farhani and Ozturk (2015) as well as Abdulrashid (2016) argue that with economic growth, environmental contaminants are growing monotonically; hence the EKC hypothesis is not true. Other researchers, on the contrary such as Ahmad *et al*. (2017), Apergis and Ozturk (2015) as well as Jebli *et al*. (2016) confirmed the existence of the EKC hypothesis.

Furthermore, whether or not the hypothesis of EKC is present, it is not enough to investigate the relationship between CO_2 emissions and economic growth without considering the other facets of economic development (Abbasi & Riaz, 2016). It is well known that virtually every sector of the economy plays an essential in economic growth and development of the economy as well affect the quality of environment. In the same vein, the financial sector undertakes an essential role in the economy as well as climate change of the country. The development of financial sector is essential in savings mobilization, transaction facilitation as well as the resource allocation for the purpose of productive activities. A sound and healthy financial sector helps in enhancing the economic growth of the country by raising the level of investment through the provision of loan at a cheaper rate, enhancing the capital market, improving risk management, supervising the operation of businesses as well as making emphasis on firms to use technologies that are friendly with the environment (Acheampong, 2019).

The kind of relationship that exists between economic growth and financial development was reconnoitered first by Schumpeter (1911), with the advent of the endogenous growth theory, much attention is given to the role that the financial sector may play in the economic growth of a country. A successful financial sector forms the backbone of a country's economic development. It provides financial services that are better through the facilitation of transactions and reducing the expense of monitoring (Shahbaz, 2009). In addition, financial development increases the consumption of energy, thereby affecting the quality of environment (Danish *et al.,* 2018).

Revisiting the hypothesis of EKC in Africa is very essential, even though Africa is considered as the least contributor to global emissions of carbon dioxide when compared with the other regions of the world but CO_2 emissions have been on an increasing trend at a faster rate in the region. For example, CO_2 emissions escalated from 658.15 million tons in 1990 to 891.37 million tons in 2000, as well to 1.22 billion tons in 2010 and further to about 1.40 billion tons in 2018 (OWD, 2020). Additionally, having an amount of 413 million people that are surviving below the line of poverty as of 2015, as such Africa is considered as the poorest region in the world. Africa is already witnessing the harmful effects of climate change in the form of rising drought, malnutrition, violence, disease spread, migration and floods (Serdeczny *et al.,* 2017).

The international community is working to keep the average global temperature below 2°C above pre-industrial levels as part of its solution to this threat. The United Nations implemented the '2030 Agenda for Sustainable Development' and the 'Paris Climate Change Agreement' in 2015 to achieve this aim. Yet, according to Halliru *et al*. (2020), the Intergovernmental Panel on Climate Change forecast that global temperatures will increase to 5.8°C by 2100, indicating that the challenge of combating climate change is daunting and that it is critical to devise strategies to tackle climate change in a manner that prevents its catastrophic impact on mankind and the environment. In order to devise strategies to reduce carbon emissions before it gets worse, it is therefore important to consider the fundamental forces behind the rising carbon emissions in Africa.

Accessible data from Our World in Data (2020) indicate that the increase in African carbon emissions is reported to follow a similar pattern with the region's economic growth from 1990 to 2016. The per capita income of the region, for example, has risen from $3,170 in 1990 to $4,340 in 2010 and then to $4,680 in 2016 (OWI, 2020). This development can be due to the region's impressive growth results, as it has risen by more than 5% since 2000 (Kwakwa

& Adu, 2016). In terms of the development of financial sector, when measured using bank credit to the private sector, Africa's average financial depth was 20.56%; meanwhile, only South Africa was doing somewhat well, while South Asia was above 46.8% on average. Specifically, Egypt had 25.5%, Nigeria had 10.9%, South Africa had 147.5%, Algeria had 24.1%, Morocco had 84.9%, Ethiopia 17.7%, Ghana 11.7% and Kenya 28% (International Monetary Fund, 2018). These statistics are what have placed these countries behind other developing countries. Some improvements have recently been made to the financial sector of African, but the least developed financial system is still in place compared to other developing regions (Ahmad *et al.,* 2018; Acheompong, 2019).

As against the background, the purpose of this study is to contribute to the current literature by analysing the validity of the EKC hypothesis in five leading African economies alongside the interactive roles of financial development between 1970 and 2019. The validity of the EKC hypothesis has been tested by many studies done by Al-mulali *et al*. (2015), Begum *et al*. (2015) energy consumption and population growth on CO_2 emissions using econometric approaches for Malaysia. Empirical results from ARDL bounds testing approach show that over the period of 1970-1980, per capita CO_2 emissions decreased with increasing per capita GDP (economic growth, Charfeddine and Mrabet (20FF17) as well as Dong *et al*. (2018) and have presented mixed results. Previous researchers have not paid attention, to the best of our knowledge, to the interactive effects of financial development with economic growth within the context EKC, either in Africa or elsewhere. The inclusion of these interaction effects has shed more light on both the partial and complete environmental degradation impacts of financial development.

In the same vein, the study contributes to EKC literature along the following dimensions: Existing research, for example, often measure financial development either through the use of credit to private sector or broad money. However, these indicators do not take into account the overall financial development image. As such the current study used five indicators of financial development and developed the financial development index by applying the technique of Principal Component Analysis (PCA) as used by Farouq *et al*. (2020) and Ahmad *et al*. (2018).

In addition, the study uses econometric techniques that take into account numerous factors which if ignored may cause spurious inferences. Indeed, it is highly predicted, via the Joint Climate Agenda in Africa, that action by individual Member States is likely to affect all other Member States. In addition, in their course of environmental destruction and pollution, there is considerable variation across Member States. As a result, such heterogeneity across countries and possible cross-sectional dependencies in our panel data model must be controlled by our econometric approach. In order to obtain accurate empirical results, we rationalised these types of biases that might occur in our panel dataset.

This research continues as follows. The associated literature is provided in the second section after this introduction section. In the third part, the dataset and econometric methodology are discussed. Empirical findings and discussion are found in the fourth section. Lastly, in the sixth segment, policy consequences and conclusions are evaluated.

Literature Review

Ever since the influential study of Grossman and Krueger (1991) a plethora of studies examined the effect of economic growth on the quality of the environment and frequently concentrated on the idea of the EKC hypothesis. By the hypothesis of EKC, there exists an inverted U-shaped association between environmental degradation and economic growth, in the state of short run, economic growth leads to environmental degradation, in the same vein, as the economy reaches the level of high income the relationship turns out to be inverse and economic growth begin to improve the quality of the environment (Tang & Tan, 2015). Most of the empirical studies on EKC hypothesis have revealed divergence findings and this may arise as a result of differences in the variables used, the frequency of the employed data as well as the phase of economic development of the investigated countries or regions.

For instance, in nine European countries, Zanin and Marra (2012) investigated the EKC hypothesis through addictive mixed models. The authors found, close to the results of Friedl and Getzner (2003), an N-shaped relationship between Austria's economic growth and CO_2 emissions. Bertinelli and Strobl (2005) conducted an analysis on a panel of countries using a semi-parametric estimator. A linear rising association between GDP and pollution is found to be present. Likewise, in a group of industrialised nations, Rezek and Rogers (2008) have shown a monotonic upward nexus between economic growth and CO_2 emissions. For a panel of highly developed countries, Focacci (2003) indicates a negative relationship between pollutant emissions and economic growth based on a time period of 40 years. For the period from 1970 to 2013, a report on ASEAN-4 by Liu *et al*. (2017) concludes that the inverted U-shaped EKC does not exist. A U-shaped association is found, instead, between economic growth and CO_2 emissions.

Similarly, to examine the presence of the hypothesis of EKC in Vietnam from 1981 to 2011. Al-mulali *et al*. (2015) established a model of pollution and applied the approach of ARDL bound testing. The findings of the study reveal that GDP is having a positive and significant effect on pollution both in the short run as well as in the long run. The findings of this study rejected the hypothesis of EKC because GDP, both in the short and long run, degrades the environment.

Heidari *et al*. (2015) applied the econometric techniques model of Panel Smooth Transition Regression (PSTR) and the relationship between economic growth, energy consumption and carbon dioxide emissions were examined to test the hypothesis of EKC in ASEAN-5 countries from 1980 to 2008. The estimated results of the study show that GDP is related positively and significantly with carbon emissions in the first regime. In the second line of the regime, GDP is negatively related to carbon emissions and is statistically significant. Henceforth, these results indicate an overturned U-shaped connection between carbon emissions and economic growth and this confirms the presence of EKC.

Contrarily, the study investigates the relationship between CO_2 emissions, financial development, economic growth and trade for panel data consisting of 12 countries of MENA covering the period of 1990-2011. Omri *et al*. (2015) applied the techniques of simultaneous equation models. The empirical results of the study show that urbanization, trade openness, energy use, FDI and GDP are positively and significantly related to carbon emissions while financial development and square of GDP are related negatively and significantly with carbon emissions. The results validate the existence of the hypothesis of EKC in the panel of MENA countries.

However, to investigate the validity of EKC in Croatia over the period 1992Q1 to 2011Q1. Ahmad *et al*. (2017) employed the techniques of ARDL, VECM test of Granger causality, FMOLS as well as DOLS. The result of the study reveals that long-run relationships between the variables of the study and CO_2 emissions exist and are related positively with GDP and negatively with GDP square. This confirms the presence of EKC in Croatia.

Furthermore, Jardón *et al*. (2017) examine the relationship between per capita CO_2 emissions and GDP in a panel sample of 20 Caribbean and Latin American countries for the period of 1971-2011. The study applied the cross-country dependence test, FMOLS and DOLS in order to achieve the objectives of the study. The outcome of the empirical research reveals a statistically significant positive relationship between income per capita and carbon emissions as well as the negative relation between the square of income per capita and carbon emission. As such the study supports the hypothesis of EKC.

Correspondingly, to examine the impact of GDP on carbon emissions for 31 selected samples of developing countries over the period of 1971 to 2013, Aye and Edoja (2017) used the panel dynamic framework of the threshold as well as the causality techniques of DH. The empirical results of the study show that economic growth is related negatively to carbon emissions in the regime of low growth hence the effect is positive in the regime of high growth with a higher marginal effect in the regime of high growth. Therefore, the findings of the study offer no support for the hypothesis of EKC.

Henceforth, Amri (2018) investigated the association between carbon emissions total factor productivity as a proxy for income, trade, ICT, energy consumption and financial development in Tunisia over the period of 1975 to 2014. The study applied the ARDL techniques of analysis with the method of the breakpoint. The result of the study shows that economic growth is related positively and significantly with carbon emissions both in the shorter term and long term but with a long-run coefficient higher than the short-run coefficient. Hence, the EKC hypothesis is not present in Tunisia.

Henceforth in spite of the numerous research on the hypothesis of EKC, few among the earlier studies took into account the issue of cross-sectional dependency. For instance, Churchill *et al*. (2018) tested the hypothesis of EKC for 20 countries of OECD over the period of 1870 to 2014. The outcome of the panel results lent support of the hypothesis of EKC, although the individual countries came out with mixed findings. Nine countries accept the EKC hypothesis in total. Precisely, an inverted U-shaped EKC is seen in five of the 20 countries. In two countries, an N-shaped EKC can be found. Interestingly, an inverted N-shaped EKC was seen in one of the 20 countries.

Similarly, Destek and Sarkodie (2019) examined the validity EKC hypothesis while applying the ecological footprint as a measure of the quality of environment, considering 11 developed countries over the period of 1977 to 2013. Their findings demonstrated support for EKC hypothesis by applying an AMG estimator and a heterogeneous panel causality test. The findings of the causality test show that the ecological footprint and economic growth have a bidirectional causal relationship.

In addition, Apergis (2016) intended to verify the hypothesis of EKC using the Common Correlated Effects (CCE) estimation technique in 15 countries for the period 1960-2013. Both for panel and individual country study, findings are illustrated. The hypothesis of EKC is valid in 12 out of the individual countries. Since the association among GDP and emissions differs across countries, in analysing the validity of the EKC, the author expressed skepticism about the suitability of using panel analysis.

Likewise, the relationship between water depletion discharge (i.e., chemical oxygen demand and ammonia nitrogen) and economic growth were examined Zhang *et al*. (2017) in China through using two unbalanced panel data sets for the periods between 1990 and 2014 and 2001 and 2014. The study applied the techniques of analysis that accommodate the issue of cross-sectional dependency. The empirical outcome of the study reveals that regarding the chemical oxygen demand as well as ammonia nitrogen in China, the hypothesis of EKC hypothesis is supported. In the same vein, between economic growth and water depletion discharge, a long-run bidirectional causality is observed.

Henceforth, it is argued that financial development has a significant environmental impact and its impact on the evolution of carbon emissions remains controversial. Some researchers are of the opinion that by minimizing carbon emissions, financial development increases the quality of the environment. Tamazian *et al*. (2009) argued, for example, that financial development will draw foreign direct investment and a higher degree of research and development, which in turn stimulates economic development and thereby enhances environmental quality. Contrary to this, another group of researchers argues that by rising carbon emissions, financial development degrades the environment. Financial growth makes it easy for customers and companies to obtain cheap credits, according to Sadorsky (2010, 2011), to patronise big-ticket goods and grow their existing business or build new ones that raise energy consumption, eventually raising carbon emissions.

Although financial development and carbon emissions are theoretically inconsistent, the results of current empirical studies remain conflicting and uncertain. For example, one group of empirical studies conducted by Al-Mulali *et al*. (2015), Tamazian and Bhaskara Rao (2010), Tamazian *et al*. (2009) reports that carbon emissions are reduced by financial development while some researchers such as Boutabba (2014), Sehrawat *et al*. (2015) and Shahbaz *et al*. (2016) claim that financial development raises carbon emissions. The last group of empirical studies of Dogan and Turkekul (2016), Maji *et al*. (2017) and Omri *et al*. (2015) also indicates that there is no relationship between financial development and carbon emissions.

To date, limited studies have examined the effect of financial development on carbon emissions, Cetin *et al*. (2018) as well as Haseeb *et al*. (2018) have indicated that more empirical studies are needed to reconcile these contradictory findings, given the contradictions in these limited studies. Research on financial development and the quality of the environment is, however, still in its infancy and further studies are required to provide a thorough understanding of the effect of financial development on carbon emissions.

Furthermore, there is a lack of empirical evidence on the moderating effect of financial development and economic growth on the quality of environment within the context of EKC model. Lastly, little is known concerning the validity of the EKC hypothesis and the effect of financial development on carbon emissions in Africa. Given the discrepancy in the literature together with the knowledge gaps, the study examines the validity of the hypothesis of EKC, together with the interactive role of financial development and economic growth on the quality of environment over a given period of 1970 to 2019 in six leading African economies.

Materials and Methods

Model Specification

The study uses the EKC framework model built on the basis of the Kuznets (1955) statement stating an inverted U-shaped association between economic growth and environmental depletion, suggesting that the environment deteriorates during the early phases of economic growth but improves after a certain amount of income is reached. As a result, to grab EKC, we add squared GDP to achieve the goals of the research. The Charfeddine and Khediri (2016), Hanif (2018), Maji (2017) and Hanif *et al*. (2019) functional form of the model based on previous studies can be represented as:

$$CO_2 = f(GDP_{it}, GDP^2_{it}, \emptyset_{it}) \quad (1)$$

This form of mathematical regression model reveals the effect of economic growth and the square of economic growth on CO_2 emissions. In order to establish an econometric form of model, an error term would be included in Equation (2) and the modification of the model would take the form of including other determinant factors of CO_2 emissions such as financial development (FD), foreign direct investment (FDI), energy consumption (EC) and the interaction term of financial development and economic growth (*GDP * FD*). The models are specified econometrically as in Equations (2) and (3) below:

$$lnCO_2 = \beta_0 + \beta_1 InGDP_{it} + \beta_2 InGDP^2_{it} + \beta_3 InFDI_{it} + \beta_4 InFDI_{it} + \mu_{it} \quad (2)$$

$$lnCO_{2it} = \beta_0 + \beta_1 InGDP_{it} + \beta_2 InGDP^2_{it} + \beta_3 InFDI_{it} + \beta_4 InFD_{it} + \beta_5 In(GDP * FD)_{it} + \mu_{it} \quad (3)$$

Equation (2) explains the EKC hypothesis and Equation (3) explains the EKC hypothesis alongside the interaction effect of financial development and economic growth in six chosen African countries. Hypotheses on the parameters in the analysis are formulated based on economic works of literature. According to the inverted U-shaped EKC hypothesis, GDP has a favorable impact on CO_2 emissions, suggesting an increase in pollution during the early stages of economic growth. GDP^2 is thought to have a negative impact on CO_2 emissions, suggesting carbon reductions after meeting a certain income level. According to the pollution-haven theory, increased FDI inflow would raise pollution in countries by rising inflows of polluted and environmentally sensitive products. CO_2 emissions are thought to rise as a result of financial development. Finally, the interacting role of economic growth and financial development are thought to decrease CO_2 emissions.

Data Source

The data for the analysis is for 6 leading African countries over the period 1970-2019. Carbon emissions measured in kilotons (kt) is used to proxy environmental quality. The current US$ of GDP has been used to represent economic growth. energy consumption was accounted for using kg of oil equivalent. Using foreign direct investment, the FDI reflecting the inflow of investment capital was measured by net inflow as a percentage of GDP. Therefore, in this study, five indicators of financial development that include domestic credit to private sector by banks as a share of GDP, domestic credit to private sector by financial sector as a share of GDP, broad money as a share of GDP, market capitalization percentage of GDP and lending were used as a single index for financial development using principal component analysis (PCA) for policy implications and better understanding of financial development. All the data used in this research came from the World Bank (2020).

Interaction Effect

Using the mechanism discussed by Jaccard *et al.* (2003), the interaction of financial development and economic growth is estimated. This means the estimation of the product auxiliary regression of two variables independently against the variables as a dependent variable (Jakada *et al.,* 2020). As follows, the equation is written:

$$(InGDP_{it} * InFD_{it}) = \beta_0 + \beta_1 In\mathrm{GDP}_{it} + \beta_2 In\mathrm{FDI}_{it} + \mu_{it}$$

where the white noise error term is denoted by: The interaction term is generated by deriving the residual of the estimated regression.

Testing for Cross-sectional Dependency Test

Among the major issues of panel data analysis is the possible presence of cross-sectional dependency among all the cross-sections. Cross-sectional dependency among the sample of countries of study arises due to the existence of financial and economic integration, unknown mutual shocks, geographical and spatial effects, externalities as well as unobserved common factors among the economies that would in turn lead to inefficient and invalid estimates (Ahmad *et al.,* 2020; Usman *et al.,* 2020). In order to take this problem into account, there is need to test and find out if cross-sectional dependency is present or not across the cross-section of the countries of study. To undertake this, the study applied the two test of cross-sectional dependency that is Breusch and Pagan (1980) as well as Pesaran (2004) that are more suitable under the condition when the time is greater than the number of the cross-section that is (N < T) for robustness Baltagi *et al.* (2012) scaled LM bias-corrected is added.

Second-generation Unit Root Test

The cross-sectionally augmented IPS (CIPS) test by Pesaran (2007), which accounts for CSD is used after checking for a possible CSD problem in the panel dataset. This test is based on the effects of panel-member-specific ADF regressions, which provide cross-sectional averages of the model's dependent and independent variables. The test is therefore appropriate for specifying in heterogeneous panels the presence of unit roots. With the null hypothesis of non-stationarity, the test statistics have a non-standard distribution.

Specifically, in the cross-sectional augmented Dickey Fuller (CADF) regression below, the CIPS test uses the cross-sectional average to capture the typical effect and create the test statistics based on the t-ratio of the OLS estimate of ρ_i $(\hat{\rho_i})$:

$$SY_{it} = \delta_i + c_i Y_{i,t-1} + d_i Y_{i,t-1} + e_i Y_{i,t-1} + \mu_{it} \quad (4)$$

The CIPS test description is as follows:

$$CIPS(C,T) = t - bar = C^{-1} a_i^{C} = {}_1 t_i(C,T)$$

Where $t_i(C,T)$ is the augmented Dickey Fuller statistics across the cross section for the ith cross section unit set by the t-ratio of bi in Equation (4).

Panel Cointegration Test

Westerlund and Edgerton (2008) developed a panel cointegration test that recognises both structural breaks and cross-section dependency. Their test allows for heteroskedastic and serially associated errors, as well as cross unit-specific time patterns, apart from cross-sectional dependency and unexplained structural breaks in both the intercept and slope. The residuals are granted to an AR (∞) narrative. By using the component of stationarity μ_{it} and the first difference of the regressors, defined vector as $w = (\varepsilon_{it}, \Delta X_{it})$ and the infinite autoregressive illustration as:

$$\sum_{j=0}^{\infty} \emptyset_{it}\tau_{it-j} = \epsilon_{it}$$

where ε_{it} signifies the stationary process; the above equation is approached with an autoregressive model of finite-order Ᵽ; we used a sieve bootstrap scheme. Additional Y_{it} and X_{it}, as new bootstrap values are gotten.

Driscoll and Kraay Estimator

The paper used the standard error estimator of Driscoll and Kraay (1998), which is robust for serial and autocorrelation, heteroskedasticity and CSD. By adjusting the standard nonparametric covariance estimator, the Driscoll and Kraay technique provides a robust result for all types of temporal dependence and cross-sectional on a large T-asymptotic. It changed the standard error of pooled and fixed effects to tackle sectional or special dependency issues. CSD can be a problem in a panel with large T times, while CSD is not a problem in a panel with low T and large N (Baltagi, 2011). Because of CSD, an estimation result may be biased (Torres-Reyna, 2007). To accommodate balance and unbalanced panel, the Driscoll and Kraay estimator was updated by (Hoechle, 2007). Consider the linear regression model:

$$Y_{it} = X'_{it}\theta + \varepsilon_{it},\ i = 1,\dots,N, t = 1,\dots,T \quad (5)$$

where Y_{it} stands for the explained variable, X_{it} denotes $(K + 1) \times 1$ is the vector of the explanatory variable where first elements are 1 and Θ is a $(K + 1) \times 1$ unknown coefficient vector time is represented by t. Cross-sectional unit denotes by i; all the observations can be stack follows.

$$Y = [\mathcal{Y}_1 t_{11} \dots \mathcal{Y}_1 T, \mathcal{Y}_2 t_{21} \dots \mathcal{Y}_N T_N]$$

$$\text{and } X = [X_1 t_{11} \dots X_1 T_2 t_{21} \dots X_N T_N]' \quad (6)$$

The construction that permitted for balance unbalanced panel since for individual i only a subset of $t_{i1}, \dots, T$, *with* $1 \leq t_{i1} \leq T_i \leq T$ of all T observations may be obtained. Established on the assumptions, Θ can dependably be estimated by OLS regression.

$$\hat{\theta} = (X'X)^{-1} X'_y \quad (7)$$

The coefficient of the estimates is reached at by square roots of the diagonal element of the asymptotic (robust) covariance matrix.

Results and Discussion

The results of the PCA are presented in this section, which are applied to reduce the five indicators of financial development into a single index form. The research uses the PCA to look for the element providing maximum information on the variables following the procedure of Jolliffe (1986) to preserve amounts of components on the grounds of their eigenvalues. The study throws down certain components with eigenvalue of less than 0.70 and holds those with a value above 0.70 (Islam *et al.,* 2020) respectively.

As shown in Table 1, on this basis, component 1, component 2 and component 3 have an eigenvalue greater than 0.7 and these three components are maintained on the basis of their respective eigenvalues.

In a similar vein the descriptive statistics (measures of dispersion and central tendency) and pair-wise correlation are provided in Table 2 for all variables (in log form). Henceforth, CO_2 emissions is significantly correlated with all the explanatory variables (i.e., GDP, FDI, financial development and energy use).

There are rising possibilities that cross-sectional dependency may prevail due to the existence of macroeconomic variables and panel data. For this reason, biased corrected scaled LM tests of Pesaran (2004)-CD, Pesaran (2004) scaled LM and Baltagi *et al.* (2012) are used to verify the existence of cross-sectional dependency as shown in Table 3. The results of these tests are useful not only to evaluate the estimation methodology, but also to determine whether first-generation test of panel unit root (Levin *et al.,* 2002; Im *et al.,* 2003) are sufficient that assume cross-sectional independence or second-generation test of panel unit (Chang, 2004; Pesaran, 2007) are more suitable that consider cross-sectional dependence. Both forms of panel unit root tests are performed in this research to prevent misleading outcomes.

As shown by the result of the cross-sectional dependence tests, the null hypothesis is that there is no cross-sectional dependence and, according to the empirical results of this research, ample evidence exists to refute the null hypothesis and to conclude that cross-sectional dependence exists between cross-sectional units.

Table 4 explains, in addition to the CD test, the results based on the homogeneity test. We confidently reject the null hypothesis that the slope coefficients are homogeneous at a level of significance of 1% using the measured

Table 1: Results of Principal Component Analysis (PCA) results

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp 1	2.561	1.54353	0.5122	0.5122
Comp 2	1.01747	0.0833424	0.2035	0.7157
Comp 3	0.934129	0.571365	0.1868	0.9025
Comp 4	0 .362764	0.238126	0.0726	0.9751
Comp 5	0.124638	----------	0.0249	1.0000

Eigenvectors or Factor Loading

Variable	Comp 1	Comp 2	Comp 3	Unexplained
Lr	0.5959	-0.0844	0.0574	0.08037
Dcp	0.5404	0.1224	0.1450	0.2172
Dcb	0.5557	0.0084	0.1629	0.1842
Bmg	-0.1076	0.8950	0.4011	0 .00499
Mc	-0.1801	-0.4204	0.8878	0.0007008

Notes: Lr = lending rate, Dcb = direct credit to private, Dcb = direct credit by the bank, Bmg = broad money growth, Mc = market capitalization

Table 2: Summary of descriptive statistics

	$lnCO_{2it}$	$lnGDP_{it}$	$lnFDI_{it}$	$lnFD_{it}$	$lnEC_{it}$
Mean	10.918	7.092	19.349	0.355	6.547
Median	11.064	7.197	19.924	0.429	6.463
Maximum	13.128	8.988	23.172	1.978	7.989
Minimum	8.033	4.955	6.907	-1.863	5.196
Std. Dev.	1.283	0.943	2.705	0.879	0.685
Skewness	-0.305	-0.151	-1.498	-0.317	0.621
Kurtosis	2.316	2.067	6.669	2.263	2.674
Jarque-Bera	10.500	12.023	280.397	11.818	20.625
Probability	0.005	0.002	0.000	0.002	0.000
Sum	3275.353	2127.634	5804.936	106.5087	1964.190
Sum Sq. Dev.	492.243	265.791	2187.298	230.949	140.450
Observations	300	300	300	300	300

Pearson Correlation Matrix

Probability	$lnCO_{2it}$	$lnGDP_{it}$	$lnFDI_{it}$	$lnFD_{it}$	$lnEC_{it}$
$lnCO_{2it}$	**1.000**				

$lnGDP_{it}$	0.780	**1.000**			
	0.000	-----			
$lnFDI_{it}$	0.458	0.463	**1.000**		
	0.000	0.000	-----		
$lnFD_{it}$	0.299	0.436	0.125	**1.000**	
	0.000	0.000	0.029	-----	
$lnEC_{it}$	0.812	0.670	0.316	0.289	**1.000**
	0.000	0.000	0.000	0.000	-----

Notes: * and ** symbolizes significant at the level of 1% and 5%. Figures in ( ) symbolizes P-values

Table 3: Results of Cross-sectional Independence Test

Variables	**Pesaran CD Test**	**Bias Corrected Scale LM Test**	**Pesaran Scale LM Test**	**Breusch-Pagan LM Test**
$lnCO_{2it}$	22.671 (0.000)	93.237 (0.000)	93.298 (0.000)	526.017 (0.000)
$lnGDP_{it}$	24.026 (0.000)	103.014 (0.000)	103.075 (0.000)	579.566 (0.000)
$lnFDI_{it}$	14.976 (0.000)	41.005 (0.001)	41.066 (0.000)	239.930 (0.000)
$lnFD_{it}$	6.941 (0.000)	52.263 (0.000)	52.324 (0.000)	301.595 (0.000)
$lnEC_{it}$	17.209 (0.000)	68.405 (0.000)	68.466 (0.000)	390.007 (0.000)

Notes: * and ** symbolizes significant at the level of 1% and 5%. Figures in ( ) symbolizes P values. Pesaran (2004) CD test takes cross-independence as the null and the p-values are for the one-sided test based on the normal distribution delta tilde and modified delta tilde values and their respective P-values. This also means that there is heterogeneity for all the variables examined in the different groups of countries, so it is important to follow heterogeneous panel methods in which parameters vary through individual cross-sections within the panels.

The results of the second-generation panel unit root tests (Pesaran, 2007), also known as CIPS and CADF tests, are summarised in Table 5. The cross-sectional dependency between the variables is considered in this test and according to these results, the variables are again mixed with the order of stationarity at the level and the first difference and no one is stationary at the second difference.

The Westerlun-Edgerton (2008) cointegration test is an advanced cointegration test that is used to verify the long-run relationship between variables since it considers problems such as heteroskedasticity, serial correlation, structural breaks and cross-sectional dependency between countries or cross-sectional units. As shown in Table 6, the Westerlund test shows that the Gt and Pt probability values of the Persyn and Westerlund (2008) cointegration tests are significant, rejecting the null hypothesis of no cointegration and confirming the long-run relationship between the variables.

In this section, the outcome of the study using the fixed effect model is discussed. Table 7 illustrates the effect of GDP growth rate, GDP

Table 4: Results from the Homogeneity test

Test	Statistics	P-value
$\tilde{\Delta}test$	9.863*	0.000
$\tilde{\Delta}Adj\ test$	10.514*	0.000

Notes: * and ** symbolizes significant at the level of 1% and 5%

Table 5: The panel unit root test results

Variables	CIPS		CADF	
	At Level	At First Difference	At Level	At First Difference
$lnCO_{2it}$	-1.923	-6.363 *	-1.672	-5.153*
$lnGDP_{it}$	-2.369	-5.877 *	-2.695	-5.134*
$lnFDI_{it}$	-3.846*	-6.420*	-3.107*	-5.614*
$lnFD_{it}$	-2.468	-6.343*	-2.316	-4.629 *
$lnEC_{it}$	-2.735	-6.239*	-2.765	-4.030 *

Notes: * as well as ** signifies the null hypothesis rejection at 1% as well as 5% level of significance

Table 6: Summary results of heterogeneous test of cointegration

Dependent Variable $LNGDP_{it}$		Constant		Constant + Trend	
Test Type	Statistics	Value	*p*-value	Value	*p*-value
Westerlund	G_t	-3.238	0.021	-3.881	0.003
	G_a	-14.008	0.368	-7.476	0.998
	P_t	-7.641	0.014	-8.455*	0.022
	P_a	-15.326	0.026	-6.777	0.979

Note: * and ** signify the null hypothesis of no cointegration rejection at 1% and 5% significant levels respectively for the test of Westerlund and Kao Test. The criteria AIC lag selection is applied in selecting the optimal lead and lag

Table 7: Driscoll and Kraay's Regression results

	Dependent Variable					
	Model 1			Model 2		
Variables	**Coefficient**	**Std. Err**	**t. Statistics**	**Coefficient**	**Std. Err**	**t. Statistics**
$lnGDP_{it}$	0.140	0.030	4.64	0.224	0.030	7.25
$lnGDP^2_{it}$	-0.554	0.214	-2.58	-0.113	0 .021	-5.27
$lnFDI_{it}$	0.296	0.141	2.10	0.030	0.012	2.35
$lnFD_{it}$	-0.932	0.442	-2.11	-0.117	0.040	-2.93
$lnEC_{it}$	0.014	0.073	0.20	0.062	0.075	0.82
$In(FD * GDP)_{it}$	-----	-----	-----	0.129	0.024	5.31
Cons.	3.240	1.037	3.12	0.283	1.111	0.25
Groups	6			6		
Observations	300			300		
Hausman Test	66.79(0.000)			63.77(0.000)		
R-squared	0.81			0.83		
F-statistics	240.60(0.000)			175.06(0.000)		

Notes: * as well as ** signifies the null hypothesis rejection at 1% as well as 5% level of significance

growth rate square, foreign direct investment, financial development and energy consumption on the quality of environment, respectively, in Model 1. For the selected sample of six leading African countries, the interactive impact of financial development on the relationship between economic growth and CO_2 emissions was therefore taken into account in Model 2. Most of the variables' coefficients are significant and their signs are in line with the theory.

As mentioned by the above table at the 1% level of significance, the effect of economic growth on CO_2 emissions is substantially positive. With economic growth that leads to more manufacturing and emissions, industrialization actually took place. Per capita income rises as economic growth increases, leading to the purchasing of cars, air conditioners and other items that increase air pollution. A rise of 1% increase in economic growth contributes to an increase of 0.140% in carbon emissions. The result is consistent with the findings of Al-Mulali *et al*. (2015) correspondingly.

The square coefficient of GDP is negative and significant, supporting the hypothesis of the EKC. This means that, at the initial stages of economic growth, emissions rise and, after reaching a certain level, emission decreases with economic growth. A 1% rise in the economic growth square will lead to a 0.55% decrease in CO_2 emissions based on the outcome of the GDP square. The positive coefficient of economic growth as well as negative coefficient of the square of economic growth confirm the validity of EKC hypothesis in these six leading African countries. The EKC hypothesis is supported and in conformity with the findings of Ozatac *et al*. (2017), Dabachi *et al*. (2020) as well as Apergis and Ozturk (2015). The explanation for the existence of the EKC hypothesis is that, according to the World Bank report (2019), all the six countries selected belong to either upper middle-income or lower-middle-income countries, thus their income levels reached the turning point.

In these leading African countries, there is a positive and significant relationship between FDI and CO_2 emissions, where a 1% increase in FDI induces a 0.296% increase in CO_2 emissions. This supports the theory of pollution heaven, which suggests that dirty factories are moving from developed countries to developing countries due to poor environmental regulations in developing countries, or polluting technologies are transferred via FDI from more developed countries to less developed countries. The finding is consistent with the studies of Ren *et al*. (2014), Elmarzougui *et al*. (2016), Sarkodie and Strezov (2019) and Jakada and Mahmood (2020).

The effect of financial development on carbon emissions is significantly negative, with a 1% increase in financial development reducing carbon emissions by 0.932% and hence improve the quality of the environment respectively. Strong financial institutions embrace technological innovations that are helpful in reducing emissions. The finding is consistent with the findings of Al-Mulali *et al*. (2015).

Energy consumption has a positive and significant impact on CO_2 emissions, with a 1% rise in energy consumption in the selected African countries raising the level of CO_2 emissions by 0.014%. According to Inglesi-Lotz and Dogan (2018), this study indicates that African energy use is a major contributor to the continent's environmental degradation. The implication is that economic growth and expansion in African countries are still considered to be the causative agent of pollutant emissions and that the growth-led environmental sustainability threshold has not yet been reached by the African countries sampled. This pattern refers to the use of non-renewable energy and the use of electricity, as the main source of energy for manufacturing, residential, commercial and transportation usage in Africa, among other areas, is still predominantly fossil fuel, resulting in the depletion of the environment.

As seen in Model 2, an emphasis is on the interactive impact of financial development on the relationship between economic growth and environmental quality. The result indicates that economic growth has been moderated by financial development to have a positive and significant impact on carbon emissions. The positive coefficient of is 0.129% and significant also at one percent level of significance. The result suggests that in the long run, a 1% increase in economic growth will lead to a 0.129% increase in the amount of carbon emissions in the presence of financial development. The outcome is consistent with the findings of Acheampong (2019) for the selected sample of Sub-Saharan African countries, which reveals that financial development represented by private sector domestic credit, banks' domestic private sector credit and broad money interacts with economic growth to have a positive and significant impact on carbon emissions.

Therefore, in accordance with the finding of this study, African financial development index complements economic growth to escalate the amount of carbon dioxide emission and hence deteriorate the quality of the environment. The result again supports the argument that the development of the financial sector of a country leads significantly to higher economic growth and affects the quality of the environment (Dar & Asif, 2017). The substantial positive impact financial development interaction with economic growth on carbon emissions indicates that the financial sector in Africa is unlikely to attract or encourage the transition of green technology to support environmental sustainability. One of the critical factors hindering financial institutions' ability to support green technology is the slow liberalisation of the African financial sector.

Conclusion

The aim of the study is to investigate the validity of EKC hypothesis, alongside the interactive roles of financial development over the period of 1970 to 2019 in six selected leading African economies: Nigeria, South Africa, Egypt, Algeria, Morocco and Kenya. The EKC hypothesis is supported in these leading African economies. Carbon emissions increase due to foreign direct investment (FDI) and energy consumption. Financial development improves the environmental quality in these leading African economies. In Model 2, the interactive role of financial development and economic growth increases CO_2 emissions thereby degrading the quality of environment.

With the above results, we were able to develop the following policy recommendations for African countries. First, countries in the region should not be complacent and wait for economic growth to address environmental degradation. To meet sustainable development goals, promoting sustained economic growth is insufficient. It must be accompanied by other policies that promote cleaner production. Increased support for sustainable growth-driven businesses, such as tax cuts and lower interest rates for crucial sectors, as well as the defense of local industries, are examples of such policies. While implementing environmental policies in a low-income region will jeopardize attempts to combat endemic poverty, economic growth should be followed in a clean-production direction. For cleaner production and a low-carbon economy, the regional body and the respective governments should look at energy efficient options.

Second, financial development benefits the environment, but when combined with economic growth, it causes environmental depletion. Policymakers must have sufficient incentives for financial institutions to realign their credit policies with their long-term regional policy objectives. Financial institutions would find it worthwhile to divert credits in favor of government-prioritized initiatives such as green energy growth which is critical for achieving cleaner production, if the correct policies and rewards were in place.

Third, given PHH credibility, as a result of this finding, developing countries will need to enact tougher environmental policies to ensure that FDI inflows to their countries are environmentally sustainable. This can also imply that developed and emerging countries share responsibility for ensuring that FDI flowing to developing countries meets the same high environmental requirements as FDI flowing to developed countries. As a result, firms looking to relocate their manufacturing operations to emerging countries do not bring any technology with them that is not suitable in their home countries.

Lastly, this study stressed the use of energy-efficient and environmentally friendly systems, as well as allocating money for energy storage and clean energy. In order to moderate environmental degradation, the government should put in place the most up-to-date measures to curb carbon emissions, such as environmental taxing tools for polluters and financial incentives for those who support recycling, emphasizing renewable and eco-efficient programs, carbon dioxide taxes and emissions sharing caps. They should also make it obligatory for all companies and businesses to issue an annual report on environmental quality. The policy recommendations are applicable to both emerging and developing countries, not just those in Africa. The lesson for future scholars is that they should take great caution when choosing FD indicators because different indicators have different effects on CO_2 emissions (negative, positive, insignificant).

There are several limitations to this research. We only included six major African countries from 1970 to 2019 due to data constraints. Future studies should expand the data's time dimension, collaborate with a larger number of African countries once the data is accessible. Similarly, future studies can use ecological footprint instead of CO_2 emissions, which was not possible in this analysis due to lack of data and this problem poses a research void for future studies.

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