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The effects of non-renewable energy, renewable energy, economic growth, and foreign direct investment on the sustainability of African countries

Highlights:

- The effects of non-renewable energy and renewable energy , economic growth and foreign direct investment on CO_2 emissions are investigated;
- First generation and second generation unit root tests, Panel Autoregressive Distributed Lag cointegration approach are employed;
- Positive effect of non-renewable energy and negative effect of renewable energy are found;
- The Environmental Kuznets Curve hypothesis does not hold;
- The Pollution Haven hypothesis is verified.

Abstract:

This study explores the dynamic effect of non-renewable energy, renewable energy, economic growth, and foreign direct investment on environmental degradation in twenty selected African countries over the period 2000-2015. We have adopted Environmental Kuznets Curve hypothesis and the Pollution Haven/Halo hypothesis simultaneously. In the first stage, this paper performs cross-independence test and found cross-sectional dependence in carbon emissions, non-renewable energy, and renewable energy. In the second stage, it applies first generation and second generation unit root tests for panel data and found that all concerning variables are I(1) except for economic growth which is found I(0). Therefore, we used the Panel Autoregressive Distributed Lag approach using Pooled Mean Group, Mean Group, and Dynamic Fixed Effect estimators. The results indicate that all independent variables are significant and positive to CO_2 emissions except for renewable energy found significant and negative to CO2 emissions in both short and long-term, and foreign direct investment found significant and positive only in the long term. Moreover, the Environmental Kuznets Curve hypothesis did not hold in our sample, while we found strong evidence for the Pollution Haven hypothesis in selected African countries. Our results will encourage sample countries to implement different eco-innovation technologies that help cleaner and environmental competency, further, eco-innovation could also support in achieving green economic growth.

Keywords: Foreign Direct Investment, Renewable energy, Pollution Haven/Halo Hypothesis, Panel Autoregressive Distributed Lag, Panel Unit Root, Africa.

Acronyms:

EKC	Environmental Kuznets Curve
FDI	Foreign Direct Investment
PHH	Pollution Haven/Halo Hypothesis
PARDL	Panel Autoregressive Distributed Lag
PMG	panel mean group estimator
MG	mean group estimator
DFE	Dynamic Fixed Effect
FMOLS	Fully Modified Ordinary Least Square
DOLS	Dynamic Ordinary Least Square
CUP-FM	Continuously Updated Fully Modified
CUP-BC	Continuously Updated bias corrected
AMG	Augmented mean group
VECM	Vector Error Correction Model
GMM	Generalized Method of Moment
QARDL	Quantile Autoregressive Distributed Lag
CCR	Canonical Cointegration Regression
NARDL	Non-linear Autoregressive Distributed Lag
SDG	Sustainable Development Goals
STIRPAT	Stochastic impacts by Regression on Population, Affluence and Technology
PVAR	Panel Vector Autoregressive

1. Introduction:

The increasing of unwholesome climate may be the result of adopting unhealthful economic policies by the governments; these policies can be a threat to humanity and the environment as well. Reaching high rates of economic growth is the initial preoccupation of the policymakers, realizing these rates without taking into account other considerations may affect negatively environmental quality. Therefore, achieving sustainable economic growth must be an essential concern for the governments of developed countries and developing countries alike. Moreover, increasing economic growth in tandem with environmental quality and mitigating environmental damages is among the most important target that countries should endeavour to achieve sustainable development goals.

Although energy is needed for economic development, it can the fundamental source of environmental degradation. The Energy-Environment nexus took an important interest from governments and researchers alike, and according to several researchers, the negative effect of the energy on environmental quality generates from non-renewable energy unlike renewable energy. Therefore, the consumption of renewable energy instead of non-renewable energy has many potential advantages including mitigation of global warming emissions, provides more diverse energy sources, and declined dependency on non-renewable energy (Belaid et al., 2019).

The economic growth-Environment association has been investigated widely in the Environmental Kuznets Curve (EKC) framework, which describes a non-linear relationship between growth and environmental degradation. The hypothesis of EKC means that in the early stage of economic growth, environmental degradation increases with economic growth, and then decreases when economic growth has reached a specific level (turning point), this phenomenon represents an inverted U-shaped relationship between aforesaid variables. The vast number of empirical research validated the underlying hypothesis. Sarkodiedet al.(2019); Usama et al.(2020); Erdogan(2020); Ahmad et al.(2020). While some empirical studies did not hold it, and suggested other non-linear relationships such as U-shaped relationships and N-shaped relationships Ozoku et al.(2017); Halliruet al.(2020); Kurniawan et al.(2020).

Another extremely important relationship has been debated among a large number of researchers is the FDI-Environment relationship, the evolution of analyzes focusing on the mentioned relationship gave rise to two essential evidence. The first one regarded that FDI inflow engendered negative effects on host environment's countries (Pollution Haven hypothesis/PHH) Shahbaz et al.(2019); Hanif et al.(2019); Malik et al.(2020); Bildiriciet al.(2020). Whereas, the second one supposed that FDI inflows generated positive effects on the environment of host countries (Pollution Halo hypothesis) Shao et al. (2019); Austet al. (2020); Hilleet al. (2019).

Several reasons motivate us to examine the impact of non-renewable energy, renewable energy, economic growth, and foreign direct investment on environmental quality in African countries, among these reasons is that there are a few studies that investigated both of EKC and Pollution Haven/Halo hypothesis for African countries and the findings of these studies was inconclusive. This papercontributes to the previous literature by re-exploring the significant difference between the effect of renewable energy and the effect of non-renewable energy (sources of energy) on environmental quality especially in the Africa region that is characterized by its wealth in the energy sector (natural resource abundance).

This study applies Panel autoregressive distributed lags (PARDL) to investigate the long run and short run relationships.

The rest of this paper is structured as follows. After this introductory section (section.1), section.2 provides a critical review of the past studies on the energy-economic growth-FDI relationship. Section.3 presents the data and discusses the methodology followed by the empirical results in section.4. Finally, section 6 concludes the main results and some policy implications.

2. Literature review:

In the last years, many studies focused their researches on the association between renewable, non-renewable energy, and environmental degradation, as well as the relationship between economic growth and environmental degradation, to investigate the benefits of renewable and non-renewable energy on both economic and environmental dimension. The results of these studies were different; among them, we will show recent studies.

2.1. energy-environment nexus:

Destek and Sinha (2020) have examined the impact of various variables on environmental degradation, among them renewable and non-renewable energy, for 24 OECD from 1980 to 2014, and they have chosen Ecological Footprint (EF) as the indicator of environmental quality, by using second-generation panel data methodologies such as panel mean group estimator (PMG), the main results indicated that the renewable energy reduces EF, whereas the non-renewable energy increases EF. Belaid and Zrelli (2019) investigated the dynamic relationship between carbon emission and renewable electricity by using a panel of 9 Mediterranean countries over the period 1980-2014, employing cointegration technique based on cross-section dependence, the empirical results imply that non-renewable electricity has a detrimental impact on the environmental quality, whereas the renewable electricity has a positive impact on the environmental quality and they suggested that the expansion of renewable energy sources is a viable strategy to protect the environment and achieve the energy security.

Alolaet al. (2019) explored the role of renewable energy in reaching environmental sustainability targets for the panel of European Union's largest economies of France, Germany, and the United Kingdom from 1990 to 2016, the results of FMOLS and DOLS showed that renewable energy consumption mitigates environmental degradation, and the findings revealed also evidence of bidirectional Granger Causality among renewable energy consumption and carbon emissions. Using a balanced regional panel of China dataset from 1995 to 2012 by Chen et al. (2019), the effect of both renewable and non-renewable energy on carbon emission was investigated by applying FMOLS and DOLS, the findings indicated that non-renewable energy had a positive effect on CO_2, and this effect is varied across the region, while renewable energy had a negative impact on CO_2 in Eastern and Western regions and the insignificant impact was found in the central region. Hanif et al. (2019) used GMM estimation on a panel of 25 developing Asian countries for the period from 1990 to 2015, the outcomes showed that non-renewable energy is a primary cause of global warming and renewable energy helps to control carbon emission.

Cheng et al.(2019) explored the impact of renewable energy on carbon emission per capita from 2000 to 2013 for BRICS countries, the results of both the panel OLS and panel quantile regression method concluded that renewable energy supply reduces CO_2 emission per capita. Zafar et al.(2019), used data of G-7 and N11 countries spanning from 1990 to 2016 and applied the CUP-FM and CUP-BC methods, both of them affirmed that renewable energy increases environmental quality by reducing carbon emissions for both groups of panel countries. Zhang and Liu (2019) explored the linkage among CO_2 emission, non-renewable and renewable energy in a panel of 10 northeast and southeast Asian countries during the period from 1995-2014, based on results of FMOLS and AMG, they concluded that non-renewable energy is the main source of carbon emissions, whereas renewable energy can reduce carbon emissions.

Other researchers affirmed the necessity of adoption of renewable energy rather than non-renewable energy to control environmental damages, like Sharif et al.(2019) whose analysed the association among renewable and non-renewable energy with environmental degradation by using a panel of data of 74 nations from 1990 to 2015, the outcomes of FMOLS showed that the non-renewable energy had a positive effect on environmental degradation while the renewable energy contributes to reducing environmental hazards. Based on ARDL bound testing approach and the VECM approach, Chen et al.(2019) examined the association between renewable energy and CO_2 emission for China covering the period 1980-2014, the findings showed that increasing non-renewable energy increases CO_2 emission, and increasing renewable energy decreases CO_2 emission.

Using the ARDL approach on time series data spanning from 1971 to 2017 for South Africa by Sarkodie and Adamas (2018), the study confirmed that renewable energy plays a huge role in promoting environmentally sustainable while non-renewable energy exacerbates pollution. Inglesi-Lotz and Dogan (2018) evaluated the role of renewable energy and non-renewable energy to the level of CO_2 emissions in Sub-Saharan Africa's big 10 electricity generators for the period 1980 to 2011, by employing panel estimation techniques robust to cross dependence, the findings confirmed that the increase in non-renewable energy intensify environmental degradation and increasing renewable energy boost environmental quality. Wang and Dong (2018) investigated the determinants of environmental degradation in SSA Countries over 1990-2014, the AMG estimator shows that non-renewable energy had a positive effect on the ecological footprint while renewable energy exerts negative effects on the ecological footprint. Jin and Kim (2018) analysed the role of renewable energy and nuclear energy on carbon mitigation by using data of 30 countries for the period 1990-2014, applying the panel cointegration analysis, Granger causality, FMOLS, and DOLS estimations, the results suggested that long-run equilibrium relationship exists among studying variables, and indicated that nuclear energy does not mitigate carbon emission unlike to renewable energy. Balsalobre-Lorenteet al. (2018) confirmed the need of increasing the source of renewable energy and enhancing energy innovation to diminish non-renewable energy damages by studying five countries from the European Union namely Germany, France, Italy, Spain, and the United Kingdom for 1985-2016 period.

Belaid and Youssef (2017) modelled the dynamic relationship between renewable energy, non-renewable energy, and carbon emissions in Algeria by employing the ARDL approach over the period 1980-2012, the non-renewable energy is found to have a negative effect on the environment and renewable energy is found to enhance environmental quality. Liu et al.(2017) examined the impact of per capita renewable energy consumption on carbon dioxide emissions in four Asian countries, by applying panel cointegration techniques, FMOLS and DOLS estimation, and causality as well, the results indicated that increasing renewable energy decrease CO_2 emissions while non-renewable energy linked positively with CO_2 emissions, furthermore, long-run feedback causality is found between renewable energy, non-renewable energy, and CO_2 emissions. Zoundi (2017) attempted to analyse the effectiveness of renewable energy in Africa by applying panel long run estimation techniques on data spanning from 1980-2012, the results provided strong evidence that renewable energy remains an efficient substitute to non-renewable energy in promoting environmental quality.

Some studies, however, conclude that both renewable energy and non-renewable energy deteriorate the environment and others did not find a significant effect of renewable energy on the environment. Among them the study of Nathaniel and Lheonu (2019) employed AMG on the panel data for 19 countries from Africa over the period 1990-2014, the findings revealed that renewable energy inhibits carbon emission insignificantly and affirmed that non-renewable energy increases carbon emission significantly, and they concluded that the influence of both types of energy sources on carbon emission vary across countries. While, Adams and Nsiah (2019) studied the relationship between renewable energy, non-renewable energy, and carbon emissions by using panel cointegration techniques for 28 Sub-Sahara Africa countries during the period 1980-2014, the results of Fully Modified OLS and GMM estimation showed that both of the renewable energy and non-renewable energy contribute to environmental degradation, and they mentioned that the renewable energy contributes more to environmental degradation than non-renewable energy, and they suggested that renewable energy has not reached the threshold required to generate a positive effect on the environmental quality.

Alolaet al.(2019) found similar results by using PMG-ARDL on panel data of 16-EU countries from 1997 to 2014 to check the role of renewable energy in achieving sustainable environmental goals, the results showed that both renewable energy and non-renewable energy affect negatively the environmental quality measured by ecological footprint in the long run. However, the estimation results indicated that renewable energy increases far lower the environmental deterioration as compared to non-renewable energy. By using ARDL, FMOLS and CCR estimate on data spanning from 1974 to 2014 for Turkey by Pata(2018), the results revealed that renewable energy had no effect on CO_2 emission and suggested that renewable energy was not at a desirable level to reduce CO_2 emissions. And Nguyen and Kakinaka (2018) investigated how the relationship between carbon emissions and renewable energy is related to the development stage by applying a panel cointegration analysis on 107 low and high-income countries covering the period from 1990 to 2013, the analysis revealed that renewable energy is associated positively with carbon emissions for low-income countries and associated negatively with carbon emissions for high-income countries.

2.2. Economic growth-environment nexus:

The relationship between economic growth and the environment was verified by various researchers within a non-linear relationship, some of them found an inverted U-shape relationship between the aforementioned variables, this type of relationship recognized in the economic literature review by Environmental Kuznets Curve (EKC) which inspired from the hypothesis income-income inequality link of Kuznets (1955). Among them, Sarkodiedet al.(2019) used the ARDL technique on data of Kenya spanning from 1971 to 2013, the findings validate the EKC hypothesis. Usama et al.(2020) employed the ARDL approach for Ethiopia over the period 1981-2015 to test this issue, the results support the existence of the EKC among real per capita GDP and per capita CO_2 emissions. Erdogan(2020) validated the hypothesis in OECD countries, by employing panel cointegration techniques and long-run estimations methods over the period 2000-2015. Boubelloutaet al.(2020) gave evidence of the existing EKC hypothesis among E-waste and economic growth within 30 European countries by using GMM estimation over the period 2000-2016. The outcomes of Ahmad et al.(2020) as well revealed the existence of an inverted U-shape relationship between income and CO_2 emissions in China. Suki et al.(2020) also confirmed the EKC hypothesis in Malaysia over the period 1970-2018 by using the QARDL approach.

Other researchers confirmed the non-linearity of the growth-environment nexus where the U-shape relationship was found among the aforesaid variables. Amidst them we find the study of Pontarolloet al.(2020) who test the EKC hypothesis within the spacial spill-overs framework over the period 2000-2014 in Romanian counties, the findings suggest a U-shape relationship, and then the EKC hypothesis does not hold. Halliruet al.(2020) employed panel quantile regression on data spanning from 1970 to 2017 for West African Countries, the empirical results exhibited a U-shaped link between CO_2 emissions and economic growth. Pataet al.(2020) did not validate the EKC hypothesis and suggested a U-shaped nexus amid economic growth and environmental pollution using both indicators of ecological footprint and CO_2 emissions in China over the period 1980-2016 by employing the ARDL procedure.

Some studies gave inconclusive findings concerning the relationship between economic growth and the environment. Among them the findings of Dogan et al.(2020) in BRICS countries over the period 1980-2014, they did not find a significant impact of growth on ecological footprint using DOLS and AMG estimators. Pataet al.(2020) employed Fourier Boostrap ARDL on six hydropower energy-consuming countries namely, Canada, the US, Brazil, Norway, China, and India over the period 1965-2016, the findings demonstrated no cointegration relationship between economic growth, ecological footprint, and hydropower energy consumption. Leal et al.(2020) indicated that the EKC hypothesis holds in High-globalized countries unlike for the Low- globalized countries by studying the 20 highest CO_2 emitters within OECD countries. Pandey et al.(2020) gave evidence that EKC is validated for supply-side analysis, but it is invalid for demand-side analysis by analyzing Asian countries over the period 1971-2014. Kurniawan et al.(2020) found a U-shape relationship among economic growth and environmental pressure measured by the components of natural capital (forest, agriculture, fossil fuels, minerals, and fishery) based on findings of Quadratic ARDL and the negative impact of growth on natural capital based on Cubic ARDL. De Pascale et al.(2020) gave evidence of supporting EKC in the short-run while offering some variation in the long-run in OECD countries.

The EKC hypothesis has been tested by two methods in the literature, the first one is by Quadratic models which are widely employed by most of the studies, these models include two coefficients, economic growth, and its square, the inverted U-shape relationship can be verified if the coefficient of economic growth is positive and the coefficient of the square of economic growth is negative. And the second one, by studying the short-run and long-run coefficients, Narayan et al.(2010) pointed out that if the long-run coefficient is smaller than the short-run coefficient, then the EKC hypothesis is verified, this implies that the pollution is reduced as economic growth increased. In our study, we will test the EKC hypothesis based on comparing the short and long-run coefficients.

2.3. Foreign direct investment-environment nexus:

The relationship between FDI and environment has been investigated within the Pollution Haven Hypothesis (PHH) and Pollution Halo Hypothesis (PHV) framework. The former holds that FDI inflows increase environmental degradation and the latter holds that FDI inflows promote environmental quality.

In terms of the PHH hypothesis, several empirical studies have confirmed this issue. Among them, Malik et al.(2020) investigated whether Pakistan is a pollution haven or not, by applying ARDL and NARDL approaches over the period 1971-2014, the findings suggested that FDI intensified carbon emission both in the short and long-run. Bildiriciet al.(2020) determined that FDI inflows to Afghanistan, Nigeria, Pakistan, Philippines, Somalia, Iraq, Syria, Thailand, and Yemen over the period 1975-2017 contributed significantly to CO_2 emissions. Singhania et al.(2020) provided evidence of PHH in 21 developed and developing countries with high carbon emissions, by using GMM and SYS-GMM estimations on data spanning from 1990 to 2016. Shahbaz et al.(2019) examined the effect of FDI on environmental quality in the U.S, they confirmed that FDI increases significantly carbon emissions. The PHH is validated in MENA countries according to Shahbaz et al.(2019) where they analyzed the association between FDI and carbon emissions by using GMM estimation over the period 1990-2015. The empirical analyzes based on DOLS and FMOLS estimations of Hanif et al.(2019) for Asian economies over the period 1990-2013 supported the existence of the PHH hypothesis. Based on ARDL estimation, Nasir et al.(2019) affirmed that in emerging Asian countries, the rise of FDI leads to an increase in environmental degradation.

With regard to PHV hypothesis, Demenaet al.(2020) used Meta-analysis on 65 studies that produce 1006 elasticities, by accounting for heterogeneity, they concluded that FDI reduces significantly the environmental degradations. In Africa, Austet al. (2020) analyzed 44 countries to inquire whether FDI supports the achievement of sustainable development goals (SDG), the findings revealed that FDI affects positively the SDG scores and the positive role of FDI in reaching SDG is higher in North Africa and lower in East Africa. Hilleet al. (2019) concluded that FDI is considered as one of the potential determinants that achieve the green growth strategy's goals and they affirmed the PHV hypothesis in Korea. Shao et al. (2019) revisited the effect of FDI on the environment by comparing BRICS countries with MINT countries, the results support the PHH hypothesis in both regions.

Some studies provided mixed results, among them, Adeel-Farooqet al. (2020) suggested that the effect of FDI on the environment depends on the sources of FDI flow, they concluded that FDI from developed countries enhances the environmental performance of host countries, while FDI from developing countries worsens the environmental performance. Xu et al. (2020) supported mixed results by studying the Chinese provincial panel from 2002 to 2016 and by employing a semi-parametric method to the STIRPAT model. Ahmad et al. (2020) confirmed the existence of both PHH and PHV in China provinces. Zhang et al.(2019) examined the data of 30 provinces in China from 2001 to 2015, by applying the PVAR model, the findings indicated that FDI has an insignificant effect on CO_2 emissions on the whole, whereas, FDI contributes significantly to CO_2 emissions over sub-regional analysis.

3. Data and methodology:

3.1. Data:

This research uses annual balanced panel data from 2000 to 2015 for 20 African countries, which include: Algeria, Angola, Benin, Cameroon, Congo, Cote d'Ivoire, Dem.Reb of the Congo, Egypt, Gabon, Kenya, Mauritius, Morocco, Mozambique, Nigeria, Senegal, South Africa, Sudan, Togo, Tunisia, and United Reb.of Tanzania as shown in Table.1.

Table.1: sample of the study

Country	OBS	Country	OBS
Algeria	16	Mauritius	16
Angola	16	Morocco	16
Benin	16	Mozambique	16
Cameroon	16	Nigeria	16
Congo	16	Senegal	16
Cote d'ivoire	16	South Africa	16
Dem .Reb of the Congo	16	Sudan	16
Egypte	16	Togo	16
Gabon	16	Tunisia	16
Kenya	16	United Reb.of Tanzania	16

This paperuses the dependent variable CO_2 emissions from fuel combustion (total) as a proxy for environmental degradation, this indicator is widely used in previous empirical studies (for e.g see Quadrelliand Peterson, 2007; Köne and Büke 2010; Ding et al., 2017 and Greer et al., 2019). We distinguish between two types of energy sources, non-renewable energy and renewable energy. For non-renewable energy, thisstudy utilises the electricity production fromoil, gas and coal sources (% of total) (for e.g. see Furlan and Mortarino, 2018; and Inglesi and Dogan, 2018).The renewable energy consumption (% of total final energy consumption) is used as a proxy for renewable energy, this proxy is employed by (for e.g. see Pérez-Lombard et al., 2008; Alcántara and Padilla, 2003; Cabeza et al., 2018 and Wang et al., 2020). We measure economic growth by annual GDP growth and Foreign Direct Investment by Foreign direct investment, net inflows as a ratio of GDP. All ourvariables are collected from the International Energy Agency (IEA) and the World Bank Development Indicators (WDI), the definitions of the variables and their sources are presented in Table.2.

Table.2: variables definitions and sources

Variable	Short name	Unit	Data source
Dependent variable			
Environmental degradation	CO_2	CO_2 emissions from fuel combustion (total)	International energy agency
Independent variables			
Non- Renewable energy	NREC	Electricity production from oil, gas and coal sources (% of total)	World bank development indicators
Renewable energy	RWEC	Renewable energy consumption (% of total final energy consumption)	World bank development indicators
Economic growth	GROWTH	GDP growth (annual %)	World bank development indicators
Foreign direct investment	FDI	Foreign direct investment, net inflows (% of GDP)	World bank development indicators

Table.3 shows the summary of descriptive statistics sample mean of all variables, regarding CO_2 emissions, the overall mean is 42.16 with the maximum value of 442.49 found in South Africa and the minimum value of 0.49 found in Congo. The between group ranges from a high average of 383.776 in South Africa to a low average of 1.473 in Congo.

The overall mean of non-renewable energy is 57.5803 with a maximum value of 98.3426 realized in Benin and a minimum value of realized in Congo. The between the group of non-renewable energy ranges from low average 0.4633 in Dem .Reb of the Congo to high average 99.3467 in Algeria. While renewable energy, the average share overall is 55.7696, with the highest value of 98.3426 observed in Dem .Reb of the Congo and the lowest value of 0.05895 observed in Algeria, Dem .Reb of the Congo remained the highest consumer of renewable energy with an average of 96.7262 whereas Algeria remained the lowest consumer with an average of 0.3242.

The average economic growth rate of the whole sample is 4.57%, Nigeria has the fastest rate which reached 15.32%, however, Dem .Reb of the Congo has the lowest rate which reached -6.9109%. The highest average rate of economic growth is 7.33% achieved by

Mozambique while the lowest average rate is 2.4315 achieved by Gabon. As for Foreign direct investment, its overall mean reached 3.6056, with a high ratio which is 49.9979 achieved by Congo and a low ratio which is -5.2081 achieved by Angola, the high mean group of net inflow of FDI is 13.0908 attained in Mozambique and the low mean group of net inflow of FDI is 0.7943 attained in Benin.

Table.3: Summary of statistics of variables

Variable		Mean	Std. Dev.	Min	Max	Observations	
CO_2	overall	42.1657	88.1258	.497599	442.494	N=	320
	between		89.1716	1.47316	383.776	n=	20
	within		13.7289	-61.0835	100.884	T=	16
RWEC	overall	55.7696	31.9203	.05895	98.3426	N=	320
	between		32.4356	.324233	96.7262	n=	20
	within		4.03831	44.4040	69.4540	T=	16
NREC	overall	57.5803	34.1757	0	100	N=	320
	between		33.4639	.463331	99.3467	n=	20
	within		10.0401	19.5451	86.2874	T=	16
growth	overall	4.57147	2.99530	-6.91092	15.3291	N=	320
	between		1.41966	2.43156	7.33343	n=	20
	within		2.65540	-7.27616	13.0301	T=	16
FDI	overall	3.60568	5.66031	-5.20812	49.9979	N=	320
	between		3.20288	.794307	13.0908	n=	20
	within		4.71837	-12.6647	42.1773	T=	16

The correlation analysis among variables are reported in Table.4, we find a positive and significant association between environmental degradation and non-renewable energy, and a positive and significant correlation between environmental quality and renewable energy, as well as among environmental quality and economic growth, and amid environmental quality and foreign direct investment as well.

Table.4: correlation matrix

	CO2	NREC	RWEC	GROWTH	FDI
CO2	1	-	-	-	-
NREC	0.5958***	1	-	-	-
RWEC	-0.6131***	-0.7496***	1	-	-
GROWTH	-0.0513***	-0.1883***	0.1805***	1	
FDI	-0.1930***	-0.2661***	0.1710***	0.1322**	1

*** p<0.01, ** p<0.05, * p<0.1

3.2. Methodology:

We choose the Panel Autoregressive Distributed Lag (Panel ARDL) to investigate the effect of Energy, Economic Growth, and Foreign Direct Investment on Environmental Degradation in Africa countries over the period 2000-2015. This approach is suitable for variables with no matter whether the order of integration of the variables is I(0) or I (1) or both I(0) and I (1), further, it provides us with the short and long-run effect simultaneously, the empirical model of ARDL (p, q,q,…,q) of Pesaran et al.(1999) is given as follows :

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta'_{ij} x_{i,t-j} + \mu_i + \varepsilon_{it} \dots \dots (01)$$

Where $x_{i,t}$ are (k*1) is the vector of explanatory variables (NREC, RWEC, GROWTH, FDI) for group i, δ'_{ij} are (k*1) coefficient vectors of the regressors, y_{it} is the dependent variable (CO_2) , λ_{ij} is the coefficients of the lagged dependent variables and μ_i represent the fixed effects, i=1,2,.....,N and t=1,2,.....,T. The long-run coefficients can be given as follows:

$$\Delta y_{it} = \phi_i y_{i,t-1} + \beta'_i x_{it} + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta^{*'}_{it} \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \dots \dots (02)$$

Where$\phi_i = -\left(1 - \sum_{j=1}^{p} \lambda_{ij}\right)$; $\beta_i = \sum_{j=0}^{q} \delta_{ij}$; $\lambda^*_{ij} = \sum_{m=j+1}^{p} \lambda_{im}, j = 1,2,..,p-1$; $\delta^*_{ij} = \sum_{m=j+1}^{q} \delta_{im}, j = 1,2,..,q-1$. And the error correction model can be written as follows:

$$\Delta y_{it} = \theta ECT + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta^{*'}_{it} \Delta x_{i,t-j} + \mu_i + \varepsilon_{it}$$

Pesaranet al.(1999) compare three estimators which are Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed Effect (DFE). The PMG estimator imposes common long-run effects (homogeneity in the long-run) without imposing common short-run effects (heterogeneity in the short-run), and the MG estimator provides a consistent estimate in the case of the slope and intercepts are varied across countries, while DFE estimator is consistent if the slopes coefficients and error variances are the same and the intercepts differ across countries.

In our study, we estimated the three models PMG, MG, and DFE, and the Hausman (1978) test has been performed to reveal consistency and efficiency amidst the concerned estimators.

Before that, the Pesaran-Yamagata (2008) homogeneity test has been applied to unveil the slope heterogeneity or the slope homogeneity, we further carried out the Cross-Section Independence (CD) test of Pesaran (2004). Followed by Panel Unit Root tests to analyze the order of integration of the series and to affirm that no one of the variables is I(2). We performed the Ficher-ADF test proposed by Maddala and Wu (1999) (MW) that known as one of the first-generation Panel Unit Root tests for the series with Cross-Independence and Pesaran (2007) (CIPS) that recognized as second-generation Panel Unit Root tests for the series with Cross- Dependence.

4. Results:

4.1. Diagnostic tests:

To know whether the explanatory variables namely non-renewable energy, renewable energy, economic growth, and foreign direct investment are independent of each other or not, we test the Multicollinearity amidst them. Table.5 indicates the outcomes of this test, it is evidenced from the results that the Tolerance values are greater than 0.2 and the Variance Inflation Factor (VIF) values are less than 5, and therefore, the Multicollinearity among the regressors is not found, which implies that, the aforesaid variables can be assumed as the explanatory variables of environmental degradation.

Table.5: Results of Multicollinearity test and Homogeneity test

VIF test			Pesaran, Yamagata. 2008 test		
Variable	VIF	Tolerance		Delta	p-value
NREC	2.40	0.4169		11.195	0.000
RWEC	2.30	0.4353	adj.	14.161	0.000
GROWTH	1.09	0.9198			
FDI	1.05	0.9532			
Mean VIF	1.71				

Table.5 also shows the results of the Homogeneity test of Pesaran and Yamagata (2008), from the results based on the calculated value of the delta and adjusted delta and their corresponding P.values, we can reject the null hypothesis of the slope coefficients are homogenous, and therefore, we must accept the alternative hypothesis of the slope coefficients are heterogeneous at 1% level of significance. Thus, the heterogeneous panel methods must be adopted.

Table.6:Results of cross-section independence test

Variable	CD-test	p-value	average joint T	mean ρ	mean abs(ρ)
CO_2	48.627	0.000	16.00	0.88	0.88
NREC	3.884	0.000	16.00	0.07	0.44
RWEC	16.554	0.000	16.00	0.30	0.51
GROWTH	1.621	0.105	16.00	0.03	0.23
FDI	.029	0.977	16.00	0.00	0.26

Notes: Under the null hypothesis of cross-section independence, CD ~ N(0,1)
P-values close to zero indicate data are correlated across panel groups.

In addition to the Multicollinearity and Homogeneity tests, we further effectuate cross-section independence test (CD) of Pesaran (2004), Table.6 outlines the outcomes, from these outcomes, we confidently reject the null hypothesis of cross-section independence in the case of CO_2 emission, non-renewable energy, and renewable energy, since the P.value close to zero which indicates that the data of these variables are correlated across panel groups. Whereas, we fail to reject the null hypothesis in the case of economic growth and foreign direct investment. Hence, we must use the first-generation Panel Unit Root for economic growth and foreign direct investment and the second-generation Panel Unit Root for CO_2 emission, non-renewable energy, and renewable energy.

Table.7 : Lag selection

lag	CD	J	J pvalue	MBIC	MAIC	MQIC
1	.9999	74.2244	.5036	-330.2976	-75.7755	-178.5582
2	.9999	45.5835	.6510	-224.0979	-54.4164	-122.9383
3	.9999	23.6016	.5424	-111.2391	-26.3984	-60.65931

The lag order selection is the most important issue in the dynamics models, particularly in ARDL models. In several studies among them the study of Pesaran et al.(1999), the lag order was chosen in each country using the recognized lag length selection criteria (AIC, SBC, BIC, etc), and the most common lag among countries was selected. In our study, we choose the overall lag selection using selection criteria proposed by Abrigo and Love(2016) and developed by Andrews and Lu(2001) based on Hansen's J statistic. Based on the findings of Andrews and Lu(2001) selection criteria reported in Table.7, the first-order lag is suitable since it has the lowest value of MBIC, MAIC, MQIC.

4.2. Properties of variables: Panel Unit Root results:

The findings of both the first and second Panel Unit Root test are depicted in Table.8. The results of the CIPS test which assumes cross-section dependence, reveal that the variables with CD, namely CO_2 emission, non-renewable energy, and renewable energy are not stationary at their levels, this implies that we fail to reject the null hypothesis of non-stationarity, however, we can reject the null hypothesis when the variables are in their first differences. These results mean that the variables have a unit root at levels, while they have not unit root at their first differences and then, these series are I(1).

Regarding the results of the MW test which applied on the variables that correlated across the group, namely, economic growth and foreign direct investment, we find that the null hypothesis of having unit root is rejected in the case of economic growth at level, this implies that the variable is stationary at the level and it is I(0). Whilst, we find that foreign direct investment hasa unit root at level, but it is stationary at the first difference, therefore, it is I(1).

Table.8:Panel Unit Root test

variables	Maddala and Wu (1999) (MW)		Pesaran (2007) (CIPS)	
	without trend	with trend	without trend	with trend
CO2	-	-	-1.054	1.575
D.CO2	-	-	-3.852***	-4.033***
NREC	-	-	-0.402	-1.878**
D. NREC	-	-	-4.808***	-2.795***
RWEC	-	-	-0.985	1.896
D.RWEC			-3.824***	-4.297***
GROWTH	116.4719***	116.3905***	-	-
FDI	71.7218***	47.9793	-	-
D.FDI	172.5427***	131.8759***	-	-

Notes: MW test assumes cross-section independence. CIPS test assumes cross-section dependence. *** p<0.01, ** p<0.05, * p<0.1

Since the investigated variables are mixed order of integration, we cannot employ panel cointegration tests such as Pedroni Panel Cointegration or Westerlund Panel Cointegration, hence, we can apply ARDL estimation.

4.3. Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed Effects (DFE) results:

Table.9 reports the results from PMG,MG, and FDE estimations for Africa countries where the dependent variable was CO_2 emissions and the independent variables were non-renewable energy, renewable energy, economic growth, and foreign direct investment. The outcomes summary the long and short coefficients and include the error correction term as well.

Table.9 :Results of PMG,MG, and FDE estimators

VARIABLES	(PMG) ECT	(PMG) SR	(MG) ECT	(MG) SR	(DFE) ECT	(DFE) SR
ECT	-	-0.0949***	-	-0.214***	-	-0.0789***
		(0.0259)		(0.0639)		(0.0240)
D.NREC	-	0.464	-	0.454	-	0.180***
		(0.363)		(0.381)		(0.0356)
D.RWEC	-	-1.268**	-	-1.440***	-	-0.680***
		(0.554)		(0.534)		(0.0992)
D.GROWTH	-	0.244***	-	0.376***	-	0.149*
		(0.0669)		(0.114)		(0.0862)
D.FDI	-	0.0410	-	-0.0783	-	0.0245
		(0.108)		(0.219)		(0.0572)
L.NREC	1.380***		3.268	-	0.705**	-
	(0.153)		(2.655)		(0.290)	
L.RWEC	0.606		0.847	-	-1.317*	-
	(0.416)		(8.693)		(0.769)	
L. GROWTH	2.225***		-1.606	-	2.726*	-
	(0.568)		(4.776)		(1.462)	
L.FDI	0.236		0.176	-	2.308***	-
	(0.352)		(5.672)		(0.861)	
Constant	-	-0.0206	-	0.686**	-	0.112*
		(0.0258)		(0.324)		(0.0576)
Hausman test	2.83	-	-	-	27.84	-
	(0.5867)				(0.0000)	
Observations	300	300	300	300	.	.

Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

With PMG estimation, the findings validate the long-run relationship amongst variables, since the coefficient of the error term is negative and statistically significant at a 1% level of significance. The short-run estimation reveals that renewable energy reduces significantly CO_2 emission by 1.27%, which implies that renewable energy contributes to the environmental quality in investigated countries in the short-run, while economic growth increase significantly CO_2 emission by 0.224% in the short-run, and thereis no significant impact of the rest of variables in the short-run. The long-run estimation givesstrongevidencethatnon-renewable energy increase significantly the environmental degradation by 1.38%, and affirms that economic growth has a negative effect on environmental quality in Africa countries, however, the findings did not exhibit anysignificant impact neither onrenewable energy nor of foreign direct investment in long-run. In sum, renewable energy affects the environment positively only in the short-run and non-renewable energy affects it negatively in the long-run, whereas economic growth affects it negatively in both the short and long-run.

In terms of MG estimation, the empirical findings of error correction coefficient confirm the long-run relationship amidst mentioned variables, we find only a short significant effect of just renewable energy and economic growth at 1% level of significance, renewable energy has a positive impact on the quality of the environment, it can reduce CO_2 emission by 1.44% whilst economic growth has a negative impact on the quality of the environment, it can increase CO_2 emission by 0.376%.

Based on DFE estimation, a significant long-run relationship is also affirmed, we find that all independent variables exacerbate significantly CO_2 emissions both in short term and long term except for FDI which affect significantly CO_2 emissions only in long term. In the short term, a 1% increase in non-renewable energy leads to an increase in pollution by 0.18%, and a 1% increase in economic growth leads to an increase in pollution by 0.149%, while an increase by 1% in renewable energy decreases pollution by 0.68%. In the long term, non-renewable energy, economic growth, and FDI contribute significantly tothe degradation of the environment, a 1% increase in non-renewable energy, economic growth, and FDI, leads to an increase in environmental pollution by 0.705%, 2.726%, 2.308% respectively. Whereas the negative impact of renewable energy on environmental pollution is confirmed in long term as well, a 1% increase in renewable energy helps to improve the environment by 1.317%.

The efficiency of PMG, MG, and DFE estimators is examined by Hausman (1978) test, the results are presented in Table.9, the results of the test show that PMG estimator is preferred than MG estimator, however, DFE estimator is the most effective and suitable than both of the PMG estimator and MG estimator. Hence we rely on our discussion on the findings of DFE.

5. Discussion:

From the selected findings (DFE), we find that non-renewable energy has a positive impact on carbon emissions in analyzed countries both in the short-run and long-run, this finding suggests that despite non-renewable energy can enhance the economic growth in these countries, however, it can aggravate the degradation of their environment, and it does not protect their environment. Empirical recent studies provided evidence of the positive impact of non-renewable energy on both economic growth and environmental degradation, and indicated that non-renewable energy contributes to economic growth at the same pace as carbon dioxide emission growth (Bildirici and Kayikci (2013), Adams et al.(2018), Rahman and Velayutham(2020), Chen et al(2019), Bekun et al.(2019)).

However, the results indicated also that renewable energy has a negative impact on carbon emissions , it means that renewable energy contributes positively and significantly to the improvement of the environment in these countries. Numerous studies confirmed the positive role of renewable energy in promoting economic growth as well as in improving environmental quality such as Irandoust (2016), Bhattacharya et al.(2017), Troster et al.(2018).

In order to achieve the 2030 agenda for Sustainable Development, particularly SDG7 and SDG13, the countries under study must make shift from dirty and unsustainable energy to clean and sustainable energy. The adoption of the renewable energies can reduce the risk of climate change such as heat wave, droughts, floods and water problems, it can mitigate also greenhouse gas emission and then reducing health risks . Moreover, for acheiving sustainable economic development in these countries , it should ensure that every one has access to clean, affordable , reliable and modern energy.

In addition, the coefficient of economic growth is positive and significant at a 10% level of significance in the short-run as well as in long run, however, the coefficient of the long run is greater than the coefficient of the short run. This result implies that the pollution is increasing as economic growth increasing, which has given us strong evidence against the EKC hypothesis, and therefore, the hypothesis of EKC does not hold for selected African countries. These findings are consistent with results presented by Pata and Caglar (2021), Pata and Aydin (2020), Halliru et al.(2020), but are contradict with the results of Sunet al.(2020), Vural (2020), Tiba et al.(2019), Sarkodic et al.(2018).

The positive effect of economic growth on environmental degradation leads us to wonder about what are the main determinants of economic growth in Africa, especially, that most of the African countries are non-renewable producing economies such as fossil fuels. According to some studies such as Ereghaet al.(2020) who suggested that oil production boosts economic growth in a panel of African countries. And other studies concluded that the major determinants of economic growth is energy sector such as Tugcuet et al.(2012). Tang and Abosedra(2014), Bilgili and Ozturk (2015), Kahia et al.(2016), Gozgor et al.(2018) and Zafar et al.(2019). Nevertheless, both economic growth and energy are considered to be the mains causes of increasing environmental degradation (Kais and Sami(2016), Rehman and Rashid (2017), Mikayilov et al.(2018), Raza et al.(2019), Zhao et al.(2019)).

In regards to the PHH or PHV hypothesis, we find that FDI has a positive and significant effect on CO_2 emissions, which implies that FDI inflow to Africa countries is harmful to their environment. Although the importance of FDI in boosting economic growth, however, it can affect negatively and significantly environmental quality.

Several studies gave empirical evidence of the significance and mixed role of FDI in both economic development and environmental quality by providing technological innovation in both fields. And other studies suggested that the negative impact of FDI on the environmental quality can be explained by the low level of FDI inflow to the receiving countries, while, if FDI inflow reached a high level, it can contribute significantly to improving the environment. Wang et al. (2020) concluded that when the magnitude of FDI inflows is weak, the technological innovation capabilities aggravate the volume of the environmental pollution, whereas, if the level of FDI inflow exceeds a higher threshold, then the technological innovation capabilities enhance environmental quality.

On the other side, the positive impact of FDI on pollution can be also an indicator that FDI is attracted by lenient environmental regulations as mentioned by Xing(2002). Thus, environmental degradation can be one of the determinants of FDI that aimed at countries with lax environmental degradation.

6. Conclusion and policy recommendations:

This research paper tries to explore the dynamic effect of non-renewable energy, renewable energy, economic growth, and foreign direct investment on environmental degradation in twenty selected African countries and over the period 2000-2015. To test two important hypotheses, the EKC hypothesis, and the PHH hypothesis, we firstly carried out the cross-independence test and we detected cross-sectional dependence in carbon emissions, non-renewable energy, and renewable energy, but not in economic growth and foreign direct investment. We, therefore, performed in second stage, both of the first generation and second generation unit root tests and found that all concerning variables are I(1) except for economic growth which was found I(0). Finally, we applied the ARDL approach using MG, PMG, and DFE estimators.

Concerning the findings of DFE estimation that was selected by the Hausman (1978) test, we reveal that there is a cointegration amid the aforementioned variables. The main findings from our estimation are that all independent variables affect significantly and positively CO_2 emissions, excluding renewable energy which affect significantly and negatively CO_2 emissions, moreover, all independent variables affect significantly CO_2 emissions both in short term and in long term, except for FDI which affects it significantly and positively only in long term. Thus, EKC is not validated in the sampled countries contrary to the PHH hypothesis (PHH) hypothesis which is verified in the long term in countries under consideration. The positive impact of FDI on carbon emission implies that this type of FDI transfers heavily-polluting industries to host countries.

In term of policy recommendation, the sampled countries must be adopting different eco-innovation technologies that support cleaner production and environmental efficiency as well, eco-innovation could help also these countries in attainting green economic growth. Policymakers should support energy productivity to face economic and environmental defies since energy productivity controls pollution by reducing energy consumption.

Switching non-renewable energy resources with renewable energy resources leads to realizing energy efficiency and thereby improving environmental quality.

In the same context, it would be better if the policymakers finance the investments in energy efficiency projects and implement public-private partnership investment (PPPI) to enhance innovative clean energy and other clean investments (Buso and stinger,2018). Thus, the appropriate public-private cooperation would be necessary to mitigate climate change by providing commercial incentives from the public sector to the private sector to invest in mitigation projects (Zhang and Maruyama, 2001).The public-private partnership can also contribute to climate adaptation investments in various economic sectors including energy as suggesting (Urwin and Jordan,2008; Wong et.al,2012; Hennessey et.al,2017). Therefore, adopting public-private partnership investment can boost economic growth on one hand, and control environmental harms on the other hand.

The policymakers in these countries should consider on alternative green trade plans that would restrict the import of unclean energy, fossil fuels and coal. This mechanism can support and develop the way for implementation of substitute energy solutions across countries and decrease CO_2. It will help environmental quality and trade balance. Therefore, some elements of Sustainable Development Goals (SDG) might be accomplished as well (for e.g. see (1) SDG 7, namely, affordable and clean energy, and (2) SDG 13, namely, climate action, UNDP 2017).

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