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Alternatif Enerji Kaynaklarının Petrol İhracatçısı Ülkeler Üzerindeki Ekonomik ve Çevresel Etkileri: Afrika Ülkeleri Üzerine Ampirik Bir Uygulama

Research Topic (ENGLISH)

Economic and Environmental Impacts of Alternative Energy Sources on Oil Exporting Countries: An Empirical Application on African countries

Danışman

Doç. Dr. Savaş ERDOĞAN

Hazırlayan

Stephen Taiwo ONIFADE

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ABSTRACT

Considering Africa's long standing historical experience with socioeconomic challenges over the years, most governments and policymakers are mainly concerned about strategy to stimulate economic growth and stability. However, the growing environmental disasters across the continent in recent times calls for prompt actions in view of Africa's susceptibility to climate change. As such, this thesis assesses the environmental impacts of the energy mix of mainly oil-producing African nations while reviewing the economic aspects of the decarbonization prospects from the perspectives of fossil energy dependence among the countries. The research also examines the illustrious Environmental Kuznets Curve (EKC) hypothesis in different frameworks of fossil energy resources abundance among the countries using a combination of econometric and analytical tools such as quantile regression (QR) approach, dynamic ordinary least square (DOLS), fully modified ordinary least square (DOLS), and the augmented mean group (AMG) among others. Empirical analyses were in three sub-groups. The first group examines the nexus of environmental pollution and energy dynamics in a globalized world. The second analysis focuses on the nexus of environmental degradation and urbanization in an ecological footprint framework. The third examines the nexus of environmental pollution with energy resources abundance in a sectoral composition framework. The two main convergence points in the three sub-categories of analysis are the usage of oil-producing African states and the exploration of the EKC hypothesis while minimal divergence points exist in the individual sample sizes and methodological procedures. From the simulations, only renewable energy use proved to be a significant decarbonization tool while the consequences of the trio of fossil fuel consumption, income growth, and globalization are diametrically opposed to achieving decarbonization. Furthermore, urbanization is inimical to environmental sustainability as urban sprawl significantly acts as a pollutant-inducing tool. Overall, the EKC conjecture does not hold convincingly since its validity significantly varies across the three sub-groups of analysis. Therefore, to foster environmental sustainability via decarbonization and to further promote the actualization of SDGs 12&13 and SDGs 1&8 among the countries, the

research recommends energy portfolios diversification alongside economic diversification and green urban infrastructural investments to address the undesirable environmental impacts of fossil energy consumption and forestall the economic demerits of resource dependency in the event of energy transition away from fossil fuels.

Keywords: Africa, Greenhouse gas (GHG) emission, Resource abundance; EKC; Renewable & Fossil Energy Consumption, Decarbonization, Ecological Footprint, Urbanization, Globalization, Sustainable Development Goals (SDGs).

ÖZET

Afrika'daki politika yapıcılar ve yetkililer, kıtayı yıllar içinde mahveden sosyoekonomik sorunların uzun tarihi göz önüne alındığında, genellikle ekonomik büyüme ve istikrar konusunda endişe duyuyorlar. Bununla birlikte, kıtanın iklim değişikliğine ve çevresel felaketlere karşı savunmasızlığı göz önüne alındığında, son zamanlarda artan çevresel bozulma zorlukları, yeterli ilgiyi gerektiriyor. Bu tez, esas olarak petrol üreten Afrika ülkelerinin enerji karışımının çevresel etkilerini değerlendirirken, karbonsuzlaştırma beklentilerinin ekonomik yönlerini ülkeler arasındaki fosil enerji bağımlılığı perspektifinden inceliyor. Araştırma ayrıca, nicel regresyon (QR) yaklaşımı, dinamik sıradan en küçük kare (DOLS), tam olarak gibi ekonometrik ve analitik araçların bir kombinasyonunu kullanarak ülkeler arasında fosil enerji kaynaklarının bolluğunun farklı çerçevelerinde ünlü Çevresel Kuznets Eğrisi (EKC) hipotezini incelemektedir. modifiye edilmiş sıradan en küçük kare (DOLS) ve artırılmış ortalama grup (AMG) diğer yaklaşımların yanı sıra. Ampirik analizler üç alt grupta yapılmıştır. Birinci grup, küreselleşmiş bir dünyada çevre kirliliği ve enerji dinamikleri arasındaki ilişkiyi inceliyor. İkinci analiz, ekolojik ayak izi çerçevesinde çevresel bozulma ve kentleşme arasındaki bağlantıya odaklanmaktadır. Üçüncüsü, sektörel kompozisyon çerçevesinde çevre kirliliğinin enerji kaynakları bolluğu ile ilişkisini incelemektedir. Analizin üç alt kategorisindeki iki ana yakınsama noktası, petrol üreten Afrika devletlerinin kullanılması ve EKC hipotezinin araştırılması iken, bireysel numune boyutlarında ve metodolojik prosedürlerde minimum sapma noktaları mevcuttur. Sonuçlardan, fosil yakıt tüketimi, gelir artışı ve küreselleşme üçlüsünün sonuçları karbonsuzlaştırmanın sağlanmasına taban tabana zıtken, yalnızca yenilenebilir enerji kullanımının önemli bir karbonsuzlaştırma aracı olduğu kanıtlandı. Ayrıca, kentsel yayılma önemli ölçüde kirletici tetikleyici bir araç olarak hareket ettiğinden, kentleşme çevresel sürdürülebilirliğe aykırıdır. Genel olarak, geçerliliği analizin üç alt grubu arasında önemli ölçüde değişiklik gösterdiğinden, EKC hipotezi ikna edici bir şekilde desteklenmedi. Bu nedenle, karbondan arındırma yoluyla çevresel sürdürülebilirliği teşvik etmek ve 12&13 SKH'lerinin ve 1 & 8 SKH'lerinin ülkeler arasında hayata geçirilmesini daha da teşvik etmek için, araştırma, fosil enerji tüketiminin istenmeyen çevresel etkilerini ele almak için ekonomik çeşitlendirme ve yeşil kentsel altyapı yatırımlarının yanı sıra enerji portföylerinin çeşitlendirilmesini önermektedir ve enerjinin fosil yakıtlardan uzaklaşması durumunda kaynak bağımlılığının ekonomik zararlarını önlemek

Anahtar Kelimeler: Afrika, Sera gazı (GHG) emisyonu, Kaynak bolluğu; EKK; Yenilenebilir ve Fosil Enerji Tüketimi, Dekarbonizasyon, Ekolojik Ayak İzi, Kentleşme, Küreselleşme, Sürdürülebilir Kalkınma Hedefleri (SKH).

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ABBREVIATIONS

AfDB	African Development Bank
ADF	Augmented Dickey-Fuller test
AIC	Akaike Information Criterion
ARDL	Autoregressive Distributed Lags
AMG	Augmented Mean Group
AU	African Union
B/D (bpd)	Barrels per day (crude oil)
BCM	Billion cubic meters (gas)
BP	British Petroleum
BRICS	Brazil Russia India China & South Africa
CO_2	Carbon dioxide
CH_4	Methane
CPI	Consumer Prices Index
CIS	Commonwealth of Independent States
CSP	Concentrating Solar Power
CD	Cross-sectional Dependency
DOLS	Dynamic Ordinary Least Squares
ECOWAS	Economic Community of West African States
EGR	Emission Gas Report
EU	European Union
EKC	Environmental Kuznets Curve
FDI	Foreign Direct Investment
FMOLS	Fully Modified Ordinary Least Squares
GDP	Gross Domestic Product
GHG	Greenhouse gases
GWh	Gigawatt-hours
Gha	Global hectares
HQ	Hannan-Quinn information criterion

IMF	International Monetary Fund
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
KWh/sq.km	kilowatt-hours per square kilometers per day
KTOE	Kilotons of Oil Equivalent
LM	Lagrange Multiplier
Mb/d	Million barrels per day
m/s	Meters per second
MWh	Megawatt-hours
MENA	Middle East and North African
N_2O	Nitrous oxide
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
OAU	The Organization of African Unity
OPEC	Organization of the Petroleum Exporting Countries
PMG	Pooled Mean Group
PP	Philip Peron tests
PPP	Purchasing Power Parity
PV	Photovoltaics
QR	Quantile Regression
RGDPC	Real Gross Domestic Product Per Capita
SDGs	Sustainable Development Goals
TJ	Terajoule
USD	United States Dollars
UN	United Nations
UNDP	United Nations Development Program
UNEA	United Nation Environment Assembly
UNEP	United Nations Environment Program

UNESCO	the United Nations Educational, Scientific and Cultural Organization
VAR	Vector Autoregressive
VECM	Vector Error Correction Mechanism
WDI	World Development Indicators
WB	World Bank

INTRODUCTION

As the world is gradually shifting from conventional energy consumption to renewable energy, there are both environmental and economic implications involved for various economies. While there are numerous benefits and opportunities in the energy transition from nonrenewable energy to clean or alternative energy, this transition could also pose potential threats to the economic stability of many oil-exporting economies around the world and especially those that are on the African continent.

Understanding the economy and the pattern of its dynamic interdependency with the hope of developing a better and more informed policy framework for solving fundamental economic problems in developing countries especially those in the African continent has become a task many researchers are committed to in recent times. The burden for this research commitment could be traced down to the uniqueness of the continent in terms of its numerous potentials and its future economic prospects.

As it is well known, the continent of Africa ranks second in terms of size among other continents across the globe. It follows up in term of area of land just immediately after the Asian continent with about 30.049 million km^2 approximately (AfDB and UNDP, 2017). Besides. the continent is vastly blessed with numerous endowments. These endowments cover two (2) major aspects of Africa’s characteristics including firstly; the demographic factors (human resources), and secondly; the resources factor (its natural resources reserves).

The continent of Africa has an abundant human resource with a fast-growing youth population. Based on available forecasts by the end of 2019, the Sub-Saharan Africa’s population alone is approximately 1.107 billion people (WDI, 2021). In addition, there are several natural resource endowments all over the continents from west to the east and from the north to the south. These factors combined have therefore made Africa an important economic target for many developed economies as well as the rising emerging economies across the globe. In this regard, the wooing of Africa by foreign countries is often viewed by many as an attempt to support the industrial needs in their domestic economies especially in the case of Western countries such as America and other former colonial masters in Europe (Rodney, 2018). However, there is now a new dimension in recent times as some countries in the Eastern blocks have also joined in the race for this continent. China is currently taking the lead in this regard as it is rapidly growing its influence on the continent (Lyman, 2006; Carmody and Owusu, 2007; Mlambo et al., 2016;).

Ayittey (2016) noted that foreign entities do not visit Africa for Africa's benefits and developments but rather for their own personal gains or interests. While the foregoing statement may be true based on some historical antecedents, there have also been arguments that foreign involvements in Africa could end up being a win-win situation for both Africa and foreign investors (Renard, 2011; Brautigam, 2020; Nnajiofor, 2020). Whichever be the case, the common ground still remains that Africa is richly endowed.

Table 1 shows a list of selected indicators for the 54 countries in Africa including their land area, population estimates, Gross Domestic Product (GDP) estimates in purchasing power parity (PPP) valuation, the GDP per capita, and average annual GDP growth between 2008 and 2016.

Table 1: Selected Basic Indicators for African Countries

Countries	**Population** (In 1000)	**Area of Land** (In 1000 of km2)	**Population density** (Pop. / km2)	**The GDP in PPP** (USD Million)	**The Per Capita GDP** In PPP (USD)	**Average Yearly real GDP growth** (2008-2016)
Algeria	40,376.00	2,382.00	17.00	609,394.00	15,093.00	3.20
Angola	25,831.00	1,247.00	21.00	187,257.00	7,249.00	4.30
Benin	11,167.00	115.00	97.00	24,312.00	2,177.00	4.70

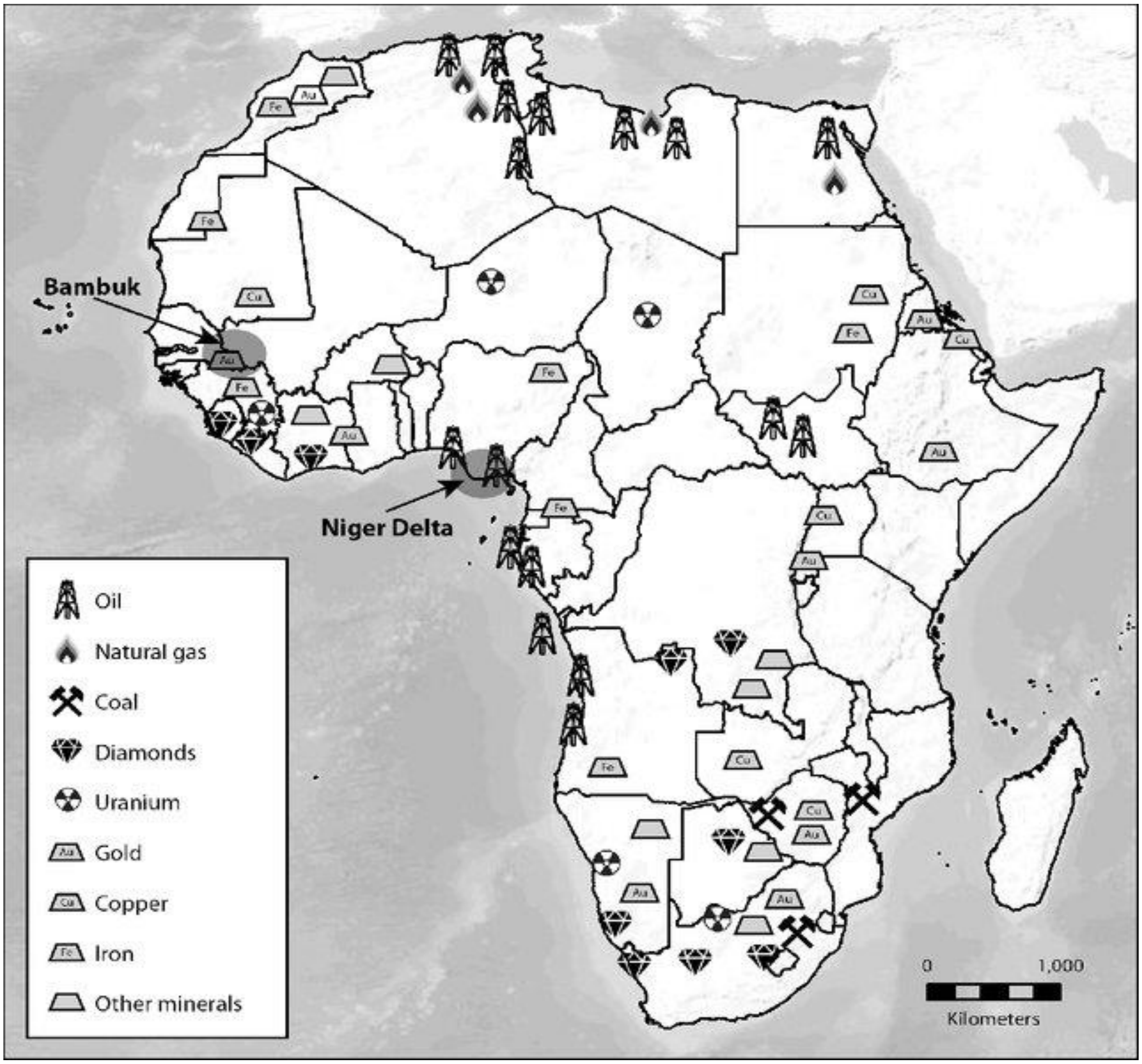
Botswana	2,304.00	582.00	4.00	36,505.00	15,846.00	3.80
Burkina Faso	18,634.00	274.00	68.00	32,985.00	1,770.00	6.40
Burundi	11,553.00	28.00	415.00	7,892.00	683.00	3.00
Cabo Verde	527.00	4.0	131.00	3,583.00	6,799.00	2.50
Cameroon	23,924.00	475.00	50.00	77,237.00	3,228.00	4.30
Central African Republic	4,998.00	623.00	8.00	3,206.00	641.00	-0.10
Chad	14,497.00	1,284.00	11.00	30,587.00	2,110.00	4.10
Comoros	807.00	2.00	434.00	1,259.00	1,560.00	2.30
Congo	4,741.00	342.00	14.00	30,272.00	6,385.00	3.80
Congo, Dem. Rep.	79,723.00	2,345.00	34.00	66,014.00	828.00	6.10
Côte d’Ivoire	23,254.00	322.00	72.00	87,120.00	3,746.00	5.90
Djibouti	900.00	23.00	39.00	3,345.00	3,718.00	5.50
Egypt*	93,384.00	1,001.00	93.00	1,105,039.00	11,833.00	3.80
Equatorial Guinea	870.00	28.00	31.00	31,769.00	36,533.00	-0.40
Eritrea	5,352.00	118.00	46.00	9,169.00	1,713.00	3.20
Ethiopia*	101,853.00	1,104.00	92.00	174,742.00	1,716.00	9.70
Gabon	1,763.00	268.00	7.00	36,218.00	20,542.00	4.50
Gambia	2,055.00	11.00	182.00	3,387.00	1,648.00	3.60

Ghana	28,033.00	239.00	118.00	120,786.00	4,309.00	6.60
Guinea	12,947.00	246.00	53.00	16,084.00	1,242.00	3.00
Guinea-Bissau	1,888.00	36.00	52.00	2,851.00	1,510.00	3.90
Kenya	47,251.00	580.00	81.00	152,735.00	3,232.00	5.30
Lesotho	2,160.00	30.00	71.00	6,019.00	2,786.00	4.40
Liberia	4,615.00	111.00	41.00	3,881.00	841.00	4.70
Libya	6,330.00	1,760.00	4.00	90,892.00	14,359.0	-2.30
Madagascar	24,916.00	587.00	42.00	37,491.00	1,505.00	2.70
Malawi	17,750.00	118.00	150.00	21,227.00	1,196.00	5.20
Mali	18,135.00	1,240.00	15.00	38,085.00	2,100.00	4.40
Mauritania	4,166.00	1,031.00	4.00	16,710.00	4,010.00	3.60
Mauritius	1,277.00	2.00	626.00	25,849.00	20,235.00	3.70
Morocco	34,817.00	447.00	78.00	282,784.00	8,122.00	3.90
Mozambique	28,751.00	799.00	36.00	35,313.00	1,228.00	6.60
Namibia	2,514.00	824.00	3.00	27,035.00	10,754.00	4.00
Niger	20,715.00	1,267.00	16.00	20,266.00	978.00	5.90
Nigeria	186,988.00	924.00	202.00	1,088,938.00	5,824.00	4.80
Rwanda	11,883.00	26.00	451.00	21,970.00	1,849.00	7.20
Sao Tome and Principe	194.00	1.00	202.00	694.00	3,573.00	5.00

Senegal	15,589.00	197.00	79.00	39,717.00	2,548.00	4.70
Seychelles	97.00	0.460	211.00	2,608.00	26,877.00	4.10
Sierra Leone	6,592.00	72.00	91.00	10,636.00	1,613.00	5.00
Somalia	11,079.00	638.00	17.00	-	-	-
South Africa	54,979.00	1,219.00	45.00	736,325.00	13,393.00	1.70
South Sudan	12,733.00	620.00	21.00	20,884.00	1,640.00	-6.00
Sudan	41,176.00	1,886.00	22.00	176,304.00	4,282.00	3.60
Swaziland	1,304.00	17.00	75.00	11,061.00	8,482.00	1.50
Tanzania	55,155.00	947.00	58.00	150,633.00	2,731.00	6.60
Togo	7,497.00	57.00	132.00	11,609.00	1,548.00	4.50
Tunisia	11,375.00	164.00	70.00	130,831.00	11,501.00	2.20
Uganda	40,323.00	242.00	167.00	84,925.00	2,106.00	6.00
Zambia	16,717.00	753.00	22.00	65,174.00	3,899.00	5.90
Zimbabwe	15,967.00	391.00	41.00	28,326.00	1,774.00	3.10
AFRICA	**1,214,428.00**	**30,049.00**	**40.00**	**6,039,933.00**	**4,973.00**	**4.00**

Sources: United Nations, Department of Economic and Social Affairs, Population Division, World Population Prospects, The 2015 Revision. AfDB Statistics Department, various domestic authorities, and AfDB estimates. Note: * For Egypt and Ethiopia, fiscal year July (n-1)/June (n).

Figure 1: An African Map Displaying the Major Exportable Natural Resources



Source: Gokee (2016)

From the map in Figure 1, it can be rightly seen that Africa is vastly endowed with natural resources including solid resources like gold, copper, diamonds, and iron. Energy resources like crude oil, uranium, coal, and natural gas. Others include livestock and arable land. Furthermore, the map also shows that the natural resource can be found across all the regions in Africa.

Therefore, the resource abundance has induced resources dependence in many African economies making several countries to gain substantial fortune from resource-based economic activities especially for those involved energy production (oil and gas) which is of interest in this research. However, regardless of the vast rents from resources abundance, Africa remains largely confronted by severe socioeconomic problems in practically all spheres of human endeavors. It is sickening and unbearable to behold the misery of millions of people in a vast majority of the African countries that are still yet underdeveloped and economically backward due to poor leadership that is often characterized by mind-boggling rates of corruption and ineptitude majorly in the public sector, but not excluding the private sector too. The highly blessed continent is still battling with challenges of poverty proliferation, rising inequality levels, serious unemployment, and under-employment. Other common challenges include political unrests and rising insecurity levels due to protracted wars, insurgencies, and terror related matters.

In recent times, the aforementioned socioeconomic problems have been exacerbated by increasing challenges from the growing threats of the risks of environmental degradation as more places are expected to witness longer seasons of droughts, worsening problems of food security due to possible disruptions of agricultural activities by changing patterns and amount of rainfall, and risks of possible flooding from a rise in sea levels (Müller et al., 2011; Mohamed, 2011; Serdeczny et al., 2017). There are also attendant adverse effects of climate variability on the lives of many people who are still practicing small-scale subsistence economic activities like pastoral agriculture, some of whom are notable disperse across many countries on the African continent (Leal Filho et al., 2020).

Concerns have also been raised about the risks of the poor capacity of many African countries in adapting to the climate changes and variability that is often associated with environmental degradation even has the continent’s population is expected to rise to about 2.4 billion people by 2050 (Adenle et al., 2017).

The deteriorating climatic condition is often associated with rising levels of Greenhouse gas (GHG) emission over the years and the transition to clean energy is an important panacea to lowering the level of global (GHG) emission. Hence, it is expected that the current global attention on fossil fuels use would gradually decline over the next couple of decades and this decline may even come much more fasters considering recent developments in the calls for renewable energy production and consumption.

As the adverse effects of climate change intensify such that it attracts more attention for a redress of the matter on a global level, several changes are expected to occur in the status-quo of the prevailing global energy mix. These changes would include among others, an inevitable energy transition from conventional energy use to clean energy.

Hence, having introduced the crucial risks posed by climate change on a global level and especially in Africa, this study seeks to address the related subject matter of fossil energy resource endowments from the perspectives of energy consumption and its impacts on the environmental quality of oil-exporting countries across the African continent amidst the growing call for a global energy transition from non-renewable energy sources to renewable alternatives.

CHAPTER ONE

GENERAL OVERVIEW OF THE STUDY

1.1. Background of the Study and Statement of Research Problem

As noted in the introduction, Africa is vastly endowed with numerous resources, and many of the nations that house these resources have become grossly dependent on them over the years. Despite all the abundant natural and human resources in Africa, the continent remains unduly exposed to several problems that reflects in practically all human endeavors. Extreme poverty and acute unemployment, social and political instability due to protracted wars, insurgencies, insecurity, and diverse terror-related matters (Botha, 2008). As of 2016, it was estimated that the economic cost of terrorism and insecurity in Africa had risen to USD 15.5 Billion from around USD 1.54 Billion in 2007, thus accounting for about 20.3% of the share of the global economic cost of terrorism (UNDP, 2019). Over this same period, Africa was said to have lost at least US$119 billion to insecurity and terrorism and the figure could be greater if other informal economic activities were accounted for (UNDP, 2019). This spike in insecurity and terrorism has been identified as key factors that have compounded public finance problems for authorities and policy makers in many Africa countries that are concerned (Abid and Sekrafi, 2020).

Table 2: Costs of terrorism in Selected African countries between 2007-2016

African Countries	Cost of Property Destruction (In Millions – constant 2017 US$)	Cost of Fatalities & Injuries (In Millions – constant 2017 US$)	Number of Deaths reported	Number of Attacks (By Terrorist)
Nigeria	US$598.80	US$40,828.60	18,952.00	**3,058.00**
Libya	US$177.40	US$5,023.90	1,413.00	**1,595.00**

Sudan	US$26.30	US$3,780.80	2,664.00	**717.00**
Kenya	US$63.30	US$1,204.50	1,426.00	**447.00**
Cameroon	US$4.60	US$874.00	1,326.00	**190.00**
Somalia	US$276.60	US$493.70	4,472.00	**2,152.00**
Tunisia	US$54.20	US$443.50	158.00	**44.00**
Uganda	US$1.50	US$408.00	1,242.00	**184.00**
Chad	US$0.40	US$341.30	629.00	**53.00**
Ethiopia	US$4.10	US$277.30	505.00	**66.00**
Mali	US$13.00	US$213.40	486.00	**271.00**
CAR*	US$2.00	US$195.20	1,136.00	**204.00**
Niger	US$0.80	US$170.90	838.00	**78.00**
Morocco	US$0.40	US$98.70	75.00	**13.00**
Tanzania	US$2.00	US$42.70	61.00	**45.00**
Senegal	US$0.80	US$25.80	92.00	**32.00**
Mauritania	US$0.40	US$22.80	27.00	**11.00**
Burkina Faso	US$0.20	US$19.70	57.00	**15.00**
TOTAL	**US$1,226.80**	**US$54,464.80**	**35,559.00**	**9,175.00**

Source: United Nations Development Program, UNDP report (2019). Estimations are done in Constant 2017, USD (million). *The Central African Republic (CAR).

From Table 2, insecurity and terrorism activities cost 18 selected African countries about USD 56.5 billion within 10 years (2007-2016). Over the same time, more than thirty-five thousand lives were lost in about nine thousand one hundred and seventy-five attacks.

The aforementioned challenges in many African countries have been compounded by environmental degradation issues in recent times just as the world is gradually shifting attention from some of those fossil energy resources that many African economies rely on, especially in the case of oil & gas, and coal among others. Fossil energy resources constitute a significant proportion of primary energy consumption in many oil-exporting African countries and even for some non-exporter. For instance, in some North African oil-rich countries like Libya fossil energy (oil & gas) accounts for almost the entire electricity generation (WDI, 2021).

Meanwhile, carbon dioxide (CO2) emissions in the energy sector alongside other greenhouse gases like methane (CH4) and nitrous oxide (N2O) are among the major drivers of climate change due to their composition in global GHG emission levels. According to the emission gas report (EGR) of the United Nation Environment Program (UNEP, 2020), carbon dioxide (CO2) emissions from fossil fuels and carbonates accounted for the lion's share of the growth in the total GHG emissions. CO2 emissions from fossil sources were estimated at 38 gigatons (Gt) with a range greater than or equal to 1.9 in 2019 (UNEP, 2020).

Countries in Africa, and those in the South & Central America region contribute the least to the global CO2 emission as of 2019 as shown in Figure 1 in section two (2). These regions contribute about 3.7% and 3.8% of the global CO2 emission respectively, while the Commonwealth of Independent States (CIS) countries and the Middle Eastern countries contributed about 6.1% and 6.3% to the global CO2 emission respectively in 2019 (BP, 2020). Emission from European countries and countries in North America accounted for about 12.0% and 17.5% of the global CO2 emission while Asia Pacific countries contributed the largest amount of emission estimated at 50.5% of the total CO2 emissions in 2019 (BP, 2020).

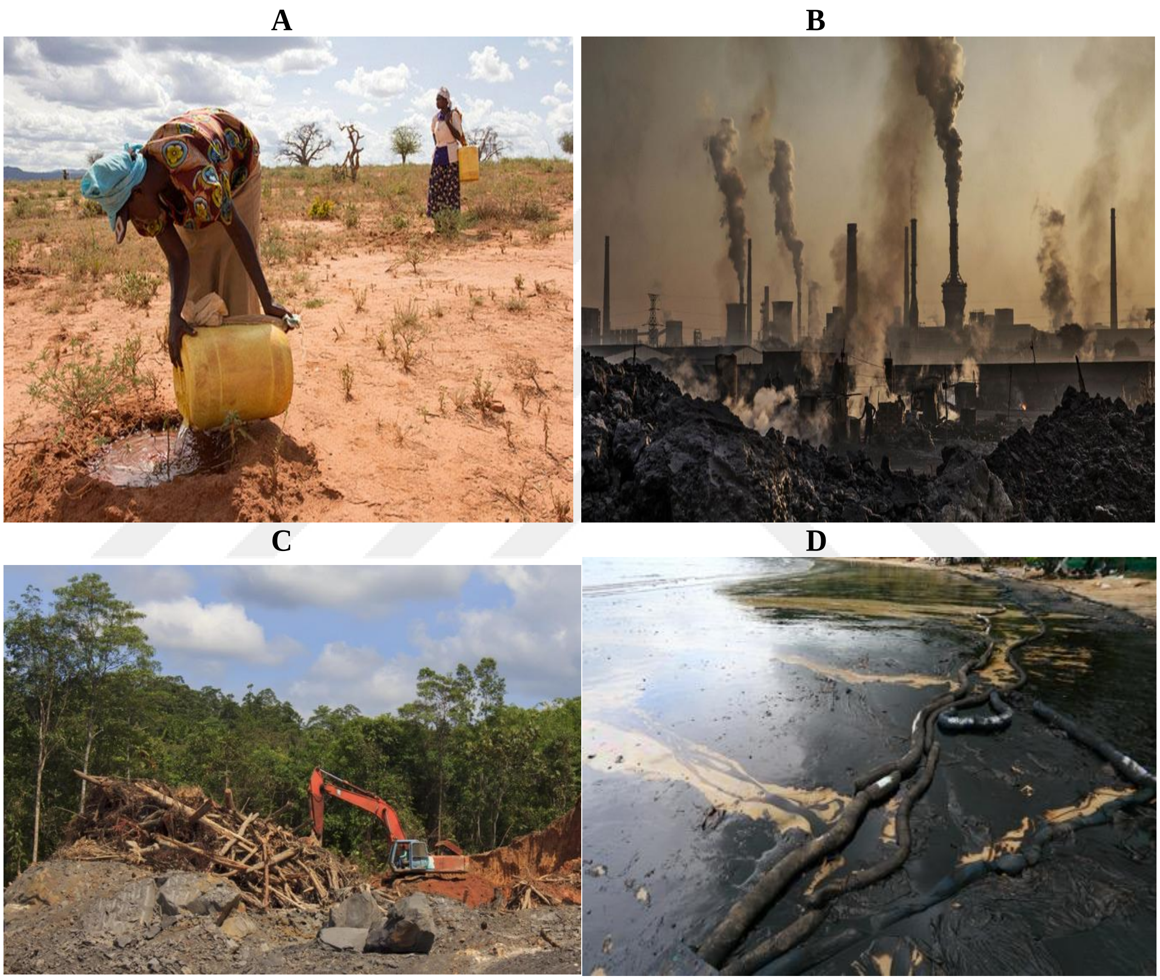
While it is well known that Greenhouse gas (GHG) emission poses a significant danger to the sustainability of our global environment, Africa might be at greater risk due to the continent's low capacity in terms of climate change adaptability. Most of the efforts made towards addressing the global climate change threats are often done based on records, studies, and data availability with more focus on the leading GHG emitting countries like China, the United States of America, the European Union (EU) member countries, and India among others (UNEP, 2020). Countries located on the African continent are often left out in such exercises due to inadequate information and statistical updates on the subject matter. This leaves Africa in a more precarious condition as millions of people on the continent are highly vulnerable to the damages of climate change.

The International Energy Agency (IEA, 2020) noted that Africa is unequally exposed to more dangers of climate change due to global greenhouse gas emission despite the fact that the continent emits just about 2% of carbon dioxide (CO_2) emission from energy induced activities.

Among the notable environmental challenges faced in recent times include food security challenges, land degradation, deteriorating quality of air amidst water and sanitation challenges, and sustainable energy challenges.

On the aspect of land degradation, it has been observed that around half a million square kilometers (0.5 million km2) of land undergo degradation annually as a result of factors like pollution, deforestation, and soil erosion in Africa (UNEA, 2020). This situation is also being complicated by the increasing rate of urbanization, and challenges of oil spillage during oil and gas exploration for the case of the lands in the oil-rich regions. This does not only pose negative impacts on agricultural practices like cropping and fishing alone, but it also goes a long way in affecting the general terrestrial ecosystem and other economic activities like tourism (Osuji and Onojake, 2004; Osuagwu and Olaifa, 2018; Ozigis et al., 2020; Magris and Giarrizzo, 2020).

Figure 2: Common environmental problems including, drought, air pollution, oil spillage, and deforestation.



Source: Multiple sources including, Flore de Preneuf/World Bank, and the Lagos today. Available at https://blogs.worldbank.org/africacan, https://thelagostoday.com/2020.

Ensuring food security is rapidly becoming a major challenge in the wake of growing threats from environmental challenges as a result of climate variability-related issues. Many communities depend on rainfall for agriculture and the disruptions in rainy seasons and its length due to climate change is affecting agricultural practices thus exacerbating food security challenges amidst other social and political conflicts in recent times (Hendrix and Salehyan, 2012; Agutu et al., 2020). A longer period of dry season and occurrence of droughts have been identified as likely consequences of climate change and this problem combined with the issues of land degradation pose serious challenges to achieving food security in Africa.

Also, the deteriorating quality of air amidst water and sanitation challenges is another important environmental challenge. Factors like poor sanitation facilities, increasing industrialization, and reliance on solid fuels like woods and charcoals for domestic necessities like cooking and heating are exacerbating deteriorating air quality, and sanitation problems in many African countries especially those in the Sub-Saharan Africa region.

While the aforementioned environmental developments signify tougher days ahead for Africa at large since agriculture is crucial to the economy of many African countries (Salahuddin et al., 2020), they may as well imply more tragedies for resource-dependent oil-exporting countries on the continent if urgent steps are not taken to save the day. Besides, it has already been estimated that African economies could even lose up to 15 percent of their economic worth in terms of (GDP) per capita growth owing to climatic change-related challenges (Baarsch et al., 2020).

1.2. Aims and Objectives of the Study

The 7th and 13th goals of the seventeen (17) sustainable development goals (SDGs) of the United Nations (UN) are set towards achieving energy for sustainable development and necessary climate actions. As global energy demand rises over the years, these goals emphasize the need for everyone to have access to sustainable and reliable energy sources at cost-effective or affordable rates and the need to also take collective actions towards preserving the global environment.

Oil and gas have significantly helped the world in meeting a significant fraction of the high energy demand over the past few decades. However, meeting the energy demand through the consumption of fossil fuels from the oil and gas industry also comes at a cost to the environment as the burning of fossil fuels has added to the global greenhouse gas (GHG) emissions over the years (IPCC, 2019; UNFCCC, 2015; UNEP, 2020).

The need to support the call for collaborations on environmental sustainability has been on a persistent increase. This is just as many countries are battling with the quest to realize sustainable economic growth and development. Although gradual signs of progress are being made across the globe however there's still a lot to be done regarding environmental protection vis-a-vis the push for decarbonization in many African countries.

Hence, this research aims at contributing to the expansion of the existing progress on the issue of energy dynamics and environmental concerns towards addressing the global decarbonization prospects from an African perspective using the empirical illustrations from the case of oil-exporting African economies. To achieve the aims, the study will significantly take care of any methodological limitations through the adoption of suitable techniques for data analysis to avoid any empirical flaws in extant studies.

The research also aims at drawing the attention of policymakers to start strategizing on the need for transition in energy use from conventional sources to renewable energy consumption. In addition, the study will provide empirical-based policy recommendations to facilitate collective actions for climate protections through decarbonization prospects, while also addressing the issue of access to sustainable and reliable energy sources for oil-exporting African economies, thereby contributing a quota to the actualization of the United Nations Sustainable Development Goals (SDGs) for these countries in specific, and the continent of Africa at large.

Lastly, the study will help to expand the research coverage of the faculty of economics and administrative sciences of Selçuk University to cover the energy sector of the oil-exporting African countries, it will also significantly help to address issues relating to the actualization of the United Nations Sustainable Development Goals (SDGs) as far as the continent of Africa is concerned.

1.3. Research Questions and Hypothesis

The following research questions are pertinent to the research framework in terms of the scope and the objectives of the study;

1. How do fossil energy resource endowments impact environmental quality through energy consumption among oil-exporting African economies?
2. Do renewable energy consumption levels have any implications for the environmental quality among hydrocarbon-driven economies on the African continent?
3. Are there any significant effects of increasing income on environmental depletion rates among oil-exporting African countries?
4. Do urbanization and globalization have any impacts on the degradation of the environment among oil-exporting economies in Africa?
5. Can oil-dependent economies on the African continent successfully implement energy conservation policy for a more sustainable environment without detrimental economic consequences?
6. What are the potential energy sources that oil-exporting African countries can rely on to save the environment and ensure sustainable growth and development in the nearest future?

Following the aforementioned research question, with the aid of appropriate empirical methodologies, we shall be testing a structured null hypothesis (H0) against alternative hypothesis (H1) in the study as follows;

H_0: Energy performance indicators {energy consumption (fossil & renewable energy sources), income levels, resource rent, globalization, etc.} have no significant effect on environmental sustainability.

H_1: Energy performance indicators (energy consumption, income levels, globalization, and resource rent, etc.) have significant effects on environmental sustainability.

1.4. Scope and Organization of the Study

There are various forms of environmental degradation means including pollution of various kinds such as land pollution, water pollution, and air pollution. The recent trend has shown that environmental challenges posed by greenhouse gas (GHG) emissions pose threats in several aspects including to economic activities and even to the very existence of life on our planet (Mora et al., 2018; Nordhaus, 2019). Human activities have led to a drastic upward rise in the level of carbon emissions over the years and many economic activities and prosperity of several economies are even directly or indirectly tied to industries that thrive on resource extraction and consumption such as in the case of many hydrocarbons rich nations.

Although there are many oil-exporting African countries currently with more new discoveries according to Graham & Ovadia (2019) and the study by IEA (2019), however, the scope of the research will cover ten (10) oil exporting countries including Algeria, Nigeria, Angola, Egypt, Libya, Republic of Congo, Gabon, Sudan, Tunisia, and Chad. Based on preliminary data sourcing activities, the study proposes to utilize data for these African countries up from the 1990s.

The decision for the scope and country selection was informed primarily by the observed challenges of data availability based on the preliminary data sourcing and consultations from open sources like the World Development Indicators of the World Bank (WDI, 2021). A possible extension of the sample scope to 2018 or 2020 is subject to data availability from other targeted organizations including the International Energy Agency (IEA), the KOF Swiss Economic Institute, and British Petroleum (BP). It is worthy to note that data may be freely accessible in most of these organizations like the World Bank Indicators, however, standard payments or subscriptions may be required to access full data sets in some organizations.

Nations that are rich in hydrocarbons deposits can be found around the world and some notable ones are in Africa as shown in Table 1 and Table 2 in the next chapter. In 2019, the total global crude oil export-based on production was estimated at 45.18 million barrels per day (mb/d) (OPEC, 2020). Export from the Middle East accounted for the largest percentage of about 39.02% followed by export from Eastern Europe and Eurasia at 16.16% while Africa was the third-largest exporter at about 14.24% (OPEC, 2020). Out of the total 6.45 mb/d export from Africa, export from Nigeria, Angola, and Libya accounted for around 67.5% as these nations exported 2.0 (mb/d), 1.31 (mb/d), and 1.03 (mb/d) respectively.

1.5. Limitations of the Study

This research essentially utilized the instrumentality of empirical methodology in carrying out the analysis of relevant data. The main constraint in this research has to do with the issues of data and empirical material sourcing. Environmental data relating to greenhouse gases (GHG) are not generated on a primary sourcing basis. Hence, researchers have to rely on secondary institutions for valid and reliable data. In some cases, accessing some of these data would require payment of standard subscription charges. Besides, the procedures in the application of empirical methodologies may also be constrained by access to data and the suitability of available data to the choice of analytical approaches to be adopted.

The scope of the study could have been widened beyond what was done in this research but due to the limitations in the availability of trusted data set, we were constrained to the sample size that was used in the study. Therefore, to overcome the constraints, utmost precautions were taken to ensure that reliable data sources were utilized for all variables of concern in the study. Various international organizations were consulted for data sourcing. In addition, there was a wide consultation on alternative methodologies before carefully adopting the most suitable approach vis-à-vis the statistical properties of the data in the study.

CHAPTER TWO

LITERATURE REVIEW

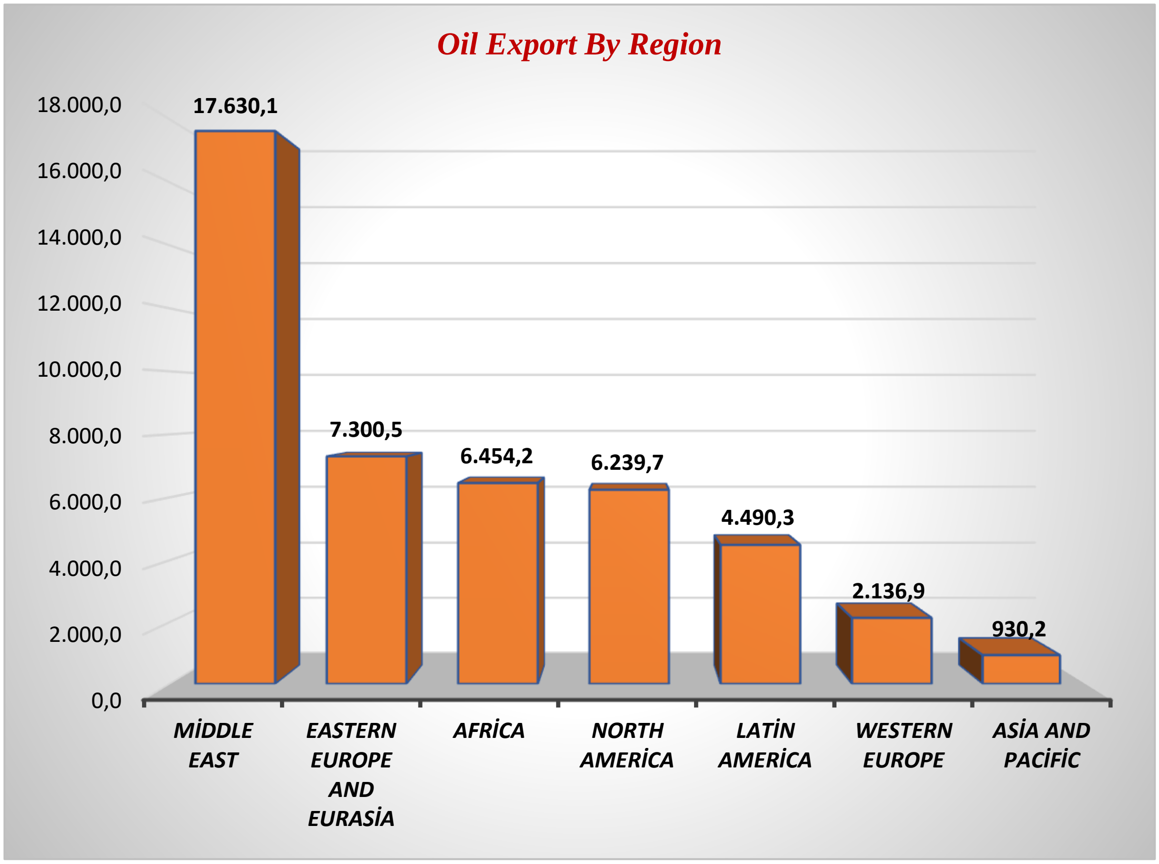
In this chapter, the historical antecedents of oil and gas production are reviewed among African countries. While doing so, we shall also be looking at how various African economies have transformed over the years in a bid to analyze whether the economic developments in these countries support the resources curse theory and the Dutch disease theory. Lastly, in this chapter, a theoretical and an empirical review of existing literature were also provided.

2.1. Trade in Oil & Gas Production in African Countries: A Combination of the Resource Curse and the Dutch Disease theories

Trading activities in oil and gas have been the backbone of some notable oil-exporting countries in Africa and more countries are joining the league as new oil and gas fields are being discovered on the continent. It has been observed that there is also a high possibility of discovering more oil & gas resources in Africa since exploration activities is relatively low in previous decades as shown by Graham & Ovadia (2019). The exporters of oil & gas in Africa have earned over $1.7 trillion from trade in oil and gas and these earnings account for about 25% of the GDP growth in Africa in the 2000s (IEA, 2019).

As shown in Figure 3, in 2019, the total global crude oil export-based on production was estimated at 45.18 million barrels per day (mb/d) (OPEC, 2020). Export from the Middle East accounted for the largest percentage of about 39.02% followed by export from Eastern Europe and Eurasia at 16.16% while Africa was the third-largest exporter at about 14.24% (OPEC, 2020). Out of the total 6.45 mb/d export from Africa, export from Nigeria, Angola, and Libya accounted for around 67.5% as these nations exported 2.0 (mb/d), 1.31 (mb/d), and 1.03 (mb/d) respectively. Over the years, several African countries have been able to attract large foreign direct investment (FDI) in their oil and gas sector from various giant multinational oil corporations partly due to the presence of these resources in commercial quantity as shown in Table 3 and 4, and also because oil and gas industry is a capital-intensive industry that often requires a high expatriate operation, especially for its offshore activities. Thus, many countries depend on capital and technology from giant investors for the development of their oil industry.

Figure 3: World crude oil exports by region (1,000 b/d) (2019)



Source: Authors' computation using data from Annual Statistical Bulletin (OPEC, 2020)

Table 3: Africa's Proved Oil reserves (billion barrels) 2010-2019

Country	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*Total Share 1*	*Total Share 2*
Algeria	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	0.7%	9.71%
Angola	9.1	9.1	9.1	9.0	8.4	9.5	9.5	8.4	8.2	8.2	0.5%	6.49%
Chad	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.1%	1.19%
*Rep of Congo**	2.0	2.0	2.0	2.7	2.9	3.0	3.0	3.0	3.0	3.0	0.2%	2.37%
Egypt	4.5	4.3	4.2	3.9	3.7	3.5	3.4	3.3	3.1	3.1	0.2%	2.45%
*Equatorial G**	1.7	1.7	1.7	1.7	1.1	1.1	1.1	1.1	1.1	1.1	0.1%	0.88%
Gabon	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.1%	1.59%
Libya	47.1	48.0	48.5	48.4	48.4	48.4	48.4	48.4	48.4	48.4	2.8%	38.48%
Nigeria	37.2	36.2	37.1	37.1	37.4	37.1	37.5	37.5	37.0	37.0	2.1%	29.41%
South Sudan	n/a	n/a	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	0.2%	2.78%
Sudan	5.0	5.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.1%	1.19%
Tunisia	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.025%	0.34%
Other Africa	2.3	2.2	3.7	3.7	3.7	4.0	4.0	3.9	3.9	3.9	0.2%	3.12%
Total Africa	**124.9**	**124.6**	**127.4**	**127.5**	**126.8**	**127.6**	**127.9**	**126.7**	**125.7**	**125.7**	**7.2%**	**100%**

Source: Author's compilation based on BP data (BP, 2020). The computed Share 1 is the share of Africa in the global proved oil reserves while Share 2 represents the share in total Africa's proved oil reserves. *Equatorial Guinea, and the Republic of Congo.

Table 4: Africa's Proved Gas Reserves (Trillion cubic meters) from the end of 1999 - end of 2019

Country	*at end 1999*	*at end 2009*	*at end 2018*	*at end 2019*	*Total Share 1*	*Total Share 2*
Algeria	4.350	4.335	4.335	4.335	2.20%	29.0410
Egypt	1.1771	2.1079	2.1377	2.1377	1.10%	14.3250
Libya	1.2493	1.4716	1.4297	1.4297	0.70%	9.5803
Nigeria	3.3360	5.0280	5.3913	5.3912	2.70%	36.1273
Other Africa	0.8445	1.2301	1.3709	1.6292	0.80%	10.9176
Total Africa	10.9578	14.1720	14.6647	14.9230	7.50%	100%

Source: Author's compilation based on BP data (BP, 2020). The computed Share 1 is the share of Africa in global proved natural gas reserves while Share 2 represents the share in total Africa's proved gas reserves.

The production and subsequent utilization of energy constitute a major influence on global economic activities. Since energy utilization is very important in production chain, energy resources (like oil and gas) have continued to be dominant essential commodities within the natural resource discussion as far as the international market is concerned. Also, energy demands have continued to rise in many economies (Onifade & Alola, 2022; Awosusi et al. 2022; Alola & Onifade, 2022; Onifade et al. 2022a; Dingru et al. 2023). Therefore, the oil & gas industry continues to attract significant investments that has produced substantial and massive economic blessings in terms of fortunes for many oil-exporting economies. There are also periodic booms in the industry especially when petroleum price rises owing to certain artificial or natural factors (shocks) that often induce positive price fluctuations. Such periods of booms are often characterized by massive rise in oil revenues that ought to be leverage for economic growth and development among the oil-exporting economies. However, the records from several oil-exporting or other resource-based economies have shown contrary evidence as huge resource revenues may not essentially produced desired developmental impacts in resource-based economies. Sadly, this has been observed in many oil-exporting nations on the African continent.

Resource rent drive economic activities in many African economies, and many of the economies have benefited in term of large revenues from resource production for a long period of time. However, the sickening situation still remains that many of these economies are yet underdeveloped and economically backward (Anyanwu & Erhijakpor, 2014; Ayittey, 2016). This is partly due to poor leadership coupled with mind-boggling rates of corruption and ineptitude majorly in public sectors but not excluding private sectors too. For example, it has been observed that some of the resource-rich countries like Nigeria has earned more than US$400 billion in its oil production sector right from the first exploration in the 1970s (Taiwo et al., 2020). However, the standard of living of more than 200 million people in the country and the general economic performance of the nation is not commensurate with the expected level of development given the available resources at the country's disposal (Taiwo et al., 2020).

The situation agrees with the resource curse theory that supports the argument that there are lower levels of economic development among resource-rich countries. The theory argues that this is generally the case among resource-rich economies unlike other nations with lower amount of natural resources. Most resource-rich nations are engulfed with challenges of poor institutional development, unpleasant cases of financial corruption and embezzlement of public funds, incessant disputes, and political conflict of diverse dimensions as noted by Vahabi (2018), Manzano and Gutiérrez (2019), Tyburski, et al., (2020), and Gritsenko & Efimova, (2020) among many others.

Frankel (2010) while recounting the origin of the theory's name as phrased by Auty (1993, 2001), provided an illustration by comparing many resources rich but underdeveloped countries on the Africa continent to other economies that have limited resources but yet managed to witness spectacular growth especially those in Asia including Japan, Taiwan, Hongkong, South Korea, and Singapore. Also, in the words of a former United Nations Secretary-General, Kofi Annan, at the Organization of African

Unity (OAU, 2000) that is now popularly known as African Union (AU), "Instead of being exploited for the benefit of the people, Africa's mineral resources have been so mismanaged and plundered that they are now the source of our misery" (Ayittey, 2016; p.1). Besides, in another related observation from the IEA (2019), huge revenue from oil and gas has often been a major basis for corruption and underdevelopment of the African continent.

Also, it is possible for resource fortune in a resource-rich economy to yield counterproductive economic outcomes in other sectors of the same economy based on the Dutch Disease conjecture following the proposition of Corden (1984). This is always the case unless the resource-rich economy is a well-diversified one. Simply because there is always an imbalance focus and attention on the natural resources therefore reducing the chances of developing the other sectors of the economy. For instance, the IEA (2019) observed that the instability in oil & gas industry negatively impact the economic performances of many resource-based African economies.

Taiwo et al., (2020), also argued that excessive gains and revenue from resources trading (export) can artificially induce nominal exchange rate alongside growing cost of labor (wages) which often aggravate the level of undue economic reliance on the oil sector. If this continues, other sectors in the economy are likely to be neglected leading to lower productivity and performance of such sectors towards the overall GDP of the oil-exporting countries and other resource-based economies. Eventually, the crowding out of other economic sectors like manufacturing sector would become inevitable when there is over dependence on resource exportation as emphasized by Krugman (1987).

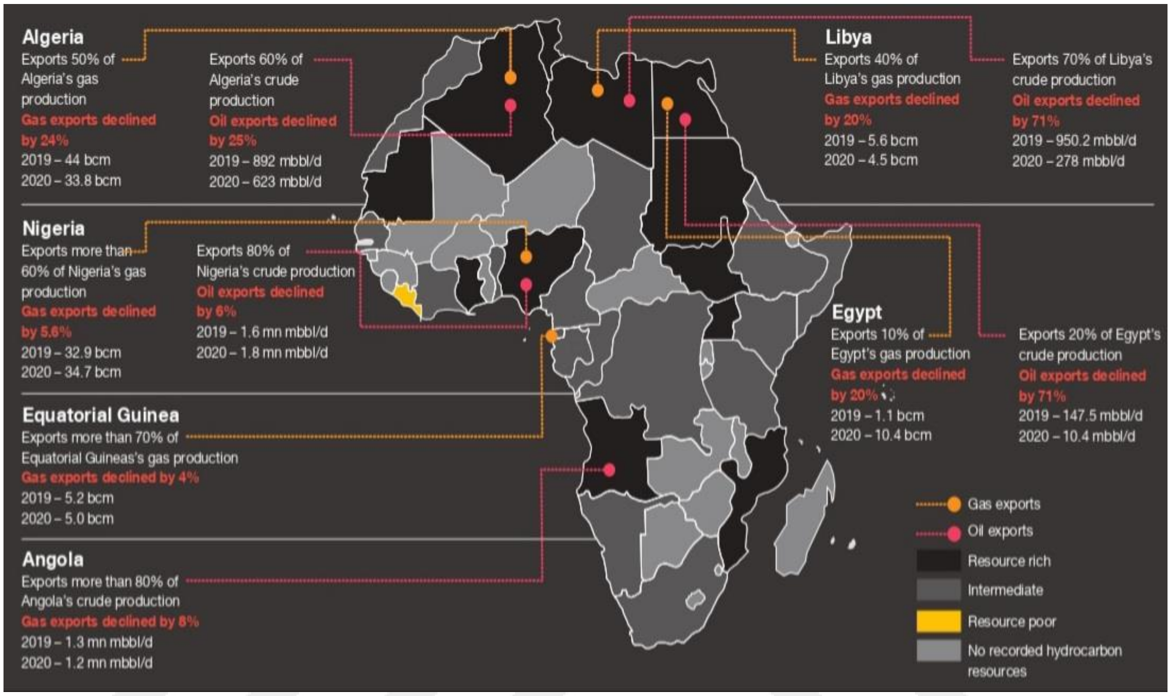
Furthermore, many oil-exporting countries and other resource-based economies in Africa often have the burden of having to deal with long-standing socioeconomic challenges like poverty and unemployment which may require various forms of financial intervention. As such, windfall profits from shocks in the global market are used for bogus fiscal financing that do not consider the real production level thereby creating other major economic problems like acute inflation.

2.2. A Synopsis of Economic Crisis Amidst Covid-19 Virus Pandemic in a Globalized World: Experiences of Oil-Exporting Countries in Africa

While the world has enjoyed and explored the benefits of diverse forms of globalization such as globalization in trade and economic activities among others, the recent emergence of the COVID-19 virus has exposed some possible threats from globalization. Right from its emergence in 2019 from Wuhan, a city in China, the COVID-19 virus has found its way into every nook and cranny, and countries in Africa are not left out in the wave of the spread. The economic consequences of this deadly virus have been felt and are still being felt in nations across the globe.

In the wake of the deadly COVID-19 virus pandemic, many nations have been struggling with how to ensure economic stability through the development of policy frameworks that could ensure resilience for the Covid-19 induced economic challenges. While some advanced countries have managed to control the damages from this global health saga, several oil-exporting countries had to deal with severe revenue crises due to abysmally low revenue generation that has seen many of these volatile economies shrink in GDP growth performances. In addition to that, the COVID-19 virus outbreak has been reported to worsen socio-economic challenges including unemployment, poverty, and deepening income inequality levels, and insecurity crisis among others (Martin et al., 2020; McKibbin and Fernando, 2020).

Figure 4: Covid-19 Outbreak and Oil Producer's Experience in Africa



Source: PwC Africa Oil and Gas Review (2020)

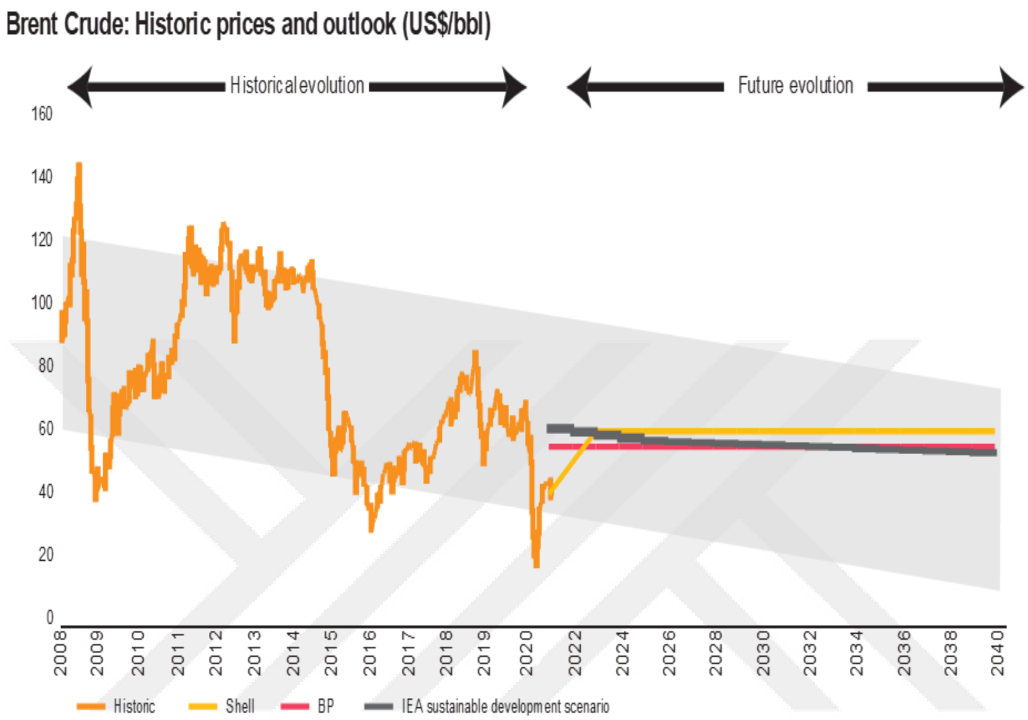
The majority of oil-exporting countries in Africa have focused on oil revenue as the major driver of their economic agenda over the years and as such, many of these countries are struggling to adapt to the "new normal" of COVID-19 induced transitions. The required level of adaptability to these changes would determine the extent to which economic growth can be sustained among these nations. For instance, African largest oil exporter, Nigeria, fell into economic recession after recording negative GDP growth in 2020 (NBS, 2020) with a growing unemployment crisis in a nation of over 200 million people that are battling with acute youth unemployment rate (NBS, 2020; Onifade et al, 2020a; Onifade et al. 2022b). This economic recession is primarily attributed to the crash in oil prices amidst a decline in oil and gas export that saw the revenue of the nation drop drastically. Besides, as it can be seen in Figure 4, there are also other oil-producing countries that are having similar experiences including Libya, Algeria, Equatorial Guinea, Egypt, and Angola.

Aside from the direct economic aspects of the COVID-19 crisis in terms of revenue generation, fiscal disruption, and shrinking GDP size, several African countries including the oil-exporters are also encountering massive setbacks in other sectors of their economies with notable severe negative impacts on sectors like education and entertainments among others.

According to data from the United Nations Educational, Scientific and Cultural Organization (UNESCO), out of the 58.4 million out-of-school children in the primary category in the world, Sub-Saharan Africa countries' children were put at 33.8 million (WDI, 2021). This implies that more than half of the world's children in this category are from Africa. This predicament might as well be exacerbated by the current COVID-19 crisis. The unpleasant aspect of the issue is that many of the countries have failed to deliver enough infrastructure for the populace and have also failed to diversify the economy to ensure sustainability in the long run despite having benefited from prolonged periods of windfalls owing to high oil prices.

Onifade et al., (2020b) noted that current situations in the oil sector following the collapse of the global oil prices which has led to a drastic reduction in oil incomes resulted in serious problems for many oil-exporting economies in the world. They further noted that crude oil sold for about US$43.82 per Barrel at the quarter that ended the year 2015 compared to an average of about US$106.47 per Barrel between the first quarter of the 2011 and 2015 respectively

Figure 5: Oil Prices Volatility and Forecast



Source: PwC Africa Oil and Gas Review (2020)

Oil prices started recovering gradually around January 2016 up until early 2019. Unfortunately, the hope of recovering in the oil industry was later interrupted with the emergence of the novel Coronavirus (COVID-19) by the end of the year. Thus, creating a significant negative shock on the global oil demand as at the first quarter of the year 2020 as seen from the oil prices trend in Figure 5.

As many nations applied a series of strategies to contain the virus such as implementing lockdowns (partial or full), maintaining social distancing, and other hygienic precautions, many sectors are affected and these sectors, in turn, create global impacts on the international oil market. Notable sectors that were hard hit include the tourism industry, aviation, and transportation industry. Hence, the global fall in oil demand led to a huge plunge in international oil prices.

As of the last week of the first quarter of 2020, oil prices have dropped to as low as US$25 per Barrel. This development will mean that many oil-exporting countries would be forced to downsize their national budget as most of these nations often benchmark their national budgets on the projection from expected revenues that is known to be highly exposed to external shocks from current situations in the international oil market.

Thus, aside from the environmental effects of burning fossil fuels from crude oil, there are also huge implications of renewable energy transitions for the economic stability of oil-exporting countries that have grown to be massively dependent on oil and gas sectors for various economic reasons including revenue generations, energy production, and energy consumption among other issues.

On the aspect of globalization, the KOF Globalization index of KOF Swiss Economic Institute shall be utilized later on in this research. This index measures globalization from 3 major perspectives including economic perspectives, political perspectives, and social perspectives. From these perspectives, the index publishes various dimensions of globalization to include, including trade globalization, financial globalization, interpersonal globalization, cultural globalization, information globalization, and political globalization. The index was originally initiated by German economist Axel Dreher (2006). This index has been widely utilized, revised, and also applied in globalization-related studies in various fields (Gygli et al., 2019; Liu et al., 2020).

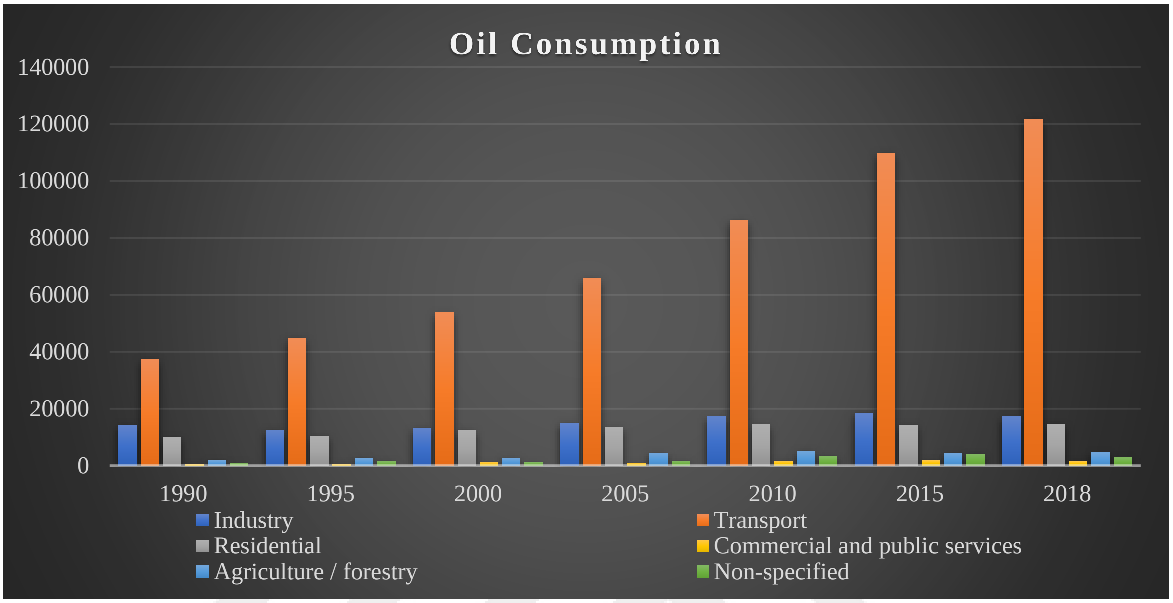
2.3. Africa’s Unsustainable Energy Consumption Amidst Vast Renewable and Alternative Energy Potentials

Africa has massive potential in both renewable energy and alternative energy sources. It is worthy to note that not all renewable energy sources could be fully categorized as alternative energy sources since environmental impacts is strictly a precondition in the case of the latter categorization while the former mainly emphasizes the disuse of fossil energy sources like crude oil and coal energy sources. Notwithstanding, Africa is richly endowed in resources in either category or both categories combined.

However, the huge potential is grossly underutilized as millions of households on the continent currently do not have access to sustainable and affordable energy sources for basic needs as electricity. While noting that Africa holds the necessary requirement for desired energy transition, the IEA listed important resources like cobalt and platinum as other potential minerals for green energy development in Africa aside from the solar resources which the continent currently has the highest potential globally. Despite the huge advantage in solar resources which is both renewable and alternative energy source, only less than 1% of the world capacity of solar photovoltaics (PV) has been reported to have been installed in Africa as the continent only generate 5 gigawatts of solar photovoltaics (PV) (IEA, 2019). Furthermore, despite having a huge potential in hydropower generation due to vast waterways with sufficient currents and dept that can aid hydro projects on the continent, Africa has only utilized just around 10% of its potential in hydropower generation which is also another important renewable and alternative source of energy (UNEP, 2017).

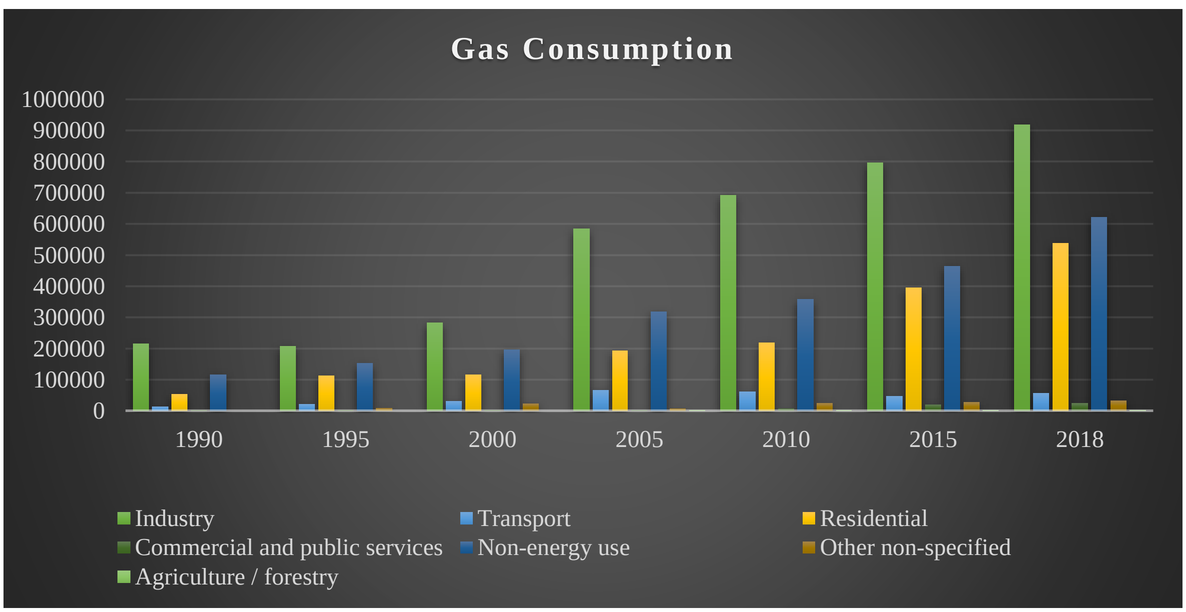
Currently, conventional energy account for the lion shares of the entire overall energy utilization in Africa as oil consumption covers about 42% of the entire energy utilization while gas consumption account for around 28% of the same. Additionally, other conventional energy sources such as coal makes up about 22% of Africa's total energy usage. Given that the continent holds around 9.1% and 6% of the world's oil and natural gas production accordingly, the observation is not unexpected although the continent is only responsible for around 4.2% and 3.9% of global utilization accordingly (UNEP, 2017).

Figure 6: Sectorial Distribution of Oil Utilization in Africa Between 1990 and 2018



Source: Computation by the author based on IEA (2020) data. Information is provided in Kilotons of Oil Equivalent (ktoe).

Figure 7: Sectorial Distribution of Gas Utilization in Africa Between 1990 and 2018



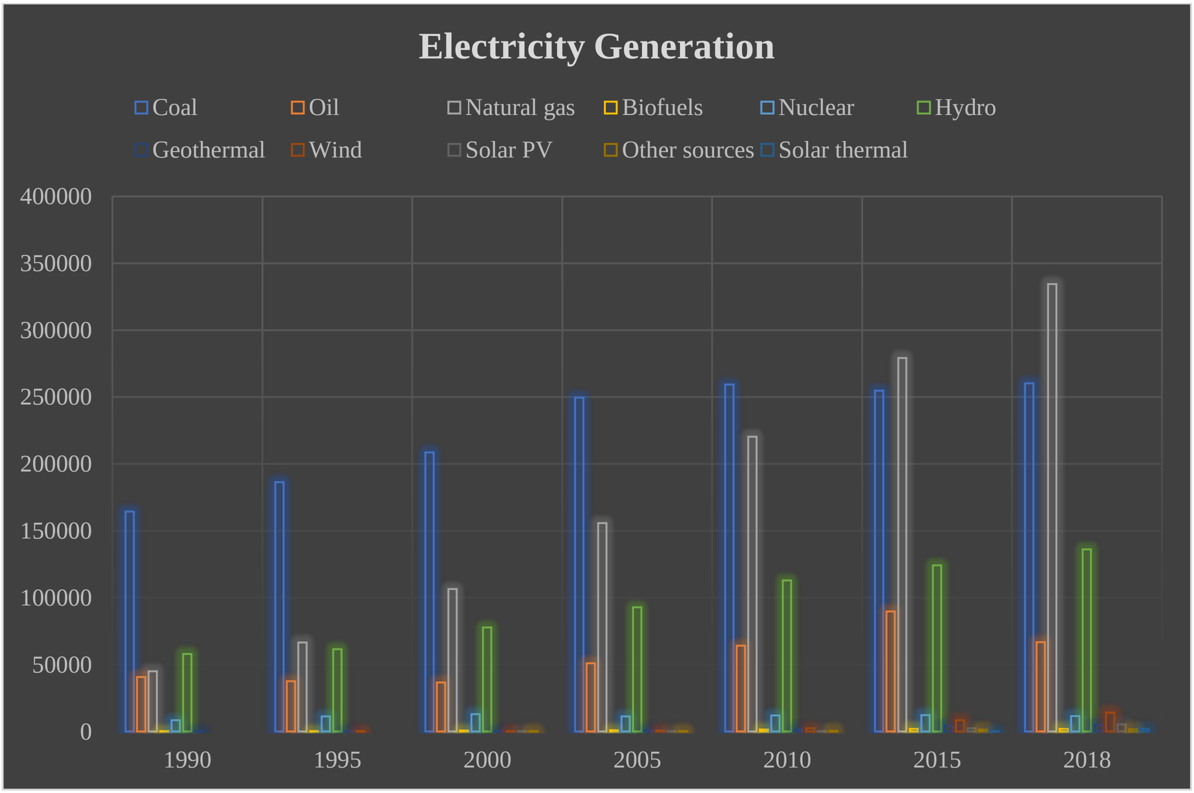
Source: Computation by the author based on IEA (2020) data. Information is provided in terajoule (TJ-gross) which is about 0.278 gigawatt-hours (GWh).

The distribution of oil and natural gas final consumptions across selected sectors in Africa is shown in Figures 6 and 7 respectively. From figure 6, transportation industry is unsurprisingly ahead in oil demand among other sectors in Africa. It is immediately seconded by the oil demand from industries then followed by the residential oil usage. For natural gas consumption, industrial consumption was the highest, next inline was the non-energy use, and then the residential consumption respectively.

There is a rapidly growing energy demand in Africa however, due to the inadequate investment in energy production millions of Africans have been cut up in total lack of access to such basic needs as electricity despite the huge resource endowments. While fossil fuels are crucial to Africa's energy mix at the moment, they can certainly not guarantee the desired environmental and economic sustainability in the long run.

Meanwhile, the 7th goal of the seven (17) sustainable development goals (SDGs) of the United Nations (UN) SDGs Conference in September 2015 is Energy for a Sustainable Development which emphasizes the need for everyone to have access to sustainable and reliable energy sources at cost-effective or affordable rates. According to UNEP (2017), more than 645 million people are not connected to electricity in Africa, and it is estimated that access to electricity may not be achieved for all until 2080. The UNEP (2017) also noted that thirteen (13) out of the twenty (20) countries with the lowest access to energy (electricity consumption) are in Africa including, Nigeria, Ethiopia, the Democratic Republic of the Congo (DRC), Tanzania, Kenya, Uganda, (the former) Sudan, Mozambique, Madagascar, Niger, Malawi, Burkina Faso, and Angola. This is an unfortunate situation as the majority of these countries are vastly endowed with the resources that are needed to light up the continent for all to have access to electricity even at an affordable rate.

Figure 8: Electricity Generation in Africa by Energy Source



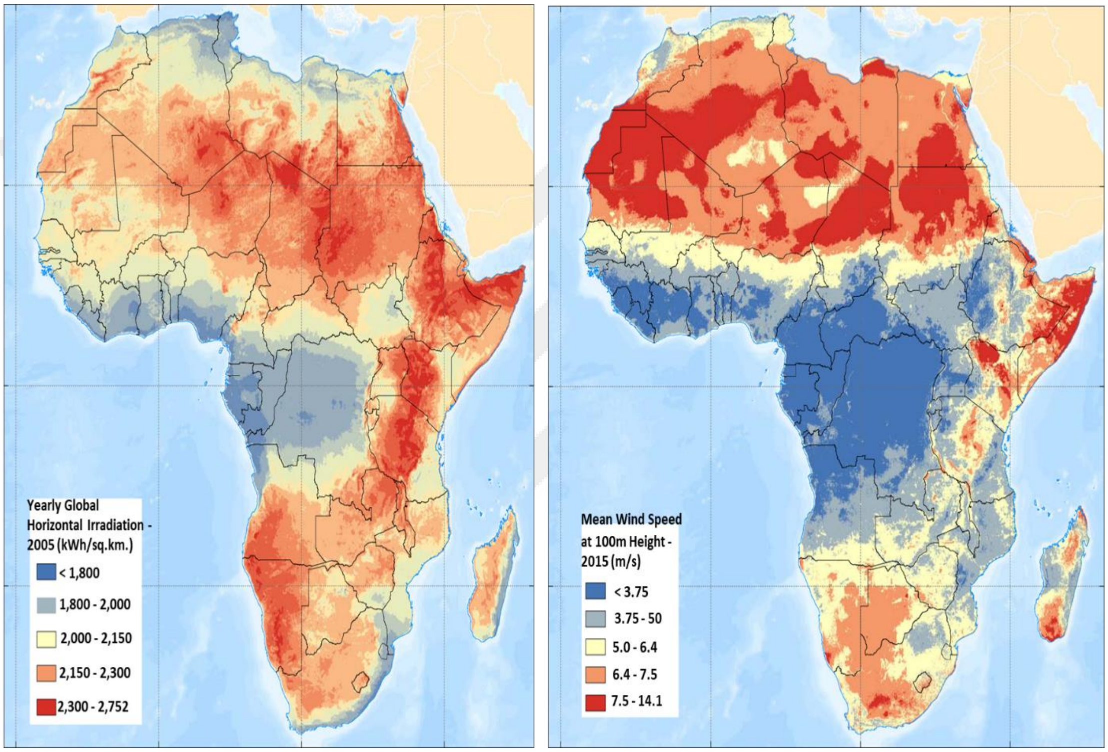
Source: Computation by the author based on IEA (2020) data. Information is provided in gigawatt-hours (GWh) (about 1,000 Megawatt-hours MWh).

Looking at the distribution in Figure 8, energy generation from coal accounts for the largest source of electricity production in Africa between the 1990s up until around 2015 when electricity generation from natural gas overtook the production from coal. In all, energy generation from natural gas and oil combine account for the largest share of the energy mix in terms of electricity generation in Africa over the last decade. Also, hydropower generation witnessed a steady increase over the same period.

Among the notable renewable energy resources in Africa are the following, wind energy resources, solar energy resources, nuclear resources, and hydropower resources. UNEP (2017) noted that Africa's huge renewable energy resources consist of solar potential which is probably inexhaustible as it is estimated that the continent has a potential of about 10 TW. Furthermore, there is also an abundant hydro potential estimated to be around 350 GW. There is also an exploitable wind energy capacity estimated to be around 110 GW, while there is also an opportunity in geothermal energy sources of about 15 GW.

Figure 9: Resource-based Potential of Wind and Solar Energy Across Africa

Panel A: Solar Panel B: Wind



Source: African Development Bank (AfDB, 2014).

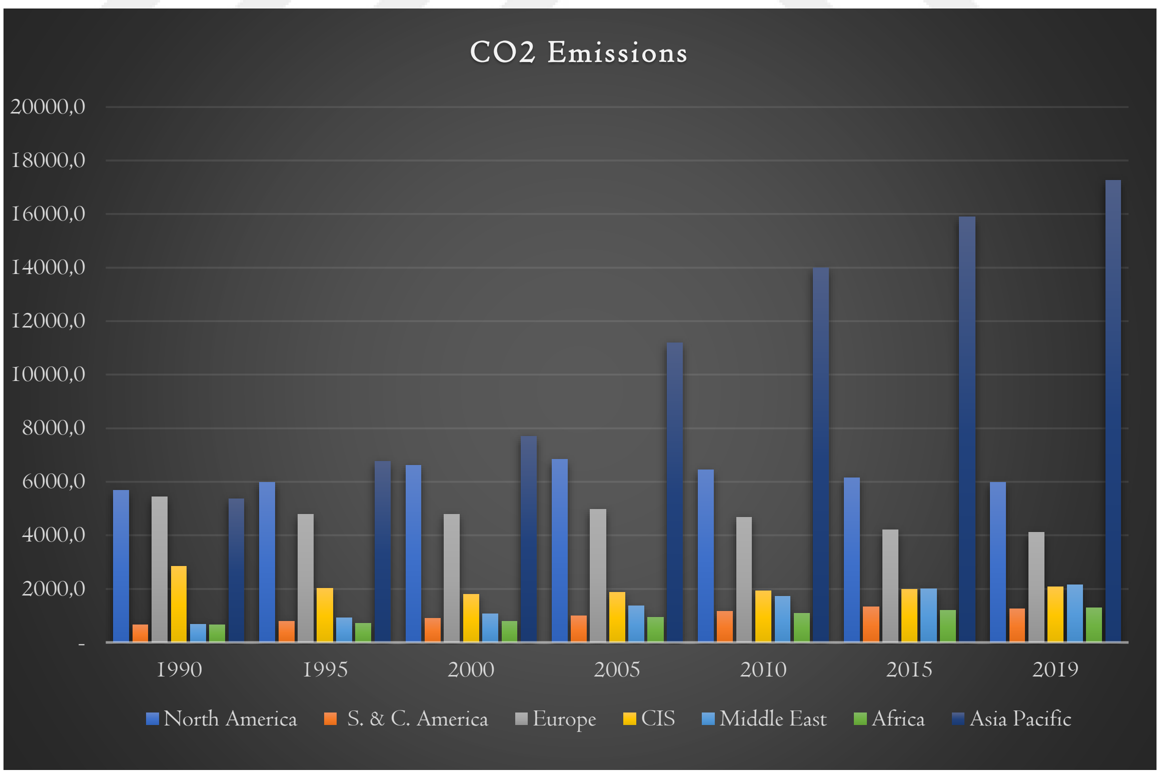
Looking at Panel A and B in Figure 9, the majority of Africa countries have ample opportunities to exploit both solar and wind energy as an important alternative and renewable energy source. Notably, vast exploitable wind energy potential spread across countries like Algeria, Libya, Egypt, Niger, Chad, Sudan, Mali, Morocco, Tunisia, and others around the Sahara in the northern part of the continent down to countries like Eritrea, Djibouti, and Somalia at the horn of Africa. Mean wind speed at 100m height could be as high as between 7.5 to 14.1 m/s among these countries.

Likewise, countries with the solar potential spread across the continent, and these energy resources are even more evenly distributed from the Northern African countries to those in the Sub-Saharan region. The annual global horizontal irradiation could be as high as between 2300 and 2752 KWh/sq.km among these countries.

While noting that economic expansion, demographic growth, and urban sprawl are essential forces that drive energy demand in Africa, the UNEP (2017) observed that above 80% of the energy consumed in the population of the sub-Saharan African nations is derived from biomass sources even though the share of biomass in the total energy mix for the continent is just above 30%.

Despite all the aforementioned renewable energy, fossil energy still remains very crucial to Africa's energy mix as it accounts for the largest share of total electricity production and sectoral distribution of energy consumption in Africa. Meanwhile, hydropower, nuclear power, and renewable energy account for just 6%, 1%, and 1% of the total energy consumption respectively.

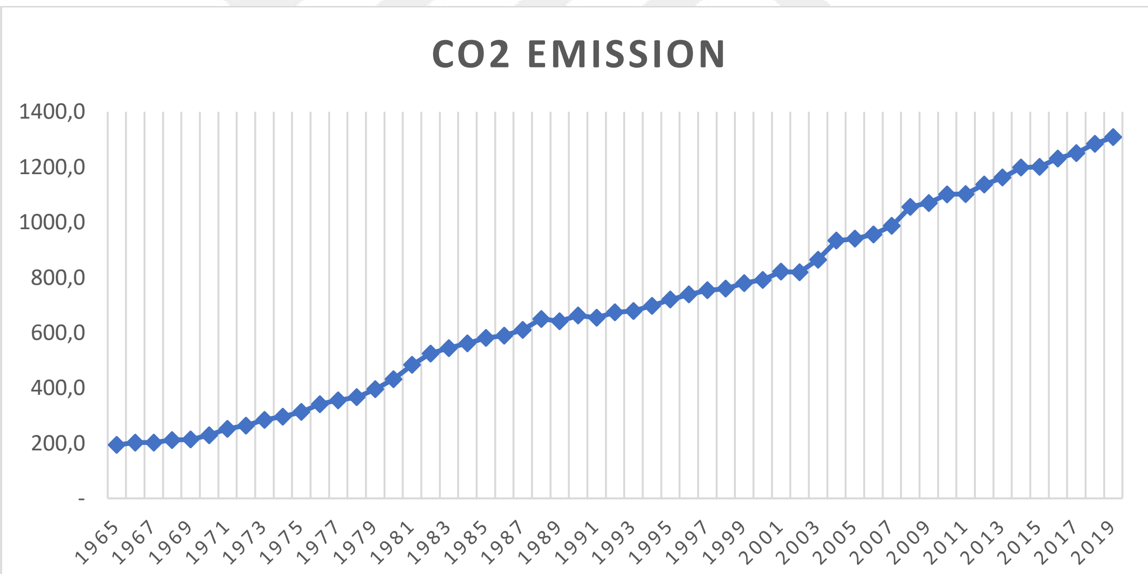
Figure 10: Growth of Global CO2 Emissions by Regions



Source: Authors' computations using Statistical Review of World Energy (BP, 2020).

From Figure 10, CIS denotes the Commonwealth of Independent States, while S. & C. are South and Central America. Data is given in Million tons of carbon dioxide. Countries in Africa, and those in S. & C. America region contribute the least to the global CO2 emission as of 2019. These regions contribute about 3.7% and 3.8% of the global CO2 emission respectively, while the CIS countries and the Middle Eastern countries contributed about 6.1% and 6.3% to the global CO2 emission respectively in 2019. Emission from European countries and countries in North America accounted for about 12.0% and 17.5% of the global CO2 emission while Asia Pacific countries contributed the largest amount of emission estimated at about 50.5% of the total CO2 emissions in 2019 (BP, 2020).

Figure 11: Trend of CO2 Emission in Africa (1965-2019)



Source: Authors' computations based on BP (2020) data.

The data in Figure 11 is given in Million tons of carbon dioxide. Looking at the trend of CO2 emissions in Africa between 1965 and 2019 as shown in Figure 11, the amount of CO2 emission in 2019 is put at 1308.52 (Million tons) compared to the estimated 193.90 (Million tons) in the mid-1960s (BP, 2020). This increase represents about 575% growth in emission over this period.

Even though Africa currently contribute a significantly low proportion of the global CO2 emission, the continuation on the path of the current energy mix may imply that Africa might as well be on its way to exacerbating the global greenhouse gas (GHG) emission even as the continent continues to experience growing energy demands and increasing urbanization over time. Thus, the reliance on fossil energy among oil-exporting countries and others in Africa does not only pose challenges to the economic sustainability of these nations but also has consequences on the concern for the desired environmental sustainability of the continent at large.

2.4. Oil Production and Sustainability Forecast: A Cost Comparison of Fossil Energy and Renewable Energy

Since fossil energy resources are non-renewable, their reserves are largely subject to depletion as extraction and consumption continue over time. Various factors determine and affect the rate of oil production which can include the level of political stability, the volume of reserves, the volume of demand (both local and international), and regulations or restrictions from international organizations or cartels such as the Organization of the Petroleum Exporting Countries (OPEC) among other factors.

Many of the oil-producing countries in Africa are a member of OPEC. The oil cartel helps them to take advantage of strategic benefits from production controls to stimulate commodity prices in the international oil market. Currently, OPEC member nations account for approximately 79.4% of the global proven crude reserves (OPEC, 2021).

Table 5: Oil Reserves and Daily Production as of July (2021)

Country	*2016*	*2017*	*2018*	*2019*	*2020*	*Daily Production as of July 2021*	*Estimated period to run out of oil*
Algeria	12,200	12,200	12,200	12,200	12,200	912	36.65 years
Angola	9,523	8,384	8,160	7,783	7,231	1319	15.02 years

*Rep of Congo**	2,982	2,982	2,982	1,947	1,811	281	17.66 years
Egypt	3,384	3,325	3,325	3,075	3,075	-	
*Equatorial G**	1,100	1,100	1,100	1,100	1,100	110	27.4 years
Gabon	2,000	2,000	2,000	2,000	2,000	161	34.03 years
Libya	48,363	48,363	48,363	48,363	48,363	-	
Nigeria	37,453	37,453	36,972	36,890	36,910	1579	64.04 years
Sudans	5,000	5,000	5,000	5,000	5,000	-	
Other Africa	6,870	6,870	6,870	6,870	6,870	-	
Total Africa	128,875	127,677	126,972	125,228	124,560	-	

Source: Compilation by the author based on OPEC (2021) data.

The data for Africa's proven crude oil reserves by country (2020) is provided in millions of barrels (mb) in Table 5 and the OPEC Members' crude oil production allocations are given in thousands of barrels per day (b/d). 'Sudans' stands for both Sudan and South Sudan, *Equatorial Guinea, and the Republic of Congo. Data for Libya's daily production is missing this may be due to the war situation that may have disrupted production activities over the years. Also, data for Egypt is missing since it is not an OPEC member state. The production in Sudan may have also been irregular due to the prolonged period of conflict between the then Sudan and the current new country of South Sudan. Based on the proven reserves and the volume of daily production, the estimated period of oil sustainability for each country is as follows;

Algeria

With a total reserve of 12.2 billion barrels of crude reserves as of December 2020, and a daily production rate of 912,000 barrels/day as of July 2021, ceteris paribus, the production is expected to last for at least 13,377.19 days. This will amount to an average of 36.65 years assuming 365days per year

Angola

With a total reserve of 7.231 billion barrels of crude reserves as of December 2020 and a daily production rate of 1,319,000 barrels/day as of July 2021, ceteris paribus, the production is expected to last for at least 5,482.18 days. This will amount to an average of 15.02 years assuming 365days per year.

Congo Republic

With a total reserve of 1.811 billion barrels of crude reserves as of December 2020 and a daily production rate of 281,000 barrels/day as of July 2021, ceteris paribus, the production is expected to last for at least 6,444.84 days. This will amount to an average of 17.66 years assuming 365days per year.

Equatorial Guinea

With a total reserve of 1.100 billion barrels of crude reserves as of December 2020 and a daily production rate of 110,000 barrels/day as of July 2021, ceteris paribus, the production is expected to last for at least 10,000 days. This will amount to an average of 27.4 years assuming 365days per year.

Gabon

With a total reserve of 2.0 billion barrels of crude reserves as of December 2020 and a daily production rate of 161,000 barrels/day as of July 2021, ceteris paribus, the production is expected to last for at least 12,422.36 days. This will amount to an average of 34.03 years assuming 365days per year.

Nigeria

With a total reserve of 36.910 billion barrels of crude reserves as of December 2020 and a daily production rate of 1,579,000 barrels/day as of July 2021, ceteris paribus, the production is expected to last for at least 23,375.55 days. This will amount to an average of 64.04 years assuming 365days per year.

NOTE:

It is important to point out that the production rates of July 2021 may not really provide a 100% picture of when the continent will run out of oil because production has generally declined in the outbreak of the Covid-19 pandemic since late 2020, and most of the countries are just recovering as of July 2021. Hence, the estimated years of production maybe a little lower than we have in Table 5. For instance, Nigeria usually produces about an average of 2.1 million barrels/day but the production has been hit by some of those issues earlier identified such as political instability in the oil-rich Niger delta areas and the outbreak of Covid-19. Considering a production rate of 2.1m b/d, it would have been about 17,576.19 days which would translate to 48.15 years. It can be concluded that oil is expected to be exhausted among these countries in the next 5 decades on an average.

2.4.1. The Search for Alternatives Energy Sources and Major Challenges

For sustainable energy production and consumption to be maintained in the future, alternatives must be sorted to replace fossil fuels dependency. As such, the attention of policymakers is rising as far as renewable energy productions are concerned. The major renewable energy used includes solar energy, wind power, hydroelectricity, geothermal power, and biomass energy. However, there are major challenges relating to the development and use of renewable energy and until the world overcomes a larger part of these challenges, the world may have to continue relying on burning fossil fuels over the next couple of decades.

Major Challenges of Renewables

- ***Uneven distribution of renewable resources***: output from renewables like solar and wind are often affected by geographical locations and factors like weather conditions that may create various disruptions to power production.

- ***Space Limitations***: production on a large scale for most renewables requires a large area of space be it land or sea and this can be a huge challenge to many countries that are constrained in space.
- ***Initial Pollution***: The production of many components of renewable energy appliances like solar photovoltaic requires the use of harmful chemicals and pollution emitting substances. Also, a lot of fossil fuels are burnt to generate energy for many renewable components.
- ***High Costs of Initial Installation***: This is applicable to most renewable energy especially wind and solar energy with the exception of hydro that may require a relatively low amount of capital for initial construction compared to the others. The Levelized cost of energy (LCOE) for renewables with the exception of hydro is often averagely higher than fossil fuel-based energy production.

Table 6: Cost of electricity by energy forms

Energy type	*Cost of electricity per kilowatt-hour (kWh)*
Concentrating solar power (CSP)	US$ 0.1820
Wind energy (offshore)	US$ 0.1150
Geothermal	US$ 0.0730
Solar photovoltaic (PV)	US$ 0.0680
Bioenergy	US$ 0.0660
Wind energy (onshore)	US$ 0.0530
Fossil energy	US$ 0.0500
Hydropower	US$ 0.0470

Source: International Renewable Energy Agency (IRENA, 2020)

According to IRENA (2020), the global weighted average cost of electricity (LCOE of electricity) of solar energy from solar photovoltaic (PV) and concentrating solar power (CSP) is US$ 0.068 per kilowatt-hour (kWh) and US$ 0.182/kWh accordingly as seen in Table 6. For wind energy (onshore and offshore) it is US$ 0.053/kWh and US$ 0.115/kWh, accordingly. Electricity from wind energy installation on land is the cheapest followed by solar PVs while concentrated solar power (CSP) is the most expensive. For bioenergy, it is around US$ 0.066/kWh while it is about US$ 0.073/kWh for geothermal.

Hydropower is the least in terms of cost but there was a rise in the LCOE of new hydro projects to about US$ 0.047/kWh in 2019 from about US$ 0.037/kWh that it used to be in 2010. The cost range for fossil energy (coal) is between US$ 0.05/kWh and US$ 0.177/kWh. Hence, the least Levelized cost of electricity from coal plants (US$ 0.05/kWh) is lower than all renewable in the exception of hydropower which accounts for about 90% of total renewable generation. Nevertheless, these figures demonstrate remarkable progress in the global renewable energy push.

However, despite the challenges, there are significant progress in renewable energy generations and cost efficiency over the years. The International Renewable Energy Agency (IRENA, 2020) has noted that the cost of renewables mainly solar and wind production has significantly dropped over the last couple of years (especially between 2010 and 2019).

Figure 12: Competitive Improvement in Renewable Energy Cost (2010-2019)

Source: International Renewable Energy Agency (IRENA, 2020)

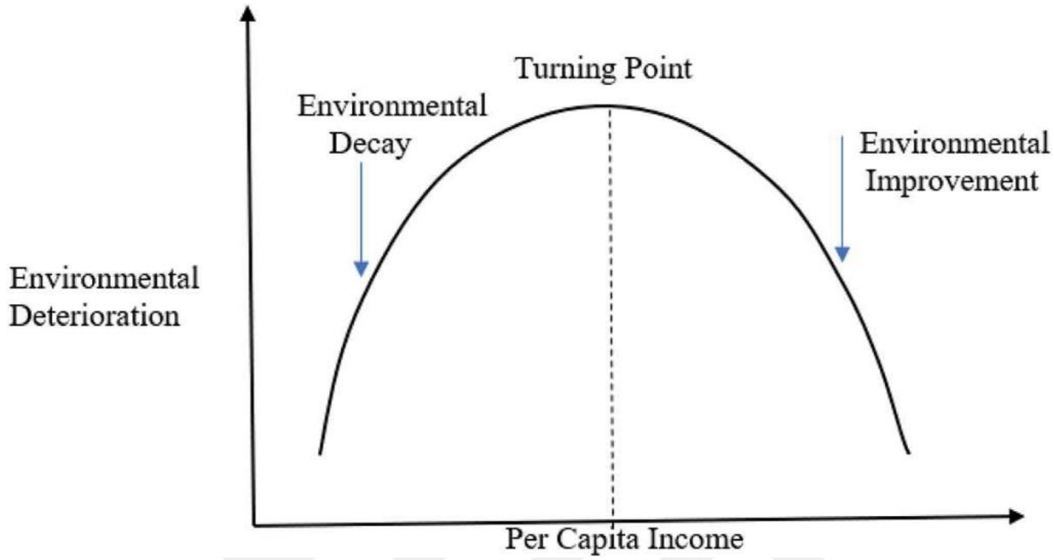
In figure 12, the cost of concentrating solar power (CSP) installation dropped by about 47% between 2010 and 2019, while those of utility-scale solar photovoltaics (PV) reduced largely by about 82% within the same period. Thus, the cost of all the renewable solar and wind technologies (the PV, the CSP, offshore, and onshore wind techs) have witnessed significant improvement over time.

2.5. Empirical Literature Review and Theoretical Framework in the EKC Perspective

The economic aspect of fossil energy resources has gained enormous attention from researchers and has ushered in several theories such as the previously discussed resources curse and Dutch diseases theories among others, the environmental aspect has also gained a lot of interest among researchers leading to developments of various theories. In this regard, the current research focuses on the environmental Kuznets curve (EKC) theory. Following the initial work of Kuznets (1955), an overall scan of the available empirical studies show that the environmental Kuznets conjecture has been examined by several researchers. Most of these studies were conducted for different countries within different conditions and assumptions. Although the initial study by Kuznets (1955) was tailored towards understanding how income inequality changes depending on the direction of economic expansion (growth) that is been witnessed in an economy. However, the application of the Kuznets curve’s concepts has now extended to many other fields including health economics, energy studies, and environment studies among others.

Based on the Kuznets curves’ illustration of the inequality movement in line with changes in economic growth, a demonstration of how the environment can also witness degradation or otherwise based on the economic growth pattern was also developed in what is commonly refers to as the environmental Kuznets curve (EKC).

Figure 13: Diagrammatical representation of the EKC conjecture



A graphical representation of the EKC is given in Figure 13 which shows an upside-down 'U'-shape connection between the degradation of the environment and economic expansion trends. In essence, based on the theory, it is expected that upward trend in growth would drive environmental pollution at an early stage, but this upward pollution trend would change the other way round (downward) at a certain point (turning point) as income continues to rise.

Until now, the question of whether the EKC always holds in an economy remains a subject of debate. In some available research works (Alola & Ozturk, 2021; Sarkodie & Ozturk, 2020; Bekun et al. 2021; Onifade et al. 2021a), but it has been declared invalid in some other research works including in the study of Koc & Bulus, (2020), the work of Sadik-Zada & Loewenstein (2020) as well as in the study of Pata & Aydin, (2020) among others.

The observed results from some empirical studies done on some African countries have also shown that the hypothesis is still subject to more research. For example, the study by El Hédi Arouri et al. (2011) on some selected Middle East and North African (MENA) countries examines the EKC conjecture within an income-pollution framework while adopting sulfur dioxide indicator as a proxy for the level of environmental degradation. They discovered that the EKC theory does not hold in the bloc. Unfortunately, their study didn't take into cognizance some other important issues that may be impacting the pollution-economic growth relationship. The study on the contrary only pays attention to the income component. The MENA region has also been examined in another research by Bibi and Jamil (2021). Besides the MENA region, their examination also includes the Sub-Saharan African countries. In a different style to the El Hédi Arouri et al. (2011), Bibi and Jamil (2021) applied carbon dioxide to represent environmental pollution while working with the fixed and random effect methods within a multivariate estimation framework. Interestingly, in contrast to the results of El Hédi Arouri et al. (2011), the findings they obtained supports the validity of the EKC theory in the examined MENA countries, but it does not support the EKC validity in the Sub-Sahara Africa countries.

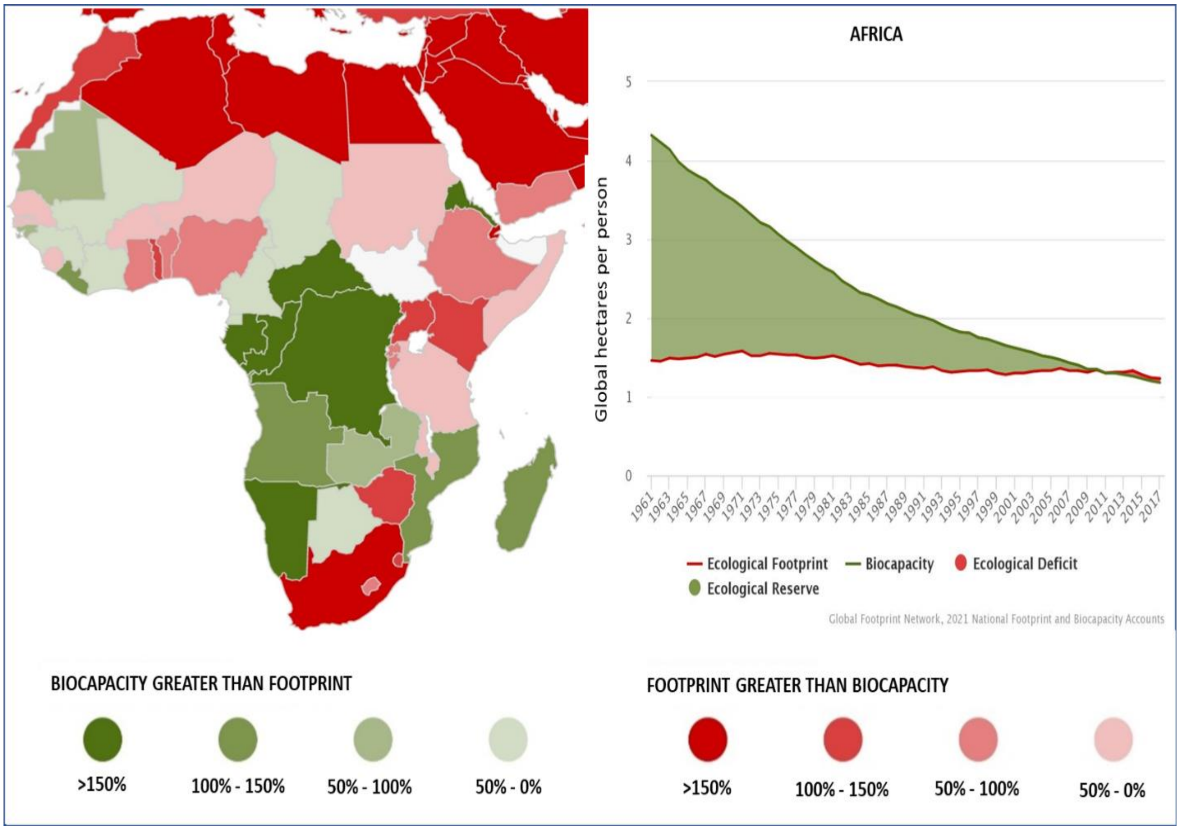
In another study, Demissew Beyene and Kotosz (2020) used the pooled mean group (PMG) method to check whether the EKC holds among a group of twelve (12) Eastern African countries. They realized that the theory is not valid for this group of countries. Unlike the EKC proportion, the research shows that the income-emission relationship follows initial negative pattern before more income growth now increases the pollution levels. Therefore, it was concluded that rather than having the normal inverted U-shape, the results support a bell shape EKC structure. In different but slightly similar research to the work of Demissew Beyene and Kotosz (2020), Onifade et al. (2021b), also the PMG approach for some selected African countries within the OPEC economic integration. They used more factors like renewable energy utilization and urbanization levels, and they discovered that these factors do not meaningfully influence the pollution level when looking at the CO2 emission trends. However, they confirmed that utilization of conventional energy sources significantly increases pollution. In addition, they did not agree with the EKC validity since their study shows a U-shape emission-income relationship unlike the expected inverted U-shape as envisaged by the theory.

However, there are also studies on African economies that support the EKC. For example, the study of Shahbaz et al. (2016) on influence of globalization in six (6) African economies confirms the EKC theory while affirming that globalization dampens pollution levels. Furthermore, Sarkodie (2018) also confirms the EKC in 17 African economies. From the study, it was discovered that the level of energy use, economic expansion and agricultural activities increases pollution levels in the African continent. Aside from Sarkodie (2018), Sarkodie & Ozturk (2020) also used a multivariate analysis to confirm the existence of the EKC in the case of Kenya. Overall, empirically, the issue of whether EKC holds or not is still contestable and it may be affected by certain factors such as difference in individual economic structures, the level of correctness of model specifications, the adopted method of analysis, and the understudied sample size among other issues. Hence, this dissertation considers a wide range of issues in creating an elaborate empirical investigation of the subject matter of energy use-environmental pollution linkage while reflecting on the validity of the EKC hypothesis in oil-exporting African economies.

2.6. Empirical Literature Review and Theoretical Framework in Ecological Footprint Perspectives

Aside from the gradual rise in CO2 emission, rising concern about environmental degradation can also be observed among many African countries when considering the amount of pressure exerted on the environment from human activities that cause the degradation of croplands and water resources alongside rising GHG emission levels vis-à-vis growing fossil energy production and consumption as encapsulated in the concept of the ecological footprint. The ecological footprint of a place is calculated in global hectares (gha) and it assesses the extent to which the biosphere is pressurized as a result of various consumption activities from the human population that makes up an environment. On the other hand, the biocapacity of an environment is the ability of its ecosystem to generate the necessary biological resources to support the need of the population as well as to process the waste generated from human consumption and production activities. According to the global footprint network (2021), there are geographical locations where the available footprint exceeds the biocapacity leading to a condition that is commonly referred to as ecological deficit. This implies that the economies in such areas are importing biocapacity via trade especially in the era of globalization, thereby depleting ecological assets, and encouraging more emission of greenhouse gas (GHG) especially carbon dioxide (CO2).

Figure 14: Ecological Footprint and Biocapacity in Africa



Source: Global Footprint Network (2021)

Ecological footprint has been on a gradual rise in many African countries while biocapacity has been on the decline over the years as seen in Figure 14. In the current study, attention is given to the bloc of oil-exporting countries considering that some of the countries are notably among the list of countries at a deficit when viewing environmental degradation from the perspective of rising ecological footprint amidst deteriorating biocapacity in Africa. Especially, those in the North Africa region including Libya, Algeria, Egypt, and Tunisia while other notable countries with increasing footprint include Nigeria and Sudan.

While it is well known that environmental degradations pose a significant danger to the sustainability of our global environment, Africa might be at greater risk as millions of people on the continent are highly vulnerable to the damages of environmental pollution such as the threats from climate change due to the continent's low capacity for adaption (UNEP, 2020). The International Energy Agency (IEA, 2019) has also noted that Africa could be one-sidedly exposed to more dangers of climate change that is been aggravated by global greenhouse gas emission even though the continent emits just about 2% of carbon dioxide (CO_2) emission from energy induced activities.

As noted earlier in the literature, environmental degradation encompasses pollution of various kinds including land pollution, water pollution, and air pollution. Environmental degradation poses threats to not just economic activities alone but even to the very existence of life on our planet (Mora et al., 2018; Nordhaus, 2019). Human activities have led to a drastic rise in the level of carbon emissions over the years and many economic activities and prosperity of several economies are even directly or indirectly tied to industries that thrive on resource extraction and energy consumption such as in the case of many hydrocarbons rich nations. Hence, there is a rising trend in the number of studies being conducted to recommend policies towards addressing the challenges of environmental pollution.

Most of the extant studies have delivered mixed findings. Several studies have utilized carbon dioxide emissions levels as the environmental quality measure (Sinha & Shahbaz, 2018; Sarkodie & Ozturk, 2020; Sadik-Zada & Loewenstein, 2020), while some have used other proxies like the ecological and carbon footprint (Charfeddine, 2017; Ansari et al. 2020; Ahmed et al. 2020a). Some of these studies have focused on understanding the roles of natural resource rents and energy consumption in the subject matter of environmental degradation. In terms of the impact of natural resource rents on environmental degradation, some studies demonstrate that natural resource rents positively affect environmental degradation, thus postulating policies to reduce human dependency on natural resources to protect the environment (Ahmed et al. 2020b; Bekun et al. 2019; Shen et al. 2021; Ansari et al, 2021).

Ahmed et al. (2020b) investigates the implication of natural resource abundance on environmental quality. The study's sample framework was drawn from China between 1970 and 2016 using ecological footprint as a proxy for environmental degradation. The methodology applied in the study follows the study of Shahbaz et al. (2018) and Ahmed et al. (2020a) which depended on the association test within the bootstrap causality method. The result demonstrates that natural resource rent is positively correlated with the ecological footprint, which suggests that higher natural resource rent induces more environmental destruction.

Furthermore, economic growth, which is in line with energy consumption, also contributes to environmental degradation as seen in the study. The positive association between energy consumption and environmental degradation was also investigated in the study of Charfeddine (2017). The study explored the impact of energy consumption and economic growth on environmental degradation with Qatar as a sample country for the period between 1970 and 2015. The study utilizes ecological footprint, carbon footprint, and CO_2 emissions as a measure of environmental degradation within the Markov-Switching Equilibrium Correction Model. The findings suggested that energy consumption, which is represented by electricity consumption, positively correlates with ecological footprint but negatively associates with ecological carbon footprint and CO_2 emissions.

In another study by Ansari et al. (2020), the link between energy consumption and degradation was also investigated in the top renewable energy-consuming countries. In their study, the ecological footprint was used to represent environmental degradation while categorizing energy consumption into renewable and non-renewable sources. The study makes use of the fully modified ordinary least square (FMOLS) and the dynamic modified ordinary least square (DOLS), in addition to the standard OLS, as the tools for the empirical analysis. Based on these methods, the study demonstrates that non-renewable energy consumption significantly contributes to environmental degradation. In contrast, renewable energy consumption was found to be insignificant in affecting environmental degradation.

Several studies have been able to demonstrate the positive impact of energy consumption on carbon dioxide emission, (Sarkodie & Ozturk, 2020; Sadik-Zada & Loewenstein, 2020; Ahmed et 2020; Umar et al., 2021; Onifade et al. 2021a; Ansari et al. 2020). However, others have also argued that a negative impact of energy consumption on environmental quality can hold in the short run (Sharif et al. 2019; Pata, 2018), while the study of Shen et al. (2021) revealed that energy consumption is contributing to the rising pollution, either in the short or long run. Furthermore, the study of Gorus and Aydin (2019) has even revealed that the relationship between energy consumption and environmental degradation can be unclear. Therefore, the nexus between natural resource rents, energy consumption, and environmental degradation still requires further studies.

In the context of oil-exporting economies, there are only a few studies that have delved into the energy dynamics and environmental degradation nexus from the perspective of the resource rents specifically by utilizing ecological footprint for environmental quality measurements such as Charfeddine (2017) for Qatar, and Charfeddine & Mrabet (2017) for MENA countries. On the other hand, using carbon emission levels for environmental degradation proxy, some studies have incorporated some oil-producing countries in their analysis such as the study of Onifade et al, (2021b) and the work of Sadik-Zada & Loewenstein (2020). Charfeddine & Mrabet (2017) observed that energy use compounds environmental challenges from increasing ecological footprint among oil-producing MENA economies. Their study also confirms the EKC proposition for the case of these economies. They also obtained evidence that demographic factors like urbanization enhance the quality of the environment.

In a closely related study, Charfeddine (2017) noted that urbanization and trade openness increase environmental degradation in the Qatari economy. The study of Sadik-

Zada & Loewenstein (2020) revealed that fossil energy consumption and natural resources drive carbon emissions in resource-rich economies. Studies on Africa countries has only received little attention in the literature compared to the cases of individual country or group of countries in other regions around the globe such as the EU countries and the OECD countries among others.

Hence, the present study explores the dynamic nexus between energy indicators and environmental destruction from the perspective of ecological footprint using the specific case of oil-exporting African economies as a single bloc. Although environmental degradation is a global challenge, the present study is highly imperative given that Africa has been identified as highly susceptible to environmental damages in particular.

2.7. Empirical Literature Review in Fossil Energy Use, Urbanization, and Globalization Perspectives

There are various forms of environmental degradation including pollution of various kinds such as land pollution, water pollution, and air pollution. As noted earlier in the background, among the notable environmental challenges many African countries are facing in recent times include food insecurity, land degradation, deteriorating quality of air amidst water and sanitation challenges, and sustainable energy challenges. On the aspect of land degradation, it has been observed that around half a million square kilometers (0.5 million km2) of land undergo degradation annually as a result of factors like pollution, deforestation, and soil erosion in Africa (UNEA, 2020). This situation is also being complicated by the increasing rate of urbanization, and the challenges of oil spillage during oil and gas exploration for the case of the lands in oil-rich regions. These problems do not only pose negative impacts on agricultural practices like cropping and fishing, but they also go a long way in affecting the general terrestrial ecosystem and other economic activities like tourism (Osuji and Onojake, 2004; Osuagwu and Olaifa, 2018; Ozigis et al., 2020; Magris and Giarrizzo, 2020).

The recent trend has shown that environmental challenges posed by greenhouse gas (GHG) emissions pose threats in several aspects including threats to economic activities and even to the very existence of life on our planet (Mora et al., 2018; Nordhaus, 2019). Human activities have led to a drastic upward rise in the level of carbon dioxide emissions over the years and many economic activities and prosperity of several economies are even directly or indirectly tied to industries that thrive on resource extraction and consumption such as in the case of many hydrocarbons rich nations. On the other hand, the need to support the call for collaborations for environmental sustainability through decarbonization has been on the increase (IPCC, 2019; IPCC, 2021; UNFCCC, 2015). This is just as many countries are battling with the quest to boost economic growth through industrialization that is often promoted on the ambient of higher energy consumption, thus raising the questions about challenges of Greenhouse gas (GHG) emission.

However, efforts made towards addressing emissions level through decarbonization have majorly focused on the leading GHG emitting countries like China, the United States of America, the European Union (EU) member countries, and India among others (UNEP, 2020). Several empirical studies have been conducted to address the impacts of energy indicators on carbon emission levels and some have also addressed the challenges of increasing ecological footprint and deteriorating biocapacity in different countries.

As noted earlier, the largest proportion of such studies has concentrated on addressing the subject matter in developed economies like the United States (US), the United Kingdom (UK), and bodies of economic integration like the European Union (EU) (González et al., 2014; Bekun et al., 2019; Destek et al., 2018; Adedoyin et al., 2020; Adedoyin & Zakari, 2020). Others have also concentrated on countries in major economic classification like the Organization for Economic Cooperation and Development (OECD) (Tajudeen et al., 2018; Mensah et al., 2018; Saidi & Omri, 2020), thus leading to a gap in the empirical literature between many African countries and the rest of the world. The major exception appears to be in the case of South Africa (SA) which has gotten substantial attention under the classification of the BRICS economies (Haseeb et al., 2018; Baloch et al., 2019; Hassan et al., 2020).

Major energy indicators that have been used for empirical analysis in most of the extant studies include energy consumption, urbanization, globalization, foreign direct investment, and income levels among other indicators. Many of the studies have attempted to explore the factors contributing to emission levels and the outcomes vary from one study to another especially in the context of the indicators used, the methods, and also in terms of the magnitudes of the impacts of the adopted indicators.

González et al. (2014) undertook a cross-country study of the EU through index decomposition analysis to explore the drivers of CO2 emissions. Their findings suggested that the improvement in energy efficiency was enough to offset the undesirable pressure from GDP growth to carbon dioxide emission in the EU. However, in a different study on 16 EU countries, Bekun et al. (2019) utilized the panel PMG-ARDL approach and observed that GDP growth aids CO2 emission in the EU. In addition, their results also confirmed the adverse effects of fossil fuels on CO2 emissions levels in the EU. Adedoyin et al (2020) applied the fully modified ordinary least square (FMOLS) and the Dynamic Ordinary Least Square (DOLS) in another study on the EU and their findings closely corroborated parts of the observations made by Bekun et al. (2019). Although the result of Tajudeen et al. (2018) through a combination of econometric techniques shows that energy efficiency helps to curtail carbon dioxide emission in the OECD, they however observed that income level acts as the highest contributor to CO2 emission in the bloc.

The significance of renewable energy towards reducing CO2 emission among OECD countries was upheld in the study of Mensah et al. (2018). Findings from another study by Saidi & Omri (2020) through the application of the Autoregressive distributed lags (ARDL) technique further supports the claims from the study of Mensah et al. (2018) regarding the roles of renewables in decarbonization. They concluded that the combination of nuclear and renewables would foster the decarbonization process among the OECD countries.

As for Africa, the recent trend to extend the literature has ushered in some changes in the dynamics of research penetration and this change has been disproportionately favorable to the case of South Africa (SA) among other African countries. Haseeb et al. (2018) utilized the FMOLS approach to examine the impacts of globalization and financial developments for the BRICS economies which covers the case of South Africa. Having validated the EKC hypothesis, they observed that globalization reduces emission while energy use is inimical to decarbonization prospects in the BRICS economies. In a different study, Baloch et al. (2019) applied the AMG approach and observed that natural resource increase carbon dioxide emissions levels in South Africa, while the findings of Hassan et al. (2020) shows that renewable energy is more effective in addressing environmental degradation than nuclear energy among the BRICS economies.

There have been mixed results on country-specific analysis for other countries in Africa. For Egypt, Mahmood et al. (2019a) examined the link between CO2 emission and energy indicators. Their study shows that foreign direct investment abates carbon emission levels while energy consumption causes more pollution. Their conclusions were drawn from the empirical analysis based on the ARDL bound test approach. Their study also confirms the EKC hypothesis for Egypt. However, their findings contradict the results of Ibrahiem (2016) where the EKC hypothesis was not supported for the case of Egypt. For the case of Tunisia, Mahmood et al. (2019b) also confirmed the EKC hypothesis with different turning points while the impacts of trade openness were not significant to carbon emission. In another study by Sghaier et al. (2019), the EKC hypothesis was confirmed for Morocco and Egypt while the hypothesis was not upheld in Tunisia.

Demissew et al. (2020) used the ARDL-PMG approach to examine the EKC hypothesis for some east African countries and concluded that the hypothesis only holds in the short run but does not hold in the long run. They further concluded that economic processes do not induce CO2 emission in East Africa. A similar result was seen from the findings of Onifade et al (2021a) in a study on a group of OPEC countries where the EKC was rejected. Their study extended to Africa because some of the oil producers in Africa are also members of OPEC. Their findings show that fossil energy consumption increases environmental degradation among these countries. The results did not uphold the validity of the EKC hypothesis for these African countries among other OPEC members.

2.8. Empirical Contributions Based on the Gaps in the Literature

There is inadequate attention in the empirical literature as far as African countries are concerned. Hence, this research aims to contribute to the expansion of the existing progress on the issue of energy dynamics and environmental concerns towards addressing the global decarbonization prospects from an African perspective by using empirical illustrations from the case of oil-exporting African economies. The contributions of this research work are therefore encompassed in the empirical analysis which is arranged into 3 major sub-categories as summarized below based on the gaps in the extant studies:

i. Firstly, there are no available studies based on sectorial examination of the EKC validity for African economies in general and for the category of the oil-exporting African economies in specific. This is a crucial aspect in understanding the likely issues of the Dutch diseases among the countries in addition to the environmental challenges. Therefore, an examination of the EKC conjecture in a wider scope that takes into cognizance the hitherto ignored possible influence of sectoral distribution in terms of the share of manufacturing and the services sectors alongside the roles of the energy sector of selected leading oil-exporting African economies helps this dissertation to make useful contribution to the growing literature.

ii. Using the broad scope of the ecological footprint which extends beyond the carbon emissions component alone, the empirical analysis of this study also contributes to the expansion of the existing debate on the issue of energy dynamics and environmental concerns from the case of oil-exporting African economies as a bloc that has generally attracted little or no attention in the past. In addition, the study provides empirical-based policy recommendations to facilitate collective actions for climate protections while taking into cognizance the issue of the quest for sustainable economic growth among African oil-exporters thereby contributing a quota to the actualization of some specific United Nations Sustainable Development Goals (SDGs-8, 11, & 13) for the understudied countries and the continent of Africa at large.

iii. Taking into cognizance the crucial risks posed by climate change on a global level and especially in Africa, and also bearing in mind that majority of the oil-exporting countries are economically tied to the revenue from the oil and gas industry that is subject to various degrees of volatility vis-à-vis the occurrence of shocks and disruptions in our increasingly globalized world, this research seeks to explore the impacts of the prevailing energy dynamics of mainly oil-producing nations towards addressing the global decarbonization prospects while also throwing light on the economic aspects of such prospects from an African perspective. In addition, the adopted empirical approach also provides relevant panaceas to potential flaws in extant literature. For instance, the study significantly takes care of the limitations of cross-sectional dependence through the adopted techniques thereby avoiding notable flaws in extant studies.

CHAPTER THREE

METHODOLOGY AND DATA PRESENTATION

In this chapter, we shall be providing the full information about the empirical approaches adopted in this research. This chapter will cover several aspects including presentation of data, the analysis of the data used, the processes involve in the analysis, justifications for methodological approaches, while the findings, and subsequent interpretation of the results will follow in the next chapter. As noted in Chapter 2, the empirical analysis is provided in three (3) sub-groups. The first is the empirical analysis that examines the nexus of environmental pollution and energy dynamics of oil producing African countries in our typical globalized world. The second analysis focuses on the nexus of environmental degradation and urbanization in an ecological footprint framework. The third is the empirical analysis that examines the nexus of environmental pollution with fossil energy resources abundance in a sectoral composition framework. There are two main convergence points in the 3 sub-categories of analysis namely; (a) The use of oil-producing African states in the empirical models, and (b) The examination of the environmental Kuznets curve (EKC) hypothesis in the estimations. However, there are a few divergence points based on the sub-groups of analysis due to some minimal variations in individual sample sizes and adopted methodological procedures.

3.1. The Nexus of Environmental Pollution and Energy Dynamics in a Globalized World

3.1.1. Scope of study and model specifications

To examine the impacts of fossil energy use and renewable energy sources in an attempt to explore the significance of energy mix for both environmental and economic sustainability of African oil-exporting countries, we proposed the energy consumption indicator model for impact analysis on carbon emission while capturing the influence of globalization and income levels among the countries, as framed in equation 1.

$$LogCO_{2_{it}} = \alpha_0 + \alpha_1 LogPY_{it} + \alpha_2 LogPY2_{it} + \alpha_3 LogFFE_{it} + \alpha_2 LogRWE_{it} + \alpha_6 LogATE_{it} + \alpha_7 LogGZ_{it} + \varepsilon_{it} \quad (1)$$

Full details about the variables presented in equation 1 are given in Table 7. The scope of the present study covers nine (9) countries including Algeria, Nigeria, Angola, Egypt, Republic of Congo, Gabon, Sudan, Tunisia, and South Africa. Some other oil-rich countries like Libya, Equatorial Guinea, and South Sudan were excluded from the study due to some obvious reasons. For instance, we left out South Sudan from the study, although rich in oil resources but data is limited for the country considering that this country is the youngest African nation.

On the other hand, while we focus on the oil-exporters, this study also incorporates South Africa (SA) in the analysis. Although SA is not a notable oil-exporter, however, it is among the leading carbon-intensive nations in the world and by far the leading in Africa due to the high level of energy demand for its industrial economy with a significant proportion of its electricity generation coming from coal which is another prominent fossil energy source (Eberhard, 2011).

Table 7: Data Information

SYMBOLS	VARIABLES	SOURCES
CO_2	The amount of carbon dioxide emissions in metric tons per capita	WDI (2021)
PY	Real GDP per Capita evaluated in value of current US$	WDI (2021)
FFE	Fossil fuel energy consumption obtained as a % of the total energy use	WDI (2021)
RWE	Renewable energy utilization taken in terms of the % of total energy utilization for the understudied economies	WDI (2021)
ATE	Alternative and nuclear energy is given as a % of the total energy consumption	WDI (2021)
GZ	Globalization KOF globalization Index	KOF index (2021)

Sources: The author's compilation using data are from the World Bank Data World Development Indicators (2021) and the globalization index of the KOF Swiss Economic Institute (Gygli et al. 2019).

3.1.2. Descriptive Statistics of Sample

This study utilizes a combination of second-generation panel data analytical approaches. The adoption of the methodologies was inspired by the crucial need to accommodate the statistical features of the obtained panel data based on the outcomes of necessary pre-estimation tests. Firstly, we presented the simple statistics that describe the analyzed data in Table 8.

Table 8: Summary Statistics and Sample Correlation Matrix

Variables	***LogCO₂***	***LogPY***	***LogPY²***	***LogFFE***	***LogRWE***	***LogATE***	***LogGZ***
Mean	0.134	1.666	4.190	1.651	1.339	-0.130	1.694
Median	0.252	1.636	2.674	1.591	1.783	0.121	1.694
Maximum	0.991	10.130	102.90	1.990	1.949	0.641	1.845
Minimum	-0.972	-0.001	6.94E-0	1.046	-1.230	-1.901	1.470
Standard D.	0.501	1.192	11.298	0.301	0.760	0.640	0.091
Observations	234.0	234.0	234.0	234.0	234.0	234.0	234.0
Matrix for the Correlation							
Variables	***LogCO₂***	***LogPY***	***LogPY²***	***LogFFE***	***LogRWE***	***LogATE***	***LogGZ***
LogCO₂	1						
LogPY	0.112[c]	1					
LogPY²	-0.087	0.936[a]	1				
LogFFE	0.707[a]	0.054	-0.082	1			
LogRWE	-0.490[a]	-0.061	0.060	-0.770[a]	1		
LogATE	-0.011	-0.038	-0.004	-0.252[a]	0.612[a]	1	
LogGZ	0.623[a]	-0.115[c]	-0.250[a]	0.613[a]	-0.341[a]	-0.071	1

Note: the superscripts a, b, and c signify statistical significance of estimates at 1%, 5%, and 10% levels accordingly

The correlation statistics in Table 8 show a weak positive correlation between income levels and carbon emission levels but a strong positive correlation with fossil fuel use and globalization. Both renewables and alternatives are negatively correlated with emission levels.

3.1.3. Estimation Procedures

Given this brief information about the variables, next, we proceed to check the panel unit root properties but before then, a cross-sectional dependency (CD) test was examined. We opted for the CD test considering that the panel-data models for the oil-exporting countries in this research are most likely to be cross-sectionally dependent especially as economic activities are likely bound to be closely linked such that the error component of the study is influenced by related common shocks among the countries.

The significance of the CD test has been spelled out in some fundamental works (Pesaran, 2007; Chudik et al., 2016). Thus, as a guide to making accurate decisions regarding choices of other techniques for empirical analysis like unit-root tests and cointegration tests among others, the CD test was not overlooked in this study.

$$Y_{it} = \delta_i + \alpha_i X_{it} + \mu_{it} \quad (2)$$

$$LM = T \sum_{i=1}^{N-1} \sum_{J=i+1}^{N} \hat{\rho}_{ij}^{2} \, \chi^2_{N(N-1)/2} \quad (3)$$

Given the generalized panel relationship model in equation 2 where the cross-section dimension (i) varies from 1 to N and the period of time (t) from 1 to T, the null assertion of absence of cross-section dependence shows that Cov(μ_{it}, μ_{jt}) = 0 while the alternative argues for the presence of CD in at least a pair of the cross-sections such that Cov(μ_{it}, μ_{jt}) ≠ 0. Following the OLS estimation of equation (2), we reported the outputs from the Lagrange Multiplier (LM) approach of Breusch and Pagan (1980) where the pair-wise correlation of the obtained residuals is denoted by ρˆij. This approach has been noted to be very suitable in analysis where the cross-section is slightly small however where T is relatively large (Destek et al. 2018; Xu, 2018).

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \left(\sum_{i=1}^{N-1} \sum_{J=i+1}^{N} \hat{\rho}_{ij}\right) \quad (4)$$

$$\hat{\rho}_{ji} = \hat{\rho}_{ij} = \frac{\sum_{t-1}^{T} \hat{\mu}_{i,t}\hat{\mu}_{j,t}}{(\sum_{t=1}^{T} \hat{\mu}_{it}^{2})^{\frac{1}{2}}(\sum_{t=1}^{T} \hat{\mu}_{jt}^{2})^{\frac{1}{2}}} \quad (5)$$

Following equations 4 and 5, we also utilized the later version of the LM test for CD by Pesaran (2015) which is better off as it is suitable for a small sample while also accounting for weak cross-sectional dependency and possible slope heterogeneity in the data set (Xu, 2018). The test statistics for the corresponding estimated residuals (μ) follow the assumption of an asymptotic distribution such that CD~N(0, 1). The results of the combination of CD tests including those of Pesaran (2007) were presented and discussed in the results sections.

Next, we proceed to examine the unit-root features of the variables before ascertaining if there is a level relationship among them. Given the presence of the CD, we applied the CIPS panel unit root test of Pesaran (2007) which is a second-generation or augmented version of the IPS unit root test (Im et al., 2003). The examination of the level relationship was carried out with the application of the Westerlund (2007) cointegration framework following the error correction process in equation 6.

$$\Delta Y_{it} = \beta_i D_t + \psi_i Y_{it-1} + \lambda_i X_{it-1} + \sum_{j=1}^{pi} \psi_{ij}\Delta Y_{i,t-j} + \sum_{j=0}^{pi} \gamma_{ij}\Delta X_{i,t-j} + \varepsilon_{it} \quad (6)$$

In equation 6, ascertaining the level relationship follows the outputs of the obtained panel statistics and group statistics (Pt, Pα Gt, Gα,) in line with the estimation of the error correction term (ψ_i). Where the vector of parameters is denoted by β_t while Dt represents the deterministic specifications which can be set at Dt = (0), Dt = (1), or Dt = (1, t), for a model that does not have a deterministic part, but contains just the constant part, and the that has a combination of trend and constant respectively. Subsequently, following the consolidated works of Koenker (2004) and Powell (2016), the proposed panel Quantile regression (QR) method of Koenker and Bassett (1978) was utilized when estimating the long-run impacts while also providing a comprehensive robustness check with the Augmented Mean Group (AMG) method of Eberhardt and Bond (2009) and Eberhardt and Teal (2010).

The QR representations shown in Equation 7 relates to the nexus among variables in equation 1 whereby $QLnCO2_{it}(\tau/\chi_{it})$ denotes the τ^{th} conditional quantile of the pollution levels as captured by carbon emissions among the countries. Given the determined quantile (τ) for the understudied data set for country i at time t, the vector of the explanatory variables is denoted by χ_{it}. As for the slopes of the independent variables, they are denoted by δ while ω_{it} represents the error term for the given vector.

$$QLogCO_{2it}\left(\frac{\tau}{\chi_{it}}\right) = \delta_i^{(\tau)} + \delta_1^{(\tau)}LogPY_{it} + \delta_2^{(\tau)}\, LogPY_{it}^2 + \delta_3^{(\tau)}LogFFE_{it} + \delta_4^{(\tau)}LogRWE_{it} + \delta_5^{(\tau)}LogATE_{it} + \delta_6^{(\tau)}LogGZ_{it} + \omega_{it} \quad (7)$$

Applying both the QR methodology and AMG approaches offers certain benefits for a study like this. Firstly, the former approach is quite flexible, and it makes assessing the impacts of the explanatory variables possible on the explained variable at desired quantiles while the latter approach offers ample insights into country-specific attributes. Secondly, both methods are preferable choices in dealing with the cross-sectional attributes of our data set compared to first-generation panel estimators (Nwaka et al. 2020). Finally, the granger causality nexus among variables was explored using Dumitrescu and Hurlin's (DH, 2012) causality approach.

3.2. The Nexus of Environmental Degradation and Urbanization in an Ecological Footprint Framework

3.2.1. Scope of study and model specifications

For this category, the study utilized panel data on a collection of ten (10) oil-exporting African economies spanning from 1990 to 2016. The World bank development indicator (WDI, 2021), and the globalization index of the KOF Swiss Economic Institute (Gygli et al. 2019) were consulted for sourcing the relevant data. Countries in the current study include Algeria, Libya, Nigeria, Angola, Sudan, Egypt, Tunisia, the Republic of Congo, Gabon, and South Africa. All these countries are notable fossil energy-rich countries being among the major oil producers on the African continent except for South

Africa. However, the inclusion of South Africa is justifiable being the top carbon-emitting nation in Africa (Ndoricimpa, 2017; UNEP, 2020). Besides, South Africa also has a high dependence on fossil energy production as coal consumption account for a significant proportion of electricity generation in the country (De Groot et al. 2013; Beidari et al. 2017).

Other notable oil-rich countries that were omitted in the current study due to the constraint of data include Equatorial Guinea, Sao Tome & Principe, and Chad. South Sudan was also left out of the study due to data constraints as the nation newly became the youngest African country in 2012.

3.2.2. Baseline Models

The environmental impacts of natural resources were observed from the perspective of the interaction between resource rent and energy production within the context of the ecological footprint of the individual country as a measure of environmental degradation. The impacts of the interaction between natural resources rent (from oil, gas, and coal sources) and the rate of energy consumption from these fossil resources were observed on the ecological footprints of the countries as seen in the baseline model in equation 1. While doing so, the impacts of other energy-related indicators like urbanization, renewable energy consumption, globalization, and income levels among the countries were also taken into cognizance.

$$LogEcFP_{it} = \alpha_0 + \alpha_1 LogRY_{it} + \alpha_2 LogNRFF_{it} + \alpha_3 LogRWC_{it} + \alpha_4 LogUBR_{it} + \alpha_5 LogGLZ_{it} + \varepsilon_{it} \qquad (1)$$

In equation 1, $EcFP_{it}$ represents ecological footprint (taken in global hectares per capita). Ecological footprint encapsulates the sum of cropland, grazing land, forest land, fishing infrastructure, and carbon. The decision to utilize ecological footprint as the explained variable in the baseline model was informed by its broad composition rather than using only the carbon emission (CO2) proxy. RY_{it} is the income levels among the countries represented by the real GDP per capita in value of current US$, while $NRFF_{it}$ denotes the interaction term for total natural resource rent and energy consumption level.

Total natural resources rents are the sum of oil rents, natural gas rents, and coal rents (fossil resources), while energy consumption was captured by the level of fossil fuel energy consumption taken as a percentage of the total energy consumption.

Rather than taking an isolated approach to looking at the impact of resource rent and fossil energy consumption, the current approach takes into cognizance the direct link between the duo of resource rent from fossil resources and energy production from them by leveraging on the product of the two variables. This is necessary considering that the natural resource rent data of the world bank (WDI, 2021) essentially covers rents on three main fossil energy resources namely oil, gas, and coal. Hence, interacting the fossil resource rent with the energy generation from the fossil sources provides a better insight into the inherent link between environmental degradation, natural resources, and energy use. UBR_{it} represents urbanization proxied by the urban population (measured as a % of the total population), while RWC_{it} represents renewable energy consumption taken as a percentage of total energy consumption. GLZ_{it} is the proxy for globalization which was drawn from Gygli et al (2019). The computation of the index encompasses different aspects of globalization including economic, social, and political dimensions of globalization. This proxy is preferable to the use of a simple variable like trade openness as seen in some related studies (Charfeddine, 2017; Onifade et al. 2021a).

$$LogEcFP_{it} = \beta_0 + \beta_1 LogRY_{it} + \beta_2 LogRY_{it}^2 + \mu_{it} \qquad (2)$$

Subsequently, equation 2 was set up to examine the validness of the environmental Kuznets curve (EKC) hypothesis for the group of countries. In the equation, RY_{it}^2 is the square of the real income level while other variables remained as previously defined. In line with contemporary studies (Sarkodie & Ozturk, 2020; Sadik-Zada & Loewenstein, 2020), it is expected that the estimated β_1 *and* β_2 coefficients turn out positive and negative respectively to validate the EKC for the countries in the panel observations.

3.2.3. Empirical Procedures

Research involving data analysis via econometric approaches requires pertinent preliminary tests for an understanding of the statistical features of the data sets to avoid methodological flaws and spurious estimations (Shrestha & Bhatta, 2018; Çoban et al. 2020). Thus, to begin with, the summary statistics of the panel data set were presented for the study (see Table 14 in Chapter 4) and subsequently examine the underlying traits of the dataset by looking at the cross-sectional dependency (CD) test while also taking into cognizance the importance of a unit root test respectively.

The CD was necessary to ensure that appropriate methodologies were chosen for the analysis. It is known that the efficiency of estimators and methodologies in panel analysis can be undermined in a situation where the error component of the panel estimations is affected by similar shocks among sample observations as noted by Pesaran (2007) and Chudik et al., (2016). Hence, the CD test by Pesaran (2015) which is an advanced version of the Langrage Multiplier (LM) test was used to examine cross-sectional dependence in the panel set. Given a cross-section dimension (i) ranging from 1 to N and the time period (t) ranging from 1 to T in a simple panel representation in equation 3, the claim of no cross-section dependence according to the null hypothesis suggests that Cov$(\mu_{it}, \mu_{jt}) = 0$ contrary to an alternative hypothesis that supports the existence of CD in at least a combination of the given cross-sections, meaning that Cov$(\mu_{it}, \mu_{jt}) \neq 0$.

$$Y_{it} = \delta_i + \alpha_i X_{it} + \mu_{it} \qquad (3)$$

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)}\left(\sum_{i=1}^{N-1}\sum_{J=i+1}^{N} \hat{\rho}_{ij}\right) \qquad (4)$$

$$\hat{\rho}_{ji} = \hat{\rho}_{ij} = \frac{\sum_{t-1}^{T} \hat{\mu}_{i,t}\hat{\mu}_{j,t}}{\left(\sum_{t=1}^{T} \hat{\mu}_{it}^{2}\right)^{\frac{1}{2}}\left(\sum_{t=1}^{T} \hat{\mu}_{jt}^{2}\right)^{\frac{1}{2}}} \qquad (5)$$

Subsequently, from equation (4) and (5), the test statistics for the observed residuals (μ) is expected to be asymptotically distributed such that CD~N(0, 1). This method is unique for relatively small sample observations as it is robust for slope heterogeneity while capturing weak-correctional dependence in panel observations (Pesaran, 2015; Xu, 2018). In Chapter 3.1.2 (see Table 7), the outcome of the Pesaran (2015) LM Test was not reported alone, but also those of the Breusch and Pagan (1980) LM Test, and Pesaran (2007) CD Tests were also reported for comparative analysis. All the approaches indicated the existence of CD thus beckoning for a reliable unit root approach and cointegration techniques that are suitable for cross-sectional dependence challenges. As such, the second-generation version of Im et al., (2003) panel unit root test known as the CIPS panel unit root test (Pesaran, 2007) was adopted, while Westerlund's (2007) cointegration technique was used to explore the level relationship between the panel variables.

The Westerlund (2007) cointegration technique has proved to be very useful in some studies (Alola et al 2019; Gyamfi et al 2021a; Adedoyin et al 2021), this technique follows the error adjustment procedures for establishing long-run relationships among variables based on the calculated panel statistics (Pt, Pα) and group statistics (Gt, Gα,) as shown in Equation (6).

$$\Delta Y_{it} = \beta_i D_t + \psi_i Y_{it-1} + \lambda_i X_{it-1} + \sum_{j=1}^{pi} \psi_{ij} \Delta Y_{i,t-j} + \sum_{j=0}^{pi} \gamma_{ij} \Delta X_{i,t-j} + \varepsilon_{it} \qquad (6)$$

From equation 6, the vector of parameters is denoted by β_t while the error correction term is represented by (ψ_i). The deterministic representations (Dt) for the model could range from (Dt = 0) for a model that has no deterministic term, to a constant term only model (Dt = 1), and a model with both constant and trend (Dt = 1, t). Subsequently, the long-run estimations were carried out with the Augmented Mean Group (AMG) method of Eberhardt and Bond (2009) and Eberhardt and Teal (2010).

The choice of the AMG approach offers unique benefits for the current study. Firstly, unlike common first-generation panel estimators, the AMG method is a preferable choice for accommodating the statistical traits of the panel observation given the presence of cross-sectional dependence in the panel set (Eberhardt and Teal, 2010; Le and Ozturk, 2020; Nwaka et al. 2020). Secondly, the approach also offers ample opportunity to take a look at the Group-specific coefficients for the study thus helping to strengthen the overall empirical observations based on a country-specific analysis.

$$\Delta Y_{it} = \alpha_i + \beta_i \Delta X_{it} + \sum_{t=1}^{T} \pi_t D_t + \varphi_i UCF_t + \mu_{it} \quad (7)$$

$$\text{AMG} = \frac{1}{N}\sum_{i=1}^{N} \varphi_i \quad (8)$$

The AMG estimator that is provided in equation 8 is obtained from the least square evaluations of the differenced equation 7, where a time-variant dummy variable is denoted by the variable D while UCF covers the unobserved common effects. From equation 7, the evaluated slope parameters of the explanatory variables (Xit) are captured by the φ_i parameter in the subsequent AMG estimator in equation 8. Lastly, the outcomes of dynamic ordinary least squares (DOLS) and fully modified least squares (FMOLS) were reported for comparative analysis and possible robustness checks, while exploring the causal nexus among variables within the framework of the Dumitrescu and Hurlin (DH, 2012) panel causality procedure.

3.3. The Nexus of Environmental Pollution with Fossil Energy Resources Abundance in a Sectoral Composition Framework

3.3.1. Scope of study and model specifications

It has been noted that there are many resource-rich countries in the world and some of them are also located on the African continent. It is almost possible to say that all African countries are typically resource rich. Also, over the past few years, many more nations are now discovering energy resources such as oil and gas in large tradable quantity which has triggered oil exploration in many previously non-oil producing economy as well as fostering newer large scale energy projects (Graham and Ovadia, 2019; IEA, 2019). Although there are many other resources, in this dissertation priority is given to oil and gas resources in the empirical analysis because of the very important influence that the oil sector has on revenue generation for the producing economies firstly, and secondly because of the important roles that oil & gas plays in ensuring energy accessibility in these economies as it is a major resources used to address energy supply for the rapidly expanding energy demand in many of the African economies.

Nevertheless, it is very important to state that the analysis would not encompass all oil-producing African countries in view of certain challenges with data availability. Hence, four economies were prioritized among the top five leading oil producers on the continent including Algeria, Nigeria, Egypt, Angola, Libya. These economies provide a fair representation of oil African oil producers in view of their highest daily production volumes while accounting for around 86.54% and 89.06% of the combined Africa's proved oil and gas reserves accordingly (see figure 15 in the Appendix). However, Libya has to be removed from the evaluation owing to the lack of sectoral composition data. Hence, Algeria, Egypt, Angola, and Nigeria were the countries included in the last sample using data spanning from 1995 to 2016 while evaluating the EKC within sectoral distribution scope which covers the share services sectors as well as the manufacturing sector while looking at roles of energy utilization in these oil-exporting states.

Given the various sectoral classification including the service sector, the manufacturing sector, and the energy sector, the general baseline equation for the study is modeled in equation (1) where carbon emission is used to measure environmental quality state of the countries.

$$LnCO2_{it} = \alpha_0 + \alpha_1 LnRI_{it} + \alpha_2 LnRI^2{}_{it} + \alpha_2 LnFEC_{it} + \alpha_4 LnNR_{it} + \alpha_3 LnMGI_{it} + \alpha_5 LnSGI_{it} + \varepsilon_{it} \qquad (1)$$

As noted, the ($CO2_{it}$) emission levels are taken in metric tons per capita to represent the quality of the environment in the understudied countries. When looking at economic growth, instead of taking the real GDP figures, current US$ values of the real per capita income (RI_{it}) were taken to measure individual country's income levels. This was done in view of the differences in population size that typically characterize the overall demographic statistics of each country in the study. Later on the values of the squared income level ($RI^2{}_{it}$) were also included in the model check the EKC conjecture as seen in some empirical studies such as in the work of Sadik-Zada & Loewenstein (2020) and those of Balsalobre-Lorente et al. (2021).

Moving on to the energy sector, fossil energy utilization as well as the attendant rents from these energy sources were included in the model. For fossil energy consumption, the levels of energy usage from this conventional energy resources were applied, and this was taken as a percentage of the total energy usage and represented with (FEC_{it}). Also, the total resources rents (NR_{it}) from fossil resources including those from oil, those from natural gas, and those from coal were collected and used in the study. When looking at the manufacturing sector, the total manufacturing value added (MGI_{it}) in view of the sectors' contribution to the overall GDP was utilized. This was done after obtaining the net output of the sector following the addition of all outputs with the removal of all intermediate inputs. However, the share of services in overall GDP (SGI_{it}) was taken for the service sector and this action covers the value-added for activities like education, retail trade, real estate services, wholesale trade, transport, health care services and others like financial services. Finally, service sector share in GDP was taken in log as well as the natural log manufacturing sector's absolute values towards dealing with collinearity challenges since their (manufacturing and service sector) values were given as a share of GDP. Notably, all the remaining variables are also log transformed.

3.3.2. Preliminary Cross-sectional Dependence Examination, the Unit root test, and the Cointegration Examination

In this research, primary commodity-driven economies are being examined and these commodities are generally exposed to price fluctuation and any other common shocks in the international commodity market. These kinds of fluctuations are usually common in oil market as a major international market thus creating a common macroeconomic patterns like price instability and dwindling in revenues among many oil-exporting states. Therefore, the panel data sample residuals were firstly checked to confirm if there are no common shocks among the sample errors via a cross-sectional dependency (CD) examination. If this was ignored, it may create series of empirical flaws in the other methodological procedures to be followed in the study. There, in view of the work of Chudik et al. (2016) based on initial propositions of Pesaran, (2007), a CD examination was conducted, and this action aligns with many other contemporary research work (Bekun et al. 2021; Gyamfi et al. 2021b).

Assuming that a cross-section dimension (i) for the observation in a panel are from 1 to N where period of time (t) ranges from 1 to T as seen in equation 2, a null hypothesis following the expression Cov(μ_{it}, μ_{jt}) = 0 would imply an absence of cross-sectional dependence in the residual contrary to an alternative hypothesis that supports a presence of cross-section correlation in the residuals provided that there is at least a pair of cross-sections in line with the expression Cov(μ_{it}, μ_{jt}) ≠ 0.

$$Y_{it} = \delta_i + \alpha_i X_{it} + \mu_{it} \quad (2)$$

$$LM = T \sum_{i=1}^{N-1} \sum_{J=i+1}^{N} \hat{\rho}_{ij}^{2} \chi^2_{N(N-1)/2} \quad (3)$$

Following the OLS application on equation (2), the coefficients from the Lagrange Multiplier (LM) method by Breusch and Pagan (1980) were obtained and there after the subsequent pair-wise correlation for the calculated residuals is denoted with ρˆij. Given that the cross-section is comparatively small in this study but requires a large T, the adopted approach can be said to be more suitable.

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \left(\sum_{i=1}^{N-1} \sum_{J=i+1}^{N} \hat{\rho}_{ij} \right) \quad (4)$$

$$\hat{\rho}_{ji} = \hat{\rho}_{ij} = \frac{\sum_{t-1}^{T} \hat{\mu}_{i,t} \hat{\mu}_{j,t}}{\left(\sum_{t=1}^{T} \hat{\mu}_{it}^{2}\right)^{\frac{1}{2}} \left(\sum_{t=1}^{T} \hat{\mu}_{jt}^{2}\right)^{\frac{1}{2}}} \quad (5)$$

Looking at the equations 4 and 5, the LM test for cross-sectional dependence by Pesaran (2015) was applied. The method considers slope heterogeneity and cross-sectional problems given a relatively small sample and the residual (μ)'s test statistics are asymptomatically distributed such that CD~N(0, 1). Later on, the CD results from the methods (Pesaran, 2015; and Pesaran, 2007) were provided in the discussion of results and they confirmed the CD issues as seen in chapter 4.

Moving on, to confirm possible cointegration within the series, the unit root methods must not ignore the CD problem. Hence, the CIPS unit root method by Pesaran (2007) was used. The method follows the IPS unit root test of Im et al. (2003) but it is an augmentation of the latter. Later on, following the error adjustment process in equation 6, the Westerlund (2007) cointegration approach was used to check for possibility of cointegration relationship in the panel series.

$$\Delta Y_{it} = \alpha_i D_t + \emptyset_i Y_{it-1} + \lambda_i X_{it-1} + \sum_{j=1}^{pi} \emptyset_{ij} \Delta Y_{i,t-j} + \sum_{j=0}^{pi} \gamma_{ij} \Delta X_{i,t-j} + \varepsilon_{it} \qquad (6)$$

The Dt represents deterministic arrangements in equation 6. Here, a model can be set up without any deterministic components such that Dt = (0), and it is also possible to model relationship with constant term alone whereby Dt = (1). Also, the model can be constructed to include trend and constant combined whereby Dt = (1, t). Moving on, α_t denotes the vector of parameters. Finally, the when the error mechanism process ($\emptyset_i$) is examined, it is possible to know whether a long-run relationship exist among variables using the generated group statistics (Gt, Gα) and the corresponding panel statistics (Pt, Pα).

3.3.3. The Estimation of the Long-run Coefficients

To get the long-run estimates, the quantile regression (QR) method was used. On the other hand, the dynamic ordinary least squares (DOLS) approach was applied to have a comparative analytical view of the QR results as robustness check. The QR technique that was applied in evaluating the long-run coefficients was based on the initial work

Koenker and Bassett (1978). Since then, there have been improvements in the method following the work of Koenker (2004) and Powell (2016). In line with the baseline model 1, the interaction among the variable is represented in Equation (7) where the τ^{th} conditional quantile of the explained variable (environmental pollution level as captured by CO2 emission levels) is denoted by $QLnCO2_{it}(\tau/\chi_{it})$. On the other hand, χ_{it} represents the explanatory variables' vector. (τ) denotes the panel samples' quantiles for chosen countries i at time t, while the individual explanatory variables' slopes are denoted by δ. On the other hand, the error term for the given vector is ω_{it}.

$$QLogCO_{2it}\left(\frac{\tau}{\chi_{it}}\right) = \delta_i^{(\tau)} + \delta_1^{(\tau)} LogRI_{it} + \delta_2^{(\tau)} LogRI_{it}^2 + \delta_3^{(\tau)} LogFEC_{it} + \delta_4^{(\tau)} LogNR_{it} + \delta_5^{(\tau)} LogMGI_{it} + \delta_6^{(\tau)} LogSGI_{it} + \omega_{it} \quad (7)$$

Certain benefits surfaces in view of the combination of the two methods (QR & DOLS). Firstly, contrary to the traditional least squares technique that only checks the relationship between a dependent variable and the conditional mean of its independent variables, the QR method yields wider results by applying the conditional quantiles of the independent variables to show their influence on the dependent variables. Secondly, OLS become less reliable and misleading whenever there the traditional normality assumption is broken. Meanwhile, the QR method can be robust and reliable for outliers and as well as error distribution. Thirdly, the method has the capacity to produce useful results where cross-sectional dependence and heterogeneous effects mar panel samples (Nwaka et al. 2020; Anser et al. 2021). In addition to the stated benefits of the QR method, the DOLS results that is based on the mean value estimations helps to create important comparative discussion since the QR results are obtained from the median values estimations. Lastly, the granger causality direction among the understudied variables was examined with the application of Dumitrescu and Hurlin (DH, 2012) causality method.

CHAPTER FOUR

EMPIRICAL ANALYSIS AND INTERPRETATION OF RESULTS

This chapter provides explanations of the empirical findings of the study. The data used were presented for the empirical analysis and thus the estimates or coefficients are provided with their corresponding interpretations.

4.1. The Nexus of Environmental Pollution and Energy Dynamics in a Globalized World

4.1.1. Outputs of preliminary analysis

Following the null hypothesis in equation 2 (See Section 3.1.2) and given the interaction among variables in equation 1, the findings from Table 9 shows that the CD test came out positive as the estimated significance level of the test statistics supported the rejection of the null hypothesis concerning the estimated residuals. The unit root estimates and cointegration results are in Table 10.

Table 9: The Outputs of the CD Test

Method	Breusch & Pagan (1980) LM Test	Pesaran (2007) CD Method	Pesaran (2015) LM Test
Equation (1)	404.61[a]	18.52[a]	43.44[b]

Here, the a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly.

Table 10: Results for the Unit root and Long-run Nexus Examination

	CIPS			
The Variables	Intercept & trend $D_t = (1, t)$			
	Levels		1st Difference	
LogCO$_2$	-2.778[c]		-5.538[a]	
LogPY	-2.596		-4.214[a]	
LogPY^2	-2.542		-4.290[a]	
LogFFE	-2.436		-5.35[a]	
LogRWE	-2.186		-5.09[b]	
LogATE	-2.318		-5.410[a]	
LogGZ	-2.510		-4.151[a]	
The Westerlund Cointegration				
Relationship	The Group		The Panel	
LnCO$_2$*=f(LogPY), (LogPY*^{2}*), (LogFFE), (LogRWE), (LogATE), (LogGZ)*	Gτ	Gα	Pτ	Pα
Statistics	-2.364[a]	-2.726[a]	-8.435[a]	-2.909[a]
Robust Prob-V	0.000	0.000	0.000	0.000

Here, author's calculations were done where the prob-V is the probability value and the a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly.

As it can be seen in Table 10, there is a just basis to decline the acceptance of a no level relationship conclusion among the variables since the test statistics for the Westerlund (2007) cointegration are significant enough to make such a decision. Therefore, we explored the underlying long-run coefficients for the variables given the existence of the level relationship among them.

4.1.2. The Long-run Outcomes and Causality Evidence

The QR estimates in Table 11 divulges the deteriorating impacts of incomes level on the environmental quality among the countries as the observed coefficients are positive, significant, and also very consistent over the whole conditional distribution of CO2 emission levels (τ = 0.10 to τ = 0.90). This observation was also consistent with the corresponding estimates from the AMG approach that also unveils an approximate 1.7% rise in carbon emission level given a 1% growth in income level among the countries. In like manner, the influence of conventional energy utilization and globalization on the conditional distribution of CO2 level at all quantiles (τ = 0.10 to τ = 0.90) toe the paths of the income effects, thus depicting a significant setback on the prospects of decarbonization among the countries. This result further buttresses how globalization can be detrimental to environmental sustainability and related results have been documented in some extant research (Le & Ozturk, 2020; Shahbaz et al. 2013) but negates findings from some other studies (Shahbaz et al. 2016; Baloch et al. 2021).

Furthermore, the undesirable impacts of the trio of income growth, fossil energy use, and globalization for decarbonization prospects among the countries can also be deciphered from the causality outputs in Table 12, following the establishment of a one-way causality from income levels to emissions and a bidirectional causality from the duo of fossil energy and globalization to emission levels. This present study has focused on oil-exporting countries, and it is common knowledge that oil and gas are international commodities that thrive well on the ambient of trade and economic globalization among countries. As oil production levels are sustained to meet up with revenue targets and international energy demands, domestic energy consumption is also expected to be induced over time and this is also supported by the obtained unidirectional causality from globalization to fossil energy consumption among the countries.

Table 11: The Outputs of the QR & AMG Evaluations

Method Used	Output of the Quantile Regression, QR Evaluations									***The AMG method***
The Explained V. $LogCO_2$	*When* $\tau =$ 0.100	When $\tau =$ 0.200	When $\tau =$ 0.300	When $\tau =$ 0.400	When $\tau =$ 0.500	When $\tau =$ 0.600	When $\tau =$ 0.700	When $\tau =$ 0.800	When $\tau =$ 0.900	
LogPY	0.081[b]	0.112[a]	0.138[a]	0.214[a]	0.291[a]	0.565[a]	0.5994[a]	0.650[a]	0.656[a]	1.721[c]
$LogPY^2$	-0.003	-0.007[c]	-0.011[b]	-0.0192[a]	-0.0254[a]	-0.054[a]	-0.051[a]	-0.061[a]	-0.062[a]	-0.276[c]
LogFFE	0.469[a]	0.525[a]	0.551[a]	0.462[a]	0.477[a]	0.728[a]	0.641[a]	0.402[a]	0.310[a]	0.990
LogRWE	-0.128[a]	-0.119[a]	-0.113[a]	-0.122[a]	-0.128[a]	-0.110[b]	-0.131[a]	-0.141[a]	-0.180[a]	-0.251[a]
LogATE	-0.073[a]	-0.061[b]	-0.048	-0.006	0.060	0.331[a]	0.340[a]	0.326[a]	0.321[a]	0.038
LogGZ	2.257[a]	1.926[a]	1.717[a]	1.696[a]	1.537[a]	0.680[a]	0.650[a]	0.770[a]	0.723[a]	1.046[a]
Amount of Observation	234	234	234	234	234	234	234	234	234	234
Total explanatory Variables	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Amount of Group	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0

Here, author's calculations were done with robust probability values for the AMG where the a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly

Table 12: DH Panel Causality test

	The Calculated Zbar-Stat						
Variables	***LogCO_2***	***LogPY***	***LogFFE***	***LogRWE***	***LogATE***	***LogGZ***	***Causality Scheme***
LogCO_2	_	-0.639	4.139^{a}	4.112^{a}	3.930^{a}	3.238^{a}	$LnCO2 \rightarrow LnFFE, LnRWE, LnATE, LnG$
LogPY	2.907^{a}	_	0.571	3.185^{a}	0.296	3.273^{a}	$LnPY \rightarrow LnCO2, LnRWE, LnGZ$
LogFFE	1.957^{b}	2.318^{b}	_	2.734^{b}	2.794^{b}	1.694	$LnFFE \rightarrow LnCO2, LnPY, LnRWE, LnAT$
LogRWE	1.913^{c}	0.365	1.319	_	3.640^{a}	2.050^{b}	$LnRWE \rightarrow LnCO2, LnATE, LnGZ$
LogATE	1.921^{c}	-0.262	5.823^{a}	8.852^{a}	_	0.234	$LnATE \rightarrow LnCO2, LnFFE, LnRWE$
LogGZ	6.194^{a}	-0.330	2.970^{a}	7.228^{a}	1.754^{c}	_	$LnGZ \rightarrow LnCO2, LnFFE, LnRWE, LnA$

Here, author’s calculations were done where a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly

On the contrary, renewable energy use proved to be a significant tool for decarbonization prospects as its impacts were negative, significant, and they are also very consistent throughout the whole conditional distribution of CO2 pollution levels. The complementary results from the AMG also unwrap a significant drop of about 0.25% in CO2 emissions as renewables usage grows by 1%. This finding upholds some contemporary results in different studies (Anandarajah & Gambhir, 2014; Onifade et al 2021b). Although the proportion of the cushioning impacts of renewables is quite low compared to that of the damage created by economic growth in terms of emission, nonetheless, the results are justifiable considering that many of these countries are still at their emerging economic status with more attention been focused on income expansion even if such expansion hinges on a deteriorating environment.

As for alternative energy use, the evidence is very mixed across quantile distribution. While alternative energy use significantly reduces emission levels at lower quantile (τ = 0.10 and τ = 0.20), however, when considering the intermediate quantiles (τ = 0.40 to τ = 0.50) the impacts were not significant until the upper quantiles. The AMG results lend credence to this inconsistency as the estimate was likewise insignificant for this variable. This outcome is not a surprise considering that the proportion of alternative energy in total energy is abysmally low among the countries.

Furthermore, a look at the country-specific analysis in Table 9 also provides more insights in this regard. Also, the obtained significant relationship between the square of income and the income level confirms the validness of the well-known EKC hypothesis for the combined analysis of the panel countries. However, there are observed variations in the validity of the EKC on a country-specific analysis. A clearer picture of the extent of the validity of the EKC for an individual country is detailed out in the country-specific analysis in Section 4.2.

Lastly, the QR technique passes the diagnostic test of slope equality that was conducted. The Chi-Square statistic for the Wald test was 530.84 with a P-value of 0.0000 as seen in Table 26 in the Appendix, thus supporting the rejection of the assumption of slope homogeneity according to the null hypothesis. As such, there is a significant variation in the obtained slope parameters across quantile levels. The slope equality test follows the Koenker and Bassett (1982) test for the equality of the slope coefficients across quantiles. The null hypothesis shows that all the slope coefficients are the same across quantiles. This null is ideal for the traditional OLS regression meaning that there is homoskedasticity since the variance of the error term is constant. The rejection of the null hypothesis here reflects heteroskedasticity, therefore, violating the assumptions of the OLS and this therefore further justifies the reasons for applying the QR techniques. The coefficient diagnostics following the computation of a 95% confidence ellipse also shows that the test statistic values were within the respective confidence ellipse 5% of the time as seen in Figure 16 in the Appendix while the graphical representation of the QR process following Koenker (2005) is provided in Figure 17 in the Appendix.

4.1.3. Country Specific Estimations

In Table 13, fossil energy consumption specifically worsens environmental degradation levels as it creates positive impacts on emission levels among some of the countries including Egypt, Gabon, Nigeria, Congo Republic, and South Africa. The magnitude of the obtained pollution inducement by fossil fuel usage was highest in the case of South Africa, followed by Egypt, Nigeria, and Congo respectively.

Table 13: AMG outputs for Country-Specific Estimations

The Explained Variable	The Explanatory Variables					
($LogCO_2$)	***LogPY***	***$LogPY^2$***	***LogFFE***	***LogRWE***	***LogATE***	***LogGZ***
The Countries	**The Coefficients**					
Egypt	2.508[c]	-0.375[c]	2.847	-0.361	-0.085	0.903[c]
Algeria	-3.211[c]	0.457[c]	-51.064	-0.152[b]	0.049	-0.021
Sudan	2.069[c]	-0.391[c]	-0.062	-3.106[a]	-0.133[b]	0.964[a]
Tunisia	0.352	-0.039	-1.909	-0.247	0.047[a]	1.427[a]
Nigeria	3.243[b]	-0.536[b]	1.888[a]	-0.267	-0.071	2.559[a]
Angola	0.699	-0.061	-0.380	0.337	-0.062	1.473
Congo Rep.	-7.661[c]	1.198[c]	1.642[a]	3.877[a]	0.751[b]	2.241
Gabon	7.137[b]	-0.927[b]	0.221	-0.171	0.244	-0.117
South Africa	1.673	-0.228	3.705[b]	-0.469[b]	0.217[c]	0.047

Here, author's calculations were done where the a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly

The positive impacts were however not significant in the specific cases of Egypt among the others. In this context, the specific findings for Nigeria and South Africa are not surprising given that the duo is the top emitter on the continent. Also, both are top nations in fossil energy production and consumption, for the former, it is mostly in terms of oil & and gas while the latter is well known for coal. On the other hand, renewable energy use has negative impacts on carbon emission in many of the countries except for the cases of Angola and the Congo Republic and the pollution abatement impacts are significant in the specific case of Algeria, Sudan, and South Africa. On the other hand, while there were negative impacts of alternative energy use in Egypt, Nigeria, Sudan, and Angola, these impacts were only significant in the specific case of Sudan. It is worth noting that the proportion of alternative energy in the whole energy utilization level has specifically steadily grown in Sudan in relative comparison to others. For instance, among the North African countries in the study where fossil resources dominate economic activities like trade (Onifade et al. 2022c), alternative energy use accounted for approximately 3.5% of the total energy use in Sudan between 2010 and 2015 while it was just 0.04%, 0.60%, and 1.46% in Algeria, Tunisia, and Egypt (WDI, 2021).

Furthermore, globalization significantly hampers the environment via emission inducement with the highest magnitudes in the specific case of Nigeria, Tunisia, Sudan, and Egypt. Finally, the country-specific analysis gives credence to the validness of the EKC hypothesis in Egypt, Sudan, Nigeria, and Gabon thus supporting the findings of (Mahmood et al. 2019; Bekun et al. 2020). For South Africa, Angola, and Tunisia the income coefficients follow the expected directions but were not statistically significant to uphold the EKC thus contradicting the results by Shahbaz et al. (2014). For Congo and Algeria, the U shape hypothesis was confirmed.

4.2. The Nexus of Environmental Pollution and Urbanization in an Ecological Footprint Framework

4.2.1. Preliminary Estimations

From the summary and correlation statistics presented in Table 14, it can be observed that the largest fluctuations in samples were seen in the income variable while the least deviations were noticeable in the globalization proxy among the countries. Also, the simple correlation analysis reveals that all the panel variables are positively correlated with the ecological footprint with different magnitudes except for renewable energy consumption. This provides important information regarding the degree of relationship, but the information cannot be deemed as sufficient considering that simple correlation analysis usually sidelines issues relating to crucial statistical traits of data. Other preliminary tests were necessary to explore the impacts of the regressors and their magnitudes on the dependent variables through appropriate techniques. When testing for cross-sectional dependency (CD), there was sufficient evidence to disregard the claim of the null hypothesis of no cross-section dependence as seen in Table 15.

Table 14: Panel Summary Statistics

The Variables	*LogEcFP*	*LogRY*	*LogRY²*	*LogNRFF*	*LogRWC*	*LogUBR*	*LogGLZ*
Mean	-0.037	3.344	11.346	2.783	1.235	1.737	1.693
Median	-0.064	3.4067	11.606	2.881	1.489	1.769	1.692
Maximum	0.418	4.158	17.288	3.834	1.949	1.948	1.850
Minimum	-0.484	2.416	5.837	-1.944	-1.230	1.457	1.464
Standard. D.	0.212	0.410	2.680	0.766	0.788	0.130	0.090
Observations	270.0	270.0	270.0	270.0	270.0	270.0	270.0

Matrix for Correlation Analysis							
Variables	***LogEcFP***	***LogRY***	***LogRY²***	***LogNRFF***	***LogRWC***	***LogUBR***	***LogGLZ***
LogEcFP	1						
LogRY	0.692[a]	1					
LogRY²	0.701[a]	0.998[a]	1				
LogNRFF	0.148[b]	0.470[a]	0.455[a]	1			
LogRWC	-0.454[a]	-0.359[a]	-0.349[a]	-0.416[a]	1		
LogUBR	0.412[a]	0.821[a]	0.821[a]	0.529[a]	-0.340[a]	1	
LogGLZ	0.467	0.475[a]	0.457[a]	0.315[a]	-0.263[a]	0.330[a]	1

Here, author's calculations were done where the superscripts a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly.

Table 15: Outputs of Cross-sectional dependency Test

The Test Method	Breusch and Pagan (1980) LM Test	Pesaran (2007) CD Test	Pesaran (2015) LM Test
Equation (1)	152.90[a]	11.38[a]	2.99[a]

Here, author's calculations were done where the superscripts a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly.

Table 16: Unit root test results

	The CIPS	
The variables	$D_t = (1, t)$	
	Levels	1st Difference
LogEcFP	-2.890[c]	-5.360[a]
LogRY	-3.250	-5.007[a]
LnRY^2	-2.998	-4.465[a]
LogNRFF	-1.655	-4.910[a]
LogRWC	-1.923	-5.139[a]
LogUBR	-2.144	-2.270
LogGLZ	-2.640	-4.453[a]

Here, author's calculations were done where a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly

Table 17: Cointegration results

The Westerlund Cointegration				
Model 1				
For the Equation 1	For the Group		For the Panel	
LogEcFP = f(LogRY), (LogNRFF), (LogRWC), (LogUBN), (LogGLZ)	Gτ	Gα	Pτ	Pα
Statistics	-3.090[a]	-3.890	-7.980[b]	-3.845[a]

Model 2 (EKC)				
For the Equation 2	For the Group		For the Panel	
LogEcFP = f(LogRY), (LogPY²)	Gτ	Gα	Pτ	Pα
Statistics	-2.226[a]	-8.282[c]	-7.260[a]	-8.116[a]

Here, author's calculations were done where a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly.

Consequently, the unit root results in Table 16 show the outputs of the test for both intercept and trend specifications. The results revealed that the panel variables are differenced stationary with an integration order of one I(1). Subsequently, a long-run relationship was established among the panel variables following the outputs of the cointegration examination as detailed in Table 17. The affirmation of the discovered long-run nexus is based on the corresponding level of significance of the group and panel statistics for the interacting variables in the baseline equations 1 and 2.

4.2.2. The Long-run Outcomes and the Causality Results

The results for the level relationship are in Table 18 and they reveal significant information about the impacts of the selected energy indicators on the environmental quality of the oil-exporting countries vis-à-vis the pressure exerted on the environment as indicated by the ecological footprint in the panel study. To begin with, it was observed that detrimental environmental consequences accompanied the pursuit of economic expansion and income growth among the countries such that a percent growth in income levels significantly exacerbate environmental degradation by about 0.067% rise in the ecological footprint. This implies that growth-inducing economic activities exert significant negative pressure on the quality of the environment. This long-run coefficient was also supported by the observed feedback causal nexus between ecological footprint and income levels as seen in Table 19.

The observed undesirable impacts of economic growth on ecological footprint were significant and consistent across other estimations techniques however with a slight difference in the magnitude and size of coefficients. The current finding buttresses conclusions made in some extant studies where economic growth is inimical to environmental quality (Sarkodie & Ozturk, 2020; Gyamfi et al. 2021).

On the aspect of natural resources rent and fossil energy consumption, it was observed that the impacts of the interaction between these variables exacerbate the undesirable pressure on the environment as a percent increase in rents from fossil resources and the corresponding level of energy consumption from these resources significantly induce the ecological footprint by 0.059% among the countries in the panel study. The result was also consistent and significant in both the DOLS and FMOLS estimates. Implying that, fossil energy resources consumption and their corresponding rents accrue to these countries at the cost of a deteriorating environment. The obtained causality nexus also reveals a uni-directional causality from the interaction between fossil energy resource rent and corresponding energy consumption to a worsening environmental quality vis-à-vis increasing ecological footprint among the countries. Thus, strongly corroborating the long-run coefficient results.

The outcome also agrees with the findings and conclusion from the research by Sadik-Zada & Loewenstein (2020) that fossil energy consumption and natural resources drive carbon emissions in resource-rich economies. The conclusion from their study was based on 37 oil-producing economies. Besides, a couple of other extant studies have also found positive impacts of fossil energy consumption and resource rent on environmental degradation, especially when using carbon emission levels as a proxy for environmental quality measurement while a few studies have utilized ecological footprint (Shahbaz et al., 2018; Sarkodie & Ozturk, 2020; Charfeddine & Mrabet, 2017; Bekun et al 2021).

However, the important practical implication from the uni-directional causal nexus between fossil energy resource component and ecological footprint is that policymakers must be proactive in putting measures in place to lessen the huge burden of the potential income disruptions when drafting and proposal for cutting fossil energy consumption and resource dependence among these countries.

As for the case of globalization and urbanization among the countries, the obtained results show that both variables are inimical to the quality of the environment among the nations since a percent rise in each variable increases ecological footprint by 0.40% and 0.81% respectively. While the deteriorating impact of globalization on the quality of the environment was significant across all techniques, that of urbanization was only significant in the DOLS and FMOLS estimates. However, the causality results show that urbanization uni-directionally granger causes the dynamics of the interaction between fossil energy consumption and resource rent among the countries. Thus, further supporting the potential threats to quality environment through an increasing ecological footprint as reflected in the long-run coefficient.

Also, the obtained positive impact of globalization on ecological footprint is not surprising considering the broad scope of the utilized KOF globalization index. The index encompasses different aspects of globalization including economic, social, and political dimensions. As such, the potential explanation for the obtained estimate is not farfetched as it revealed the detrimental environmental consequences of increasing fossil energy-driven trade volumes coupled with the common oil and gas sector-driven foreign direct investment (FDI) among the understudied economies. As oil trade volumes grow among the majority of the countries and the rest of the world, domestic energy production and consumption also tend to gravitate towards fossil fuel dependence. Available data from the World Bank show that conventional energy (like coal, oil & gas) account for about 100%, 99.3%, 89.88%, 97.52%, and 77.95% of the total electricity production in Libya, Algeria, Egypt, Tunisia, and Nigeria between 2005 and 2016 respectively (WDI, 2021). On the other hand, amongst all the energy indicators used, only renewable energy consumption reduces environmental degradation among the countries as a percent rise in renewables use significantly lowers ecological footprint by 0.40% among countries in the panel study. The obtained estimates were significant and consistent in all techniques concerning the impact of renewable energy use on ecological footprint. In addition, the result was corroborated by the obtained feedback causality nexus among the variables.

Lastly, the result from model 2 revealed that the EKC hypothesis is refuted for the panel study. Although the coefficients for the variables follow the right signs, however, they were found to be insignificant to uphold the validness of the EKC. This finding contradicts the EKC affirmation as observed in the research of Charfeddine & Mrabet (2017) for the case of oil-producing MENA countries but lends credence to the rejection of the inverted U-shape growth-emission nexus as seen in the study of Sadik-Zada & Loewenstein (2020) for 37 oil-producing economies and the study of Onifade et al. (2021b) for a group of selected OPEC countries. The implication is that income expansion does not necessarily create any cushioning impacts on environmental degradation among the oil-exporting countries in the panel study as commonly postulated for the relationship between income growth and environmental destruction in the EKC.

Table 18: Long-run Estimates

Dependent Var LogEcFP	**The Model 1**		
	AMG	**DOLS**	**FMOLS**
LogRY	0.068[b]	0.039[a]	0.085[a]
LogNRFF	0.059[a]	0.069[a]	0.107[b]
LogRWC	-0.401[a]	-0.299[a]	-0.355[a]
LogUBN	0.814	0.526[b]	1.121[a]
LogGLZ	0.401[b]	0.296[b]	0.537[a]
The Wald test	32.870[a]		
Prob-V	(0.000)		

The Regressors Number	5.0	5.0	5.0
Number of Observations	270.0	270.0	270.0
The Number of Group	10.0	10.0	10.0
R^2		0.964	0.794
	The Model 2- EKC		
For Depend. Var LogEcFP	**(AMG)**		
LogRY	0.226		
Prob-V	(0.684)		
$LogRY^2$	-0.062		
Prob-V	(0.521)		
The Regressors Number	2.0		
Number of Observations	270.0		
The Number of Group	10.0		

Here, the ***, ** and * are 1%, 5% and 10% significant level respectively

Table 19: DH Panel Causality test

	Zbar-Stat						
Variables	**LogEcFP**	***LogRY***	***LogNRFF***	***LogRWC***	***LogUBN***	***LogGLZ***	***Causality Scheme***
LogEcFP	_	3.220[a]	0.555	3.525[a]	10.651[a]	3.740[a]	$LnEcFP \rightarrow LnRY, LnRWC, LnUBN, LnG$
LogRY	3.023[a]	_	1.195	4.054[a]	5.047[a]	3.156[a]	$LnRY \rightarrow LnEcFP, LnRWC, LnGZ, LnU$
LogNRFF	2.424[b]	3.278[a]	_	6.405[a]	1.031	2.277[b]	$LnNRFF \rightarrow LnEcFP, LnRY, LnRWC, LnG$
LogRWC	2.811[a]	3.723[a]	-0.297	_	7.237[a]	0.745	$LnRWC \rightarrow LnEcFP, LnRY, LnUBN$
LogUBN	5.841[a]	6.971[a]	6.312[a]	3.422[a]	_	7.458[a]	$LnUBN \rightarrow LnEcFP, LnRY, LnNRFF, Ln$ $LnGLZ$
LogGLZ	2.526[b]	4.371[a]	0.557	4.313[a]	3.223[a]	_	$LnGLZ \rightarrow LnEcFP, LnRY, LnRWC, LnU$

Here, author's calculations were done where a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly.

4.2.3. Country-Specific Analysis

Although the majority of these countries have many things in common especially in terms of being primary commodities exporters, however, factors like the size of the economy, level of income, and differences in the composition of individual country's energy consumption could explain some notable observations in the group-specific analysis. Looking at Table 20, the devastating impacts of resource rent and fossil energy consumption on environmental quality vis-à-vis growing ecological footprint are notable in all countries excluding Gabon. These impacts are however only significant with the highest magnitude in the specific cases of Tunisia, South Africa, Nigeria, and Sudan respectively.

Similarly, the devastating impacts of urbanization and globalization on environmental degradation vis-à-vis growing ecological footprint are significantly notable in the specific cases of Libya, Tunisia, and Egypt. Again, this outcome is not surprising because environmental degradation as measured by a rise in ecological footprints is much pronounced among this group of North African countries where biocapacity has drastically deteriorated over the years. On the other hand, while globalization is significantly detrimental to environmental quality in terms of footprint pressure in Libya and Egypt, there is evidence of potential environmental benefits from globalization in Tunisia and Sudan. Meaning that these countries can leverage on green technology transfer strategies that can be developed on the ambient of globalization to tackle threats from environmental degradation.

As for renewable energy consumption, the desirable roles were only significant in the specific case of Egypt and Libya. Finally, there was insufficient evidence to validate the EKC hypothesis for individual country's ecological footprint except in the case of Egypt and Nigeria. The current findings thus lend credence to the results from a few country-specify research works that has affirmed the EKC in Egypt and Nigeria (Sghaier et al. 2019; Bekun et al. 2020).

Table 20: Country-Specific Coefficients (Model 1 & 2)

The Dependent Variable	**For the Model 2 (EKC)**		**For the Model 1**				
(LogEcFP)	***LogRY***	***LogRY²***	***LogRY***	***LogNRFF***	***LogRWC***	***LogUBN***	***LogGLZ***
The Countries	**The Coefficients**		**The Coefficients**				
Algeria	-0.615	0.105	0.068	0.048	-0.007	-5.448	0.386

Libya	0.722	-0.091	-0.009	0.015	-0.763a	15.667a	0.722b
Egypt	2.634^{a}	-0.382^{a}	0.105	0.012	-0.593^{b}	-6.650	0.863^{b}
Sudan	-0.0515	0.005	0.125^{b}	0.068^{a}	-0.470	-1.123	-1.476^{a}
Tunisia	0.679	-0.093	0.075	0.207^{a}	-0.274	5.689^{b}	-3.895^{a}
Nigeria	1.527^{a}	-0.272^{a}	0.133^{a}	0.074^{b}	-0.602	-8.366^{a}	0.139
Angola	-1.826^{a}	0.316^{a}	0.017	0.042	-0.716	-2.804	0.789
Congo Rep.	0.026	0.004	0.003	0.074	-0.212	-36.930	-0.004
Gabon	6.747	-0.870	0.248	-0.127	0.689	1.431	0.949
South Africa	-1.312	0.187	-0.044	0.115^{a}	-0.276	14.593	0.213

Here, author's calculations were done where a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly.

4.3. The Nexus of Environmental Degradation with Fossil Energy Resources Abundance in a Sectoral Composition Framework

4.3.1. Results Analysis

In Table 21, the discussion of the entire results begins with the descriptive statistics for the whole panel samples. It can be seen that a strong and significant positive correlation exists between CO2 emissions and the level of income. This is also the case with fossil energy utilization levels and manufacturing sector. However, it was different in the case of natural resources rents and service sector since no significant negative and positive correlation was obtained accordingly. While a conclusion cannot be reached from this correlation results since it is important to take many issues into cognizance, however, they provide some important insights. For example, if the findings in Table 22 are considered, the issue of CD must be addressed since the test on the residuals show that the absence of cross-sectional dependence must be rejected. Thereafter, results for the unit root examination and those from cointegration examination were reported in Table 23.

Table 21: An Overview of the Data's Statistical Summary

The Variable	***LogCO₂***	***LogRI***	***LogRI²***	***LogFEC***	***LogNR***	***LogMGI***	***LogSGI***
The Mean	0.141	3.250	10.670	1.700	1.238	1.119	1.620
The Median	0.188	3.286	10.741	1.829	1.254	1.215	1.640
The Maximum	0.586	3.758	14.044	1.990	1.763	1.690	1.787
The Minimum	-0.506	2.599	6.701	1.201	0.490	0.461	1.321
The Stand. D.	0.317	0.341	2.125	0.327	0.295	0.352	0.087
The Observation	88.0	88.0	88.0	88.0	88.0	88.0	88.0
The Matrix of Correlation Analysis							
The Variable	***LogCO₂***	***LogRI***	***LogRI²***	***LogFEC***	***LogNR***	***LogMGI***	***LogSGI***
LogCO₂	1						
LogRI	0.631[a]	1					

LogRI²	0.624[a]	0.985[a]	1				
LogFEC	0.932[a]	0.468[a]	0.456[a]	1			
LogNR	-0.096	0.022	0.045	-0.201[c]	1		
LogMGI	0.641[a]	0.215[c]	0.189[c]	0.643[a]	-0.253[b]	1	
LogSGI	0.111	0.423[a]	0.390[a]	0.088	-0.701	0.101	1

Here, author's calculations were done where a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly.

Table 22: The Outcomes of the CD Test

The Method Used	The Breusch and Pagan (1980) LM Method	The Pesaran CD (2007) Method	The Pesaran LM (2015) Method
For the 1st Model	24.031[a]	1.910[c]	5.216[a]

Here, author's calculations were done where the superscripts a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly.

Table 23: Results for Unit root Analysis and the Cointegration Checks

	For The CIPS Method	
The variables used	For the Intercept and trend *Specification Where D_t equals (1, t)*	
	For Levels Checks	For 1st Difference
$LogCO_2$	-2.410	-5.610[a]

LogRI	-2.060	-3.590[a]		
$LogRI^2$	-2.170	-3.520[a]		
LogFEC	-2.990[c]	-4.770[a]		
LogNR	-2.300	-4.050[a]		
LogMGI	-2.150	-3.710[a]		
LogSGI	-2.070	-4.880[a]		
The Westerlund Cointegration Analysis				
The Examined Model	For Group Result		For Panel Result	
$LogCO_2$=f(LogPY), ($LogPY^2$), (LogFEC), (LogNR), (LogMGI), (LogSGI)	Gτ	Gα	Pτ	Pα
The Calculated Statistics	-2.790[a]	-5.730[a]	-5.259[a]	-7.230[a]
The robust Prob-V.	(0.000)	(0.000)	(0.000)	(0.000)

Here, author's calculations were done where the prob-V is the probability value and the a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly.

Since the group and panel statistics for the long-run test in Table 22 are significant, it is rational to reject the conjecture of no level relationship in the panel series therefore affirming a cointegrating relationship in the dataset. Hence, the impacts of all dependent variables were estimated and subsequently outlined in Table 23. A granger causality report was also detailed in Table 24 to support and contrast outcome with the long-run coefficients.

4.3.2. Estimation of Long-run Relationship and Causality Movement

The findings from the QR estimations in Table 24 reveal three important propellers of environmental pollution in view of the level of CO2 emissions. These factors include fossil energy utilization, the level of income, and the manufacturing sector. The results fundamentally show the triggering effects of fossil energy consumption on the level of CO2 emissions among these oil-exporting countries. Fossil energy utilization level exerts an intense positive effect on CO2 and the exerted impacts are very statistically relevant and they are also unchanged throughout the whole conditional distribution of CO2 levels starting with the low quantiles categories where (τ = 0.10 to τ = 0.30) up until the mid-quantiles where (τ = 0.40 to τ = 0.60) and to the upper quantiles where (τ = 0.70 to τ = 0.90). The findings do not contradict some past studies like (Adedoyin et al. 2021; Sarkodie & Ozturk, 2020; Alola et al. 2021; Sarkodie, 2018; Gyamfi et al. 2021b) which have shown that conventional energy usage is a major propeller of emission. Also, if the findings from the DOLS mean estimations method are considered, it can be seen that the QR findings are reaffirmed since CO2 emission levels increase by around 0.67% if conventional energy usage increases by one percent in these group of countries. Furthermore, a significant two-way causality direction exists between fossil energy utilization and pollution levels in displayed in Table 25. This further solidifies the inferences drawn from the observed long-run estimates.

When examining the environmental roles of the sectoral composition, the finding reveals that the only significant propeller of CO2 emission level within the understudied economies is the manufacturing sector. In view of the presented QR findings, the significant positive influence of this sector on the pollution levels is regular throughout the conditional distribution CO2 emission level. Sadik-Zada and Loewenstein (2020) confirmed the detrimental roles of the manufacturing sector on some countries' environmental performances. Therefore, this research work reaffirms their conclusion. From the DOLS results, it is evident that CO2 emission level increases by around 0.14% if the manufacturing sector's share increases by one percent. This implies that fossil energy usage has been supporting the energy demand for the production activities in the manufacturing sector although at the jeopardy of environment. Also, looking at Table 25, the one-way causality nexus from conventional energy utilization level flowing to the share of manufacturing sector further supports this inference.

However, the case is different when considering the service sector since the influence of this sector on CO2 emission is not significant throughout the quantiles as seen in the QR results. Besides, the DOLS estimates were not significant, thus revealing that service sector unlike the manufacturing sector is not a main propeller of carbon emission levels within these countries. Therefore, it can be said that the manufacturing sector's carbon footprint is the only important environmental inclinations when considering the economic share of sectoral composition.

Contrary to the triggering effects of fossil energy utilization on which were consistent throughout the conditional distribution of CO2 levels, the observed effects of natural resources rent and those of income levels are mixed with significant differences from one quantile to the other. Notably, the levels of income show some important positive (triggering) effects on carbon emission levels mainly within the lower and the middle quantiles where (from τ = 0.10 to τ = 0.40). Similarly, the cushioning (negative) effects of the squared income square were just significant at the middle and lower quantiles. Therefore, the EKC conjecture can be said to be displaying important quantile effects. As such, it implies that the likely pollution reducing impacts of income expansion as asserted in the EKC mainly depend on the conditional distribution of income growth level among these resource-rich African states. Despites the fact that Tenaw & Beyene (2021) have validated the EKC in a group of some resource-rich economies, the conjecture only holds at middle and lower quantiles in the case of these oil-exporting African states. These results cannot be seen as an isolated case because they support the final inferences from some research carried out by Onifade et al. (2021b) and those of Saidik-sada (2020) which have also refuted the EKC validity among fossil energy resource-rich economies.

Meanwhile, even though the natural resources level positively influence CO2 emission trend throughout the quantiles, the positive effects are not significant when looking at the lower quantile. Generally, the significance level for the resource rent is not high and they are just at 10% for the mid quantile and these were not consistent even at the upper quantile levels. Therefore, the environmental impacts of the income levels have better significance and reliability levels unlike the resource impacts. Furthermore, results from the DOLS the rent levels were not the significant propeller of CO2 emission level in contrast to the income levels that significantly trigger pollution.

This result does not conform with findings from some extant studies where resources rents were found to be a significant propeller of environmental degradation (Baloch et al. 2019; Hussain et al. 2020; Onifade et al. 2021c). The result is explainable in view of the causality nexus between real income levels and fossil energy utilization in Table 25 where causality runs from the former to the latter and not the other way round. Also, rents from resources significantly granger cause the income levels meanwhile the income does not granger cause rent but rather the CO2 emission.

Lastly, the QR technique also passes the diagnostic test of slope equality that was conducted. The Chi-Square statistic for the Wald test was 21.73 with a P-value of 0.0406 as seen in Table 27 in the Appendix, thus supporting the rejection of the assumption of slope homogeneity according to the null hypothesis. As such, there is a significant variation in the obtained slope parameters across quantile levels. The slope equality test here also follows the Koenker and Bassett (1982) for evaluating if slope are equal throughout the given quantiles. The null hypothesis shows that all the slope coefficients are the same across quantiles. This null is ideal for the traditional OLS regression meaning that there is homoskedasticity since the variance of the error term is constant. The rejection of the null hypothesis here reflects heteroskedasticity, therefore, violating the assumptions of the OLS and this therefore further justifies the reasons for applying the QR techniques.

The coefficient diagnostics following the computation of a 95% confidence ellipse also shows that the test statistic values were within the respective confidence ellipse 5% of the time as seen in Figure 18 in the Appendix. The graphical representation of the QR process following the Koenker (2005) process is provided in Figure 19 in the Appendix.

Table 24: The Outcomes of the QR & the DOLS Evaluations

The Method	**Outcomes of the QR Method**									***The DOLS Outputs***
The Explained Variable ($LogCO_2$)	*When τ = 0.100*	When τ = 0.200	When τ = 0.300	When τ = 0.400	When τ = 0.500	When τ = 0.600	When τ = 0.700	When τ = 0.800	When τ = 0.900	
LogRI	1.983[a]	3.029[a]	3.320[a]	2.823[a]	1.830	1.450	0.801	0.180	-0.146	-0.575
$LogRI^2$	-0.261[b]	-0.431[a]	-0.450[a]	-0.401[a]	-0.257	-0.191	-0.097	0.001	0.050	0.140[b]
LogFEC	0.734[a]	0.736[a]	0.710[a]	0.750[a]	0.742[a]	0.720[a]	0.720[a]	0.695[a]	0.673[a]	0.687[a]
LogNR	0.096	0.093	0.070	0.134[c]	0.130[c]	0.150[b]	0.143[a]	0.085	0.072	-0.083
LogMGI	0.160[a]	0.136[b]	0.121[b]	0.090[a]	0.104[c]	0.130[b]	0.151[a]	0.158[a]	0.172[a]	0.145[b]
LogSGI	0.206	-0.110	-0.164	0.013	0.030	0.110	0.065	-0.162	-0.237	-0.440
Amount of Observation	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0
Total explanatory Variables	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Amount of Group	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

Here, author's calculations were done where the superscripts a, b, & c signify significance states of results at 1%, 5%, & 10% levels accordingly

Table 25: The Sample Causality Exploration

	The Calculated Zbar-Stat						
The Variable	***LogCO₂***	***LogRI***	***LogFEC***	***LogNR***	***LogMGI***	***LogSGI***	***The Movement of Causality***
LogCO₂	--	1.862[c]	3.417[a]	0.105	2.100[b]	2.030[b]	$LnCO2 \rightarrow LnFEC, LnMGI, LnSGI, LnRI$
LogRI	4.810[a]	--	3.501[a]	1.303	1.201	5.650[a]	$LnRI \rightarrow LnCO2, LnFEC, LnSGI$
LogFEC	3.730[a]	1.620	--	1.902[c]	2.250[b]	2.150[b]	$LnFEC \rightarrow LnCO2, LnNR, LnMGI, LnSGI$
LogNR	2.020[b]	4.201[a]	-0.421	--	1.982[c]	0.991	$LnNR \rightarrow LnCO2, LnRI, LnMGI$
LogMGI	-0.726	10.310[a]	-0.900	-0.667	--	1.175	$LnMGI \rightarrow LnRI$
LogSGI	0.590	-0.641	-0.375	2.703[a]	0.910	--	$LnSGI \rightarrow LnNR$

Here, author's calculations were done where the a, b, & c signify significance states of results at 1%, 5%, & 10% stages accordingly.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

In this last chapter, a summary of what has been done in the study was provided and the valid conclusions that could be drawn from the empirical results were discussed in practical terms. We also proceed further to provide recommendations for policymakers and suggestions that could help researchers in future studies. The conclusions were drawn based on the three sub-categories of empirical analysis.

5.1. Summary and Conclusion of the Study

5.1.1. Summary and Conclusion from the first sub-category of empirical analysis: The Nexus of Environmental Pollution and Energy Dynamics in a Globalized World

The impacts of the energy mix on the quality of the environment were examined among oil-producing nations in Africa towards addressing the global desire for decarbonization while also throwing light on the economic aspects of such prospects. The impact analysis hinges on the strengths of second-generation estimation techniques of quantile regression (QR) and Augmented Mean Group (AMG) estimators in deciphering the roles of the energy indicators on carbon emission levels across the countries between 1990 and 2015. The study utilized data from oil-producing African nations to include Algeria, Nigeria, Angola, Egypt, Tunisia, Gabon, Congo Republic, and Sudan. In addition, the analysis was also extended to cover the unique case of South Africa being the leading carbon emitter on the continent with vast fossil resources in terms of coals.

The vast majority of the oil-producing African nations have increasingly become ever reliant on their conventional energy sources. The review of recent developments suggests economic shortfalls of such reliance to include challenges of dwindling revenue generation, fiscal disruptions, and shrinking GDP size. Moreover, aside from the identified economic shortfalls, the environmental aspects of the energy mix based on the empirical analysis among the countries reveal other paramount information vis-à-vis the prospects of achieving decarbonization for a sustainable environment.

The empirical analysis was done via the adopted methodologies while also providing additional details on the country-specific setting. According to the empirical results, among the countries, only renewable energy sources support decarbonization of the environment by 0.25% with respect to a percentage rise in their usage. Besides, the consequences of the trio of fossil fuel consumption, income growth, and globalization are diametrically opposed to achieving decarbonization as the rise in their usage significantly acts as pollutant-inducing tools.

The undesirable impacts of the trio of income growth, fossil energy use, and globalization for decarbonization prospects among the countries were further deciphered from the causality outputs following the establishment of a one-way causality from income levels to emissions and a bidirectional causality from the duo of fossil energy and globalization to carbon emission levels. The first category of analysis furthers establishes the EKC hypothesis. However, there is more clarity on the EKC with more insights on the validness of the hypothesis given the specific case of the individual countries.

5.1.2. Summary and Conclusion from the second sub-category of empirical analysis: The Nexus of Environmental Degradation and Urbanization in an Ecological Footprint Framework

The second sub-category of the empirical analysis provides a synthesis of the implications of energy indicators on the ecological footprint of oil-exporting African economies using panel data estimation techniques for sample data between 1990 and 2016. The analysis focuses on the roles of fossil energy resources (its rents and consumption) among the countries while controlling for the roles of renewables and globalization amidst rising urbanization in the rapidly growing continent of Africa. The adopted AMG estimator produced very insightful information in the study and also offers the additional advantage of taking a look at country-specific outcomes in the empirical analysis. The results were further corroborated by estimates from the DOLS and FMOLS approaches.

It was observed that the interaction between fossil energy resource rent and its consumption increases ecological footprint among the countries thereby constituting a significant threat to environmental quality. In like manner, evidence from the period of the study suggested that the combination of globalization & economic growth also worsen the pressure exerted on the environment alongside the undesirable impacts of urbanization on rising ecological footprint among the countries. Overall, the income-footprint relationship depicting the EKC hypothesis was rejected for the panel of all countries while its validity was only upheld in Egypt and Nigeria on a country-specific basis, thus reflecting the likely roles of individual country's specific differences. The obtained causality outputs also corroborated the long-run estimates by revealing the inherent links between the variables and the ecological footprint. As such, the study opines important practical implications for the understudied oil-exporting African economies.

5.1.3. Summary and Conclusion from the third sub-category of empirical analysis: The Nexus of Environmental Pollution with Fossil Energy Resources Abundance in a Sectoral Composition Framework

The QR approach was utilized to observe the effects of the sectoral share of the economy and energy components on environmental pollution's conditional distribution in view of the CO2 emission levels between 1995 and 2016. The research utilized some major African states that are rich in fossil energy resources including Nigeria, Angola, Egypt, and Algeria. The dynamic ordinary least square (DOLS) approach was also utilized to essentially provide an additional comparative analysis from a mean estimations point of view in contrast to the median estimates from the QR approach.

The empirical analysis demonstrated that three major propellers of environmental pollution exist in view of the CO2 emission levels among these economies including the share of manufacturing sector, the income levels, and fossil energy utilization. In addition, although income growth is a significant propeller of carbon emission levels, however, the

EKC conjecture is not clearly upheld since the findings reveal that the income-pollution nexus exhibits an important quantile effect for the sample countries.

In addition, the important two-way causality movement between fossil energy utilization and CO2 emission levels also strengthens the environmental pollution-triggering effects of the energy utilization levels which were observed from the conducted long-run evaluations of the sample countries. As for the nexus between real income levels and fossil energy consumption, causality runs from the former to the latter and not the other way round. Additionally, rents levels granger causes the income levels while causality evolves from the latter to the emission levels. As for the sectoral effects, causality was not established from the income level to manufacturing sector but rather to the service sector alone thus showing the mono-economy pattern among the sample countries. Most of these countries are mainly reliant on services in the oil and gas industry including resource trading activities. Unfortunately, this may not be a long-term path to sustainable economic growth since the energy industry is often susceptible to global fluctuations and shocks.

5.2. Practical Implications and Policy Recommendations

5.2.1. The First Sub-category of Empirical Analysis

Decarbonization has desirable outcomes as it is a critical step towards addressing environmental problems vis-a-vis averting possible damages of climate change which are even expected to be more catastrophic for less developed African economies. Therefore, given the aforementioned findings, we recommend concerted efforts for more investment in renewables technologies from both the public and private sectors especially in sources like solar, wind, and hydro energy generation. These sources are not only renewable but also feasible and sustainable alternative energy sources for the countries in the study and by extension to other countries on the continent given Africa’s strategic geographical advantages. For instance, it's been noted that African has about 10-terawatt (TW) capacity of solar energy potential with other exploitable energy capacities for sources like wind, hydro, and even geothermal estimated to be about 110 gigawatts (GW), 350 gigawatts (GW), 15 gigawatts (GW) respectively (UNEP, 2017). Sadly, this huge potential is still largely untapped and as such offers more prospects for the continent. Some oil-producing Northern African countries in the study like Algeria, Egypt, and Tunisia have higher advantages in the development of both solar and wind energy.

In addition, the countries should also take advantage of the oil proceeds to kick start necessary green energy projects by offsetting the Levelized cost (LC) of investment for such sustainable projects with necessary supports from the oil industry. We are well aware that the initial cost could be high, but then, that is where the advantage of the oil revenues is expected to come in. The nation can strategically set up special green energy investment funds and such funds should cover a long-term design to harness the benefits of windfall revenues from oil and gas for sustainable energy transition programs towards a post-oil era. Also, given the alarming cases of corruption in public spheres on the continent as well documented in the literature (Hope, 2020; Sassi & Ali, 2017), policy measures and legislation must be put in place to strengthen relevant institutions towards ensuring prudent management of green energy investment funds.

Furthermore, we believe that globalization is a strong tool that offers both the good and the ugly. Economically, although the causality evidence shows that it has enhanced income growth, its impacts were however ugly for the environment as it does not support environmentally desirable outcomes when considering carbon emission levels. Hence, we further recommend taking advantage of globalization through technology transfers for desirable environmental benefits. In this regard, the countries in the study are implored to channel their income expansion for the acquisition of clean energy technologies through globalization for environmental quality improvements. This strategy is practically applicable to all the countries in the study and most especially for the individual cases of Nigeria, Egypt, Sudan, and Gabon where the EKC hypothesis was specifically verified.

5.2.2. The Second Sub-category of Empirical Analysis

One of the major practical implications from the second sub-category of empirical analysis under the ecological footprint is that any environmental action through energy conservation policy implementation to curtail the rise in ecological footprint among this group of countries must carefully take into cognizance the issues of a potential setback on economic growth or income target. This issue is pertinent given that the countries are mostly at the emerging stage of their economic drive with a substantial level of pressure to increase and sustain per capita income growth. Fiscal revenue and public expenditures alongside GDP growth projections are often carried out on oil and gas as the major export commodities in the majority of the understudied oil-exporting countries. The only potential exception among the countries in the panel study is the case of South Africa where the economy has witnessed some levels of diversifications over the years being the industrial hub of Africa. However, this does not in anywise imply that South Africa is isolated as far as the potential setbacks of implementation of energy conservation policies are concerned. For instance, South Africa still faces substantial environmental degradation not just from fossil electricity production alone in terms of GHG emission from burning coal, but it is also confronted with degradation relating to coal mining activities (Bell et al. 2001; Campbell et al. 2017).

A such, it is strongly suggested that the policymakers and authorities in the sample economies should come up with a blueprint on energy transition from fossil resources dependency to renewables to lessen the pressure exerted on the environment. Fortunately, the countries in the panel study can leverage on proven potential in alternative energy sources like wind and solar (UNEP, 2017). For instance, vast exploitable wind energy potential spread across countries like Algeria, Libya, Egypt, Sudan, Tunisia, and others around the Sahara in the northern part of the continent, spanning from the northwestern region to the horn of Africa at the eastern borders. Mean wind speed at 100m height could be as high as between 7.5 to 14.1 m/s among these countries (UNEP, 2017). Likewise, solar potential spread across the continent, and these energy resources are even more evenly distributed from the Northern African countries to those in the Sub-Saharan region with annual global horizontal irradiation ranging between 2300 and 2752 KWh/sq.km in most of the countries.

In addition, while the pursuit of the energy transition is on track, policymakers must strive harder to gravitate the countries towards economic diversification away from oil and gas dependence to ensure sustainable economic growth and wealth creation outside the confine of petroleum revenues. Energy transition action will enhance the achievements of SDGs-13 and 11 that emphasize the needs for climate action amidst the quest for sustainable cities and communities, while economic diversification will enhance the achievements of SDGs-8 that emphasize job creation and sustainable economic growth.

Aside from the GHG emission from burning fossil fuels like oil and gas, various activities in the oil sector including exploration, extraction, and processing stages in both downstream or upstream activities, often result in different degrees of damages to the ecosystem and natural environment and this calls for environmental protection and other climate actions (Onyena & Sam, 2020; Parra et al. 2020). As such, two major tools are very important, namely green technology investment and government environmental regulations. If technology is not sufficient to counterbalance the speed of natural resource exploration, environmental degradation and its consequences could be more pronounced. The majority of the understudied countries are much more vulnerable to environmental degradation due to lower technology compared to developed economies. It is therefore recommended that a massive investment should be made in green technology to cushion the deteriorating biocapacity as the natural resources are being exploited among the countries.

Finally, to reduce the undesirable environmental impacts of increasing urban population among the oil-exporting economies, it is recommended that authorities and policymakers pursue urban infrastructural investment based on reliable and regular population projection while putting necessary regulations for environmental conservation in place. This action will not only encourage a quality urban experience but can also help to moderate the average cost of living as pressure on social amenities is being strategically cut down. The sample economies also need to pursue more strategic investments in green infrastructures, and this must be intentionally targeted at the sector with very high energy demand. In view of this, Figure 6 and Figure 7 have already shown that more attention should be given to sectors like industry and transport.

The implementation of green infrastructure investment plans in urban and rural areas would essentially benefit the sample economies in this study in two dimensions. First of all, the investments can induce desirable environmental advantages via an increased environment quality level vis-à-vis the lowering of greenhouse gases since green infrastructures do not emit GHG. Secondly, green infrastructures can also help these countries in addressing the rising challenges of the pressure on urban facilities that has been aggravated by rural-urban migration. Overall, these actions will in turn boost the standard of living of people and citizens' quality of life, thereby helping the sample countries in actualizing SDG 11 in view of the ongoing campaign for sustainable cities and communities.

5.2.3. The Third Sub-category of Empirical Analysis

Hence, it is important for the government of the sample oil-exporting countries to ensure that policy strategies for economic diversification are adopted to deal with over reliance on resources. A diversification policy that encourages development in other sectors like manufacturing will help in ensuring sustainable economic growth which can in turn help these countries to combat poverty levels and create sufficient wealth thereby fostering the realization of SDGs 1 & 8. Rather than just over relying on resource rent, a well-developed manufacturing sector (real sector) can produce enormous economic benefits especially in terms of jobs creation with an attendant effect of wealth creation among people who are gainfully employed in an economy. Recall from the results, the income levels are mainly affected by resources rent in the sample nations based on the causality analysis, meanwhile on a sectoral basis, the only one-directional income causality nexus was flowing towards the service sector. On the other hand, the causal linkage between income and manufacturing was from the latter to the former unlike what was seen in the service sector case showing that the manufacturing sector may not have seen the expected economic benefits of the resources-induced income levels.

Since conventional energy utilization create more environmental degradation in the sample oil-exporting African economies, policymakers also need to develop practicable strategies for diversification of the energy portfolios in these economies. Instead of encouraging business as usual situation whereby conventional (fossil) energy forms make up more than 90% of whole energy utilization as currently obtainable in many of the sample states, deliberate actions should be taken to diversify into renewable/alternative energy resources. Luckily for most of this oil-exporting African economies, their renewable resource potentials are really great. For example, solar energy potential is calculated to be between 2300 and 2752 KWh/sq.km based on the yearly horizontal irradiation. Besides this, average wind speed for most of the sample countries for the range of about 100m height is estimated as high as 14.1 m/s from about 7.5 m/s based on a study by UNEP, (2017). Therefore, the development of their renewable energy resources will help these nations to attain transition to the desired sustainable energy utilization for environmental gains.

Finally, the government also need to invest more in green manufacturing technical know-how to help reduce the environmental damages from the fossil-energy induced manufacturing activities. Adequate investments in green manufacturing technologies will also enhance the ecological atmosphere and fosters biocapacity preservations. Green technologies can lower environmental pressure from resource exploitation through cleaner and more advance techniques of resources exploration and exploitation. Therefore, in view of the emphasizes on responsible production and consumption as broadly outlined in SDGs 12, the economies will benefit immensely from investments in greener technical know-how. Overall, following the outlined recommendations on energy diversification, green manufacturing technologies, and green infrastructural investments, the understudied oil-exporting African states stand to attain more environmental benefits within the auspices of their desire for a sustainable economic growth.

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APPENDIX

Figure 15: The Share of Oil Reserves in Oil Producing African States

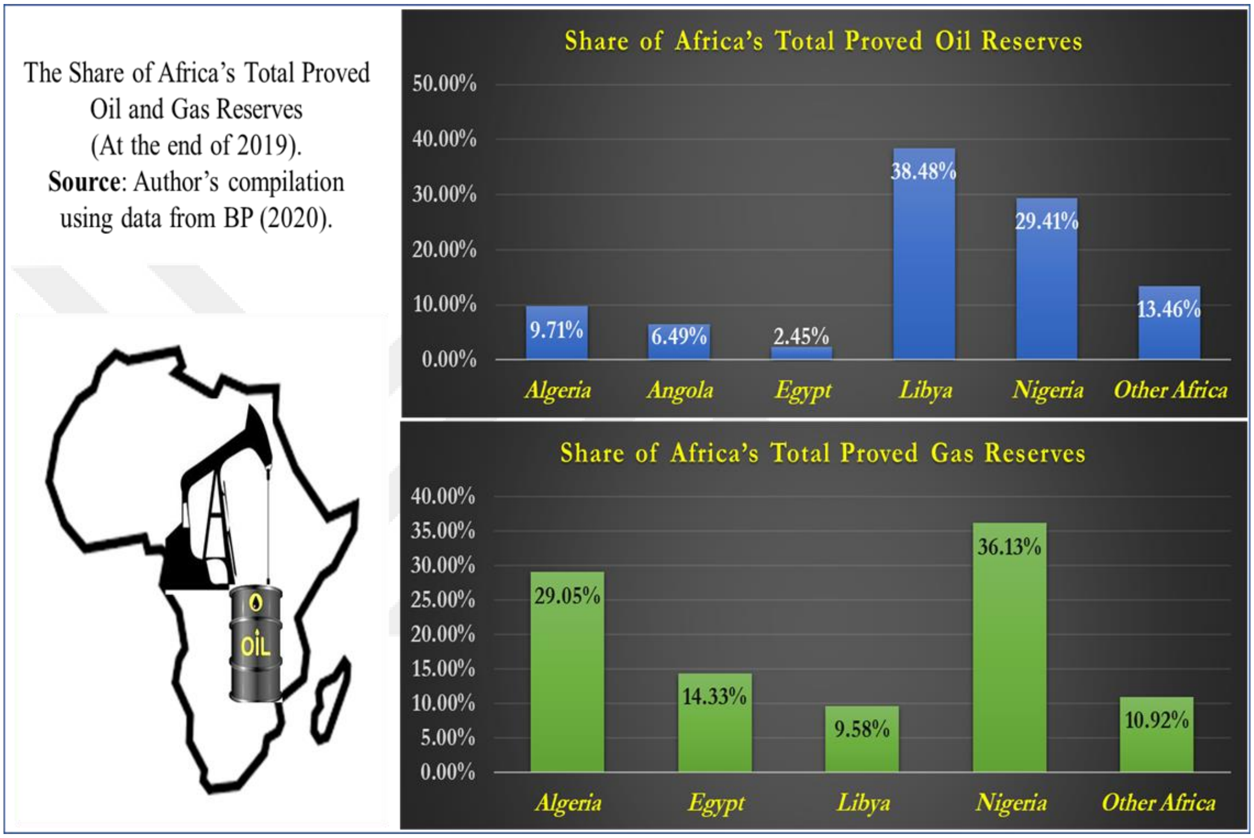

Table 26: The Slope Equality Test for the Quantiles

The calculated equation where quantile tau is
0.5
All coefficients The coefficients are used to compare the
test statistics

Summary of test	The Chi-Square. Statistic	Chi-Sq. d.f.	Prob.
Wald Test	530.8401	48	0.0000

Table 27: The Slope Equality Test for the Quantiles

The calculated equation where quantile tau is
0.5
All coefficients The coefficients are used to compare the
test statistics

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Wald Test	21.73229	12	0.0406

Figure 16: Diagnostics for the Coefficients (Confidence Ellipse)

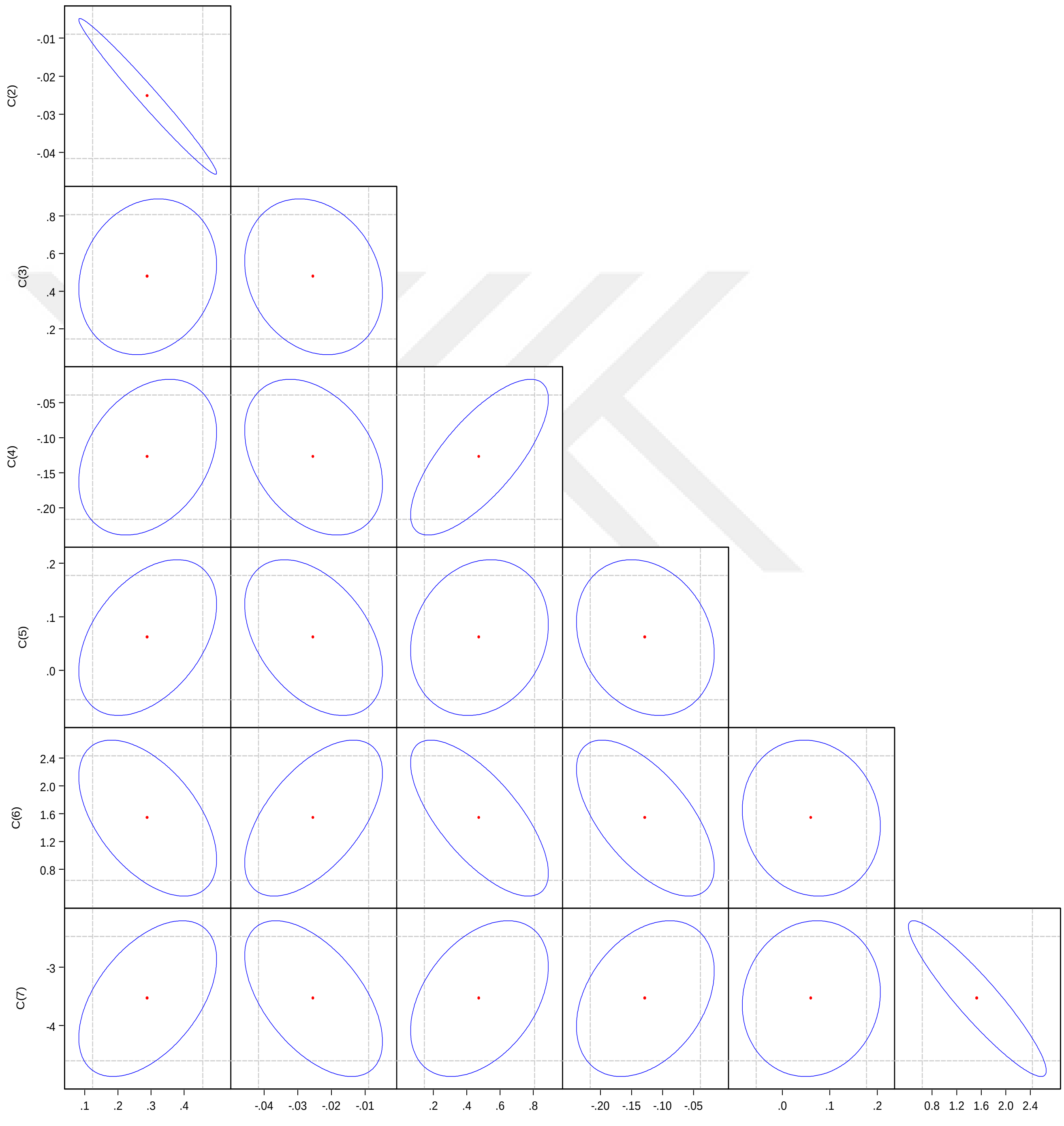

Figure 17: The Quantile Process

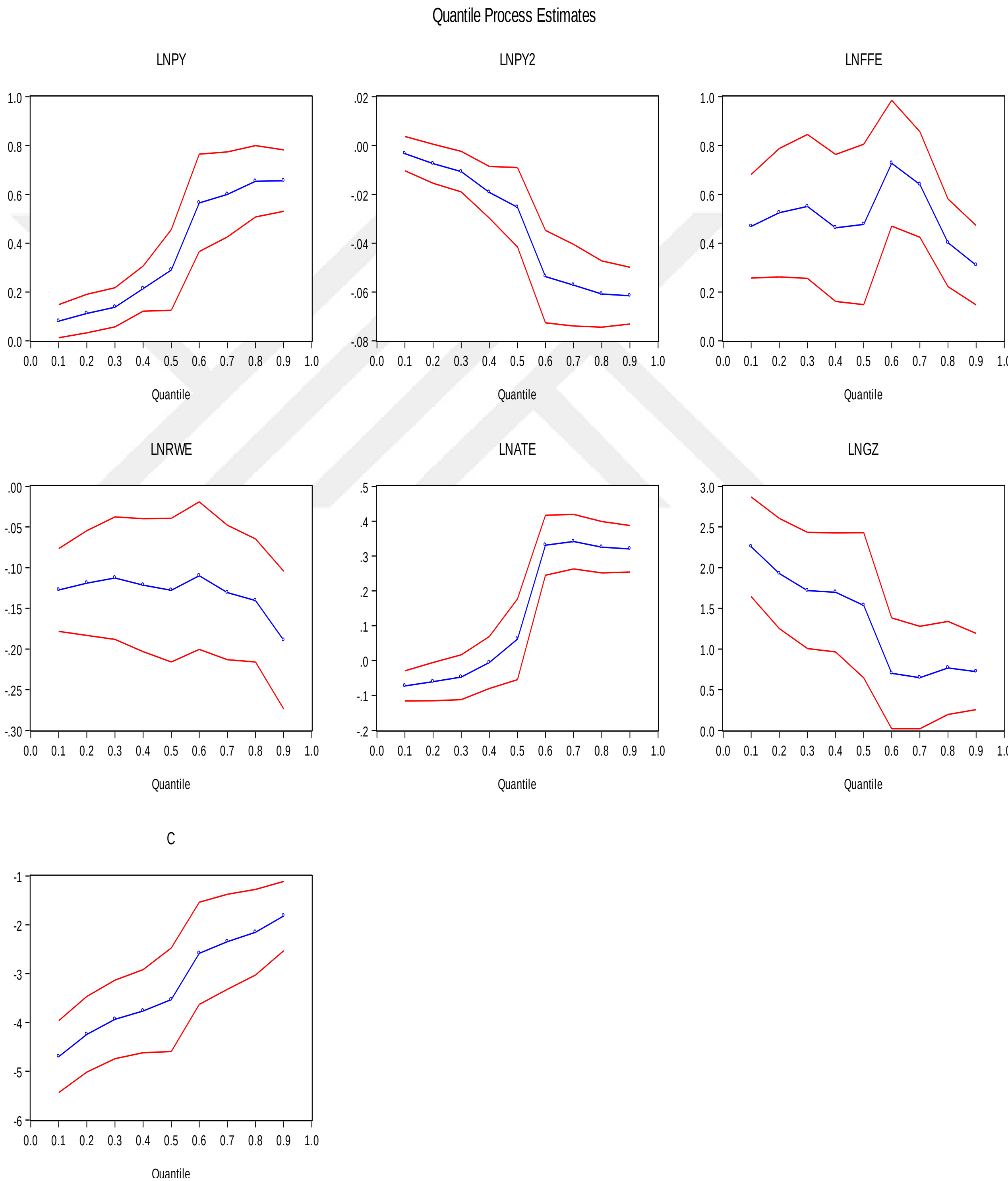

Figure 18: Diagnostics of Coefficients (Confidence Ellipse)

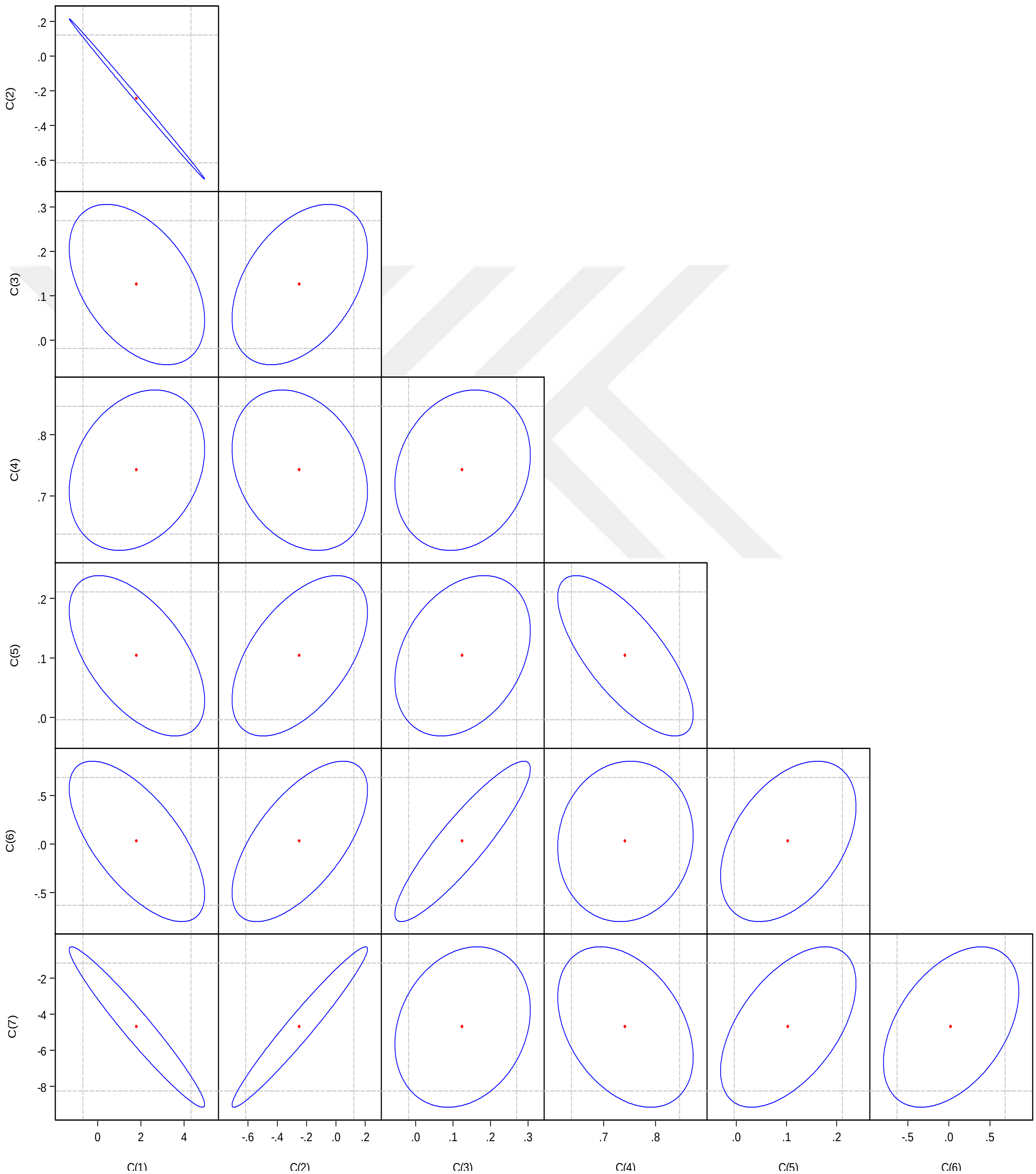

Figure 19: The Quantile Process