Highlights:

- non-renewable energy, renewable energy, economic growth, and foreign direct investment-CO_2 emissions relationship is investigated.
- First generation and second-generation unit root tests, Panel ARDL is performed.
- 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.

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

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.

1. Introduction

The increasing unwholesome climate may be the result of adopting unhealthy 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, without due consideration of 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 goals around improved environmental quality and mitigating environmental damages is among the most important endeavour for countries to achieve sustainable development.

Although energy is needed for economic development, it can also be the fundamental source of environmental degradation. The Energy-Environment nexus has become an important consideration for governments and researchers alike, and according to several researchers, the negative effects on the environment stems from non-renewable energy, not renewable energy. Therefore, increasing consumption of renewable energy rather than non-renewable energy has many potential advantages including mitigation of global warming emissions, diversity of energy sources, and decreased dependency on non-renewable energy (Belaid et al., 2019).

The impact on the environment of economic growth-goals has been investigated widely in the Environmental Kuznets Curve (EKC) framework, which describes a non-linear relationship between growth and environmental degradation. The EKC framework sets out 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 the two variables. A vast amount of empirical research has validated this hypothesis, including Sarkodiedet al. (2019); Usama et al. (2020); Erdogan (2020); Ahmad et al. (2020). Some empirical studies have suggested otherwise that there are 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 important relationship that has been debated among a large number of researchers is the FDI-Environment relationship. Research in this area has given rise to two essential hypotheses. The first one, the Pollution Haven Hypothesis (PHH) sets out that FDI inflow engenders negative effects on the host environment's countries Shahbaz et al. (2019); Hanif et al. (2019); Malik et al. (2020); Bildiriciet al. (2020). Whereas the Pollution Halo Hypothesis claims that FDI inflows generate 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 the context of African countries. For instance, there are few studies that investigate both EKC and the Pollution Haven/Halo hypothesis in the African context, and the findings of these studies are inconclusive. This paper contributes to previous literature by 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 African context which is characterised by its wealth in the energy sector (natural resource abundance).

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

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

2. Literature review

In previous studies in this area, researchers focused their studies on the association between renewable, non-renewable energy, and environmental degradation, as well as the relationship between economic growth and environmental degradation, in order to investigate the benefits of renewable and non-renewable energy on both the 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) examined the impact of different variables on environmental degradation, including renewable and non-renewable energy, for 24 OECD from 1980 to 2014. They selected Ecological Footprint (EF) as the indicator of environmental quality and employed second-generation panel data methodologies such as the Panel Mean Group estimator (PMG). The results indicated that renewable energy reduces the EF, whereas the non-renewable energy increases the EF. Belaid and Zrelli (2019) investigated the dynamic relationship between carbon emission and renewable electricity of 9 Mediterranean countries over the period 1980-2014, employing the cointegration technique (and?) based on cross-section dependence. The empirical results imply that non-renewable electricity has a detrimental impact on environmental quality, whereas renewable electricity has a positive impact on environmental quality. The results suggest that the expansion of renewable energy sources is a viable strategy to protect the environment and achieve energy security.

Alolaet al. (2019) explored the role of renewable energy in reaching environmental sustainability targets for the European Union's largest economies, including 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 also revealed evidence of bidirectional Granger Causality among renewable energy consumption and carbon emissions. Chen et al. (2019) investigated the effect of both renewable and non-renewable energy on carbon emission in China from 1995 to 2012 , applying FMOLS and DOLS. The findings indicated that non-renewable energy had a positive effect on CO_2, and this effect was varied across the country, while renewable energy had a negative impact on CO_2 in the Eastern and Western regions. An insignificant impact was found in the central region. Hanif et al. (2019) used GMM estimation to explore 25 developing Asian countries from 1990 to

2015. The outcome showed that non-renewable energy is a primary cause of global warming and renewable energy helps to control carbon emission.

As a further example, 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 OLS and quantile regression method concluded that renewable energy supply reduces CO_2 emission per capita. Zafar et al. (2019) examined the data from G-7 and N11 countries spanning from 1990 to 2016 and applied the CUP-FM and CUP-BC methods. Both methodologies affirmed that renewable energy increased environmental quality by reducing carbon emissions for both groups of countries. Zhang and Liu (2019) explored the linkage among CO_2 emission, non-renewable and renewable energy for 10 northeast and southeast Asian countries from 1995 to 2014. Based on the results of FMOLS and AMG (methodologies?), they concluded that non-renewable energy is the main source of carbon emission, whereas renewable energy can reduce carbon emission.

Other researchers have affirmed the advantages of renewable energy over non-renewable energy to control for environmental damages, such as Sharif et al. (2019) for example, who analysed renewable and non-renewable energy with environmental degradation by examining a total of 74 nations between 1990 and 2015. The outcomes of (the?) FMOLS showed that the non-renewable energy had a positive effect, and was contributing to environmental degradation, while the renewable energy reduced environmental degradation. Based on (the?) 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 to 2014. The findings showed that increasing non-renewable energy resulted in higher CO_2 emission, and meanwhile, increasing renewable energy resulted in decreased CO_2 emission.

Using the ARDL approach on time series data spanning from 1971 to 2017 for South Africa, Sarkodie and Adamas (2018) confirmed that renewable energy plays a huge role in promoting environmentally sustainability while non-renewable energy exacerbates pollution. Inglesi-Lotz and Dogan (2018) evaluated the role of renewable energy and non-renewable energy with regard 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 and robust to cross dependence, their findings confirmed that the increase in non-renewable energy intensified environmental degradation and an increase in renewable energy would boost environmental quality. In another study, Wang and Dong (2018) investigated the determinants of environmental degradation in SSA Countries between 1990 and 2014. The AMG estimator showed that non-renewable energy had a positive effect on the environment while renewable energy exerts negative effects. Jin and Kim (2018) analysed the role of renewable energy and nuclear energy on carbon mitigation using the data of 30 countries between 1990 and 2014. Applying cointegration analysis, Granger causality, FMOLS, and DOLS estimations, the results suggested that a long-term equilibrium relationship exists among the variables, and indicated that nuclear energy does not mitigate carbon emission, unlike renewable energy. Balsalobre-Lorente et al. (2018) confirmed the need to increase renewable energy and enhance energy innovation to diminish non-renewable energy damages. They studied five countries from the European Union, including Germany, France, Italy, Spain, and the United Kingdom between 1985 and 2016.

Further studies yield the same conclusion. Belaid and Youssef (2017) modelled the dynamic relationship between renewable energy, non-renewable energy, and carbon emissions in Algeria, employing the ARDL approach between 1980 and 2012. The non-renewable energy was found to have a negative effect on the environment and renewable energy was 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 using cointegration techniques, causality, FMOLS and DOLS estimation and the results indicated that increasing renewable energy would decrease CO_2 emissions while non-renewable energy linked positively with increased CO_2 emissions. Furthermore, in the same study, long-term feedback causality was 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 long-termestimation techniques on data spanning from 1980 to 2012. The results provided strong evidence that renewable energy remains more efficient than non-renewable energy in promoting environmental quality.

Some studies, however, concluded 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. For instance, Nathaniel and Lheonu (2019) employed the AMG methodology for 19 countries from Africa over the period 1990 to 2014. The findings revealed that renewable energy inhibits carbon emission insignificantly and affirmed that non-renewable energy increases carbon emission significantly. They also concluded that the influence of both types of energy sources on carbon emission varies across countries. Meanwhile, Adams and Nsiah (2019) studied the relationship between renewable energy, non-renewable energy, and carbon emissions using cointegration techniques for 28 Sub-Sahara Africa countries between 1980 and 2014. Tthe results of the Fully Modified OLS and GMM estimation showed that both renewable energy and non-renewable energy contributed to environmental degradation, and they mentioned that the renewable energy contributes more to environmental degradation than non-renewable energy. They also suggested that renewable energy has not reached the threshold required to generate a positive effect on environmental quality.

Alola et al.(2019) found similar results using PMG-ARDL for 16 EU countries from 1997 to 2014 to investiage the role of renewable energy in achieving sustainable environmental goals. The results showed that both renewable energy and non-renewable energy negatively affect environmental quality as measured by the ecological footprint in the long term. However, the estimation results indicated that renewable energy contributes to environmental deterioration far less than as compared to non-renewable energy. Pata (2018) utilised ARDL, FMOLS and CCR methodologies for data spanning from 1974 to 2014 for one EU country, Turkey, and. the results revealed that renewable energy had no effect on CO_2 emission and actually suggested that renewable energy was not at a desirable level to reduce CO_2 emissions. Nguyen and Kakinaka (2018) investigated how the relationship between carbon emissions and renewable energy is related to the development stage by using cointegration analysis on 107 low and high-income countries between 1990 to 2013. The analysis revealed that renewable energy is positively associated with carbon emissions for low-income countries and negatively associated with carbon emissions for high-income countries.

2.2. Economic growth-environment nexus

The relationship between economic growth and the environment has been verified by various researchers within a non-linear relationship, some of whom found an inverted U-shape relationship between the two variables. (As explained earlier?)This type of relationship is recognised in the economic literature review as the Environmental Kuznets Curve (EKC), which was inspired from the hypothesis income-income inequality link of Kuznets (1955).

In examining the economic growth-environment nexus, Sarkodied et al. (2019) employed the ARDL technique on data from Kenya spanning from 1971 to 2013. The findings validate the EKC hypothesis and confirm that [insert specifics]. To test the same variables, Usama et al. (2020) employed the ARDL approach for Ethiopia over the period from 1981 to 2015. The results also support the EKC hypothesis among real per capita GDP and per capita CO_2 emissions. Erdogan (2020) also validated the hypothesis, this time in OECD countries, by employing panel cointegration techniques and long-term estimations methods between 2000 and 2015. Similarly, Boubellouta et al.(2020) evidenced the EKC hypothesis among E-waste and economic growth within 30 European countries using GMM estimation over the period 2000 to 2016. The outcomes of Ahmad et al. (2020) also revealed the existence of an inverted U-shape relationship between income and CO_2 emissions in China, and Suki et al. (2020) also confirmed the EKC hypothesis in Malaysia between 1970 and 2018 using the QARDL approach.

On the other hand, other researchers have confirmed the non-linearity of the growth-environment nexus and the presence of the U-shape relationship among the [insert specific] and [insert specific] variables. Amongst these we find the study of Pontarollo et al. (2020) who tested the EKC hypothesis within the spatial spillovers framework over the period 2000-2014 in Romanian counties. The findings confirmed a U-shape relationship so that the EKC hypothesis does not hold. Halliru et al. (2020) employed the quantile regression methodology 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. In another study, Pata et al. (2020) did not validate the EKC hypothesis and suggested a U-shaped nexus for economic growth and environmental pollution using the indicators of ecological footprint and CO_2 emissions in China over the period of 1980 to 2016 by employing the ARDL methodology.

Some studies resulted in inconclusive findings with regard to the relationship between economic growth and the environment. Among them, the findings of Dogan et al. (2020), who studied BRICS countries from 1980 to 2014. Their results did not show a significant impact of growth on the ecological footprint using the DOLS and AMG estimators. Pata et al. (2020) employed the Fourier Boostrap ARDL methodology on six hydropower energy-consuming countries; namely Canada, the US, Brazil, Norway, China, and India, over the period from 1965 to 2016. The findings demonstrated no cointegration relationship between economic growth, ecological footprint, and hydropower energy consumption. By studying the 20 highest CO_2 emitters within OECD countries, Leal et al.'s (2020) study indicated that the EKC hypothesis holds in highly globalised countries as opposed to the low globalised countries. Pandey et al. (2020), by analysing Asian countries between 1971 and 2014, evidenced that EKC is validated for supply-side analysis, but it is invalid for demand-side analysis.

Kurniawan et al.(2020) found a U-shape relationship between economic growth and environmental pressure, measured by the components of natural capital (forest, agriculture, fossil fuels, minerals, and fishery). This study was derived from the findings of Quadratic ARDL and the negative impact of growth on natural capital based on Cubic ARDL. De Pascale et al.'s (2020) study supported EKC in the short-term while offering some variation in the long-term 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. The second method used in the literature is to study the short-term and long-term coefficients.

Narayan et al. (2010) pointed out that if the long-term coefficient is smaller than the short-term coefficient, then the EKC hypothesis is verified. This implies that pollution is reduced as economic growth increases. In our study, we test the EKC hypothesis based on a comparison of the short and long-t coefficients.

2.3. Foreign direct investment-environment nexus:

The relationship between Foreign Direct Investment (FDI) and the environment has been investigated within the Pollution Haven Hypothesis (PHH) and Pollution Halo Hypothesis (PHV) framework. The former holds that FDI inflow increases environmental degradation and the latter holds that FDI inflow promotes improved environmental quality.

In terms of the PHH hypothesis, several empirical studies have confirmed this. Among them, Malik et al. (2020) investigated whether or not Pakistan is a pollution haven by applying ARDL and NARDL approaches over the period 1971 to 2014. The findings suggested that FDI intensified carbon emission both in the short and long-term. Bildirici et al. (2020) determined that FDI inflow to Afghanistan, Nigeria, Pakistan, Philippines, Somalia, Iraq, Syria, Thailand, and Yemen, over the period 1975 to 2017, contributed significantly to CO_2 emissions. Singhania et al. (2020) evidenced PHH in 21 developed and developing countries with high carbon emissions by using the 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 and confirmed that FDI significantly increases carbon emissions.

The PHH hypothesis is validated in MENA countries according to Shahbaz et al. (2019) who analysed the association between FDI and carbon emissions using GMM estimation over the period 1990-2015. The empirical analyses based on the DOLS and FMOLS estimations of Hanif et al. (2019) for Asian economies over the period 1990 to 2013 also supported the PHH hypothesis. Finally, the ARDL estimation of Nasir et al. (2019) affirmed that in emerging Asian countries, a rise in FDI leads to an increase in environmental degradation.

With regard to PHV hypothesis, Demenaet al. (2020) used the meta-analysis methodology on 65 studies that produced 1006 elasticities, by accounting for heterogeneity. They concluded that FDI reduces significantly the environmental degradations. Meanwhile, Austet al. (2020) analysed 44 countries to inquire as to whether FDI supports the achievement of sustainable development goals (SDG). The findings revealed that FDI positively affects the SDG scores and the positive influence of FDI in reaching SDG is higher in North Africa and lower in East Africa. Hille et al. (2019) concluded that FDI is considered as one of the potential determinants to achieve SDGs and they confirmed the PHV hypothesis in the context of Korea.

Shao et al. (2019) revisited the effect of FDI on the environment by comparing BRICS countries with MINT countries, and the results similarly support the PHH hypothesis in both regions.

It is interesting to note that some studies provided mixed results. Among them, Adeel-Faroog et 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 provinces from 2002 to 2016 by employing a semi-parametric method to the STIRPAT model.

Ahmad et al. (2020) confirmed the existence of both PHH and PHV in Chinese 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 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
Egypt	16	Togo	16
Gabon	16	Tunisia	16
Kenya	16	United Reb. of Tanzania	16

This paper uses 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 example, 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, this study utilises electricity production from oil, gas and coal sources (% of total) (for example, 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 in previous research (for example, 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 FDI by foreign direct investment net inflows as a ratio of GDP. All our variables 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: Definitions and sources of variables

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 emission, 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 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 realised in Benin and a minimum value of [insert] realised in Congo. The non-renewable energy ranges from a low average of 0.4633 in Dem .Reb of the Congo to a high average of 99.3467 in Algeria. For 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 growth rate, which reached 15.32%, meanwhile, 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 of 49.9979 achieved by Congo and a low ratio of -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 is set out 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. There is also a positive and significant correlation between environmental quality and foreign direct investment.

Table.4: Correlation matrix

	CO_2	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) methodology to investigate the effect of Energy, Economic Growth, and Foreign Direct Investment on Environmental Degradation in African countries between 2000 and 2015. This approach was selected as it is suitable whether the order of integration of the variables is I(0) or I (1) or both I(0) and I (1), and further, it provides the short and long-term effect simultaneously. The empirical model of ARDL (p, q,q,…,q) of Pesaran et al. (1999) is given as follows :

$$CO2_{it} = \sum_{j=1}^{p} \lambda_{ij} CO2_{i,t-j} + \sum_{j=0}^{q} \delta'_{1ij} NREC_{i,t-j} + \sum_{j=0}^{q} \delta'_{2ij} RWEC_{i,t-j} + \sum_{j=0}^{q} \delta'_{3ij} growth_{i,t-j} + \sum_{j=0}^{q} \delta'_{4ij} FDI_{i,t-j} + \mu_i + \varepsilon_{it} \dots \dots (01)$$

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-term coefficients can be given as follows:

$$\Delta CO2_{it} = \phi_i CO2_{i,t-1} + \beta_1 NREC_{i,t} + \beta_2 RWEC_{i,t} + \beta_3 Growth_{i,t} + \beta_1 FDI_{i,t} + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta CO2_{i,t-j} + \sum_{j=0}^{q-1} \delta^{*'}_{1it} \Delta NREC_{i,t-j} + \sum_{j=0}^{q-1} \delta^{*'}_{2it} \Delta RWEC_{i,t-j} + \sum_{j=0}^{q-1} \delta^{*'}_{3it} \Delta RWEC_{i,t-j} + \sum_{j=0}^{q-1} \delta^{*'}_{4it} \Delta Growth_{i,t-j} + \sum_{j=0}^{q-1} \delta^{*'}_{5it} \Delta FDI_{i,t-j} + \mu_i + \varepsilon_{it} \dots \dots (02)$$

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:

$$\Delta CO2_{it} = \theta ECT + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta CO2_{i,t-j} + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta CO2_{i,t-j} + \sum_{j=0}^{q-1} \delta_{1it}^{*'} \Delta NREC_{\ \ i,t-j} + \sum_{j=0}^{q-1} \delta_{2it}^{*'} \Delta\ RWEC_{\ \ i,t-j} + \sum_{j=0}^{q-1} \delta_{3it}^{*'} \Delta RWEC_{\ \ i,t-j} + \sum_{j=0}^{q-1} \delta_{4it}^{*'} \Delta Growth_{\ \ i,t-j} + \sum_{j=0}^{q-1} \delta_{5it}^{*'} \Delta FDI_{\ \ i,t-j} + \mu_i + \varepsilon_{it} \dots \dots (03)$$

Pesaran et al. (1999) compared three estimators which are Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed Effect (DFE). The PMG estimator imposes common long-term effects (homogeneity in the long-run) without imposing common short-run effects (heterogeneity in the short-run). The MG estimator provides a consistent estimate in the case of the slope and intercepts are varied across countries. The DFE estimator is consistent if the slope's 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 was performed to ensure consistency and efficiency.

Before that, the Pesaran-Yamagata (2008) homogeneity test was 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 analyse 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 is known as one of the first-generation Panel Unit Root tests for the series, with Cross-Independence and Pesaran (2007) (CIPS) that was recognized as second-generation Panel Unit Root tests for the series with Cross- Dependence.

3.3. the econometric model

This study attempts the following model:

$$CO_{2i,t} = \beta_0 + \beta_1 NREC_{i,t} + \beta_2 RWEC_{i,t} + \beta_3 Growth_{i,t} + \beta_1 FDI_{i,t} + \mu_i + \varepsilon_{it}$$

Where CO2 refers toCO2 emissions from fuel combustion (total), NREC is Electricity production from oil, gas and coal sources (% of total), RWEC represents the Renewable energy consumption (% of total final energy consumption), GROWTH is GDP growth (annual %) and FDI is Foreign direct investment, net inflows (% of GDP).

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 their Multicollinearity. 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. This implies that the selected variables can be assumed to be explanatory variables of environmental degradation.

Table 5: Results of the 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 that the slope coefficients are homogenous, and therefore, we must accept the alternative hypothesis that 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 effectuated a 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 is close to zero and this indicates that the data of these variables are correlated across panel groups. On the other hand, 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 p-value	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, including the study of Pesaran et al. (1999), the lag order was chosen in each country using the recognised lag length selection criteria (AIC, SBC, BIC, etc.), and the most common lag among countries were 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) (and the?) 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 set out 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. These series are then I(1).

Regarding the results of the MW test which was 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). Meanwhile we find that foreign direct investment has a 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
CO_2	-	-	-1.054	1.575
D.CO_2	-	-	-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 the ARDL estimation.

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

Table 9 sets out the results from PMG, MG, and FDE estimations for the African 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

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

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

Based on DFE estimation, a significant long-term relationship is also confirmed. We find that all independent variables significantly exacerbate CO_2 emission both in the short term and the long term, except for FDI, which significantly affects CO_2 emission only in the 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%. Finally, an increase of 1% in renewable energy decreases pollution by 0.68%. In the long term, non-renewable energy, economic growth and FDI contribute significantly to the degradation of the environment. For instance, 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. The negative impact of renewable energy on environmental pollution is confirmed in the long term as well, whereby 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 the Hausman (1978) test and the results are presented in Table 9. The results of the test show that the PMG estimator is preferred over the MG estimator, however, the DFE estimator is the most effective and suitable than both of the PMG estimator and MG estimator. Hence, for our discussion, we rely on the findings of the DFE.

5. Discussion

From the selected findings of the DFE estimator, we find that non-renewable energy has a positive impact on carbon emissions in the analysed countries both in the short term and long term. This suggests that despite the fact that non-renewable energy can enhance economic growth in these countries, it can aggravate the degradation of their environment, and therefore does not protect their environment. Recent empirical studies have evidenced 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 also indicated that renewable energy has a negative impact on carbon emissions . This means that renewable energy contributes positively and significantly to the improvement of the environment in these countries. Numerous studies have 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 shift from dirty and unsustainable energy to cleaner, sustainable energy. The adoption of renewable energies can reduce the risk of climate change, such as heatwaves, droughts and flooding. It can also mitigate greenhouse gas emission, thereby reducing health risks. Moreover, in line with acheiving sustainable economic development in these countries, such steps would work to ensure that everyone has access to clean, affordable, and reliable energy.

The results of this study have also shown that the coefficient of economic growth is positive and significant at a 10% level of significance in the short term as well as in the long term. However, the coefficient of the long term is greater than the coefficient of the short term. This implies that the level of pollution is increasing as economic growth is increasing. This is strong evidence against the EKC hypothesis, and therefore, the hypothesis of EKC does not hold for the selected African countries. These findings are consistent with the results presented by Pata and Caglar (2021), Pata and Aydin (2020) and Halliru et al. (2020), but contradict the results of Sunet al. (2020), Vural (2020), Tiba et al. (2019) and Sarkodic et al.(2018).

The positive effect of economic growth on environmental degradation leads us to consider the main determinants of economic growth in Africa, especially given that most of the African countries are producers of non-renewable energies, such as fossil fuels. According to some studies, such as Eregha et al.'s (2020) research into African countries, , oil production boosts economic growth. Other studies have concluded that one of the major determinants of economic growth is the energy sector, i.e. 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 (see Kais and Sami (2016), Rehman and Rashid (2017), Mikayilov et al. (2018), Raza et al. (2019) and 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 emission, which implies that FDI inflow to Africa countries is harmful to their environment. Although the FDI is important in boosting economic growth, it can negatively and significantly affect environmental quality.

Several studies have provided empirical evidence of the significance and mixed role of FDI, in terms of both economic development and environmental quality, by providing technological innovation in both fields. Other studies suggested that the negative impact of FDI on environmental quality can be explained by the low level of FDI inflow to the receiving countries. On the other hand, 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 inflow 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 flipside of this, the positive impact of FDI on pollution can be also an indicator that Financial Direct Investors are attracted to lenient environmental regulations, as mentioned by Xing (2002). Thus, environmental degradation can be one of the determinants of FDI whereby it is directed towards countries with lax environmental policies/regulation?

6. Conclusion and policy recommendations

This research paper 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 to 2015. To test two important hypotheses, the EKC hypothesis, and the PHH hypothesis, we firstly carried out the cross-independence test and 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 at a second stage of research 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, our results find that there is a cointegration amid the aforementioned variables. The main findings from our estimation are that all independent variables significantly and positively affect CO_2 emission, excluding renewable energy which significantly and negatively affects CO_2 emission. In addition, all independent variables significantly affect CO2 emission both in the short term and in the long term, except for FDI, which affects it significantly and positively only in the long term. Therefore, we can conclude that EKC is not validated in the sampled countries contrary to the PHH hypothesis which is verified in the long term in the 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 terms of policy recommendations, we would recommend that the sampled countries adopt different eco-innovation technologies that support cleaner production and environmental efficiency. Eco-innovation could also help these countries in attainting green economic growth. Policymakers should support energy productivity to face economic and environmental deficits? since energy productivity controls pollution by reducing energy consumption. Switching non-renewable energy resources with renewable energy resources leads to energy efficiency and thereby improved environmental quality.

In the same context, it would be advantageous for policymakers to finance investments in energy efficiency projects and implement public-private partnership investment (PPPI) to enhance innovative, clean energy and other similar investments (Buso and Stinger, 2018). Thus, an ideal public-private cooperation would 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 suggested by Urwin and Jordan, 2008; Wong et.al, 2012 and 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 alternative green trade plans that would restrict the import of unclean energy, fossil fuels and coal. This mechanism can support the implementation of substitute energy solutions across countries and decrease CO_2. It will help environmental quality and trade balance. Therefore, some elements of the Sustainable Development Goals (SDG), in particular SDG7 (affordable and clean energy) and SDG 13 (climate action), might be accomplished at the same time

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