Effects of Energy Poverty

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ABSTRACT

This study examined the relationship between energy poverty and environmental quality using panel data of 9 ECOWAS nations for the period of 2000 to 2020. The study adopted cross-sectional Augmented Im, Pesaran, and Shinpanel unit root test and the panel non-linear Autoregressive Distributed Lag techniques as analytical tools with Foreign Direct Investment (FDI) and Gross Domestic Product (GDP) per capita as control variables. Results indicate the presence of significant symmetric and asymmetric relationship between energy poverty index and ecological footprint (EF) in the long run and further confirms the existence of the Environmental Kuznet Curve (EKC) Hypothesis only in the long run. The study also reveal that FDI has no significant influence on EF, while GDP leads to a significant increase in pollution via the ecological footprint. The study recommended some macro energy policies for the ECOWAS nations to improve their performance in tackling energy poverty and increasing environmental quality.

1.CHAPTER ONE: INTRODUCTION

This chapter introduces the topic of study by laying the foundation or background leading to the study, the motivation and objectives that guide the study, which are translated into testable research hypotheses. The benefits and scope of the study are also discussed.

1.1 Background to the Study

Preserving and protecting the environment has become a topical issue in recent social, health, economic and political discussions. This is contingent on the rising environmental effects of climate change and global warming. Climate change, as highlighted by Nathaniel and Adeleye (2020), alters the natural environment, inhibits economic progress, and undermines societal well-being. Ntarmah, Kong, and Manu (2020) note that, although Sub-Saharan Africa (SSA) is the world's least significant contributor to carbon emissions, the region is thought to be the most vulnerable to climate change-related issues. This is because agriculture and natural resources provide a livelihood for most of the African people and the region cannot withstand the environmental effect on their quality of life (Nathaniel & Iheonu, 2019).

Iheonu, et al (2021), concludes that owing to the quest for economic growth by developing economies to provide improved well-being for their people, rise in emissions is projected to continue to increase. As a result, given global concern about current and future climate change implications, policymakers are progressively more concerned about carbon emission drivers since understanding such drivers is critical for mitigating the deleterious effects of carbon emission. One of such drivers discovered in the extant literature is energy.

Energy poverty is seen as the absence of sufficient choice in accessing adequate, affordable, reliable, high quality, safe and environmentally benign energy services to support economic and human development (Reddy, 2000). The geographical distribution of energy poverty is concentrated in the developing world, representing an estimated 2 billion people worldwide, mostly in rural areas of Africa where energy poverty manifests as the lack of access to safe, clean fuels and reliance mainly on traditional energy sources such as biomass (Kaygusuz, 2011). Energy poverty occurs when a household is unable to secure a level and quality of energy services, cooling and heating, cooking, appliances, information technology sufficient for its social and material needs. This is somewhat contested and broad definition lies at the tip of a vast scientific and policy iceberg, involving complex socio-technical relations that extend across the planet. Energy poverty affects millions of people worldwide, even if the causes and consequences vary depending on context. Historically, the existence of this condition in the Global North has been attributed to contingencies such as low incomes, energy inefficient homes and high energy prices, while in the Global South, the infrastructural lack of access to more technologically advanced energy carriers has been seen as the main culprit (Bouzarovski & Petrova, 2015). It is estimated that more than one billion people across the world suffer from this condition; and it has received significant prominence thanks to high-profile international drives such as the 'Sustainable Energy for All' initiative, aimed at 'reducing the carbon intensity of energy while making it available to everyone on the planet' so as to contribute to a 'cleaner, just and prosperous world for all' (Sustainable Energy for All, 2017).

According to Ozughalu and Ogwumike (2018), energy poverty refers to difficulty in accessing clean fuels and high reliance on traditional fuels such as firewood and biomass as well as insufficient cooking devices with high pollution characteristics. The continuous utilization of traditional fuels has various negative implications on the environment (Wu, Zheng, You & Wei, 2018) causing Co2 emission. The first and most obvious negative consequence is that the demand for biomass has an impact on biodiversity and ecological stability. For instance, firewood represents the primary source of biomass for rural families in developing regions, but unsustainable fuel wood collection affects local ecosystems, including soil erosion, river siltation, and the extinction of valuable species (Köhlin et al., 2011). Second, the burning of biomass like leaves and straw contributes significantly to outdoor air pollution, such as smog or haze ad Co2 emission (Wu et al., 2018). Third, the utilization of traditional biomass to meet domestic needs causes indoor air pollution – carbon monoxide emission (Fullerton et al., 2008), which is significantly linked to health risks (Rinne et al., 2007). Indoor smoke pollution, in particular, raises the risk of respiratory ailments in adults, such as chronic bronchitis, and acute respiratory illnesses in children. The World Health Organization estimates that 3.8 million deaths occur annually from illnesses linked to household air pollution (WHO, 2018).

Sokolowski, et al (2020) also showed that CO_2 emissions have a significant impact on infant and under-five mortality rates in Africa. CO_2 emissions are not only responsible for the threat of climate change, but also contribute to global warming, accounting for around 60% of all greenhouse gases (GHGs). Statistics from the World Development Indicators show that CO_2 emissions have steadily increased in SSA with its attendant implications. For instance, in 1960, SSA's CO_2 emissions were estimated to be around 126,346kt before climbing significantly to 823,424kt in 2018 (World Bank, 2020). This increase is largely attributed to the fact that the region has hitherto and continues to rely on utilising environmental and natural resources for both production and exports.

The level of economic growth is critical in evaluating environmental quality-energy poverty-economic growth nexus. In recent empirical works, very little attention has been given to the role of sizes of economic expansion in relation to the Environmental Kuznets Hypothesis in a panel of countries. This study, therefore, investigates the relationships between energy poverty and environmental quality within the context of different income groups. Given this background, this study makes a four-pronged contribution to the literature. First, this study examines the implication of energy poverty on environmental quality by utilizing various proxies of energy poverty namely are access to electricity (% of the population); access to electricity, urban (% of urban population); access to electricity, rural (% of rural population); access to clean fuels and technologies for cooking, renewable energy consumption (% of total final energy consumption) and renewable electricity output (% of total electricity output). The utilization of these proxies for this inquiry assists in better comprehension of the effect of different types of energy poverty proxies on environmental quality. Second is that income level/sizes are considered with a view to determining if they matter in determining environmental quality. As suggested by the N-shaped EKC, initially, environmental degradation increases as income increases, but once it reaches a certain income level (first turning point 1, see figure 1), environmental degradation will instead decrease while income continues to increase. However, once income reaches another income level (turning point 2, see figure 1), environmental degradation will worsen while income grows. It implies that the original EKC hypothesis could be only temporary and may not hold in the long run. The N-shaped EKC occurs because improvement due to technological efficiency will only hold till a certain level of further income growth will result in net environmental degradation (deBruyn, van den Bergh, & Opschoor, 1998).

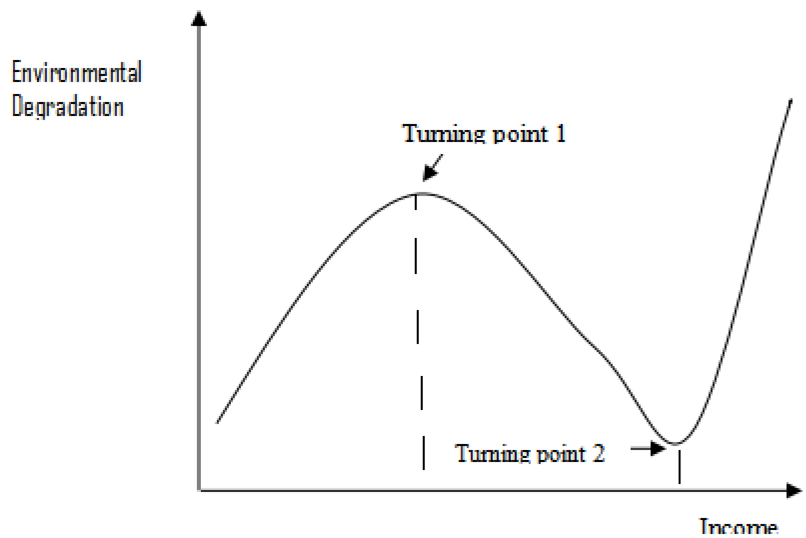

Figure 1: N-shaped EKC
Source: deBruyn, van den Bergh, & Opschoor, 1998

It is observed in Figure 2 that there are different levels of carbon emission (Co2) in selected ECOWAS countries. Nigeria, Benin and Ghana appear to be amongst the ECOWAS countries with highest emission from 2006. Between the periods 1999 to 2009, Nigeria was the highest in carbon emission followed by Cote d'Ivoire between the periods 1999 to 2005 while Benin took over from 2006 to 2013 as the second highest emitter of carbon. It is not known whether the different levels/sizes of income or development matter in the different levels of carbon emissions, which is part of the crux of this research.

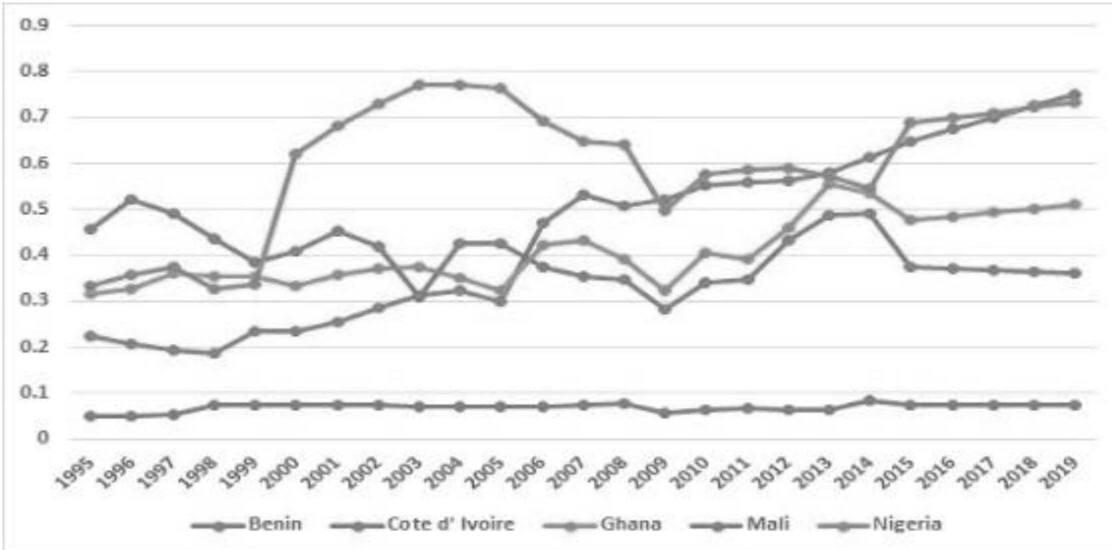

Figure 2: Co2 emission for selected African countries
Source: Authors' compilation

Furthermore, ECOWAS sub-region is made up of 16 countries namely Benin, Bukina Faso, Cape Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo. These countries are further categorized into low-income and lower-middle-income nations. Ten (10) countries such as Benin, Burkina Faso, The Gambia, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger Republic, Sierra Leone, and Togo are categorized as low-income countries while the other countries such as Cabo-Verde, Cote d'Ivoire, Ghana, Nigeria and Senegal are categorized as lower-middle-income nations. Figure 3 shows the different levels/sizes of income as proxied by the GDP per capita. It further indicates that GDP per capita within the ECOWAS sub-region is not markedly different, which suggests the need for more development/growth, with attendant implication on the environment.

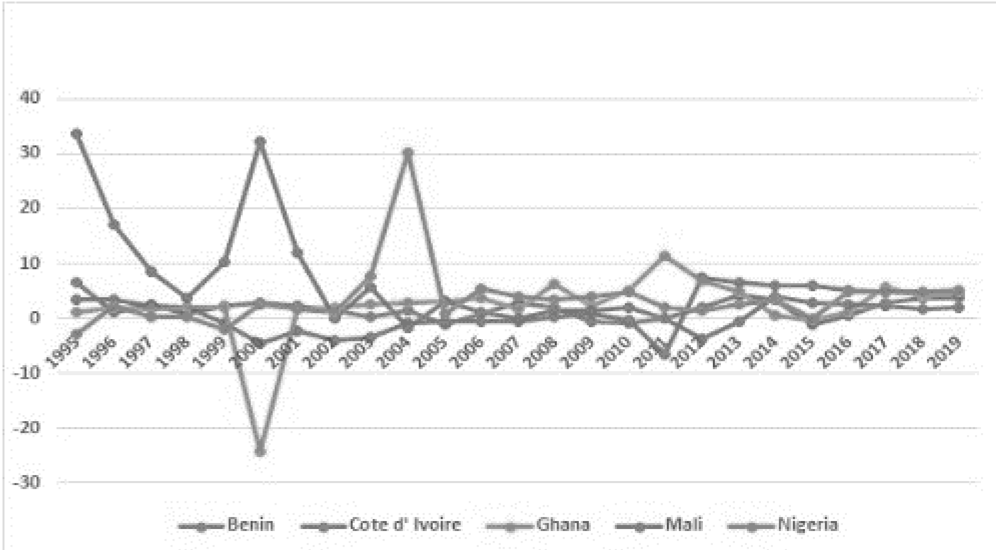

Figure 3: GDP per capita of selected ECOWAS countries
Source: Authors' compilation

The focus on these two income country groups is predicated on the fact that over two-thirds of Africa's population lives in these income groups and their economies also vary significantly across nations. These countries in the broad income groups have in recent years been undergoing industrialization, which means that their industrial output has been increasing, thus leaving an environmental impact. Given the expected development in these two broad income groups, it is essential to understand that to what extent their income levels matter in the nexus between energy poverty and environmental quality both in the short and long-runs respectively.

Third, unlike prior studies (Mewamba-Chekem & Noumessi, 2021; Zhao et al., 2021) that used CO_2 emissions to capture environmental quality in the energy poverty-environment nexus, this study departs from this practice to employ the ecological footprint variable to capture environmental quality in this research field. The ecological footprint is a composite measure that is considerably superior to CO_2 emissions as a proxy for environmental quality (Nathaniel &Khan, 2020; Dimnwobi et al., 2021). Hence, this study utilises ecological footprint to capture environmental quality in the ECOWAS sub-region. In so doing, policymakers and researchers will better realise the environmental implications of energy poverty.

Lastly, to have robust findings, this study applied advanced econometric techniques in assessing the energy poverty and environmental quality nexus in ECOWAS sub-region. For instance, the issue of cross-sectional dependency is addressed by utilizing second-generation panel unit root tests. Analogously, this study applies the Panel Non-linear Autoregressive Distributed Lag (PNARDL) technique to investigate the symmetric and asymmetric nature of the connection between economic expansion, energy poverty and environmental quality in the ECOWAS sub-region. These techniques will aid in providing outcomes capable of repositioning the policy framework in ECOWAS for the reduction of energy poverty as well as guaranteeing a sustainable environment.

Therefore, this research is aimed at providing answers to the following research questions:

i. What is the impact of energy poverty on environmental degradation in middle-income and low-income countries of ECOWAS?
ii. Is there any evidence of the Environmental Kuznets Curve for middle-income and low-income countries of ECOWAS in the short and long runs?

1.2 Significance of the Study

ECOWAS nations are signatories to the Paris Climate Agreement aimed at reducing the global increase in average temperature, greenhouse gas emission reduction and help nations meet their Intended Nationally Determined Contribution (INDCs). When INDC is ratified by nation-states, INDC becomes Nationally Determined Contribution (NDC). For instance, in Nigeria, her NDC action plan (residential sector), the country pledged to significantly upscale electricity access and encourage the use of energy-efficient appliances and other modern cooking and household items.

Therefore, the outcome of this study would assist the countries within ECOWAS to be abreast of the targeted policies to pursue in order to surpass their NDC targets by 2030.

The purpose of this study is to provide the requisite reference in energy policy formulation with a view to repositioning the energy sector to support economic development in ECOWAS sub-region. It is no longer news that nations within sub-Saharan Africa were unable to achieve the Millennium Development Goals in 2015; however, efforts are on top gear towards achieving Sustainable Development Goals by 2030. This study will, therefore, assist regional governments especially ECOWAS in achieving sustainable development goals 1 (No Poverty), 4 (Quality Education), 7 (Affordable and Clean Energy) and 8 (Decent Work and Economic Growth) through deliberate efforts to implement the recommendations of this study towards eradicating energy poverty.

1.3 Scope and Limitation of the Study

This study is limited to ECOWAS sub-region of Africa. A panel data is drawn from 9 ECOWAS countries covering the periods 2000 to 2020. Countries chosen are influenced by data availability both in terms of ecological foot print and energy poverty proxies. Most data for energy poverty started around 2000, which set the start date. The cross-sectionally Augmented Im, Pesaran, and Shinpanel unit root test and the panel non-linear Autoregressive Distributed Lag techniques were applied, whereas Foreign Direct Investment (FDI) and Gross Domestic Product (GDP) per capita were introduced as control variables. The limit set by data availability would not affect the reliability of the result. Five countries of Benin, Burkina Faso, Mali, Niger and Togo were drawn from low income ECOWAS countries while four countries of Cote d'Ivoire, Ghana, Nigeria and Senegal were drawn from low-middle income ECOWAS countries respectively.

1.4 Organization of the Study

This thesis is divided into five chapters and the first one being the introduction which presents the background and objectives of this paper. Chapter two features the theoretical and empirical literature reviewed, while Chapter three presents the details of the dataset and the method of estimation used. The fourth Chapter dwelt on empirical findings while the fifth Chapter consists of conclusion, recommendations and policy implications of the study.

2. CHAPTER TWO: REVIEW OF RELATED LITERATURE

This chapter discusses theoretical and empirical foundations related to the present field of study. It also discusses the conceptual and theoretical frameworks adopted for the study.

2.1 Review of Theoretical Literature

According to Zaoh, et al (2021), there are three ways of assessing energy poverty, which includes energy service availability, energy service quality and satisfaction with energy demand for human survival and development. The study further noted that energy service availability measurements are commonly constructed through a series of indicators, such as consumption of traditional biomass and share of the population with access to electricity.

Conceptualizing Energy Poverty: Supply-Side and Demand-side Approaches

Some definitions have focused on defining energy poverty from a supply-side approach. Four common approaches have received a great deal of attention in the literature. The first approach focuses on the physical availability of modern energy fuels; including modern energy carriers as a single dimension of energy access. This definition views access in terms of the availability of modern energy fuels and carriers which help meet the basic cooking, heating and lighting needs of a household (IEA, 2016). However, this approach considers physical availability of energy as an indicator of improved level of service without accounting for challenges arising from poor quality or reliability (Mirza & Szirmai, 2010; Pachauri, 2011). As such, it may be problematic to rely only on this definition of energy access.

The second approach focuses on the physical energy requirements. This approach defines energy access by measuring the amount of energy required to carry out basic cooking, lighting and heating activities in a household (Bravo *et al*., 1979). However, estimating the minimum energy requirement is rather a technical process and often adopts a more engineering-like methodology based on certain assumptions. In cases where basic needs vary, due to varying socioeconomic factors such age, gender, household composition or time period, among other factors, these assumptions would either underestimate or overestimate the minimum required energy of basic use (Pachauri, 2011).

The third supply-side approach defines access in terms of reliability of energy supply. Reliability is defined as a measure of the capability of an energy supplier's system to meet the demand for the customer (Reddy, 2015). For instance, customers with electric-grid connections may still experience physical unavailability of electricity in a day owing to planned or unplanned interruptions. Even with carriers such as liquid petroleum gas (LPG), access may be limited.

The fourth approach, which is the demand side approach defines energy access in terms of the deprivations people face. Nussbaumer *et al*. (2012) defines energy poverty and the lack of energy access in terms of the multiple deprivations such as access to electricity, modern cooking fuel, access to a cooking space without indoor pollution, telecommunication means (landline or mobile phone), entertainment/education (radio or television), and household appliance ownership. In other words, they employ a multidimensional approach to understanding energy poverty: analyzing energy poverty from more than one dimension.

Energy systems in Africa are characterized by heavy reliance on biomass, which impacts on biodiversity, high fossil fuel imports, which impacts on climate change, insignificant use of renewable energy and high energy intensity (USAID, 2018c). In Africa, recent estimates showed that 633 million people are living in energy poverty while 792 million people rely heavily on traditional biomass as their primary energy source for cooking (such as charcoal, animal dung and firewood) for their cooking needs in the informal economy (IEA, 2018). While efforts at electrification are expected to bring down the number of people who do not have access to electricity, the number of people using unimproved cooking facilities is expected to increase through 2030 (Africa Progress Panel, 2015).

For instance, Nigeria provides an important example of both the potential and the barriers to dramatically increase electricity access and reliability. An estimated 45% of the population has access to grid electricity, meaning that 20 million households do not (USAID Power Africa, 2018). Even for those connected to the grid, electricity service has fundamental problems related to extremely limited supply capacity compared to demand as well as poor reliability. The country's average electricity consumption per capita per year is low even for Africa at 144 kWh compared to 167 for Kenya, 355 for Ghana and 4,200 for South Africa (USAID, 2018c). With 5,500MW of available grid capacity, albeit this is not fully utilized, supply availability is a far cry from the electricity demand, which is conservatively estimated to be about 40,000MW (Nigeria Electricity Hub, 2017a). Hence electricity supplied to consumers varies by location and on average is limited to about 6 – 12 hours per day on a nationwide basis. Today, more Nigerians are climbing down the energy ladder moving from electricity, gas and kerosene to fuel wood and other traditional biomass energy forms (International Energy Agency, 2018).

Energy poverty is conceptualized by the following underlying indicators: the absence of sufficient choice in accessing adequate, affordable, reliable, quality, safe and environmentally sound energy services to support development (Winkler, 2009). This is in line with IEA (2014) definition of energy poverty as the "lack of access to modern energy services such as electricity and clean cooking facilities which do not cause indoor air pollution". By modern energy sources, we mean broadly those that are not biomass fuels. Figure 4 below highlights the framework for addressing electricity access deficit in Africa which will inevitably unlock the potentials of the informal sector economy by making it resilient, robust and responsive to the larger populace that depends on it. If the symptomatic barriers are taken care of, the energy sector would lead to a transformation of the economies (creating jobs and rising income both for the formal and informal sectors) leading to greater energy access.

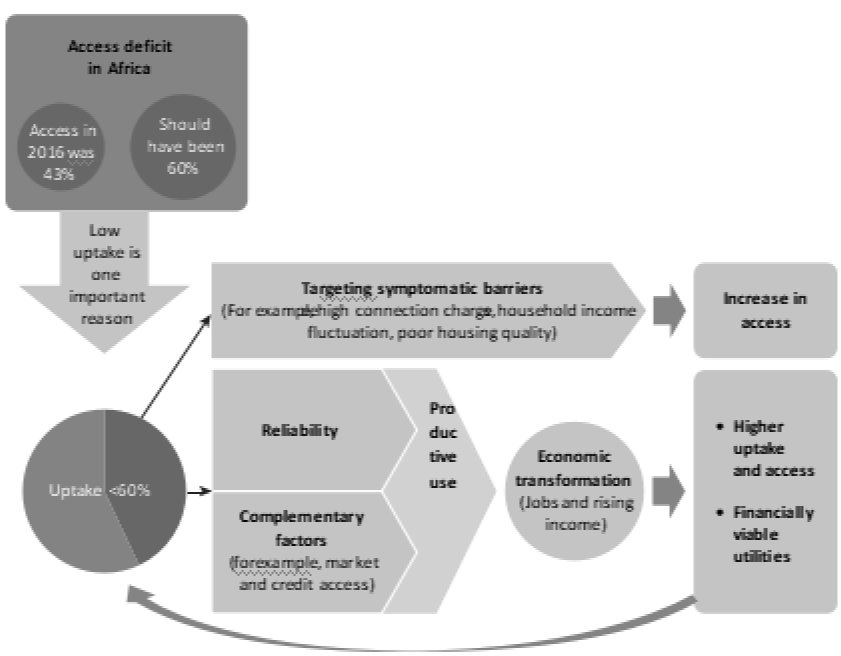

Figure 4: A framework for addressing electricity access deficit in Africa

Source: Researcher, 2022.

Conceptual Framework

The link between energy poverty and environmental quality is demonstrated in figure 5 below. There is a broad consensus that energy consumption is closely correlated with national growth and income levels. The relationship runs both ways, as energy is a pre-requisite to increase gross domestic product (GDP), while simultaneously demand for energy increases with increase in GDP. Economic growth and poverty reduction are enabled through improved productivity, reduced costs due to increased energy use efficiency and improved human capital through better living standards. However, the use of non-renewable energy and biomass as a result of lack of access to renewable and clean energy has the implication on biodiversity and ecological stability. Firewood, for instance, represents the primary source of biomass for rural families in developing regions, but unsustainable fuel wood collection affects local ecosystems, including soil erosion, river siltation, and the extinction of valuable species, thus affecting environmental quality.

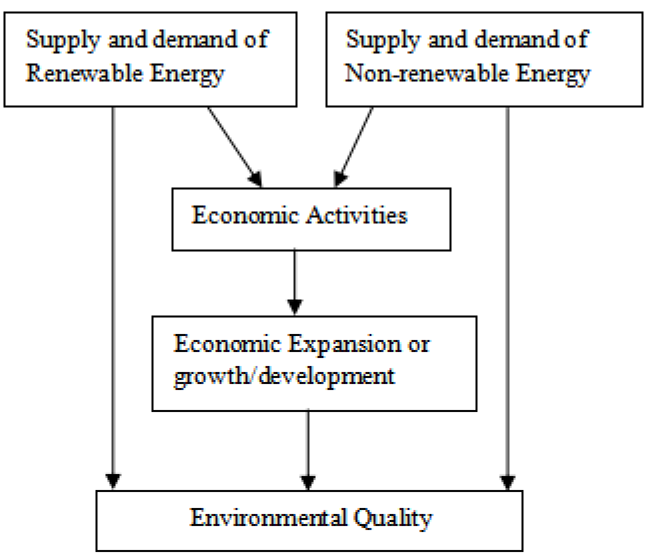

Figure 5: Environmental Quality and Energy Poverty nexus.
Source: Authors, 2022

Basic Theory: The Energy Stacking Model

The energy stacking model (ESM) was popularized by the works of Davis, 1998, Heltberg, 2004, Pachauri and Spreng, 2003 respectively. This model refers to the diverse energy use pattern, a situation whereby households combine different energy sources to satisfy their energy needs. Recent experience has revealed that as income rises, developing country households do not switch to more advanced energy sources, but rather combine lower and higher energy sources (Ogwumike, Ozughalu and Abiona, 2014). Rather than move up the energy ladder as their income rises, households choose a variety of energy sources based on their current tastes, needs and budgets. The theory assumes that energy consumption decisions are influenced by multiple factors rather than a single factor. Therefore, households do not fully switch after adopting cleaner fuels making it a very common model in developing countries.

Several factors could drive energy stacking. The supply of modern energy in developing countries is often unreliable. So, stacking the modern carrier to earlier carriers would protect against supply failures. Similarly, variations in energy prices could also trigger energy stacking behaviour.

2.2 **Review of Empirical Literature**

This section presents previous studies reviewed in two facets: The first part highlights the few studies on energy poverty-environmental quality nexus while the latter part presents studies on the determinants of environmental quality

2.2.1. Studies on Energy Poverty and Environmental Quality

Energy poverty is a multifaceted topic, but in the context of developing countries, it could refer to the inability or difficulty of people to access modern and reliable energy services. It specifically refers to the insufficient availability of electricity and contemporary clean cooking fuels. This restricted access poses a major impediment to socioeconomic development and has negative environmental repercussions (Mewamba-Chekem & Noumessi, 2021). As much as I know, studies on energy poverty and environmental degradation are sparse in the literature and this section presents the few studies that investigated the energy poverty-environmental nexus in the extant literature.

Chakravarty and Tavoni (2013) assessed the nexus between energy poverty and CO_2 emissions in a sample of countries cutting across the various regions of the world. They conclude that energy poverty reduces CO_2 emissions. Similarly, González-Eguino (2015) highlighted that the utilization of biomass produces indoor pollution signifying that energy poverty hurts the environment. In a study in rural Brazil, Pereira et al. (2019) conclude that transition to cleaner and modern sources of energy (that is reducing energy poverty) decreases CO_2 emissions.

Mewamba-Chekem and Noumessi (2021) applied the Panel-corrected standard errors (PCSE) and Feasible Generalized Least Squares (FGLS) on a sample of 20 SSA nations between 1996 and 2015 to investigate the impact of energy poverty and energy consumption on CO_2 emissions. The study established that while energy poverty does not influence CO_2 emissions, energy consumption influences CO_2 emissions. In a similar study, Zhao et al (2021) employed the system-generalized method of moments (SYS-GMM) method to uncover the implications of energy poverty on CO_2 emissions in 30 Chinese provinces over the period 2002 to 2017. The study discovered that energy poverty promotes CO_2 emissions.

2.2.2 Studies on Determinants of Environmental Quality

In response to growing concerns about environmental pollution, numerous studies have focused on the factors that affect emission. These studies have documented valuable insights which in this section, some of these studies are presented with a priority focus on multi-country studies.

For instance, Lin et al. (2017) analysed the predictors of carbon emission in 53 developing economies from 1991 to 2013. Their work revealed that population, energy intensity, affluence, and CO2 emission intensity promote carbon emission. Shuai et al. (2017) assessed the drivers of carbon emission in 125 nations for the period 1990 to 2011 and reported technology, affluence, and population as the major drivers of carbon emission. Román-Collado and Morales-Carrión (2018) utilized the Logarithmic Mean Divisia Index (LMDI) to examine the case of the Latin America region over the period 1990 to 2013. The study outcome shows that population and activity effects, as well as carbonization and fossil fuel effects, are the key drivers of emissions. Solarin and Al-Mulali (2018) appraised the drivers of emissions in 20 countries over the period 1982 to 2013. Utilizing a variety of methods, the study established that urbanization, energy use, and real gross domestic product (GDP) per capita are significant contributors to carbon emissions. Chontanawat (2018) found in the Association of Southeast Asian Nations (ASEAN) region that population growth and income are the major drivers of emission. Similarly, in a sample of 7 countries from ASEAN over the period 1990 to 2017, Salman et al. (2019) revealed that energy intensity and population size increased carbon emissions while technology innovation reduced them. For Organization for Economic Cooperation and Development (OECD) nations, Hashmi and Alam (2019) underlined the importance of affluence and population as the major predictors of emissions. Gorus and Aslan (2019) discovered that energy consumption and inflows of foreign direct investment intensified pollution in MENA nations. Coskuner et al (2020) utilized Fully Modified Ordinary Least Squares (FMOLS) and a sample from the Organization of Petroleum Exporting Countries (OPEC) countries to study the determinants of carbon emissions between 1995 and 2014. The estimation outcome shows that urbanization, international trade, and fossil fuel energy consumption significantly drive carbon emission in the selected OPEC member nations. Solarin (2020) applied the Generalized Method of Moments (GMM) for a sample of 35 developing and emerging nations between 2010 and 2017. The findings showed that fossil fuel subsidy increase, urbanization, population size, real GDP per capita, resource rent, globalization, and industry share enhanced environmental degradation.

Environmental issues have also stimulated the interest of researchers in Africa. This strand of studies focuses on studies on the continent. In a panel of 13 African nations, Shahbaz et al. (2015) reported that energy intensity and real GDP increase emission. With an emphasis on 5 African nations, Lin et al (2016) reported that energy intensity and energy structure stimulate emission while urbanization and population growth discourage the same. Wang and Dong (2018) adopted an Augmented Mean Group (AMG) estimator to assess the determinants of environmental degradation in 14 SSA for the period 1990 to 2014. The results indicate that urbanization, non-renewable energy consumption, as well as economic growth, have a positive impact on the ecological footprint (EF), whereas renewable energy consumption inhibits EF in SSA. Utilizing panel data (1991 to 2013) for 17 African nations, Sarkodie (2018) evaluated the determinants of environmental degradation and identified economic growth, food production, fertility rate, birth rate, agricultural land, energy use, and permanent crop as the key determinants, while also confirming the Environmental Kuznets Hypothesis (EKC) hypothesis. Adams and Klobodu (2018) pinpointed urbanization, economic growth, and financial development as the major variables that stimulate environmental degradation in 26 SSA countries. Acheampong et al. (2019) investigated the drivers of emissions for 46 SSA economies for the period 1980 to 2015. The outcome of the random and fixed effect estimation revealed that foreign direct investment and renewable energy reduce emission, while financial development and population growth boosts emission. Nathaniel and Iheonu (2019) reported that while emission is decreased by renewable energy, non-renewable energy drives emission in 19 African economies. A similar effect of renewable energy on emission was discovered by Asongu et al (2019) for 40 African nations. Aluko and Obalade (2020) reported that, whilstfinancial development hinders emission, technology, affluence, and population promotes emission in SSA countries over the period 1985 to 2014.

In more recent African studies, Dimnwobi et al (2021) utilized the Cross-sectionally Augmented autoregressive distributed lag (CS-ARDL) on a group of five most populous African nations and discovered that population growth rate, population density, energy consumption, per capita GDP growth rate, and trade openness are significant drivers of environmental quality while urbanization was insignificant. Analogously, Iheonu et al (2021) applied the quantile regression for data from 34 SSA nations between 1990 and 2016 and the study found that whereas economic growth and urbanization increase CO2 emissions, renewable energy consumption, and international trade significantly reduce emissions in SSA. In a related study, Onuoha et al (2021) utilized the Panel Non-Linear Autoregressive Distributed Lag (PNARDL) Model as well as data from 15 nations of the Economic Community of the West African States between 1990 and 2016. The study concludes, among other things, that economic expansion, agricultural land use, as well as non-renewable energy use, increases the carbon footprint.

3. CHAPTER THREE: ESTIMATION METHODS AND PROCEDURE

3.1 Data Measurement and Description

The annual data of the 16 ECOWAS nations spanning the period 2000 to 2020 were obtained through the World Development Indicators (WDI) database of the World Bank. The study excluded some countries within ECOWAS sub-region due to insufficient data across the sample period. The countries used in this analysis are: Five countries of Benin, Burkina Faso, Mali, Niger and Togo were drawn from low income ECOWAS countries while four countries of Cote d'Ivoire, Ghana, Nigeria and Senegal were drawn from low-middle income ECOWAS countries respectively.

Among the three basic methods popularly utilized in the extant literature in measuring energy poverty, González-Eguino (2015) averred that technological threshold is preferred over the economic and physical thresholds in studies utilizing cross-country samples because of its comparability. The issue of defining "necessities" across nations is one of the major drawbacks of the physical threshold approach. The economic threshold method is mainly interested in energy prices, purchasing power, and the challenge of having appropriate levels of temperature across nations for comparison (González-Eguino, 2015). The most appropriate metrics of capturing energy poverty according to most prior studies (Nguyen et al. 2021; Nguyen and Su 2021a,b,c), are access to electricity and clean energy and modern cooking technologies. Therefore, the key descriptions of energy poverty adopted in this research are access to electricity and access to clean energy and modern cooking technologies. To expand the depth of our analysis, I used four energy access variables namely; the population's access to electricity, access to electricity in the urban population, rural population's access to electricity, and access to clean energy and technologies for cooking. As a novel contribution, this study goes a step further by using additional proxies for energy poverty. The literature highlights that energy poverty is a major aspect of sustainable development (Churchill and Smyth 2020), and proposed that sustainable energy production and consumption be considered in the advancement of sustainable development (United Nations 2019). As a result, I include renewable energy consumption and renewable electricity output as additional energy poverty proxies. To obliterate convergence issues arising from an insufficient number of countries in the different income groups, I employed the principal component analysis to represent energy poverty multivariate data set as a smaller set of variables to observe trends, jumps, clusters, and outliers.

Consistent with recent environmental literature (Nathaniel and Khan 2020; Nathaniel and Adeleye 2020; Dimnwobi et al. 2021), this study utilizes ecological footprint to capture environmental degradation. In alignment with previous studies (Mewamba-Chekem and Noumessi 2021; Zhao et al. 2021), I used real GDP per capita and foreign direct investment as control variables. Table 1 shows the description of these variables.

Table 1: Variables Description and Measurement

Symbols	Variable	Measurement	Data source	Previous recent studies that utilized the variable
EP1	Energy poverty 1	Access to electricity (% of population)	World Bank (2020)	Nguyen and Su (2021a,b,c)
EP2	Energy poverty 2	Access to electricity, urban (% of urban population)	World Bank (2020)	Nguyen and Su (2021a,b,c)
EP3	Energy poverty 3	Access to electricity, rural (% of rural population)	World Bank (2020)	Nguyen and Su (2021a,b,c)
EP4	Energy poverty 4	Access to clean fuels and technologies for cooking (% of the population)	World Bank (2020)	Nguyen and Su (2021a,b,c)

EP5	Energy poverty 5	Renewable energy consumption (% of total final energy consumption)	World Bank (2020)	Nguyen and Su (2021c)
EP6	Energy poverty 6	Renewable electricity output (% of total electricity output)	World Bank (2020)	Nguyen et al (2021); Nguyen and Su (2021c)
EP	Energy Poverty Index	Computed using EP1-EP6 via PCA	World Bank for EP1-EP6	As documented above
EF	Ecological footprint	Global hectares per capita	Global Footprint Network Database	Nathaniel and Adeleye (2020); Nathaniel and Khan (2020); Dim nwobi et al.(2021)
FDI	Foreign direct investm ent	Foreign direct investment, net inflows (% of GDP)	World Bank (2020)	Mewamba-Chekem and Noumes si(2021); Zhao et al. (2021)
GDPCP	Gross Domestic Produ ct Per Capita	In constant 2010 US$	World Bank (2020)	Mewamba-Chekem and Noumes si(2021); Zhao et al.(2021)

Note: WDI represents the World Development Indicators database of the World Bank

Source: Authors Computation

3.1.1. Principal Component Analysis

The principal component analysis (PCA) is adopted to construct an energy poverty index using the six variables identified as representing energy poverty in our study. The PCA is a special type of factor analysis that permits the creation of an index by grouping variables together based on their variance. Therefore, a single weighted measure covering energy poverty variables is ideal in understanding the trends, jumps, clusters, and outliers between energy poverty and environmental quality. According to Ahmed et al. (2020), the PCA comprises standardized variables creation, determination of eigenvectors, etc.

3.2 *Model Specification*

The main goal is to investigate how energy poverty impacts environmental quality (ecological footprint). In trying to achieve this, variables such as Foreign Direct Investment (FDI) and Gross Domestic Product per capita (GDPpc) were used as control variables. Resulting from the studies of Nguyen and Su (2021c) and Zhao et al. (2021), we specify the model's functional form, as:

$$EF = f\ (EP\_P, EP\_N, GDPpc, FDI) \qquad (1)$$

Where: EF is Ecological Footprint, representing environmental quality indicator. EP_P is the positive effect of energy poverty while EP_N is the negative effect of energy poverty. GDPpc is Gross Domestic Product per capita while FDI represents Foreign Direct Investment (FDI).

The regression form and log transformation of equation 1areas follows:

$$LEF = \alpha_0 + \alpha_1 EP\_P_{it} + \alpha_2 EP\_N_{it} + \alpha_3 LRGDPpc_{it} + \alpha_4 LFDI_{it} + \varepsilon_{it} \qquad (2)$$

Where: L stands for the natural log of the variables presented in Equation 1. ε_{it} is the error term, the subscripts 'i' and 't' represent the country (i = 1. . .n) and time (2000-2020). The coefficients, α1, α2,α3, and α4 denote the long-run elasticity estimates of the explanatory variables.

3.2.1. *Panel Non-linear ARDL*

The Shin et al (2014) non-linear autoregressive approach is used in panel form in this investigation. This simply implies that the dynamic heterogeneous panel utilized for larger T panels has a non-linear representation. The basis for this approach is that the panel data are of big T and small N type (i.e., T > N size), referred to as a dynamic heterogeneous panel data, with N=5 and N=4 nations for the model, and T = 21 years. Another justification is that the technique enables us to observe asymmetries nonlinearly, thus violating linear assumptions. Furthermore, the justification for using this technique is that it enables the estimation of both long-run and short-run elasticities for series that are stationary at first difference [I(1)] or a mixture of first difference [I(1)] and level [I(0)] but not more than I(1), as well as determining the possibility of an asymmetric effect of positive and negative cause variables on the effect variable over long and short term periods.

Consequently, the following linear equations are developed to describe the long-run link between energy poverty, GDPpc, FDI, and environmental quality:

$$LEF_{it} = \beta_{0i} + \beta_{1i}EP\_P_{t-1} + \beta_{2i}EP\_N_{t-1} + \beta_{3i}LGDPpc_{t-1} + \beta_{4i}LFDI_{t-1} + \mu_{it} \quad (3)$$

i = 1,2 3……….N;, T = 1, 2, 3,……..T

where = LEF_{it} is the log of the ecological footprint for each unit 'i' over time 't'; EP_P_t denotes positive shock to energy poverty index at period 't'; EP_N_t denotes the negative shock to energy poverty index at period 't'; LGDPpc is the log of Gross Domestic Product per capita at period 't'; and $LFDI_t$ stands for the log of Foreign Direct Investment.$\beta_{1\text{-}4}$ are the long-run coefficients, while μ_{it} is the error term.

This study builds on the works of Teng et al. (2021) and Hotak et al. (2020), who both applied the panel linear ARDL on time series data, as well as Munir and Riaz (2020), who also utilised the NARDL on time series data, to construct the non-linear panel form of the model in order to obtain the long-run and short-run asymmetric association among the variables. We, therefore, derive the following panel non-linear equation:

$$EF_{it} = \partial_{0i} + \partial_{1i}LEF_{t-1} + \partial_{2i}^{+}EP\_P_{t-1}^{+} + \partial_{2i}^{-}EP\_N_{t-1}^{-} + \delta_{3i}IGDPC_{t-1} + \delta_{3i}IFDI_{t-1} + \mu_{it} \quad 4$$

Where ∂_{it} indicates coefficient vectors for long-run parameters to be estimated and $EP\_P_{t-1}^{+}$ and $EP_N_{t-1}^{-}$indicate the positive and negative partial sum process variation in EP. The values of $EP\_P_{t-1}^{+}$ and $Ep_N_{t-1}^{-}$can be obtained via the following equations (4a and 4b).

$$lEP\_P_{it}^{+} = \sum_{j=1}^{t} \Delta EP_{P_{jt}}^{+} = \sum_{j=1}^{t} = max\left(\Delta EP_{P_{jt}}, 0\right) \quad (4a)$$

$$lEP\_N_{it}^{-} = \sum_{j=1}^{t} \Delta EP\_N_{jt}^{-} \quad = \sum_{j=1}^{t} = min(\Delta EP\_N_{jt}, 0) \qquad (4b)$$

In order to derive the asymmetric PARDL estimates by differentiating it from the long-run and short-run asymmetric linkages, we substitute equations 4a and 4b into equation 3 and obtain the following equation;

$$\begin{aligned} LEF_{it} = {} & \vartheta_{0i} + \vartheta_{1i} LEF_{t-1} + \vartheta_{2i}^{+} EP_{t-1}^{+} + \vartheta_{2i}^{-} EP_{t-1}^{-} + \vartheta_{4i} LGDPC_{t-1} + \vartheta_{4i} LFDI_{t-1} \\ & + \sum_{j=1}^{\rho 1} \gamma_{ij} \Delta lEF_{i,i-j} \\ & + \sum_{j=0}^{\rho 2} \lambda_{ij} \Delta EP_{t-j}^{+} + \sum_{j=0}^{\rho 3} \lambda_{ij} \Delta EP_{t-j}^{-} \sum_{j=0}^{\rho 4} \lambda_{ij} \Delta LGDPC_{t-j} + \sum_{j=0}^{\rho 5} \lambda_{,ij} \Delta lFDI_{i-j} + \mu i \\ & + \quad \varepsilon t \end{aligned} \qquad 5$$

Where Δ represent differenced variables, $\rho 1$ to $\rho 4$ are the respective lag orders, ϑ = (ϑ_{1i}, ϑ_{2i}^{+} and ϑ_{2i}^{-}) are the coefficients of the long-run positive and negative shocks to EP on ecological footprint, while $\sum_{j=0}^{\rho 2} \gamma_{,ij} \Delta EP\_P_{i-j}^{+} + \sum_{j=0}^{\rho 3} \gamma_{3,ij} \Delta EP\_N_{i-j}^{-}$ contain the short-run positive and negative effects of energy poverty on ecological footprint. Also, the long-run impact of positive and negative shocks to the EF can be calculated as λ = – $\vartheta_{2i}\vartheta_{1i}$.

3.2.2. ***Cross-sectional dependence Test and Panel Unit Root Tests***

If cross-sectional dependency is present across data panels, the preferred unit root test is the second generation unit root test, which includes SURADF, CADF, and CIPS. When there is cross-sectional dependence between nations, such as in this study, the cross-sectionally Augmented Im, Pesaran, and Shin (CIPS) panel unit root test is recommended.

4. CHAPTER FOUR: PRESENTATION OF RESULTS AND DISCUSSION

In this chapter, results of the study are presented, interpreted and discussed.

4.1. *Cross-Sectional Dependence and Unit Root Tests*

Table 2 reveals that the Pesaran CD exhibits the presence of cross-sectional dependence because the null hypothesis of no cross sectional dependence is rejected at 1% and 5% levels of significance for all the variables in all the region of ECOWAS. This requires a second generational panel unit root test which allows for cross-sectional dependency.

Table 2: Cross Sectional Dependence Test Result for ECOWAS nations

Variables	*Breusch-Pagan LM*	*Pesaran scaled LM*	*Bias-corrected scaled LM*	*Pesaran CD*
LEF	150.2356***(0.0000)	13.46280*** (0.0000)	13.225*** (0.0000)	3.087***(0.0020)
EP_P	307.763*** (0.0000)	32.027***(0.0000)	31.791*** (0.0000)	14.671***(0.0000)
EP_N	491.868*** (0.0000)	53.724*** (0.0000)	53.487*** (0.0000)	13.446*** (0.0000)
LGDPC	492.191*** (0.0000)	53.762*** (0.0000)	53.525*** (0.0000)	21.845***(0.0000)
LFDI	89.362*** (0.0076)	6.288*** (0.0000)	6.0519*** (0.0000)	0.204** (0.0231)

Note: values in brackets are the probability values. ** and *** denote 5% and 10% levels of significance respectively.

Source: Researcher's computation.

The Pesaran panel unit root test for presence of cross-sectional dependence (CIPS) is contained in table 3.

Table 3: CIPS Result (second generation Panel Unit Root test)

	ECOWAS COUNTRIES		
Variables	Level	Ist Diff	Decision
LCF	-1.724	-4.534	I(1)
EP_P	-3.092	-4.615	I(0)
EP_N	-1.994	-4.988	I(1)
LGDPC	-1.752	-3.487	I(1)
LFDI	-1.898	-4.785	I(1)
	critical values		
	10%	5%	1%
	-2.21	-2.34	-2.6

The CIPS test in table 3 indicates that all variables in West African nations are integrated of order one, with the exception of the positive value of the energy poverty index, which is integrated of order zero. Hence, there is mixed order of integration which attracts the use of Panel ARDL in a non-linear system.

4.2. Panel Non-Linear ARDL results

Table 4 consists of the estimates of the panel Non-linear ARDL for the ECOWAS nations. Both the mean group and pool mean group estimates of the ARDL method were estimated and selections between the two specifications were made based on the Hausman test. The null hypothesis of Hausman states that the PMG estimator is more appropriate, but where otherwise MG is better. Hence, based on the insignificant nature of the output of the Hausman test probability values, the PMG estimator becomes the most efficient estimator for modelling the environmental – energy poverty index linkage for the region. The results of both long-run and short-run asymmetry are shown below the short-run estimates. The null hypothesis of the asymmetric test asserts that there exist no asymmetric or nonlinear relationships between the variables of interest, whereas the alternative hypothesis posits that there is a nonlinear or asymmetric link.

Findings show that reducing energy poverty significantly reduces emissions via ecological footprint in the long run at both 10% and 5% level of significance but increasing energy poverty harms the environment. In the short run, positive shocks to energy poverty increases the chances of environmental degradation in the short run significantly although negative shocks to energy poverty do not affect environmental quality significantly in the same time period. In the long and short run, however, increase in economic expansion contributes considerably to an increasing ecological footprint. Furthermore, FDI, in both time periods, does not determine the ecological impact significantly.

Furthermore, the long-run asymmetric test indicates a Wald test probability value of 0.114 for ECOWAS nations. This implies that the null hypothesis is accepted, indicating that there exist no long-run asymmetric association between energy poverty and environmental quality in the ECOWAS countries. Similarly, the probability value of the Wald test for short-run asymmetry is 0.024. This means there exists short-run asymmetric linkage between energy poverty and ecological footprint in ECOWAS region.

Table 4: Panel Non-linear ARDL Result

	Mean Group		*Pool Mean Group*	
Variables	***Coefficient***	***Prob***	***Coefficient***	***Prob***
	ECOWAS COUNTRIES			
Long Run Elasticities				
Constant	*-1.085*	0.600	*0.521*	0.001
EP_P	*-0.097*	0.682	*0.018*	0.074
EP_N	*-0.474*	0.314	*0.037*	0.000
LGDPC	*0.952*	0.227	*0.224*	0.000
LFDI	*-0.350*	0.373	*0.005*	0.290
Shor Run Elasticities				
ECT(-1)	*-0.756*	*0.000*	*-0.412*	0.001
EP_P	*0.088*	0.062	*0.081*	0.047
EP_N	*-0.031*	0.316	*0.024*	0.497
LGDPC	*0.655*	0.051	*1.164*	0.007
LFDI	*-0.050*	0.044	*-0.014*	0.269
Asymmetric relationship				
Long run Asymetery				
EP	*2.49*	0.014		
Short Run Asymetery				
EP	*2.99*	0.124		
Hausman test		0.9389		

The coefficients of ECT (Error correction term) is negative and statistically significant with the ECT value being -0.412. The negative and significant coefficient of ECM met *the a priori* expectation and as such suggesting that errors are corrected annually at the adjustment speed of 41% from short run to long-run in the region.

4.3. Discussion of Results

We started with a cross-sectional dependence test to guide us on the type of unit root test to adopt (that is the generation of panel unit root test). The CSD test shows the presence of cross-sectional dependency across the ECOWAS nations under study. Hence, we employed CIPS which is a second-generation stationarity test usually employed in the case of cross-sectional dependence outcomes. Overall, the stationarity test demonstrates that the variables are mixed order integrated. Thus, variables are integrated of both order one and zero [I(1) and I(0)].

The pool mean group of the panel non-linear ARDL shows that for the case of ECOWAS sub-region, increase in positive shocks to energy poverty significantly increases emissions via ecological footprint in the short run while decrease in positive shocks to energy poverty reduces environmental degradation. Conversely, an increase or decrease in negative shocks to energy poverty has no significant effect on environmental quality in the short run. This result confirms that energy poverty is an important determinant of environmental quality and both are related symmetrically.

Similarly, the pool mean group of the panel non-linear ARDL also shows that for the case of ECOWAS sub-region, reducing energy poverty significantly reduces emissions via ecological footprint in the long run at 10% and 5% levels of significance but increasing energy poverty hurts the environment significantly. These findings attune with the outcome of Chakravarty and Tavoni (2013) and Pereira et al. (2019) but contradicts the findings of Gonzalez-Eguino (2015). In the long and short run, however, economic expansion contributes considerably to an increasing ecological imprint. In both time periods, FDI does not determine the ecological impact.

The outcome of the study further shows that economic growth results in a significant increase in pollution via the ecological footprint in ECOWAS countries in both short and long runs. The explanation for the adverse effect of economic growth on the environment is predicated on the fact that ECOWAS sub-regions had considerable development in the last three decades, which has increased energy demand. The environmental impact of economic expansion is also influenced by the fact that inefficient industrial processes and practices are prevalent in this sub-region. The sub-region's growth drive is not environmentally friendly, and the main task is to discover ways to expand their economy without harming the environment. this is highlighted in the studies of Dimnwobi et al. 2021, which is in consonance with Onuoha et al. (2021) for African nations and Ahmed et al. (2020) for Latin American and Caribbean countries while contradicting Nathaniel and Iheonu (2019).

The study found that FDI has no substantial or significant impact on the ecological footprint of ECOWAS countries. Although, Adams and Klobodu (2018) supports the technological transfer theory which avers that when a country's economy opens up, knowledge, skills and technology become available and the implications of the effects of these available technologies and knowledge is contingent on the various policies in the economy. However, the results obtained for ECOWAS show that this sub-region has not been carried away with the several advantages of FDI and may have implemented stringent policies that lower the negative influence of FDI on the environment.

The coefficient of error correction term (ECT) for ECOWAS is correctly signed (-0.412) and statistically significant (prob. 0.001). The negative and significant coefficient of ECM met *a priori* expectation and as such suggests that errors are corrected annually at the adjustment speed of 41% respectively from short run to long-run in the respective regions.

Furthermore, the long-run asymmetric test indicates a Wald test probability value of 0.014 for ECOWAS. This implies that the null hypothesis is rejected for ECOWAS sub-region indicating that a long-run asymmetric association does exist between energy poverty and environmental quality, while a short term non-linear relationship does exists between environmental quality and energy poverty index (0.124). This result confirms the presence of the Environmental Kuznet Curve (EKC) Hypothesis although in the long run. The short and long run results show that increase in income increases environmental degradation although this positive relationship may not be sustained for a long time. As policy makers take positive actions on environmental protection policies in the midst of development programmes, a negative relationship could ensue. But this could only happen in the long run as evidenced by the significant asymmetric relationship of the result of the study.

5. CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATION

This study is set out to determine the nexus between energy poverty and environmental quality in ECOWAS sub-Region employing composite measures of energy poverty (access to electricity, urban electrification, rural electrification, access to modern and clean energy, renewable electricity output and renewable energy consumption) and ecological footprint to proxy environmental quality, while FDI and GDPpc were introduced as control variables. Furthermore, to deal with geographic heterogeneity and possible disparities in energy poverty and environmental consequences across countries, this investigation focused distinctively on panel data from 2000 to 2020. For estimation purposes, the CIPS was adopted bearing in mind the presence of cross-sectional dependence outcomes, while the Panel Non-linear ARDL was applied as a result.

Major findings confirm that increase or decrease in energy poverty in ECOWAS nations increases or decreases environmental quality in the long run. This implies that energy poverty is an important determination of environmental degradation in ECOWAS sub-Region in the long run. Akin to this finding, this study also found symmetric and asymmetric relationship between energy poverty, economic growth and environmental quality in the long run, thus, confirming the presence of Environmental Kuznet Curve (EKC) Hypothesis for ECOWAS sub-Region, while EKC is not confirmed in the short run. The study also confirms the significance of energy poverty and economic growth in determining environmental quality in ECOWAS sub-Region in the short run.

Concluding this study, it has been found that improvement in energy poverty is critical in ensuring quality environment. In order to achieve this, renewable and clean energy sources and use should be promoted by the government and stakeholders so as to protect the environment. Since poverty is a rising phenomenon in many ECOWAS countries, there is need for deliberate efforts to grow the income of these countries, which must trickle down and become inclusive in order to help poor households have access to cleaner energy. In growing the income of the nation, government must be careful not to do so at the detriment of the environment.

The following policy recommendations are made based on the presented findings. ECOWAS nations should deepen environmental sustainability policies through enhanced cooperation by governments, regulatory agencies, economic actors, and international development partners to guarantee that energy sector policies align with environmental aspirations. Awareness on promoting energy efficiency and environmentally friendly production and consumption practices by the populace should be stepped up. Specifically, the sub-region's policymakers need to enforce policies tailored to the scope and capabilities of households, enterprises, and institutions towards embracing renewable energy, through bolstering consumption incentives and/or supporting investments that deploy green technology. To dissuade polluters from damaging the environment, policymakers should consider the utilization of market-oriented mechanisms like eco or carbon taxes and the 'polluter-pays' concept as a deterrent measure.

For energy poverty to be addressed, supportive efforts by governments are critical by enhancing investments and subsidies to aggressively build energy infrastructure, including gas pipelines and electricity grids to improve inhabitants' access to green, affordable and efficient energy. Again, the need to explore and exploit the wealth of renewable energy sources (especially to boost rural electricity access) should be of utmost importance to ensure seamless energy transition without jeopardizing energy supply. The widespread usage of polluting fossil fuels and other inefficient energy resources in ECOWAS sub-Region demonstrates this. In addition to releasing serious environmental pollutants, these hazardous energy choices are becoming a worrying cause of growing occurrences of respiratory ailments, cancer and other medical problems.

On the other hand, the higher degree of economic development in ECOWAS sub-Region with lesser energy poverty can help to eliminate energy poverty and advance environmental progress. Governments in this region should pursue policies that further encourage clean energy production and consumption while maintaining a healthy feedback channel to monitor the efficacy of policy actions. The level of energy sector governance in the region should be transparent, inclusive and effective to avert possible bottlenecks that undermine efficient operations in the sector. This will ensure the existence of quality institutions to preclude corruption and maladministration in the energy space.

Given the capital-intensive nature of energy infrastructure projects and the domestic funding gap within the sub-region, it is no surprise that foreign direct investment leads to an insignificant increase in ecological footprint in sub-region. This was highlighted in our findings that FDI has no significant influence on EF. Initiatives that attract increased green FDI should be paramount for regional policymakers to revisit existing investment promotion policies to expand the inflows towards eco-friendly energy sector financing. To foster the revolution of the regional energy industry, their governments should emphasize the establishment of an enabling energy investment climate, with a specific focus on renewable energy sectors, knowledge, and technology-based investment. Furthermore, because FDI promotion policy falls under the umbrella of macroeconomic policy, sound macroeconomic management is required to account for foreign exchange instabilities, balance of payment imbalances, devaluation issues, and overall financial sector development that will allow for consistent returns and rightful allotment of economic dividends.

Finally, improving environmental quality is a critical component of the United Nations Sustainable Development Agenda, which was launched in 2015. With less than eight years until the 2030 deadline, ECOWAS nations are urged to undertake aggressive efforts to address energy poverty, economic growth difficulties, and environmental quality for the benefit of their countries and people, as well as the rest of the globe.

References

Adams, S., & Klobodu, E. K. M. (2018) Financial development and environmental degradation: Does political regime matter? Journal of Clean Production 197: 1472-1479.https://doi.org/10.1016/j.jclepro.2018.06.252

Acheampong, A. O., Adams, S., and Boateng, E. (2019). Do globalization and renewable energy contribute to carbon emissions mitigation in Sub-Saharan Africa? Science Total Environmen. https://doi.org/10.1016/j.scitotenv.2019.04.353

Ahmed Z, Nathaniel SP, Shahbaz M (2020) The criticality of information and communication technology and human capital in environmental sustainability: evidence from Latin American and Caribbean countries. J Clean Prod. https://doi.org/10.1016/j.jclepro.2020.125529

Aluko, O. A., & Obalade, A. A. (2020). Financial development and environmental quality in sub-Saharan-Africa: is there a technology effect? Sci Total Environ. http://dx.doi.org/10.1016/j.scitotenv.2020.141515

Bouzarvoski, S. & Petrova, S. (2015). A global perspective on domestic energy deprivation: Overcoming the energy poverty-fuel poverty binary. *Energy Research and Social Science, 10*, 31-40

Chakravarty S, Tavoni M (2013) Energy poverty alleviation and climate change mitigation: Is there a trade off? Energy Econ 40: S67–S73. https://doi.org/10.1016/j.eneco.2013.09.022

Chontanawat, J., Hunt, L. C., and Pier se, R, G. (2018). Causality between energy consumption and GDP: Evidence from 30 OECD and 78 non-OECD countries. Surrey Energy Economics Discussion Paper

Coskuner, C., Khaligh, M., Olasehinde-Williams, G., and Akadiri, S. (2020). Economic and social determinants of carbon emissions: Evidence from Organisation of Petroleum Exporting Countries. Journal of Public Affairs, 20(2-3). DOI:10.1002/pa.2092

Churchill SA, Smyth R (2020) Ethnic diversity, energy poverty and the mediating role of trust:Evidence from household panel data for Australia. Energy Econ. https://doi.org/10.1016/j.eneco.2020.104663

Davis, M. (1998). Fuel choice in rural communities. *Energy for Sustainable Development, 2*(3); 45-48.

DeBruyn, S. M., Bergh, J. V. D., and Opschoor, J. B. (1998). Economic growth and emissions: Reconsidering the empirical basis of environmental Kuznets curves. *Ecological Economics, 25*(2), 161-175.

Dimnwobi, S. K., Ekesiobi, C., Madichie, C. V., & Asongu, S. A. (2021). Population dynamics and environmental quality in Africa. Science Total Environment. https://doi.org/10.1016/j.scitotenv .2021.149172

Wang J, Dong K (2018) What drives environmental degradation? Evidence from 14 Sub-SaharanAfrican countries. Sci Total Environ 656: 165-173. https://doi.org/10.1016/j.scitotenv.2018.11.354

Fullerton, D. G., Bruce, N., & Gordon, S. B. (2008). Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. *Trans Roy Soc Trop Med Hyg, 102*: 843-851.

González-Eguino M (2015) Energy poverty: an overview. Renew Sustain Energy Rev 47: 377-385. https://doi.org/10.1016/j.rser.2015.03.013

Heltberg, R. (2005). Factors determining household fuel from eight developing countries. *Energy Economics*, *26*(5), 869-887

Hotak S, Islam M, Kakinaka M, Kotani K (2020) Carbon emissions and carbon trade balances: international evidence from panel ARDL analysis. Environ Sci Pollut Res 27: 24115-24128. https://doi.org/10.1007/s11356-020-08478-w

IEA (2014), "Outlook for African Energy to 2040", in *World Energy Outlook 2014*, International Energy Agency, Paris, https://doi.org/10.1787/weo-2014-16-en .

IEA (2017). Energy Access Outlook 2017. IEA, Paris. Available at:https://www.iea.org/publications/freepublications/publication/WEO2017SpecialReport_EnergyAccessOutlook.pdf

IEA (2018) *World Energy Outlook 2018*. IEA, Paris. Available at: https://www.iea.org/weo2018/

International Energy Agency (2010). Energy poverty: How to make modern energy access universal? Paris, France: IEA

Iheonu, C. O., Anyanwu, O. C., Odo, O. K., & Nathaniel, S. P. (2021) Does economic growth, international trade, and urbanization uphold environmental sustainability In sub-Saharan Africa? Insights from quantile and causality Procedures .Environ Science Pollution Research. https://doi.org/10.1007/s11356-021-12539-z

Kaygusuz, K. (2011). Energy services and energy poverty for sustainable rural development. *Renewable and Sustainable Energy Reviews*, *15*(2), 936-947

Kohlin, G., Sills, E. O., Pattanayak, S. K. & Wilfong, C. (2011). Energy, gender and development: What are the linkages? Where is the evidence? World Bank Policy Research Working Paper No. 5800.

Lin, B., Omoju, O. E., Nwakeze, N. M., Okonkwo, J. U., & Megbowon, E. T. (2016) Is the environmental Kuznets curve hypothesis a sound basis for environmental policy In

Africa?*Journal Clean Production 133*: 712-724.ttps://doi.org/10.1016/j.jclepro.2016.05.173

Mewamba-Chekem J, Noumessi FW (2021) Do energy poverty and energy consumption drive CO2 emissions? evidence from Sub-Saharan Africa. South Asian J Soc StudEcon 11(4): 23-37

Munir K, Riaz N (2020) Asymmetric impact of energy consumption on environmental degradation: evidence from Australia, China, and USA. Environ Science PollutionRes 27: 11749-11759. https://doi.org/10.1007/s11356-020-07777-6

Nathaniel, S. P., & Adeleye, N. (2020). Environmental preservation amidst carbon emissions, energy consumption and urbanization in selected African countries Implication for sustainability.J Clean Prod. https://doi.org/10.1016/j.jclepro.2020.125409

Nathaniel, S. P., & Iheonu, C. O. (2019). Carbon dioxide abatement in Africa: The role of renewable and non-renewable energy consumption. Science Total Environment. https://doi.org/10.1016/j.scitotenv.2019.05.0

Nathaniel, S., & Khan, S. A. R. (2020). The nexus between urbanization, renewable energy, trade and ecological footprint in ASEAN countries. J Clean Prod. https://doi.org/10.1016/j.jclepro.2 020.122709

Ntarmah, A. H., Kong, Y., & Manu, E. K. (2020). Investigating the dynamic relationships between credit supply, economic growth, and the environment: Empirical evidence of sub-regional economies in sub Saharan Africa. Environ Science Pollution Reseach. https://doi.org/10.1007/s11356-020-10875-0

Nigeria Electricity Hub (2017a). Retrieved June 12, 2018:http://www.nigeriaelectricityhub.com/2017/05/22/ how-nigeria-can-fix-power-sector/

Nigeria Energy Support Programme, (2015). The Nigerian energy sector: An overview with special emphasis on renewable energy, energy efficiency and rural electrification , Abuja: NESP.

Nussbaumer, P., Bazilian, M. & Modi, V. (2012). Measuring energy poverty: Focusing on what matters. *Renewable and Sustainable Energy Reviews, 16*(1), 231-243.

Nguyen CP, Su T D, Bui TD, Dang VTB, Nguyen BQ (2021) Financial development and energypoverty: global evidence. Environ Sci Pollut Res 28(26): 35188-35225.

https:// doi.org/10.1007/s11356-021-13038-x

Nguyen CP, Su TD (2021a) Does energy poverty matter for gender inequality? Global evidence. Energy Sust Dev 64: 35-45. https://doi.org/10.1016/j.esd.2021.07.003

Nguyen CP, Su TD (2021b) The influences of government spending on energy poverty: evidence from developing countries. Energy.https://doi.org/10.1016/j.energy.2021.121785

Nguyen CP, Su TD (2021c) The “vicious cycle” of energy poverty and productivity: insights from 45 developing countries. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-021-14614-x

Ogwumike, F. O., Ozughalu, U. M. & Abiona, G. A. (2014). Household energy use and determinants: Evidence from Nigeria. *International Journal of Energy Economic and Policy, 4*(2), 248-262.

Onuoha, F. C., Uzoechina, B. I., Ochuba, O. I., & Inyang, N. F. (2021). Economic expansion, energy sources and environmental quality in ECOWAS sub-region: evidence from a heterogeneous panel non linear Autoregressive Distributed Lag (PNARDL).Environ Sci

Pollut Res. https://doi.org/10.1007/s11356-021-16173-7.

Ozughalu, U. M & Ogwumike FO (2018). Extreme energy poverty incidence and determinants in Nigeria: A multidimensional approach. Soc Indic Res.https://doi.org/10.1007/s11205- 018-1954-8

Pachauri, S., Mueller, A., Kemmler, A., & Spreng, D. (2004). On measuring energy poverty in

Indian households. *World Development Vol. 32(12)* 2083-2104.

Pachauri, S. & Spreng, D. (2011). Measuring and monitoring energy poverty. *Energy Policy, 36*(11), 4022-4035.

Pereira, M. G., Silva, N. F. D. & Freitas, M. A. V. (2019) Energy transition: The nexus between poverty and CO2 emissions in Brazil. International Journal Innovative Sustainable Development 13: 376-391. https://doi.org/10. 1504/IJISD.2019.100398.

Reddy, B. S., & Srinivas, T. (2009). Energy use in Indian household sector: An actor-oriented approach. *Energy, 34,* 992-1002.

Reddy, B.S. (2015). Access to modern energy services: An economic and policy framework.

Renewable and Sustainable Energy Reviews. 47 (2015): 198-212.

Rigaud, K. K., A. de Sherbinin, B. Jones, J. Bergmann, V. Clement, K. Ober, J. Schewe, S. Adamo, B. McCusker, S. Heuser, A. Midgley (2018f), Groundswell: Preparing for Internal Climate Migration. World Bank, Washington DC. Available at: https://openknowledge.worldbank.org/handle/10986/29461.

Rinne, S. T., Rodas, E. J., Rinne, M. L., Simpson, J. M., & Glickman, L. T. (2007). Use of biomass fuel is associated with infant mortality and child health in trend analysis. American Journal Tropical Medicine Hyg 76: 585-591.

Román-Collado (2018). Towards a sustainable growth in Latin America: A multiregional spatial decomposition analysis of the driving forces behind CO2 emissions changes. *Energy Policy 115*. Doi: 10.1016/j.empol.2018.01.019

Salman, M., Long, X and Muhammad, S. (2019). Different impacts of export and import on carbon emissions across 7 ASEAN countries: A panel quantile regression approach. Science of the Total Environment. DOI: 10.1016/j.scitotenv.2019.06.019

Sokolowski, J. Lewandowski, P., Kielezewska, A., & Bouzarovski, S. (2020). A multidimensional index to measure energy poverty: The Polish case. *Energy Sources, Part B. Economics and Policy*, 1-20.

Sarkodie, S. A. (2018). The invisible hand and EKC hypothesis: What are the drivers of environmental degradation and pollution in Africa? Environ Sci Pollut Res 25(22): 21 993-22022. https://doi.org/10.1007/s11356-018-2347-x

Shahbaz M, Solarin SA, Sbia R, Bibi S (2015) Does energy intensity contribute to CO2 emissions?a trivariate analysis in selected African countries. Eco Ind 50: 215-224. Htt ps:// doi.org/10.1016/j.ecolind.2014.11.007

Shin Y, Yu B, Greenwood-Nimmo M (2014) Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In: Festschrift in honor of Peter Schmidt. Springer, New York, pp 281-314

Shuai, C., Shen, L., Jiao, L., and Tan, Y. (2017). Identifying key impact factors on carbon emission: Evidences from panel and time-series data of 125 countries from 1990 to 2011. Applied Energy, 187, 310-325. DOI: 10.1016/j.apenergy.2016.11.029.

Solarin, S. A., & Al-Mulali, U. (2018) Influence of foreign direct investment on indicators of environmental degradation. Environ Sci Pollut Res 25: 24845-24859.

https://doi.org/10.1007/s11356-018-2562-5

Sustainable Energy for All (2017). Sustainable energy for all forum held at Duggal Greenhouse in Brooklyn, New York from April 3 – 5, 2017.

Teng, J. Z., Khan, M. K., Khan, M. I., Chishti, M. Z., and Khan, M. O. (2021). Effect of foreign direct investment on CO2 emission with the role of globalization, institutional quality with pooled mean group panel ARDL. Environ Sci Pollut Res 28(5):5271–5282

USAID (2018c) Nigeria Power Africa Fact Sheet. Available at: https://www.usaid.gov/powerafrica/nigeria United States Agency for International Development (USAID) (2020). Nigeria power Africa fact sheet. Accessed from https://www.usaid.gov/powerafrica/nigeria. Accessed 5th March, 2022.

USAID, Power Africa. (2018). Power Africa Fact Sheet. Available at: https://www.usaid.gov/powerafrica/nigeria

World Health Organization (2018) Household air pollution and health. World Health Organization, Geneva.

World Bank (2020) World Development Indicators. World Bank, Washington DC

Wu, S., Zheng, X., You, C., & Wei, C. (2018). Household energy consumption in rural China:Historicaldevelopment, present pattern and policy implication. J Clean Prod https://doi.o rg /10.1016/j.jclepro.2018.11.265

Zhao J, Jiang Q, Dong X, Dong K (2021) Assessing energy poverty and its effect on CO2 emissions: the case of China. Energy Econ. https://doi.org/10.1016/j.eneco.2021.105191