



UNIVERSITY OF KWAZULU NATAL

**ENERGY CONSUMPTION AND ECONOMIC GROWTH:
EVIDENCE FROM AFRICAN OIL EXPORTING
COUNTRIES**

by

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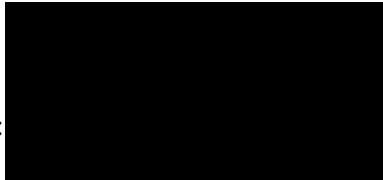
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Dedication

This thesis is dedicated to God Almighty, the author and finisher of my faith, my late parents, Chief Moses Folayan Ogunsola and Mrs Modupe Felicia Ogunsola, my lovely wife, Ebunoluwa Abiola, and my son, Oluwakorede Daniel.

Abstract

This thesis examines the relationship between energy consumption and economic growth in a sample of African oil-exporting countries (AOECs). The group comprises Algeria, Angola, Egypt, Gabon, Nigeria and the Republic of Congo. The thesis presents three separate, but interconnected essays based on annual data on the period 1980 to 2018. **The persistent energy consumption issues are ascribed to the failure of energy planners to understand the various macroeconomic factors that influence energy consumption.** Therefore, the first essay in Chapter 3 investigates the factors influencing energy consumption, using the cross-sectional autoregressive distributed lag and the cross-sectional distributed lag modelling estimators. These estimators consider the time dynamics and the heterogeneity of the different countries. Moreover, they are robust to cross-sectional dependence. The study explores the relationship between energy consumption and its major determinants, such as openness, economic structure and per capita income. The results reveal that openness has a positive and significant effect on energy consumption in AOECs during the period under study, while the economic structure has a negative and significant effect. The third variable of interest, namely per capita income, does not impact significantly on energy consumption. It is, therefore, recommended that these countries transform their economies structurally such that it will make economic growth more inclusive, driven by domestic value-added and not exogenous income from primary product exports.

Most African net oil exporters are characterised by a unique paradox. They have low energy consumption despite their large energy deposits, and their economic growth rates are lower than both the global and African average. Hence, the second essay in Chapter 4 investigates the causal relationship between energy consumption and economic growth. The study uses both linear and non-linear estimators. The study estimates a panel smooth transition vector error-correction model, which is robust to cross-sectional dependence and endogeneity and conduct a regime-wide Granger causality test. The study finds that the nonlinearities between the two variables are better explained whenever energy consumption is the transition variable. The Granger causality results show that in the short run, neither energy consumption nor economic growth causes each other in both low and high-growth regimes. In the long run, however, energy consumption Granger causes economic growth in high-growth regimes only. The economic growth variable, Granger causes energy consumption in both regimes. We conclude that a high economic growth rate drives energy consumption in AOECs. Consequently, it is recommended that **conservation policies such as eliminating fossil fuels** should be implemented efficiently, as they can hinder growth in the long run.

A close connection exists amongst oil price shocks, energy consumption and economic growth. This connection has consequences for the growth of an economy. Using the Bayesian structural vector autoregressive model, the third essay in Chapter 5 analyses the impact of oil price shocks on energy consumption and economic growth. The study finds that the oil price shocks impact energy consumption and economic growth of all six AOECs. Conversely, the domestic variables of energy growth and economic growth does not impact oil price inflation. The unexpected variations in energy consumption impacts positive influence on economic growth in Nigeria, the Republic of the Congo and Gabon, whereas it is an inverse relationship in Angola, Egypt and Nigeria. The shock of economic growth leads to positive change in energy consumption in Angola, the Republic of the Congo, Egypt and Nigeria, but with inverse relationship in Algeria and Gabon. It is on this basis that we recommend the diversification of these economies to lessen the effect of external shocks in AOECs.

Abbreviations and Acronyms

ADF:	Augmented Dickey-Fuller
AfDB:	African Development Bank
AOECs:	African Oil Exporting Countries
ASEAN:	Association of Southeast Asian Nations
BLUE:	Best Linear Unbiased Estimator
BPD:	Barrels Per Day
BSVAR:	Bayesian Structural Vector Autoregressive
BVAR:	Bayesian Vector Autoregressive
CADF:	Cross-Sectional Augmented Dickey-Fuller
CD:	Cross-Sectional Dependence
CIPS:	Cross Sectionally Augmented Im Pesaran and Shin
CIS:	Energy Independent States
CS-ARDL:	Cross-Sectional Autoregressive Distributed Lag
CS-DL:	Cross-Sectional Distributed Lag
CTOT:	Commodity Terms of Trade
DSGE:	Dynamic Stochastic General Equilibrium
EC:	Energy Consumption
ECM:	Error Correction Model
ES:	Economic Structure
FAVAR:	Factor-Augmented Vector Autoregressive
GCC:	Gulf Cooperation Council
GDP:	Gross Domestic Product
GLS:	Generalised Least Squares
GMM:	Generalized Method of Moments
GNI:	Gross National Income
GNP:	Gross National Product
IEA:	International Energy Agency

IPCC:	Intergovernmental Panel on Climate Change
IPPs:	Independent Power Producers
IRENA:	International Renewable Energy Agency
MDGs:	Millennium Development Goals
MG:	Mean Group
MTOE:	Million Tonnes of Oil Equivalent
NIPALS:	Nonlinear Iterative Partial Least Squares
OECD:	Organisation for Economic Co-operation and Development
OLS:	Ordinary Least Squares
OP:	Oil Price
OPEC:	Organisation of Petroleum Exporting Countries
OPEN:	Openness
P-ARDL:	Panel Autoregressive Distributed Lag
PEC:	Panel Error Correction
PERINC:	Per Capita Income
PMG:	Pool Mean Group
PSTR:	Panel Smooth Transition Regression
PSTRVEC:	Panel Smooth Transition Vector Error Correction
PVEC:	Panel Vector Error-Correction
SDGs:	Sustainable Development Goals
SSA:	sub-Saharan Africa
STIRPAT:	Stochastic Impacts by Regression on Population, Affluence and Technology
STR:	Smooth Transition Regression
SVAR:	Structural Vector Autoregressive
SWF:	Sovereign Wealth Fund
US EIA:	The United States Energy Information Administration
VAR:	Vector Autoregressive
VECM:	Vector Error Correction Model
WDI:	World Bank Development Indicators

Thesis Distribution

Published Articles

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- i. Determinants of Energy Consumption in African Oil Exporting Countries (AOECs): Evidence from Cross-Sectional Autoregressive Distributed Lag (CS-ARDL). (Paper Presentation). *Biennial Conference of the Economic Society of Africa (ESSA)*, 3-5 September 2019, Birchwood Hotel, Johannesburg, South Africa.
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CHAPTER 1

INTRODUCTION

1.1 Background

Before the oil crisis of 1973, the world had failed to recognise the impact of energy in the production process and how disruptions to its supply chain can affect the global economy. Considering this crisis, Dunkerley (1982) posits that energy is an essential input in tandem with capital and labour in the production process. Ebohon (1996), Templet (1999) and Faisal et al. (2018) agree by stressing that rapid economic growth may rely on the extent to which energy and other variables like capital and labour complement one another.

Generally, energy remains the major driving force for both the industrial expansion and economic growth of every country. In addition, it is at the centre of environmental issues because access to clean, constant, effective and sustainable energy is required for global economic growth and development. Developing countries such as African oil-exporting countries (AOECs) need robust access to dependable and modern energy sources owing to an expanding population and increasing socioeconomic activities. Access to clean and reliable energy will enhance productivity, reduce poverty, sustain competitiveness and promote economic growth (Ajayi & Ajanaku, 2009; Abam et.al., 2014; Cui, 2016).

Over the years, the controversy surrounding the correlation between energy consumption and economic growth has been well researched in the economic literature (see, Ozturk, 2010; Arouri et al., 2012; Omri, 2014; Kasman & Duman, 2015; Antonakakis et al., 2017). Both theoretical and empirical evidence show that the role of energy consumption in economic development and growth cannot be ignored. However, consensus is lacking on the causal relationship between energy consumption and economic growth (Soytas & Sari, 2003; Narayan et al., 2008; Ozturk, 2010; Souhila & Kourbali, 2012; Ozturk & Al-Mulali, 2015; Antonakakis et al., 2017). Study results even differ in the direction of causality and the long versus short-term effects on energy policy. **These may be due to differences in methodologies, sample periods and model specifications being employed.** Moreover, the distinction between the short and the long-term effects is important because they determine the sustainability of an energy policy and how it ensures energy conservation and efficiency. Therefore, an understanding is needed of the direction of causality between energy consumption and economic growth in the long-term in AOECs because of the policy implications of the relationship between these variables (Masih & Masih,1996).

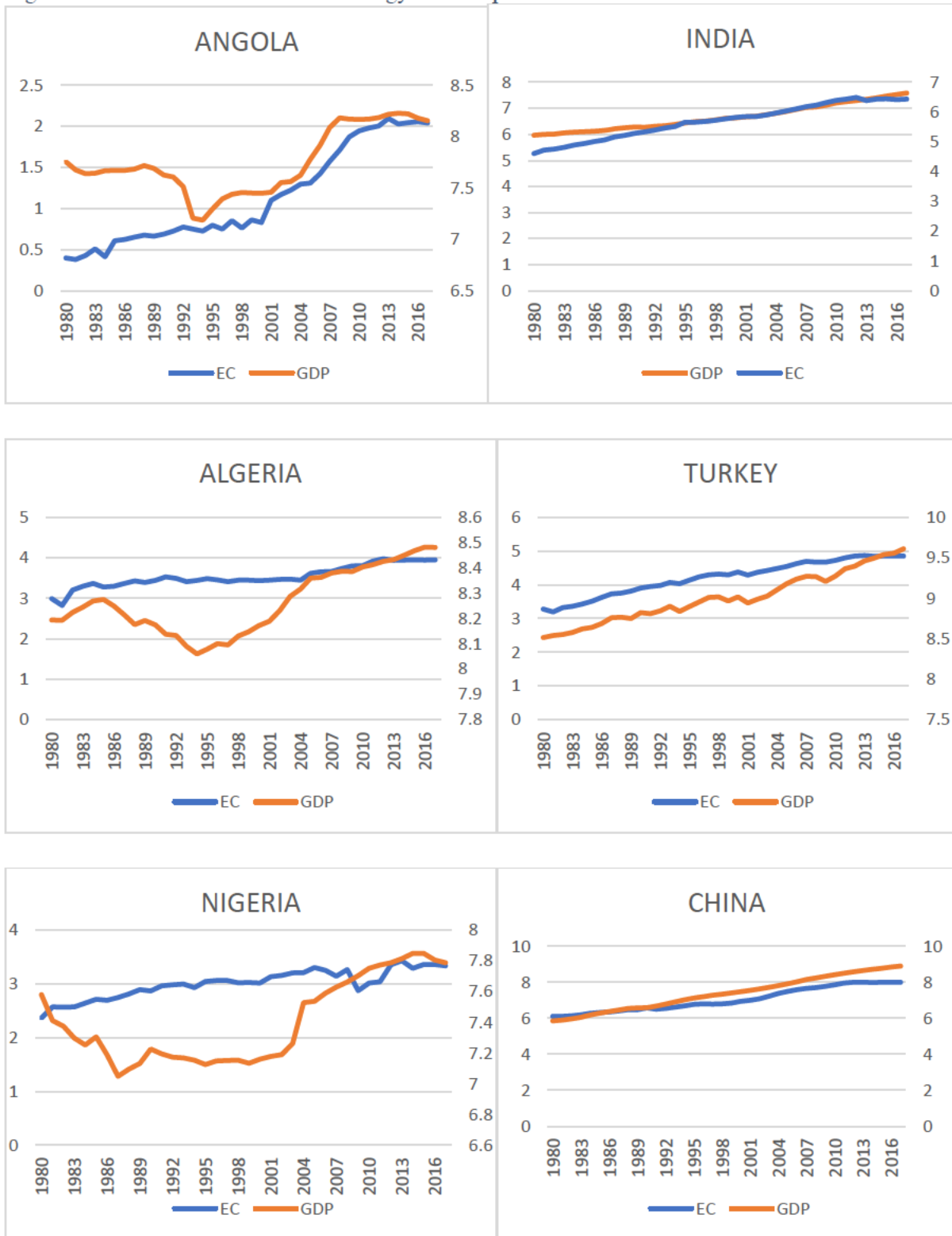
As indicated in Figure 1.1 below, a comparative analysis using data from the World Bank Development Indicators (WDI, 2017) provides an understanding of the real gross domestic product (GDP) and energy consumption trends of selected AOECs (Angola, Algeria and Nigeria) and some emerging economies

(Turkey, China and India). The trends reveal a contrasting pattern. In the AOECs, energy consumption maintains fluctuating and sluggish upward movements, except for Angola that witnessed a surge in energy consumption with the end of the Civil war in 2002. In the emerging economies, energy consumption tracks almost perfectly the real GDP during the period under review. The sluggishness of energy consumption in AOECs could be attributed to the huge consumption of traditional forms of energy, such as biomass and waste (Kebede et al., 2010). The AOEC's electricity sector is largely characterised by an unreliable power supply, low access levels, deficient maintenance, difficulty in finding spare parts and low-capacity utilisation (Karekezi, 2002a; IEA, 2010).

The constant upward movement of energy consumption in emerging economies could be ascribed to access to clean and modern energy due to the sophisticated industrial and service sectors that dominate these emerging economies (US EIA, 2016). For instance, out of 267 Mtoe¹ of total energy consumed in sub-Saharan Africa (SSA) including AOECs, 54 percent was from traditional energy (IEA, 2014a). Kebede et al. (2010) and Kolawole et al. (2017) state that a traditional form of energy is inefficient for sustainable economic development. Moreover, according to the US EIA (2016) report, the proportion of modern energy consumed contributed exceedingly to the growth of the real GDP of emerging economies. For instance, in India 44 percent of energy sources were from coal, followed by 23 percent from petroleum, while others, such as liquids, biomass and waste, contributed 23 percent. China and Turkey recorded a similar pattern with coal contributing about 66 percent, oil 20 percent, hydroelectric 8 percent and coal 28.5 percent, natural gas 35 percent, oil 27 percent and hydro 7 percent. Figure 1.1 below presents the trends of real GDP and energy consumption.

¹ Million Tonnes of Oil Equivalent, see EIA, 2017

Figure 1.1: Trends of real GDP and Energy Consumption



Source: Computed by the author with data from (WDI, 2017)

Pollution and global warming have become a focus of energy policies, which aim to minimise the negative effects of climate change by, for example, reducing fuel consumption (Dinda & Coondoo, 2006; Cui, 2016; Nain et al., 2017). However, although such a measure would mitigate environmental harm, it would negatively affect economic growth (Liddle & Lung, 2010; Mukhtarov et al., 2017) because of the role played by energy consumption in the economic growth. Thus, whether an energy conservation policy can effectively be implemented in an economy has become a major concern in the energy literature since the late 1970s (Saidi & Hammami, 2015; Yasar, 2017). **Nevertheless, the relationship between energy consumption and economic growth and, in particular, the direction of causality between these variables need to be understood clearly before deciding the viability or otherwise of any energy conservation policy and this will help in designing a better energy policy.**

In the AOECs, the occurrence of certain events, such as structural reforms, economic crises and oil price shocks, affects the behaviour of certain variables, including energy consumption and economic growth. As noted by Eggoh et al. (2011) and Lee and Chiu (2011b), not paying attention to these occurrences may likely lead to the misspecification of the long-run properties of a dynamic system as well as inadequate estimation and testing measures. Therefore, an empirical study of the correlation between energy consumption and economic growth must take into account these occurrences, because it may cause structure changes in the pattern of energy consumption, especially in AOECs (see Poterba, 1991; Hooker, 2002; Raheem & Yusuf, 2015).

According to Abdel-Aal (2008) and Sokona et al. (2012), the importance of energy consumption necessitates an understanding of current demand patterns and the factors influencing energy consumption, which will benefit preparation and outlay decisions about storage, transportation and distribution, for example. The factors determining energy consumption differ significantly from country to country owing to differences in policies, the level of development, the degree of energy dependency and sources of energy, for instance (Bhattacharyya, 2011). An important reason for renewed interest in energy consumption mix is the environmental impact of energy, especially in the poorest countries of the world where energy policies are not environmentally friendly (Mukhtarov et al., 2017).

Two distinct features of AOECs should be considered when examining the causal relationship between energy consumption and economic growth. The first is that despite their dependence on oil exports as the main source of foreign earnings, the energy consumption of these economies tends to be low and dominated by dirty fuel². The second is that their economic growth is driven mostly by oil exports since it is positively correlated with oil prices (see, for instance, Mehrara, 2008; Farzanegan & Markwardt, 2009; Behmiri &

² Biomass

Manso, 2013) and therefore, AOECs are vulnerable to energy price shocks (Eggoh et al., 2011; Eregha & Mesagan, 2017). These two features of AOECs, which are low-income net oil-importing countries, have extensive implications for the causal relationship between their energy consumption and economic growth, which differs from that of high-income countries (see, Mahadevan & Asafu-Adejaye, 2007; Kahsai et al., 2012; Bazilian et al., 2013). Therefore, an analysis of the impact of oil price shocks on energy consumption and economic growth in the AOECs needs investigation.

1.2. A brief overview of the African net oil-exporting countries

Africa is endowed with huge amounts of both fossil and renewable energy resources and leads the world in its frequent new findings of oil and gas. It is a major contributor to the crude oil exports of the world's oil-exporting regions (US EIA, 2018). Out of the 54 African countries, 20 are involved in the oil-related business, with more than 500 multinationals operating in their upstream and downstream oil industry (OPEC, 2018b). Of the 20 countries, 11 are net exporters of crude oil, of which 5 (Nigeria, Algeria, Angola, Gabon and Libya) are supervised by the Organisation of Petroleum Exporting Countries (OPEC), which is a permanent intergovernmental organisation formed in Baghdad in September 1960, by its founding members, Iran, Iraq, Kuwait, Saudi Arabia and Venezuela to regulate the oil output of member countries. In addition, OPEC coordinates its members' oil policies to ensure oil price stability and global oil supply. Oil revenue is a large part of the foreign exchange income of oil-exporting countries, thereby contributing substantially to government resources and making the oil sector a key economic determinant for more than five decades in most AOECs (Iwayemi & Fowowe, 2011). Akpan (2009) opines that oil might be a curse in disguise because it has led to uneven wealth distribution, corruption, pilfering and a dysfunctional economic system. Hence, massive oil revenue does not necessarily yield positive outcomes and most AOECs are associated with poor socio-economic indicators due to the poor management of oil resources (Caselli and Michaels, 2013; Hausmann et al. 1993; Van der Ploeg & Venables, 2011). **Additionally, Sachs and Warner (2005) and Olomola (2010) argue that nations endowed with rich natural resources demonstrate poor economic performance in comparison with those with fewer natural resources.** However, oil remains the mainstay of these economies, contributing the major chunk to their foreign earnings and government revenues (Ayodele, 2010; Ajayi, 2012).

Over the years, oil reserves in Africa, where oil and natural gas deposits are increasingly found, have grown by over 25 percent, while growth in gas is by more than 100 percent (US EIA, 2019). Africa's rich oil fields and the prospects for more discoveries have transformed the continent into an important player in global oil production and resource extraction. Specifically, Africa's share of world oil production has fairly

increased by 0.3 percent in 2016 to 8.7 percent (8.1 million) bpd³ in 2017 (OPEC, 2018). It is expected that oil production will increase by 6 percent yearly in the conceivable and a large proportion of crude oil production is expected to come from Algeria, Angola, Nigeria, Sudan and Libya, producing approximately 90 percent of the continent's reserves (US EIA, 2019). Approximately two-thirds of the world's energy requirements are met by oil and gas supplies, while the remainder is met by other sources (Behmiri & Manso, 2013). Nearly 90 percent of the energy consumed worldwide is provided by the three non-renewable fossil fuels (oil, gas and coal).

The production of which on a commercial scale is consistently distributed throughout the continent. For instance, coal is produced in southern Africa (notably South Africa), while crude oil production is concentrated in North Africa (Algeria, Egypt, Libya, and Sudan), central Africa (Angola, Gabon and the Republic of the Congo) and West Africa (Nigeria). Only East Africa does not produce these energy sources (Olumuyiwa, 2008). Although Africa, including the AOECs of the study (Algeria, Angola, Egypt, Gabon, Nigeria, and Republic of Congo amongst others), accounts for about 15 percent of the world's population, it consumes only 3 percent of global energy (US EIA, 2017). Thus, as empirical studies indicate that per capita energy consumption is linked to socio-economic development in both developed and developing nations (Dritsak & Dritsaki, 2014; Siddique & Wazir, 2016; Wolde-Rufael, 2006), Africa's low energy consumption indicates a low level of industrialisation and socio-economic development (Kebede, et al., 2010).

Despite the heterogeneity of African countries, a few economic trends are similar, as shown in Table 1.1 below, which presents the macroeconomic development indicators of the AOECs at the end of 2016. Gabon's energy consumption is the lowest with 1.5Mtoe, following by the Republic of the Congo with 2.3Mtoe, whilst Egypt's energy consumption level is the highest with 90.4Mtoe (US EIA, 2017). Economic structure proxied by the share of industrial contributions to GDP shows that the Republic of the Congo has 53.5 percent, which is the highest in the group and may be due to the mining sector dominating its economy (Cho & Tien, 2014). This may also account for its trade openness, which is 159 percent, the highest in the bloc, and was followed by Gabon with 45.47 percent. Nigeria, one of the largest producers of crude oil in the region, has the lowest in the group with 22.3 percent, which may be due to both the size of its economy and mostly informal agriculture and service sectors dominating it (Okolo, 2004; Adenikinju & Falobi, 2006; Golub, 2012).

³ Barrels per day.

Table 1.1 Development Indicators at the end of 2016

Indicators	Algeria	Angola	Egypt	Gabon	Nigeria	Congo
Population ('million')	41.39	29.82	96.44	2.06	190.87	5.11
Population Growth Rate (percent)	2.1	3.4	2.1	2.5	2.6	2.5
Population Ranking in Africa	9 th	12 th	3 rd	44 th	1 st	36 th
GDP (Constant per capita @ 2010, '\$ billion)	4793.87	3409.93	2817.32	9203.99	2412.37	2651.7
GDP Ave Annual Growth (percent)(1980-2017)	2.8	3.9	5.0	2.3	3.2	3.8
Major Resource owned	Crude Oil	Crude Oil	Crude Oil	Crude Oil	Crude Oil	Crude Oil
Trade Openness (percent)	55.88	52.26	45.13	75.07	26.35	159.2
Economic Structure (proxied by percent share industrial sector to GDP)	37.21	42.17	33.75	45.47	22.32	53.52
Carbon Dioxide Emissions Per Capita 2014)	3.74	1.29	2.23	2.76	0.55	0.65
Unemployment (percent)	12	7.14	11.77	19.37	6.01	10.16
Energy Consumption (Mtoe)	51.80	7.7	90.42	1.5	28.20	2.29
Oil Reserves ('billion barrels)	12.2	8.27	4.4	2	37.06	2.98
Percent of World Oil Reserves by countries	0.74	0.5	0.27	0.12	2.25	0.18
Crude Oil Production ('million barrels)	1.31	1.67	0.63	0.20	1.95	0.24

Source: Author's computation (2022), using data from the World Bank's World Development Indicator and United States Energy Information Administration (US EIA).

Nigeria's population is the highest in the group with more than 190 million inhabitants, while Gabon has the smallest at 2.1 million. The population growth rate of Angola is the highest with 3.4 percent, followed by Nigeria at 2.6 percent, 2.1 percent for Algeria and 2.5 percent for Gabon and the Republic of the Congo. Of the oil reserves in Africa stands at 487.8tcf, which is about 7.1-7.5 percent of those globally (OPEC, 2018, 2019), Nigeria has the most at 2.25 percent, followed by Algeria with 0.74 percent, Angola with 0.5 percent and Egypt with 0.27 percent. In the table 1.1 above, the effect of carbon dioxide emissions is slight in Algeria at 3.74 percent, followed by Gabon with 2.76 percent and Nigeria with the lowest at 0.55 percent. Crude oil production in the table is 1.95, 1.67, 1.31 and 0.63 million bpd for Nigeria, Angola, Algeria and Egypt, respectively (US EIA, 2017).

1.3 Statement of the Problem

Low energy consumption is one of the main concerns of policymakers in AOECs owing to its negative effect on economic growth. Low energy consumption indicates a lack of industrialisation and therefore low capital formation, unemployment and poor standards of living (Karekezi & Kimani 2004; Mukhtarov et al., 2017). **The importance of high and appropriate energy consumption as a driver of economic development is emphasised in Goal 7 of the Sustainable Development Goals (SDGs). This goal is to ensure access to affordable, reliable, sustainable and modern energy for all. This is basically because high energy consumption is an evidence of the economic development, on one hand, while clean energy consumption drives energy sustainability and economic development, on the other hand. It is therefore important to understand how AOECs can improve their energy consumption while also making the appropriate energy transition as they aim to achieve their SDGs targets.**

In AOECs such as Nigeria, the average GDP growth rate is low, for instance, 4.5 percent between 2005 and 2012 (Abam et al., 2014), which is similar in Angola, Algeria, the Republic of Congo and Gabon with annual average growth rates of 3.7 percent, 2.9 percent, 3.6 percent and 3.3 percent, respectively, between 2008 and 2017 (see World Bank, 2016). These rates, according to Tamba (2017), are below the minimum 6 percent fixed by the Poverty Reduction Strategy Document for poor economies to achieve the Millennium Development Goals (MDGs). The per capita energy consumption is also low in these countries with Angola at 0.28Mtoe, the Republic of the Congo at 0.42, Gabon at 0.80 and finally Nigeria at 0.15 (US EIA and WDI, 2016). Apart from Gabon, Wandji (2013) asserts that these consumptions are too low compared with the African average of 0.48mtoe per capita. Within this group of countries, none is close to the world average of 1.25mtoe per capita.

In addition, Nigeria's share of energy consumption pattern in 2011 shows that biomass and waste accounted for about 82 percent of the total energy consumed. Moreover, the country's electrification rate is low with

only 18 percent of the population having electricity in 2011 and 79 million people having no access (Abam et al., 2014). This raises a pertinent question: why these net oil exporters are low energy consumers? In Gabon, biomass was the predominant energy source, constituting about 80 percent of the domestic sector energy consumption, rural electrification stands at 44.9 percent and 98.1 percent of urban inhabitants have electricity (US EIA, 2017). However, the country is not developing economically. This raises another question: why is Gabon not experiencing economic growth despite its high energy consumption? These questions indicate that the energy-growth nexus needs exploration.

The governments of AOECs attempt to reform their energy sectors to improve energy consumption by, for example, privatizing and commercialising them through the introduction of independent power producers (IPPs) and amending of the law guiding the power sector (Wamukonya, 2005). For instance, in Nigeria, in July 1988, the privatisation and commercialisation of electricity provision were introduced, which was a strategy adopted by Angola, Gabon and other countries to ensure an uninterrupted power supply (Solarin & Shahbaz, 2013). Other reforms were introduced by AOECs governments to complement those of the power sector, including increased water levels, appropriation of funds, the protection of energy facilities and capital investment in coal production (Clark et al., 2004; Karekezi & Kimani, 2002; Ministry of Planning & Territorial Development, 2012). However, these countries continue to have low rate of energy consumption, which indicates that energy policies need have been inappropriate (Wamukonya, 2005; Solarin & Shahbaz, 2013).

AOECs like many other countries in the world are vulnerable to climate change (Kebede *et al.*, 2010). This is a result of the adverse effect of fossil fuel which is a major source of energy to these countries (Stern, 2006; IPCC, 2007; Alkathlan & Javid, 2013). Nowadays, various organizations advocate the use of clean and renewable energy. However, the technology needed for this type of energy in African in general and in the AOECs in particular is costly. These countries face a dilemma. Indeed, a reduction of fossil fuel consumption due to the environmental issues may have a detrimental effect on their economies. It becomes essential to ascertain the relationship between energy consumption and economic growth as well as the direction of the causality for policy purposes. Determining the direction provides a better understanding of how energy conservation policies should be undertaken. For instance, if energy consumption causes economic growth, then energy reduction policies could hinder the economy. If there is no causality, then these polices can be undertaken without jeopardizing growth (see Masih & Masih, 1997).

This study is, therefore, different from previous studies in a number of ways. Firstly, this study uses a modelling estimator that consider time dynamic and heterogeneity of different countries to explore the determinants of energy consumption among these net oil exporters. This is unique because it is capable of

revealing how the structures of these economies explain the paradox of low growth and energy consumption of net oil exporters. Secondly, the study investigates the causality between energy consumption and economic growth in order to establish how energy consumption drives economic growth in a nonlinear framework. Thirdly, the study explores the effect of oil price shocks on both energy consumption and economic growth among these countries using Bayesian modelling. This is unique in the sense that, it helps to isolate how these countries react to oil price shocks. **These three approaches make this study a novelty by improving our understanding of why net oil exporters exhibit both low energy consumption and low growth rates.**

Factors that affect energy consumption in AOECs differ from those in other countries, as they are producers and exporters of energy resources (Bhattacharyya, 2011). According to Olumuyiwa (2008), these factors have implications for the relationship between economic growth and energy consumption because they are energy consumption shift drivers and that their identifications can affect both the utilisation and maximisation of energy resources for economic growth (IEA, 2016).

In addition, the literature indicates that almost all the AOECs' energy resources are non-renewable, fossil fuels with less than 10 percent being renewable, which makes these economies vulnerable to incessant, unpredictable and fluctuating oil prices and the resultant effect on economic growth and energy consumption (Kebede *et al.*, 2010; Mehrara & Mohaghegh, 2011; Perry and Olivera, 2009; Eregha & Mesagan 2017). In light of the literature claim that energy consumption positively affects economic growth, a sudden upsurge in the oil price (oil price shock) would reduce domestic energy consumption in AOECs but increase foreign exchange earnings, which would improve economic growth. Moreover, these countries could invest the revenue due to increased oil prices in strategies to improve domestic energy consumption. However, a sudden decrease in oil price would tend to increase domestic energy consumption but reduce foreign exchange earnings in AOECs, which would hinder economic growth (Eregha & Mesagan 2017). However, improved domestic energy consumption might promote domestic output and thus, offset the downturn in economic growth. Nevertheless, to discover the feasibility of this scenario, an investigation into the energy-growth nexus in AOECs needs to be conducted, which would provide answers to the research questions and achieve the research aim and objectives listed below.

1.4 Research Questions

- i. What are the factors influencing energy consumption in African oil-exporting countries?
- ii. What is the causal relationship between energy consumption and economic growth in African oil-exporting countries?

- iii. What are the effects of oil price shocks on energy consumption and economic growth in African oil-exporting countries?

1.5 Aim and Objectives of the Study

To achieve the research aim of understanding the relationship between energy consumption and economic growth in AOECs, the following specific objectives need to be realised:

- i. Identify the factors influencing energy consumption in African oil-exporting countries.
- ii. Examine the causal relationship between energy consumption and economic growth in African oil-exporting countries.
- iii. Analyse the effects of oil price shocks on energy consumption and economic growth in African oil-exporting countries.

1.6 Justification for the Study

Energy consumption not only facilitates lighting and household tasks such as **cooking, but also sustains** the economic growth of high-income and industrialised countries. These countries are now pioneering the use of renewable energy such as solar power to offset the destruction of the planet due to fuel emission. Legislation introduced in 2000 and updated in 2014 maintains this shift in energy production in developed countries, which has not hindered their industrial activities and economic development (Oh & Lee, 2004; Lee & Chang, 2008; Stern & Kander, 2012).

African countries especially AOECs are aware of the connection between energy consumption, industrialisation and economic development, on the one hand, and how fossil fuel which they use and export, cause CO₂ emissions which not only destroys the atmosphere but also causes environmental degradation, on the other hand (Kebede et al., 2010; US EIA, 2018; Rennings et al., 2012). However, despite the policies formulated by the governments of AOECs, in particular, those addressing the production and use of fossil fuels, crude oil remains the principal source of revenue accounting for 86 percent of the income of these economies, which indicates the need for economic diversification (Wamukonya, 2005; Dogan, 2016).

The empirical findings of the study reinforce the urgent need by the governments of AOECs to diversify their economies and formulate an energy policy that will reduce non-renewable energy consumption and increase energy consumption overall for economic growth. However, confirmation is needed of the link between energy consumption and economic growth as well as the causal direction of the relationship, which would not only enrich the existing literature on the energy-growth nexus but also inspire future research as to what drives demand for energy in a developing economy.

1.7 Contributions to Knowledge

The study aims to contribute to knowledge in several insightful ways. Firstly, the study looks at a panel of African economies that are net oil exporter. These countries should, theoretically, have high energy consumption. However, this is not the case. The study therefore starts by examining the determinants of energy consumption in a panel of AOEC's. The study uses estimators that are robust to cross-sectional dependence and small sample size. The former occurs, amongst others, when a set of countries have common characteristics. The study also opens new space for further research on what drives demand for energy in a developing economy. Secondly, the relationship between variables may vary over time. Variables may have regime shifts as policy changes and past events reoccur. The study takes this into account by modelling the non-linearities that may exist between energy consumption and economic growth. This is done using the PSTRVEC. The literature on these countries has not considered non-linearities. Thirdly, most of studies earlier carried out on the relationship between energy consumption and economic growth in AOECs are country specific, for example Eddrief-Cherfi and Kourbali (2012) in Algeria, Mustapha and Fagge (2015) in Nigeria whose findings may not be enough for generalization. Similarly, related studies on group of selected countries like, Akinlo (2008) in sub-Saharan, Mehrara (2007) in eleven oil-exporting countries Africa, Raheem and Yusuf (2015) in fifteen selected African economies and Eggoh et al. (2011) in twenty-one African countries, amongst others, might not be sufficient to make general policy recommendations, specifically, when compared to groups of countries like AOECs, that are net oil-exporting countries. Fourthly, the environmental consequences of AOECs reliance on fossil fuels as a main source of energy, require alternative sources. Findings from the study, especially on the granger causality, will provide empirical support for policymaking in that direction by suggesting how to give priorities to the usage of clean and efficient energy and ensuring environmental sustainability. Lastly, to the best of the author's knowledge, this is the first study to consider AOECs in a Bayesian framework to understand the impact of oil price shocks on energy consumption.

1.8 Scope of the Study and Justification

As will be demonstrated later in this thesis, the study spans the period 1980 to 2018, a choice informed by the availability of data and the several policy adjustments associated with energy sector reforms during that period (see, for instance, Wamukonya, 2005; Solarin & Shahbaz, 2013). The countries considered are: Algeria, Angola, the Republic of the Congo, Egypt, Gabon, and Nigeria, Libya is left out due to the paucity of data. The choice of countries is based on the OPEC information classification index of 2017, which structures the oil-exporting countries in terms of production capacity.

The six countries listed above form the bulk of oil production in the African continent (see, OPEC, 2017). According to OPEC (2017), based on their volumes, all the AOECs are ranked as follows: Nigeria (1st),

Algeria (2nd), Egypt (4th), Libya (5th), Equatorial Guinea (6th), Sudan and South Sudan (7th), the Republic of the Congo (8th), Gabon (9th), South Africa (10th), Chad (11th), Cameroon (12th), Ghana (13th), Tunisia (14th), Cote d' Ivoire (15th), the Democratic Republic of the Congo (16th) and Niger (17th).

The entire production of these countries constitutes nearly 90 percent of proven oil reserves and about 70 percent of oil production in Africa (OPEC, 2018b). Moreover, out of the world's proven oil reserves estimated to be more than 1.7 billion barrels, 73 percent is controlled by OPEC while approximately 10percent is controlled by the six top oil-exporting countries in Africa, which are Algeria, Angola, Egypt, Gabon, Libya and Nigeria (OPEC, 2018b). Furthermore, these countries are the **largest producers and consumers of energy among their contemporaries in AOECs** (see, US EIA, 2017).

Given this background, the conclusions arising from the current study might be generalised to all the AOECs. Therefore, the pooling indicated above is based on OPEC's classification of AOECs into three segments based on their oil export capacities and proven oil reserves as shown in Table 1.2 below. The first segment encompasses countries the production of which is more than 1,000,000 bpd. The second segment comprises countries with an oil production greater than 500,00 bpd but less than 1,000,000 bpd in the first segment. The last segment is countries with an oil production of less than 500,000 bpd. Therefore, for the study, we take two countries from each of the segments to represent the AOECs. As provided earlier, the overall total exports of these countries are more than 90 percent and 70 percent of oil reserves and production, respectively, in Africa, which stands the chance of providing unbiased, empirical representations of the AOECs. We choose- Nigeria, Angola, and Algeria for the study from the first segment because their production capacities exceed 1,000,000 bpd, and there is data available for the countries. Similarly, the second segment contains Egypt and Libya. Egypt is in the study because the country has a complete dataset. The study excludes Libya because of the non-availability of data required for the study, and the country is in the second segment due to a decline in its production after being in the first segment as a result of a national dispute in Libya in 2013. The third segment, which is the last, comprises four countries (the Republic of the Congo, Gabon, Equatorial Guinea and Sudan), although only two are included in the study due to the availability of data and the order of their export capacities: the Republic of the Congo (244 bpd) and Gabon (199 bpd).

Table 1.2. Classification of AOECs

Segments/Measurement	Countries	Oil Export ('000 bpd)	Proven Oil Reserve (billion)
1 st (Exports >1m bpd)	Nigeria	1,945	37.06
	Angola	1,666	8.27
	Algeria	1,305	12.20
2 nd 500,000 ≤ Exports (bpd) ≤ 1 m	Libya	897	48.36
	Egypt	630	4.40
3 rd Exports < 500,000 bpd	Republic of the Congo	244	2.98
	Gabon	199	2.00
	Equatorial Guinea	188	1.10
	Sudan	102	5.00

Source: Author's computation (2022), using data source from the WDI.

As shown in Table 1.3 above, the composition of energy production and energy consumption in the AOECs indicates that the countries selected for the study produce energy for both local and national consumption. While Algeria recorded the highest production with 169.3 Mtoe, which is followed by Nigeria with 168.9, Angola with 98.5, Egypt with 95.1, the Republic of the Congo with 16.3 and Gabon with 12.8 Mtoe. As indicated in the table, the energy consumption of these countries is in varying degrees.

Table 1.3. Composition of Energy Production and Energy Consumption for AOECs (2017)

Country	Energy Production (Mtoe)	Energy Consumption (Mtoe)
Nigeria	168.9	28.2
Angola	98.5	7.7
Algeria	169.3	51.8
Libya	65.6	18.4
Egypt	95.1	90.4
Republic of the Congo	16.3	2.3
Gabon	12.8	1.5
Equatorial Guinea	20.8	1.67
Sudan	13.2	7.3

Source: Author's computation (2022), using data source from the US EIA(2018).

1.9 Structure of the Thesis

The thesis is structured into six chapters. The first chapter introduces the study, presenting the background and the statement of the problem, which followed by the research aim, objectives and questions. The justification, contribution and scope of the study are explained, which is followed by the outline of the chapters of the thesis. The second chapter presents the empirical and theoretical literature on energy consumption and economic growth in each of the AOECs. The third chapter (paper 1) presents the identification of the determinants of energy consumption in AOECs using cross-sectional autoregressive distributed lag (CS-ARDL) and cross-sectional distributed lag (CS-DL) estimating techniques. The fourth

chapter (paper 2) is on the Granger causality between energy consumption and economic growth in AOECs using panel smooth transition vector error correction (PSTRVEC) model. The fifth chapter (paper 3) presents the study of the impact of oil price shocks on energy consumption and economic growth in AOECs using Bayesian structure vector autoregressive (BSVAR) model. The sixth chapter summarises and concludes the empirical findings of the work, makes policy recommendations and identifies areas for future research.

CHAPTER 2

AN OVERVIEW OF ENERGY CONSUMPTION AND ECONOMIC GROWTH IN AFRICAN OIL EXPORTING COUNTRIES

2.1. Introduction

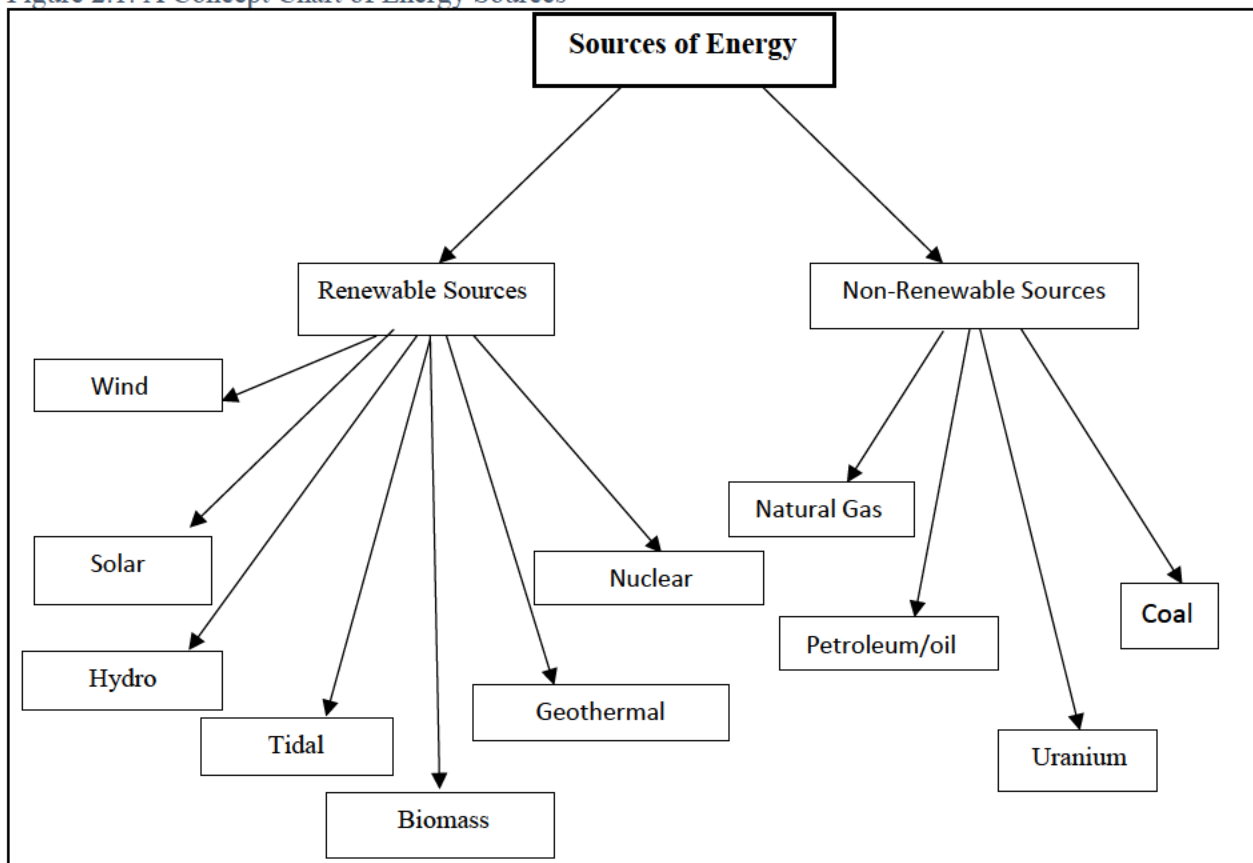
This chapter presents an overview of energy consumption and economic growth in AOECs. It begins by clarifying the concepts in the study, which involves describing renewable and non-renewable energy in detail. The chapter then presents an explanation of energy consumption and the energy consumption mix in AOECs. Economic growth is explained thereafter, which is followed by an overview of the AOECs. The chapter ends with an explanation of the prospects and challenges in the oil industry/ sector.

2.2 Clarification of Concepts

2.2.1 Sources of Energy in AOECs

Africa including AOECs is endowed unevenly with the sources shown in Figure 2.1 below. Energy used for domestic and industrial purposes can be classified into renewable energy (solar, hydro, tidal, biomass, geothermal and nuclear power) and non-renewable energy (natural gas, petroleum, coal and uranium) (Ferreira, 2013).

Figure 2.1: A Concept Chart of Energy Sources



2.2.2 Renewable Energy

Renewable of energy sources, which can be recycled or replenished because they are obtained directly from nature, play a vital role in sustainable economic development (Oyedepo, 2012). In addition, the development and appropriate use of renewable energy address the need to reduce the consumption of fossil fuels, which is linked to global climate change. In AOECs, environmental concerns, the instability of oil prices and, the over-reliance on crude oil exports for foreign exchange earnings is currently driving a shift to green energy, which reduces the detrimental effects of carbon emissions, generates enough electricity for the teeming population and promotes sustainable development (Apergis & Payne, 2010; Aguirre & Ibikunle, 2014).

2.2.2.1 Wind Energy

Wind energy entails moving and stirring air particles to turn large turbines, which are connected to a generator that produces electricity. For this to be achievable, a strong, steady wind is needed to generate a sufficient uninterrupted amount of electricity (Mpholo et al., 2012). Besides being used for onsite electricity generation, wind turbine systems in the form of big wind farms are used for a grid-connected supply of electricity, particularly in developed economies, such as China, Europe and the United States (US) (Suberu et al., 2013), to put a stop to CO₂ emissions from fossil fuel power generation. Moreover, its use has increased globally and quickly in part because of its cost-effectiveness (Saidur et al., 2010). According to the 2019 report of the International Renewable Energy Agency (IRENA), global on and offshore wind energy generation moved from 7.5 gigawatts in 1997 to 564 gigawatts in 2018. Moreover, the production of wind electricity doubled between 2009 and 2013 and in 2016, contributed around 16 percent to renewable energy (IRENA, 2019).

The deployment of this source of energy in AOECs today is , however, not considered satisfactory when compared to hydropower, even with the declining cost of electricity from onshore wind technologies. The International Energy Agency (IEA) reports that the wind potential in SSA is approximated at about 1300GW, although wind that is strong enough to drive turbines only in a few areas in Africa, notably parts of West and Central Africa, eastern Kenya and parts of Southern Africa. Sudan, Libya and Egypt are amongst the African countries with the highest onshore wind potential, while offshore wind energy potential is around the coast of Angola, which is one of the net oil-exporting countries (IEA, 2014b).

2.2.2.2 Hydropower

Hydropower is generated by downward pouring water, which drives turbines in a power station. The stations must be at dams or waterfalls because they require a heavy flow of water to harness the energy.

Unlike coal power stations, the water does not need to be heated and can be used again. Hydropower is a commonly used renewable source in African, although according to Eberhard et al. (2011), more than 900TWh, which is approximately 220GW, of the installed capacity of viable hydropower potential in Africa is left untapped in Angola, Gabon and Nigeria, for example. Moreover, the Intergovernmental Panel on Climate Change (IPCC) estimates the technical hydropower potential at 1174 TWh yearly or relatively 283 GW of installed volume. The IPPC maintains that this amount of electricity is three times higher than the current electricity consumption in SSA including oil-exporting countries. Despite the enormous exploitable capacity of this source of energy, its share of entire power generation is quite low, accounting approximately for only 18 percent of the whole energy generation in Africa (Kahsai et al., 2012). Brazilian et al. (2014), affirm that up to 10 percent of the potential has not been exploited so far in Africa.

2.2.2.3 Solar Energy

To produce solar power, panels are used to absorb the radiant energy from the sun, which is transformed into stored potential energy. According to IEA (2014b), Africa is rich in solar energy potential with the greater part of the continent benefitting from an average of more than 320 days yearly of bright sunlight and radiance levels of estimated 2000kwh per square metre per year. Nevertheless, solar technology has not played an active part in the energy sector in Africa and has been to lighting and operating simple appliances in rural and urban communities. Solar-powered cookers, solar water heaters, building integrated photovoltaics and solar photovoltaic power systems are restricted to a few economies in Africa (Silva et al., 2017). This type of energy source is common in nations like South Africa and Mauritius where there is a growing propensity to accept evolving renewable energy technology in line with the gradual global shift to renewable energy consumption (IEA, 2014b).

2.2.2.4 Nuclear Energy

Mostly considered a non-renewable energy source, nuclear energy is produced through nuclear fission whereby, the nucleus of an atom splits. This takes place in power plants that can control nuclear fission to produce electricity. The material most frequently used in nuclear power plants is the element called uranium, which is found in rocks in many countries of the world. Nuclear power plants do not pollute the air and they are popular for generating electricity all over the world (IEA, 2014b). Nuclear energy is a clean and cost-effective energy source with socio-economic benefits, which promote economic growth. According to Ahmed et al., (2014), nuclear energy has tremendous potential in Africa owing to its energy dense fuel and use in purification and mist generation. South Africa presently has the continent's only commercial nuclear power in Africa generating 1,940 MW, while 100MW is under construction in South Sudan (IAEA, 2011). Countries, such as Ghana, Kenya, Egypt, Morocco, Niger and Nigeria, are

contemplating implementing nuclear power and have consulted IAEA to evaluate the feasibility of embarking on a nuclear programme. Algeria, Tunisia, Uganda and Zambia are also assessing the viability of nuclear energy.

2.2.2.5 Tidal Energy

This energy source involves large subsurface turbines placed in areas with high tidal movement to capture the kinetic movement of the receding and rushing of ocean tides to generate electricity (Balaji, 2014). Although it has potential, globally, tidal energy is mainly unexplored and at its early stage of development. According to Kempener and Neumann's (2014) study, East Africa has resources for tidal power generation.

2.2.2.6 Geothermal Energy

Geothermal energy is heat obtained within the earth's sub-surface from where water or vapor conveys energy to the surface of the earth. Geothermal energy can be used for heating or cooling and connected to generate clean electricity, depending on its features. However, for generating electricity, high or medium temperature resources are required. Geothermal power station situated near tectonically active regions generate electricity in nations, such as New Zealand, Iceland, Kenya and El Salvador and account for more than 90 percent of heating demand in Iceland (IRENA, 2019).

Despite the presence of geothermal energy resources in Africa, especially in Kenya's Great Rift Valley, with an estimated potential of 9000 MW, it contributes little to energy production in the region (Karekezi & Ranja, 1997; Kahsai et al., 2012). The Great Rift Valley has the potential for geothermal energy of approximately 10 GW to 15 GW, which is more than East Africa's entire current power generation capacity, which is concentrated in Ethiopia and Kenya.

2.2.2.7 Biomass Energy

Biomass energy relies on biomass feedstocks comprising wood and crops such as corn, which are processed and burned to create electricity (Naik, 2010). However, the production of biomass energy requires sustainable quantities of solid waste, forest, agricultural and residual biomass for it to be considered renewable. It can be perceived as non-renewable energy if people failed to re-plant biomass feedstocks as quickly as they are used. As explained by Jumbe et al. (2009), between 80 percent and 90 percent of the people in Africa depend solely on biomass fuels, which contributes more than 75 percent of household energy consumption. Biomass for electricity generation has not been widely tapped in most regions in Africa, except for South Africa and Mauritius, where both countries used sugarcane in combustion power plants. According to Suberu et al. (2013), biomass energy production in Africa including oil-exporting

countries has traditionally been dominated by the direct burning of biomass for heat production, notably for cooking and heating purposes.

Another promising clean source of energy for household cooking and small power generation in the rural community is biogas. This source of energy is obtainable from varieties of decomposable waste raw materials. Used solely for cooking in less developed nations, biomass is used for both cooking and power generation in developed countries. Meanwhile, ongoing renewable energy programmes in SSA are vigorously promoting biogas production for cooking. Various countries in SSA have tested bioelectricity conversion technologies like gasification, on a very small scale (see Suberu et al., 2013).

2.2.3 Non-renewable sources

Non-renewable sources of energy, which cannot be re-used or replenished speedily enough to keep up with their use, account for 84 percent of global energy consumption. They include oil, coal, natural gas and uranium used for nuclear energy (US EIA, 2015). Energy from these sources of energy is produced from partly decayed plant and animal substances concealed in the earth's crust, which are later transformed into carbon-rich material that are burned to create energy. Carbon is the main element in fossil fuels, which take millions of years to form. The benefit of fossil fuels is that it is relatively inexpensive to generate energy from them.

2.2.3.1 Petroleum/oil

Also referred to as oil or crude oil, petroleum is, formed in underground rock, which is rich in organic materials. When the oil is formed, it moves upward into permeable reservoir rock like limestone, where it is covered by water-resistant rock. Therefore, to remove oil from the rock, boreholes are drilled into the oil reservoirs. In 2017, the world attained a new oil production record of 96.6 million barrels per day (which was the uninterrupted 8th year of improved oil production) with the US becoming the major oil producer, producing 13 million barrels per day for the first time. Saudi Arabia and Russia recorded the second and third positions in the same year in a list of major oil-producing countries with 12 and 11.3 million barrels per day, respectively (British Petroleum, 2017).

More than 50 percent of global oil is concentrated in the Middle East, followed by the US, which has considerable extra reserves. Virtually unknown oil reserves are now being exploited at a rate that surpasses the rate of finding them and if the rate of consumption continues to rise, without the discovery of new sources, the supply of oil may be soon depleted. Notwithstanding its inadequate supply worldwide, oil is cheap, compared to other sources, and preferred to other sources such as coal, with corresponding kilowatts

of energy production. In addition, oil burns cleaner than does coal, with a 50 percent less sulphur dioxide production (US EPA. 2011; Salim et al., 2014)

2.2.3.2 Coal

A black or brownish rock, coal can be burned in fires for heat or in a coal stove for cooking. It can also be used by power stations to generate electricity. Coal is an abundant source of energy. According to the IEA (2017), coal provides one-third of the world's energy supply, constituting more than 40 percent of electricity generation, as well as playing a very significant industrial role. Although, its quality differs from one region to another, as noted by US EIA (2010), countries such as Australia, Canada and the US have a high quality of cooking coal. However, the major benefit of using coal is for power generation, which is inexpensive and contributes about 50 percent of electricity generation in the US. Additionally, it is also used for cooking and heating in the less developed countries of Africa including the AOECs and the rural communities of developed nations (US EIA, 2019).

2.2.3.3 Natural gas

Natural gas is found in deep underground rock formations and mostly with other fossil fuels, such as coal and oil. Made up of methane, which is a gas that burns easily and releases a lot of energy when it is burnt, natural gas is a clean energy source, which is easy and cheap to transport when pipelines are laid. In most developed nations, this type of energy source is used for heating, cooking and producing electricity. The overall estimate of natural gas reserves as of 2017 stands at 7490 trillion cubic feet of gas, with Russia topping the list of countries with the largest proven reserves followed by the Middle East and Eastern Europe (US EIA, 2017). Although the use of natural gas is a fraction of global fossil fuel, consumption, it grew by about 143 trillion cubic feet from 2006 to 2017. This shows that with the speed of world natural gas consumption, the natural resources may last for only another 50 to 55 years (US EIA, 2017).

Natural gas is the preferred fuel in many regions of the world for power generation primarily because of its smaller carbon emission compared with coal and oil the use of which policy makers attempt to minimize because of their harmful greenhouse gas emissions. Additionally, natural gas serves as an important alternative source of fuel for turbines that power generator owing to the low investment involved and favourable thermal productivity (US EIA, 2017).

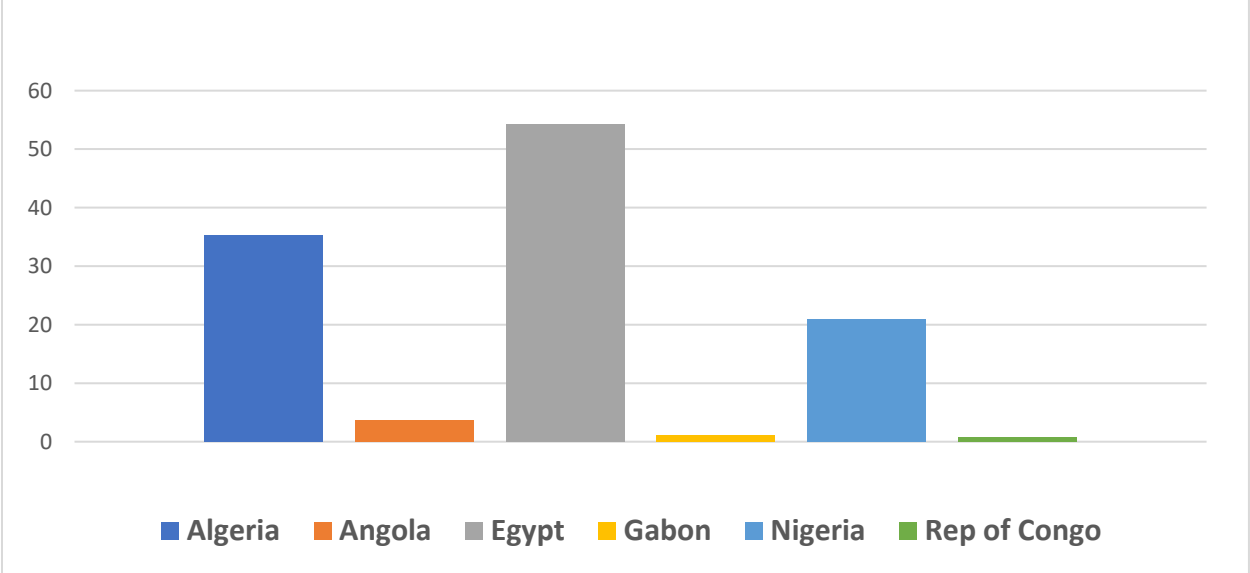
2.3 Energy Consumption

Energy consumption, which affects the transformation of an economy (Augutis et al., 2011) and sustainable economic development, depends on access to sustainable and environmentally friendly energy from diverse

sources. The standard of living of a given nation can be linked to per capita energy consumption (Esen & Bayrak, 2017) for the following: For instance, necessities, such as lighting, ironing, cooking and pumping water; manufacturing, mining, commerce, industry, essential health care services such as intensive care and refrigerating vaccines; education, for example, teaching with electronic equipment; communication systems involving television, radio and the internet and transportation system (Mohamed & Sami, 2017).

The demand for energy in Africa is greatest in North Africa, Nigeria and South Africa (US EIA, 2019). In 2018, energy demand in Africa, including oil-exporting countries was estimated at 830 Mtoe, of which (North Africa, Nigeria and South Africa) accounted for more than 60 percent despite having only 35 percent of the population (US EIA, 2019). However, in the AOECs under study (Algeria, Angola, Egypt, Gabon, Nigeria and the Republic of the Congo), the total primary energy consumption differs. For example, from 1980 to 2017, Egypt (96.4million people) recorded the highest with 54.2 Mtoe, while Algeria (41.4million people) and Nigeria (190.9 million people) recorded 35.3 and 20.9 Mtoe, respectively (see Figure 2.2 below). This contradicts claims that an economy with a large population consume more energy than those with a smaller population (see Adenikinju, 2008). The above statistics reveal that in AOECs, there is a weak correlation between energy consumption and population size. A plausible reason might be the inability of these countries to utilise the various energy resources at their disposal to produce energy for consumption. Figure 2.2 below presents the average primary energy consumption, which is the measure of the total energy demand of a country, in AOECs, Algeria, Angola, Egypt, Gabon, Nigeria and the Republic of the Congo between 1980 and 2017.

Figure 2.2: Average Primary Energy Consumption in African Oil Exporting Countries (1980-2017)



Source: Author’s computation (2022), using data sourced from the US EIA (2019b)

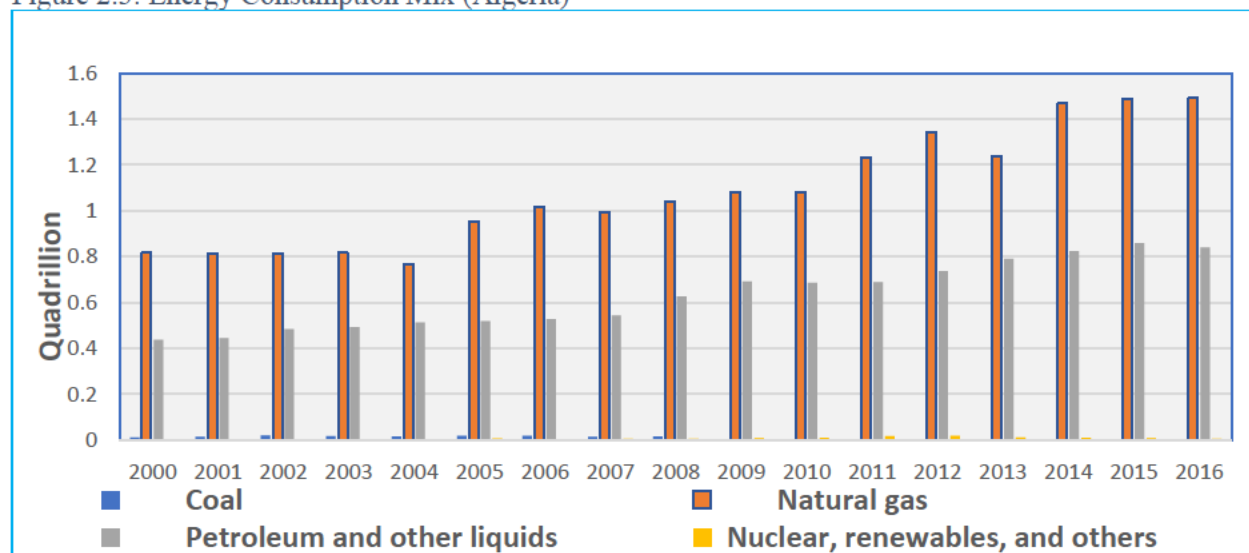
2.3.1 Energy consumption mix in selected African Oil Exporting Countries

The major energy source in Africa is fossil fuels, which contribute about 80 percent of the total energy produced. Globally, 65.8 percent of the total energy produced is from fossil fuels (US EIA, 2017). The global energy mix consists of coal, natural gas, petroleum and other liquids, nuclear power and various renewables and others. However, the energy mix and the consumption levels of the various types of energy vary in the AOECs.

2.3.1.1 Energy Consumption Mix in Algeria

Fossil fuels usage is relatively dominant in Algeria. The fossil fuels in this country comprise oil, coal and natural gas, which contribute about 63.6 billion kilowatt-hours to electricity generation, with wind providing 0.01, solar 0.3 and hydropower 0.2 billion (US EIA, 2017). Figure 2.3 below shows the energy mix in Algeria, with natural gas contributing a substantial amount, which is followed by petroleum and other liquids. The country is dependent on crude oil as the mainstay of the economy, which suggests that coal and renewable energy are not fully exploited. The total primary energy consumption has consistently been on the increase since 2005 with a slight fall in 2016. Figure 2.3 below presents the energy consumption mix in Algeria.

Figure 2.3: Energy Consumption Mix (Algeria)

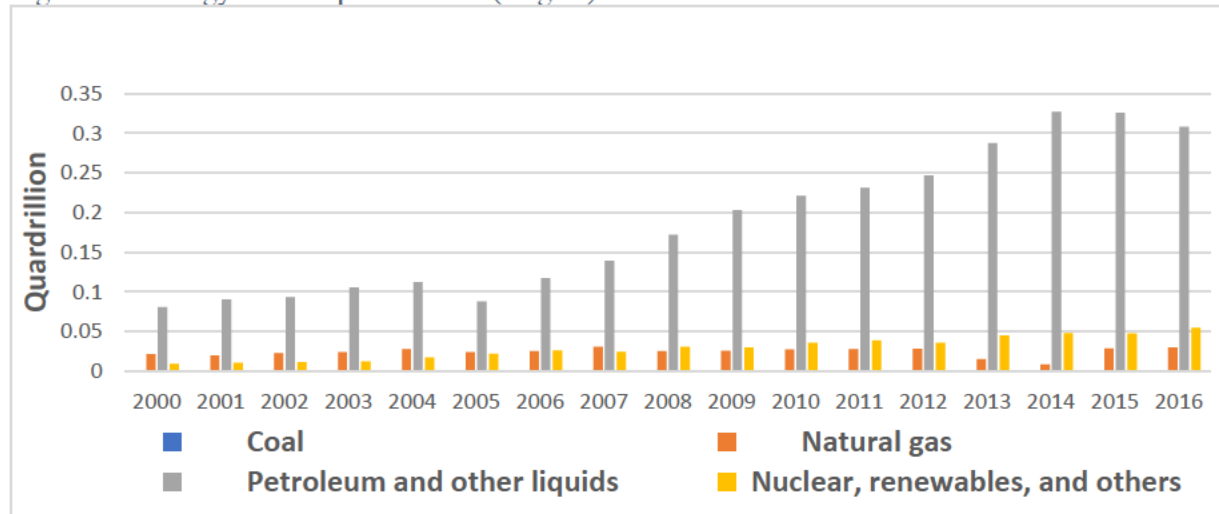


Source: Author's computation (2022), using data sourced from US EIA (2017)

2.3.1.2 Energy Consumption Mix in Angola

In Angola, fossil fuel energy provides 3.67 billion kilowatt-hours per year and solar 0.02 billion (US EIA, 2017). Figure 2.4 below shows the country's energy consumption mix, with petroleum and other liquids contributing the most, whilst natural gas and hydropower provide a minimal proportion of the energy consumed in the country. However, despite the vast potential of solar energy, renewable and nuclear energy are not used.

Figure 2.4: Energy Consumption Mix in (Angola)

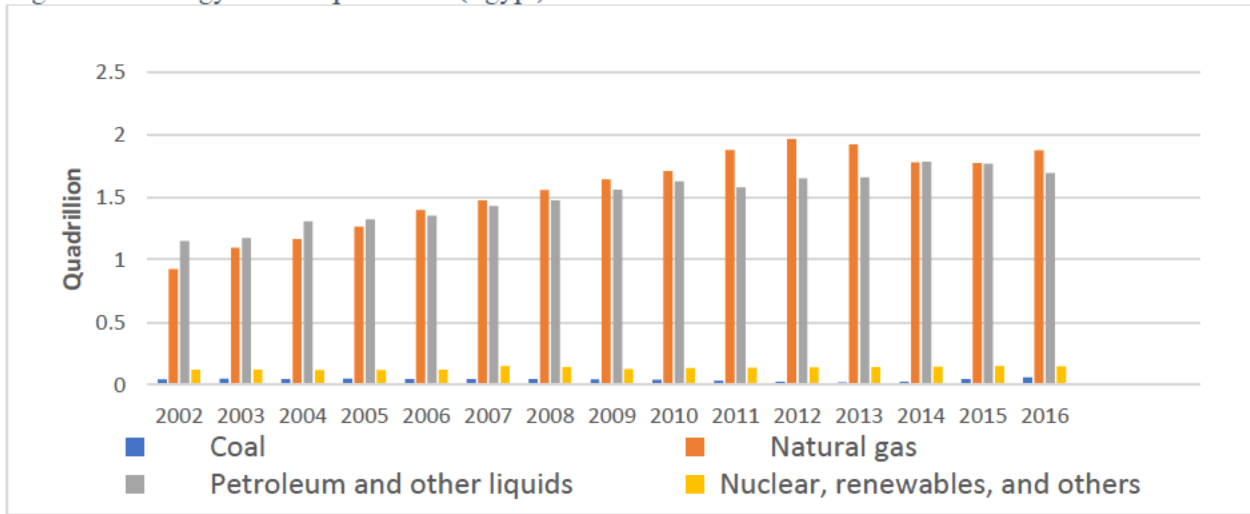


Source: Author's computation (2022), using data sourced from the US EIA (2017)

2.3.1.3 Energy Consumption Mix in Egypt

In Egypt, fossil fuels produce the most energy with 156.13 billion kilowatt-hours in a year, followed by hydropower at 13.26, wind at 1.99 and solar at 0.21 billion (US EIA, 2017). Figure 2.5 below shows that natural gas has dominated Egypt's energy consumption mix of Egypt since 2006, followed by petroleum and other liquids. The rapid growth in these two sources of energy could be attributed to increased industrial output, population growth and an increase in private and commercial vehicle sales in the country. Other sources of energy consumption, such as hydroelectric and renewable energy, also contribute to the generation of electricity in Egypt owing to series of gas supply shortages and inadequate generation and transmission capacity. However, the use of coal is minimal, a plausible reason for which could be the dominance of crude oil and natural gas, which covers more than 53 percent of primary energy consumption (US EIA, 2017).

Figure 2.5: Energy Consumption Mix (Egypt)

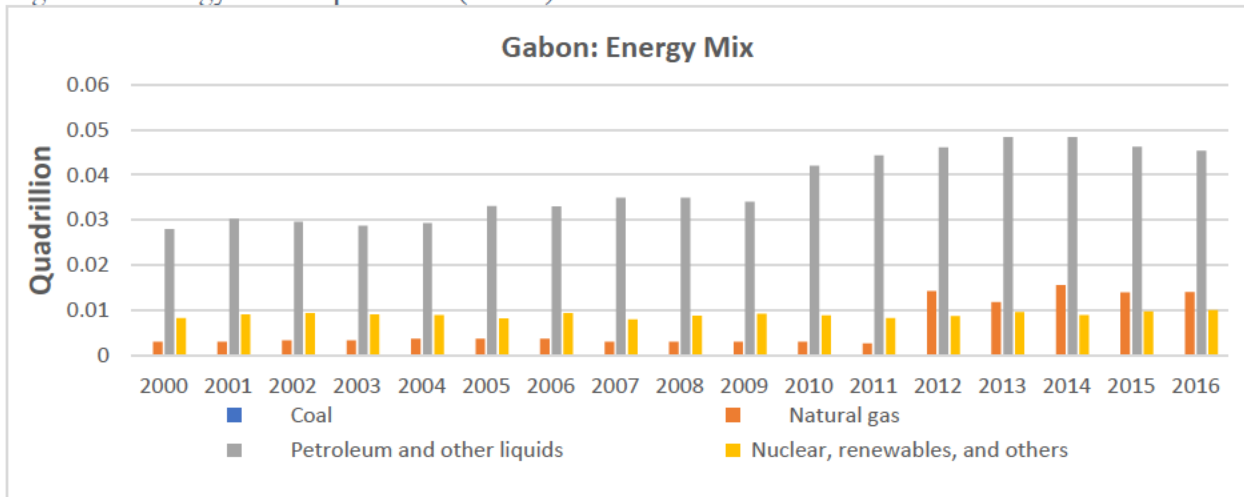


Source: Author’s computation (2022), using data sourced from the US EIA (2017)

2.3.1.4 Energy Consumption Mix in Gabon

US EIA (2017) records that in Gabon, petroleum and other liquids constitute the largest share of energy consumption with 1.18 billion kilowatt-hours per year, followed by hydropower with 0.89 billion. In Figure 2.6 below, natural gas has been a noticeable supplementary energy source since 2012, while coal is not being exploited, which may be because, Gabon relies on oil for both its export revenue and its domestic energy production (US EIA, 2017).

Figure 2.6: Energy Consumption Mix (Gabon)

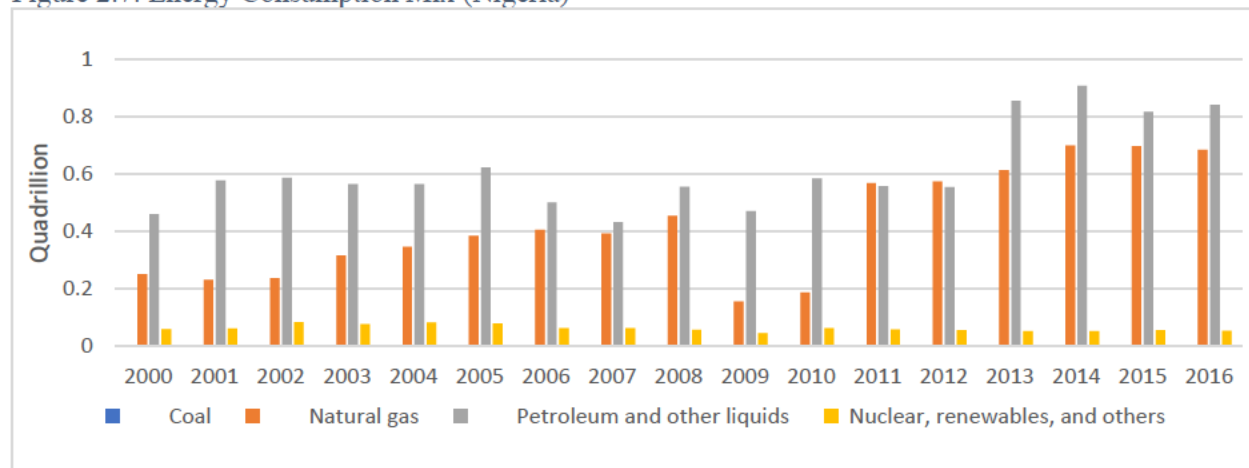


Source: Author’s computation (2022), using data sourced from the US EIA (2017)

2.3.1.5 Energy Consumption Mix in Nigeria

Nigeria is the most populated country in Africa and has the continent's biggest oil reserves. Expectedly, fossil fuel energy sources contribute a substantial quantity to its energy consumption at 24 billion kilowatt-hours per year, while hydropower and solar contribute 5.45 and 0.02 billion, respectively (US EIA, 2017). In addition, as shown in Figure 2.7 below, Nigeria's natural gas contributes enormously to the proportion of its energy consumption. Coal is not exploited in the country possibly because it has been substituted with gas as an energy source (see Abam et al., 2014; NBS, 2007)

Figure 2.7: Energy Consumption Mix (Nigeria)

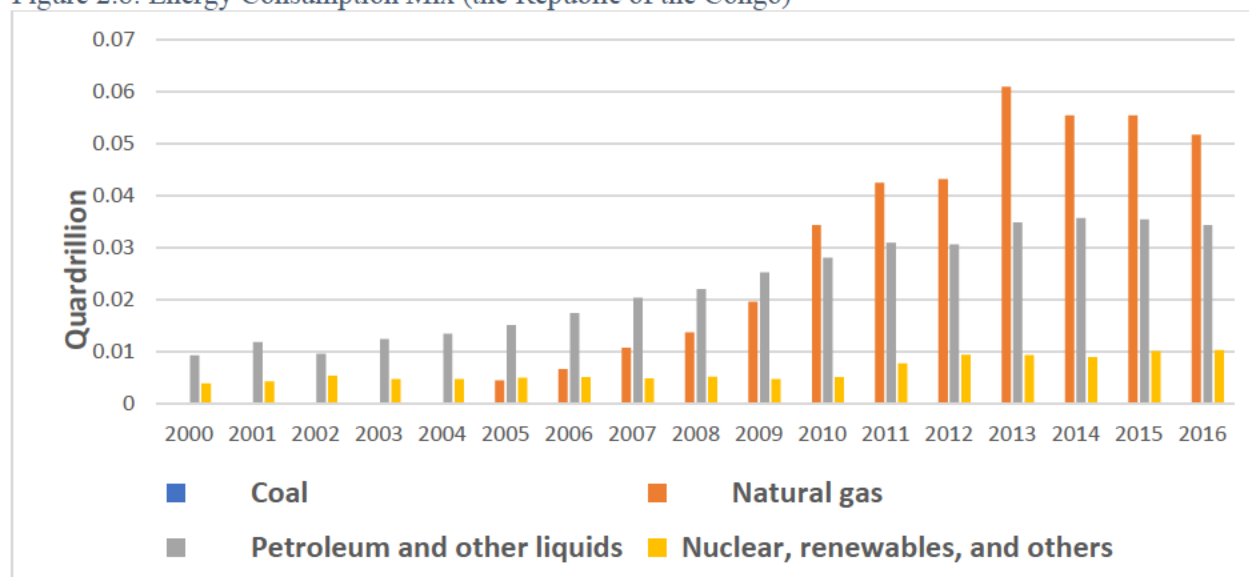


Source: Author's computation (2022), using data sourced from the US EIA (2017)

2.3.1.6 Energy Consumption Mix in the Republic of the Congo

In the Republic of the Congo, fossil fuel energy sources contribute largely to the generation of electricity with 1.35 billion kilowatt-hours per year, followed by hydropower with 1.06 billion (US EIA, 2017). Evidence from figure 2.8 below shows that, in the Republic of the Congo, petroleum and other liquids have been substantially used over the years, although the consumption of natural gas has increased since 2019. This suggests that the country is transiting gradually to gas because of its inherent advantages over liquid fuel. However, hydropower is mostly untapped, and coal is not exploited for electricity generation as in other AOECs.

Figure 2.8: Energy Consumption Mix (the Republic of the Congo)



Source: Author’s computation (2022), using data sourced from the US EIA (2017)

In summary, the available statistics show that energy from natural gas, petroleum and other liquid is mostly consumed by the countries under review, while coal is the least utilised. In addition, the consumption of this energy mix is consistently on the increase with a peak during the period 2011 to 2014, although the statistics reveal a general decrease in energy consumption in 2014, except for Algeria whose energy consumption was relatively stable from 2014 to 2016. The general fall might be due to the global oil price shock of 2014. Hence, the economic implication is that the over-reliance of these countries on fossil fuels as their main source of energy make them intermittently vulnerable to external shocks.

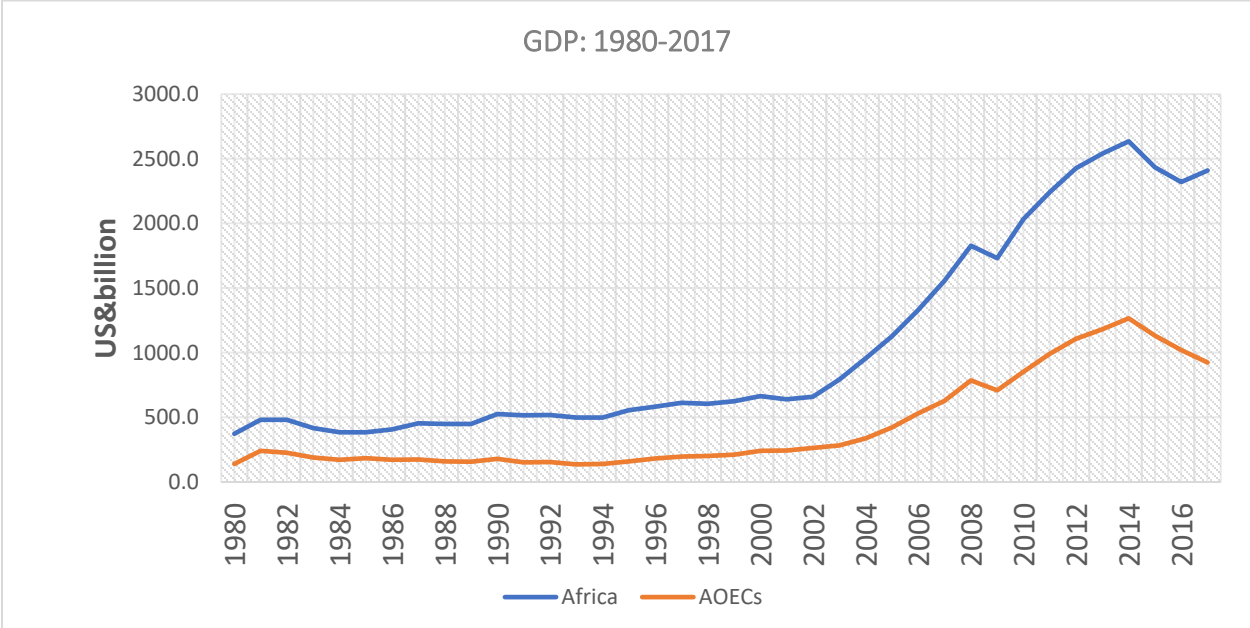
2.4 Economic Growth

Economic growth is the expansion of a country’s output of goods and services per member of the population over a specific period and is measured using indicators such as the gross domestic product (GDP), gross national income (GNI) and per capita income (PCI). GDP is calculated from a nation’s national accounts, which generate yearly data on revenue, expense and assets for each division of the economy. Economic growth, which is determined by an increase in capital, capital goods, human capital and technology, reduces poverty because it leads to more jobs and earnings (Boldeanu & Constantinescu, 2015).

Figure 2.9 below presents the trend of upward GDP growth in Africa and AOECs from 1980 to 2017. The figure shows a sharp growth rate since 2002 but a decline in 2008, due to the global financial crisis referred to as ‘The Great Recession’ and in 2014, due to the drop in oil prices owing to an excess of crude oil, which

was driven by the discovery of shale oil in North Dakota, the US and lower demand from China (Kilian, 2014).

Figure 2.9: Real GDP (1980-2017)

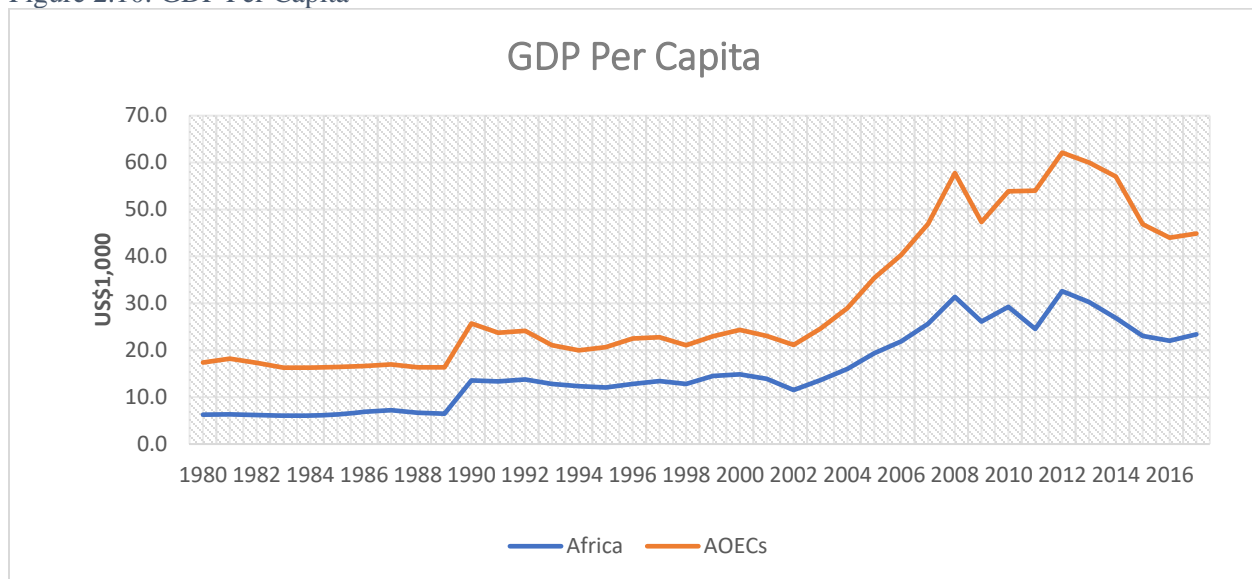


Source: Author’s computation (2022), using data sourced from the World Bank (2017)

GDP per capita, which is calculated by dividing the total GDP of a country by its population, is hypothetically the amount of money that each person receives, thereby indicating people’s standard of living and development in terms of infant mortality, life expectancy, political and civil rights and even environmental conditions, for example. Nevertheless, a nation with a high GDP but a large number of inhabitants will have a low GDP per capita, which implies an unfavorable standard of living. A high GDP per capita would indicate a country has an efficient economy, even if it had a large population (Boldeanu & Constantinescu, 2015).

Figure 2.10 below shows a parallel and weak trend of GDP per capita in Africa and AOECs from 1980 to 1988, which rises steadily during the period 1990 to 2008 before, a sharp decline, notably in 2008, due to the global recession. The figure shows an upward rise in Africa in 2011, but a decline in AOECs. In addition, the figure shows a decline in Africa and AOECs from 2012 to 2014 due to the fall in oil prices (Kilian, 2014).

Figure 2.10: GDP Per Capita



Source: Author's computation (2022), using data sourced from the World Bank (2017)

2.5 An Overview of African Oil Exporting Countries

In Chapter 3, we examine the correlation between energy consumption and economic growth and how structural events emanating from external shocks and policy reforms, for example, affect these two fundamentals in Algeria, Angola, Egypt, Gabon, Nigeria, and the Republic of the Congo. However, to provide empirical ground for the assessment, this section describes the historical, economic and macroeconomic characteristics of the energy consumption of these countries and its effect on economic growth.

2.5.1 Algeria

Algeria is one of Africa's largest producers of oil with a proven reserve of 12.2 billion barrels. The economy has always been driven by the oil sector, and hydrocarbons (oil and gas) account for 95 percent of total exports and contribute up to 30 percent of GDP (US EIA, 2018). Other sectors, such as market service, construction and public works, agriculture and the non-oil manufacturing industry, contribute 25 percent, 10.6 percent, 10.6 percent and 5 percent of GDP, respectively. The construction and public works sector is primarily sustained by public investment programmes funded by the state, while the size of market services is basically due to the increase in imports (consumer goods) that produce few skilled works. The agricultural sector is largely determined by climatic conditions. The non-oil manufacturing industry ranks the least among the productive sectors (US EIA, 2018).

Therefore, the structure of the economy emphasises the necessity to hasten economic diversification. Additionally, the size of GDP is also affected by changes in oil price. For example, the country's GDP dropped from \$207.9 billion in 2012 to \$166.84 billion in 2015 because of the fall in global oil prices during this period. Nevertheless, as the world's sixth-largest gas exporter in the past few years, it has produced foreign reserves close to \$200 billion. Besides, its status as a major debtor is well-known, following a debt rate of 38.26 percent of GDP in 2018, which continues to increase (US EIA, 2018).

Table 2.1 below shows that, Algeria's, economic performance indicators correlate with fluctuations in oil price like most oil-dependent economies. In the table, the average real GDP growth rate fall sharply from 4.8 percent to 0.3 percent between 1981/85 and 1991/95 owing to the decrease in oil price during these periods. The table also shows a decline in growth performance from 3.3 percent in 2011/2015 to 2.3 percent in 2016/2017 during periods of a decrease in oil prices. This is subsequently reflected in the drop in the per capita growth rate within these periods from 1.4 percent in 2011/2015 to -5.4 percent in 2016/2017. Furthermore, the country's export, according to the table, contributes an average of 43.5 percent of GDP in 2006/2010 dropping to 21.7percent in 2016/2017. The pattern of the trade balance is weak and not too impressive in 1986/1990, 1991/1995 and 2016/2017, although it is positive in 1981/1985, 1996/2000, 2001/2005, 2006/2010 and 2011/2015. In the table, the current account balance reports negative balances, except for the periods 1981/85 and 2006/2010. The macroeconomic growth indicators in the table show the negative effect of the mid-1980s oil shock that plunged the country into a recession and triggered a spiral of revolts, Islamist electoral victories, and finally a military coup, repression, and civil war. In Table 2.1 below, which presents Algeria's economic indicators from 1981to 2017, GDPR represents real gross domestic product (average percent); PGDPR is GDP per capita growth; EXP represents exports of goods and services as a percentage of GDP; IMP is imports of goods and services as a percentage of GDP; CAB represents current account balance as a percentage of GDP and TB is trade balance as a percentage of GDP.

Table 2.1: Economic Indicators (Algeria)

Year	GDPR	PGDPR	EXP	IMP	TB	CAB
1981-1985	4.8	1.6	28.5	27.9	0.6	0.3
1986-1990	0.8	-2.0	16.9	23.5	-6.6	-1.3
1991-1995	0.3	-2.2	24.9	25.1	-0.2	-
1996-2000	3.5	-0.4	30.7	22.3	8.4	-
2001-2005	5.2	1.1	39.5	24.3	15.2	-
2006-2010	2.5	1.8	43.5	28.6	14.9	14.9
2011-2015	3.3	1.4	32.4	31.2	1.2	-1.1
2016-2017	2.3	-5.4	21.7	34.1	-12.4	-14.8

Source Author's computation (2022), using data sourced from the WDI

As a foremost energy provider to industry and consumers around the world, Algeria is, in principle, capable of producing the energy needed for its consumption and development, although, natural gas is already a vital source of electricity for the national grid. The challenges encountered with local energy supply over the years are regularly to do with the problems of increasing and sustaining the electricity transmission network. Therefore, in the years to come, solar energy will possibly become more important (US EIA, 2017). Moreover, considering the growing population and declining oil reserves, solar energy is attractive and environmentally friendly. So, investing in this renewable source for domestic use will give way for extra hydrocarbon products for export. Additionally, the widespread production of solar energy could put an end to air pollution and the emission of greenhouse gases that support global warming (US EIA, 2017).

2.5.2 Angola

Angola is the second-largest oil producer in Africa with a proven reserve of 8.27 billion barrels. It is also a net producer of natural gas (US EIA, 2018). In addition, apart from Botswana and the Democratic Republic of the Congo, Angola is the third-largest producer of diamonds in the continent of Africa, which contributes to being the third-largest economy in SSA. The country is dominated by the oil and gas industry, which accounts for 50 percent of its GDP and 70 percent of the primary source of income for the country (OPEC, 2018b). Aside from the diamonds, Angola also produces granite, marble, gold and gypsum, and owns abundant undeveloped minerals with potential for extraction together with copper, lignite, mica, clay and silver. The contribution of the country's industrial sector represents 42 percent of GDP and 8 percent of its workforce.

Despite its potential, the performance of the agricultural sector has not been impressive and is underdeveloped. Its contribution to GDP is 10 percent, yet, it employs 50 percent of the country's labour

force. Notably, one-third of the country's arable land is used for producing crops, of which only 100, 000 hectares out of millions deploy machinery for sowing and harvesting (US EIA, 2018). Angola's major industrial crops are coffee and cotton. The government of Angola invests in ethanol, sugarcane and coffee productions, to assist in expanding agricultural exports and revenue. Additionally, the services sector comprising the bank, telecommunication and tourism are growing rapidly, contributing 47 percent to the GDP and providing employment for 43 percent of the country's population (US EIA, 2018), although it is constrained by the high cost of input and the shortage of skilled labour

Despite reforms, such as exchange rate liberalisation and VAT, the Angola economy still suffers because the oil sector on which it is dependent, is vulnerable to external shocks, such as that of 2008 from which it never recovered. Only about one-third of the residents have access to electricity, and although per capita income is rising steadily in urban areas, unemployment and poverty rates remain high. An African Development Bank report indicates that poverty is still dominant in rural areas for 58 percent of the population despite the drop from 68 percent in 2000 to 37 percent in 2018. The rate of unemployment is 28 percent of which 39 percent are youth in urban (AFDB, 2019).

Table 2.2 below indicates the trend of incessant decline in the average real GDP rate: 9.4 percent in 2001/2005, 8.5 percent in 2006/2010, 4.5 percent in 2011/2015 and -1.4 percent in 2016/2017. In the table, the average per capita income follows the same trends with 5.7 percent recorded 2001/2005, 4.6 percent in 2006/2010, 0.9 percent in 2011/2015 and -4.6 in 2016/2017. The table shows a slightly upward trend in the export proportional contribution of 64.8 percent to GDP in 2001/10, but a strident decline to 28.5 percent in 2016/17. Between 2001 and 2017, imports decrease from 51.8 percent to 24.3 percent, although, the trade balance is weak but positive for all the periods. The table below depicts the decrease in current account balances throughout the period 1986/1990 to 2016/2017, except in 2006/2010 and 2011/2015. The fall in current account balances could be a result of the impact of civil war during the period (Pearce, 2012). Similarly, the improvement recorded between 2006 and 2010 could be associated to development in the oil and primary commodity sectors on which not only is the economy is dependent but also trade and current account balances. The decline between 2011 and 2015 could be in connected to the drop in oil prices. The lack of data on the country's export, import and trade balance from 1981/1985 to 1996/2000 could also be attributed to the unrest destroying large parts of the economy because of a lack of meaningful trading activities. Table 2.2 below presents the Angola's economic indicators for the period 1981 to 2017 as discussed above.

Table 2.2: Economic Indicators (Angola)

Year	GDPR	PGDPR	EXP	IMP	TB	CAB
1981-1985	1.7	-1.7	-	-	-	-
1986-1990	1.9	-1.5	-	-	-	-1.5
1991-1995	-2.5	-5.6	-	-	-	-7.8
1996-2000	6.1	2.8	-	-	-	-3.2
2001-2005	9.4	5.7	62.1	51.8	10.3	-0.8
2006-2010	8.5	4.6	64.8	45.3	19.5	8.6
2011-2015	4.5	0.9	48.4	35.8	12.6	3.4
2016-2017	-1.4	-4.6	28.5	24.3	4.2	-1.8

Source Author's computation (2022), using data sourced from the WDI

2.5.3 Egypt

Egypt's economy ranks fifth in North Africa and the Middle East after Saudi Arabia, the United Arab Emirates, Israel and Algeria. However, its per capita GDP is lower than these countries. It has the largest population of around 96.4 million (as of 2017) in the Middle East and North Africa. Egypt's economy is the second-largest in Africa after Nigeria.

Egypt implemented an economic restructuring programme in agreement with the International Monetary Fund (IMF) in 2016 to improve the economy and address macroeconomic imbalances via the liberalisation of the exchange rate, fiscal consolidation, and energy sector reforms. These actions mean that Egypt has now the highest growth rate in the region, with its GDP in 2017 reaching 235.4 billion dollars, compared with 332.9 dollars in 2016 and 332.7 billion dollars in 2015. The GDP per capita rate is also improving with 2817.3 dollars in 2017, compared to 2761.4 and 273.7dollars in 2016 and 2015, respectively. The rate of inflation, which had been on the increase against a backdrop of political turmoil and loss in the value of the Egyptian pound, declined to 13.9 percent in 2019 from 20.9 percent in 2018 (Central Bank of Egypt).

According to the World Bank (2018b), agriculture in Egypt contributes about 11.2 percent of GDP and employs 25 percent of the active population. The sector is very crucial for the development of Egypt, as it accounts for 20 percent of total exports and foreign exchange earnings. The atmospheric and climatic conditions and the rich Nile water give room for numerous annual agricultural harvests. The non-oil sector of the country remains rather inadequate. For instance, the secondary sector including textile production, automotive, cotton cultivation, steel manufacturing, and construction, accounts for 35.1 percent of GDP and employs 25 percent of the labor force (AFDB, 2019). Despite the efforts of economic diversification, Egypt continues to depend on the Suez Canal for a huge part of its foreign revenue (Richter and Steiner,

2008). In 2018, petroleum and gas extraction, including mining sectors grew by about 7.7 percent. Manufacturing expanded by 4.8 percent, thereby positioning the country for the seventh uninterrupted year of growth (AFDB, 2019)

The Egyptian service sector represents 51.4 percent of the country's GDP and employs almost half of the population (IMF, 2016). This sector is majorly dominated by revenues from telecommunications and tourism sectors, particularly, the latter, which is one of the major drivers of Egypt's economy and increased its revenue by 28 percent in 2018/2019 to reach \$12.570 billion (Central Bank of Egypt). Before this development, the sector experienced a series of attacks perpetrated by the Islamic State (ISIS) but was able to achieve this due to the improvement in the security apparatus. Unemployment is also a major problem in Egypt, particularly amongst the youth. The challenges of employment include poor recruitment process and a lack of the necessary skills needed by the employer.

The trend shown in Table 2.3 below reveals rapid growth in the Egyptian economy during the 1980s reaching a peak of an average of 7.6 percent between 1981 and 1985. Thereafter, the growth rate is volatile. The global drop in oil price in 2014 is reflected in the table by the drop in the growth performance of Egypt's economy in 2011/2015 to its lowest level. Macroeconomic indicators still show instability in export, import, current account and trade balances in Egypt, such as the decrease in the export of goods as a percentage of GDP from 27.9 percent in 2006/2010 to 13.1 percent in 2016/17, compared with the slight increase in imports from 23.3 percent in 2011/2015 to 24.6 percent in 2016/2017 as a percentage contribution to GDP, respectively. The table shows the conventional structural deficit in the trade balance, which is indicative of an import-dependent economy possibly due to a dramatic change in the composition of exports, such as agricultural commodities, particularly cotton, which now represents 10 percent compared with 70 percent before (Tignor, 2017). Most exports are now hydrocarbons, metals and minerals, for example, while imports include agricultural commodities, such as wheat and maize, pharmaceuticals and manufactured goods, such as spare parts and vehicles (Hamdi & Sbia, 2013).

Table 2.3: Economic Indicators (Egypt)

Year	GDPR	PGDPR	EXP	IMP	TB	CAB
1981-1985	7.6	4.9	23.8	35.1	-11.3	-5.5
1986-1990	4.9	2.2	16.4	29.0	-12.6	0.9
1991-1995	3.4	1.3	25.4	30.4	-5.1	4.4
1996-2000	5.7	3.6	17.4	24.6	-7.2	-1.4
2001-2005	3.5	1.6	23.2	26.3	-3.1	2.4
2006-2010	6.2	4.3	27.9	32.6	-4.7	-0.4
2011-2015	2.7	0.4	16.3	23.3	-7.1	-2.6
2016-2017	4.3	2.1	13.1	24.6	-11.5	-4.8

Source Author's computation (2022), using data sourced from the WDI

2.5.4 Gabon

Gabon is located on the Atlantic Ocean and shares boundaries with Equatorial Guinea, Cameroon and the Republic of the Congo, with a population of about 2.1 million, inhabiting a land area of 256000 square kilometers. The country is covered with forests, estimated to be about 85 percent of the landmass. Formerly dependent on timber and manganese as export commodities, Gabon began to exploit in large quantities offshore in the 1970s. As the fifth-largest oil producer in Africa, its economy is mainly driven by the oil extraction industry, notably oil. Revenue from oil accounts for 45 percent of GDP, more than 80 percent of total exports and 60 percent of its government revenue. The agricultural sector contributes more 5.4 percent of its GDP, employing an estimated 37 percent of the population (World Bank, 2017).

The agricultural sector grows food crops, palm oil and rubber in the north. The industrial sector of this country accounts for 48.8 percent of GDP and employs close to 10 percent of its total population. The country is involved in petroleum production, timber processing, textile, chemical and cigarette manufacturing and manganese mining. The services sector contributes about 40 percent of GDP and employs 53 percent of the active population of the country, with the government as the biggest employer of labour. Tourism is still at its initial stage of development owing to poor infrastructure. Gabon has one of the highest numbers of people in urban centres, with more than four out of every five of its citizens' resident in the cities. The dominance of the petroleum sector is reflected in the performance of the macroeconomic indicators, which are vulnerable to changes in world prices for this commodity. The rate of economic growth tends to fluctuate as shown in Table 2.4 below with the average growth rate declining from 2.6 percent in 1981/1985 to 1.7 percent in 1986/1990 following the collapse of petroleum prices in 1986. The table shows a rebound in oil prices from 2001 to 2013 with an increasing growth rate from 1.5 percent to

5.2 percent during the period 2001-2015. The table indicates Gabon’s favourable export growth rate in 1981/1985 of 61 percent thereby differing from other major exporting countries, such as Algeria, Egypt and Nigeria. However, there is a decline thereafter 58 percent in 2006/2010, 54 percent in 2011/2015 and 47 percent in 2016/2017 percent. However, the performance of the exports and imports is mirrored in the surplus record of the trade balance throughout the period, except in 1986/90 when a deficit trade balance of -1.5 percent due to low oil prices weakens imports and affects trade and current account balances (see Table 2.4 below).

Table 2.4: Economic Indicators (Gabon)

Year	GDPR	PGDPR	EXP	IMP	TB	CAB
1981-1985	2.6	-0.1	61.6	44.3	17.3	4.0
1986-1990	1.7	-1.0	41.3	42.8	-1.5	-12.5
1991-1995	3.1	0.4	52.6	35.1	17.5	3.0
1996-2000	0.4	-2.1	60.0	37.9	22.1	8.1
2001-2005	1.5	-1.0	54.8	28.1	26.7	12.2
2006-2010	1.4	-1.7	58.2	28.9	29.4	14.1
2011-2015	5.2	1.5	54.1	30.1	24.1	8.3
2016-2017	1.3	-1.6	47.1	25.5	21.7	-

Source Author’s computation (2022), using data sourced from the WDI

2.5.5 Nigeria

Nigeria is Africa’s leading economy, in close competition with South Africa. As of 2017, it has an estimated population of more than 191 million people. With this population, the household sector is the highest determinant of the country’s energy demand and accounts for more than 70 percent of its energy consumption. Globally, Nigeria is the 30th largest economy by GDP volume (US EIA, 2018). The country’s economy is dominated by crude oil. According to OPEC reports, hydrocarbon energy sources contribute more than 10 percent of the country’s GDP, 70 percent of government revenue and 83 percent of the country’s total export earnings. Worldwide, Nigeria is the 8th largest oil exporter, and its oil reserves are more than 35 billion barrels. The country is amongst the leading exporters of liquefied natural gas, which contributes to an additional 15.5 percent of exports (US EIA, 2018). Nigeria also extracts coal and tin ore for local consumption.

Another key sector in the Nigerian economy is agriculture, which employs 36 percent of the population and accounts for more than 21.1 percent of GDP. Various regions of the country cultivate one or more crops, such as millet and sorghum in the northern area, which also farm livestock and yams, maize and rice in the

southern and central regions. Other major crops spread across the country include cassava, cocoa beans, beans, cashew nuts, rubber and soya beans. The country's agriculture sector consists of subsistence farming and is not modernised. The industrial sector accounts for 25.7 percent of GDP and employs 12 percent of the country's workforce. However, its development has been constrained by inadequate investment in physical infrastructure such as road and energy networks, and soft infrastructure such as trade facilitation. The country's largest sectors are the petroleum industry, agriculture, tourism and mining, its large mineral deposits. However, the petroleum industry is presently battling against oil theft, which accounts for a lost revenue estimated to be \$ 10.9 billion (US EIA, 2018). The services sector plays a major role in the economy, accounting for 52 percent of GDP and employing about 52 percent of the country's labour force. The banking sector, telecommunications and retail, in particular, are very active. Tourism is also an important sector, but is constrained by a lack of harmonisation, poor power supply and inadequate road infrastructure, for example. The Nigeria's economy has not been in a better position to transform its wealth in the oil sector to improve the quality of the lives of ordinary citizens. However, economic problems are aggravated by the high spate of ethnic conflicts and kidnappings. In addition, herdsman farmer conflicts have disrupted farming activities in most parts of the country.

Nigeria's economy depends highly on oil and is therefore very susceptible to fluctuations in global crude oil price and production. The effect of this is largely felt on the performance of important indicators as shown in Table 2.5 below, which demonstrates the weak performances of the country's key economic indicators. For instance, the average growth rate is negative records in 1981/85 and 2016/17 with -5.2 percent and -0.4 percent, respectively. However, the peak period is noted in 2001/05 with a growth rate of 8.9 percent, which is reflected in the growth rate of the per capita GDP. In the table, the export base of the country is relatively weak, compared to counterpart oil-exporting countries, such as Gabon and the Republic of the Congo. The table shows the increase in exports between 1980 and 2000 (from 6.9 percent to 25.4 percent) the subsequent decline to 11.2 percent in 2016/17. The trade balance appears positive during the period covered in the table, except 2016/17 with a deficit of -1.1 percent. In Table 2.5 below, exports appear prone to changes in world oil prices, which are determined by the forces of demand and supply, especially demand from the major oil importers, such as the US and China.

Table 2.5: Economic Indicators (Nigeria)

Year	GDPR	PGDPR	EXP	IMP	TB	CAB
1981-1985	-5.2	-7.6	6.9	5.5	1.4	-2.0
1986-1990	4.9	2.6	15.1	7.0	8.1	2.3
1991-1995	0.2	-2.3	21.1	13.1	8.1	-0.7
1996-2000	3.1	0.5	25.4	17.5	8.0	2.4
2001-2005	8.9	6.1	23.9	16.9	7.0	8.2
2006-2010	7.1	4.3	24.1	16.2	7.9	8.5
2011-2015	5.0	2.3	22.1	14.2	7.9	1.4
2016-2017	-0.4	-3.0	11.2	12.3	-1.1	1.7

Source Author's computation (2022), using data sourced from the WDI

2.5.6 The Republic of the Congo

The Republic of the Congo is sparsely populated by 5.1 millions inhabitants as of 2017 spread over a surface of 342000 square kilometers, with more than half of the population settled in its two major cities, Brazzaville and Pointe-Noire. The country mostly consists of tropical forests and massive areas of unused arable representing a third of its total area. The Republic of the Congo is dependent on offshore petroleum production with hydrocarbons comprising 70 percent of its exports, 45 percent of its GDP and most of its foreign revenue. The country's reliance on oil prices makes growth procyclical. French giant, Total, and other foreign companies dominate the country's economy contributing 70 percent of the total annual oil production. Congo's agriculture sector accounts for 7.1 percent of GDP and employs 36 percent of the working population (World Bank, 2018), although it fails to meet domestic demand, and the country has to rely on food imports. The services sector accounts for 40 percent of GDP, employs 42 percent of labour force and mostly supports the oil sector. The banking sector in Congo, although buoyant, is not active, compared to other countries in the region. Tourism barely survives owing to security threats and inadequate infrastructure.

The Republic of the Congo's economy is affected when oil prices fall, which is manifested by the macroeconomic indicators shown in Table 2.6 below. The table presents the sharp fall of average real GDP rate from 10.6 percent in 1981/1982 to -0.3 percent in 1986/1990. A slight improvement is indicated by the rate of 0.5 percent in 1991/1995, 2.5 percent in 1996/2000, 4.1 percent in 2001/2005 and 5.3 in 2011/2015. However, the table shows the sharp decline from 4.0 percent in 2011/2015 to -3.0 percent in 2016/2017. GDP per capita follows the same pattern, particularly the decline from 1.4 percent in 2011/2015 to -5.4 percent in 2016/2017. The performance of GDP per capita mirrors the RGDP growth rate. The table shows

the impressive and favourable export base with a persistent surplus in the trade balance, excluding 1981/1985 with -1.7 percent. The economic implication of the high rate of exports and imports is that the country's economy is prone to fluctuations in world oil prices and is influenced by the country's major oil importers, notably, China, Australia, and the US. In addition, Table 2.6 below shows the unfavourable performance of the current account balance throughout the period under review except in 2001/2005 with 7.7 percent.

Table 2.6: Economic Indicators (the Republic of the Congo)

Year	GDPR	PGDPR	EXP	IMP	TB	CAB
1981-1985	10.6	7.4	58.0	60.0	-1.7	-11.1
1986-1990	-0.3	-3.0	44.5	37.3	7.2	-15.0
1991-1995	0.5	-2.2	50.0	42.7	6.9	-26.2
1996-2000	2.5	-0.4	74.6	59.1	15.5	-6.9
2001-2005	4.1	1.7	80.9	57.7	23.2	7.7
2006-2010	5.3	1.9	78.6	54.2	24.5	-4.6
2011-2015	4.0	1.4	78.0	70.2	7.8	-0.7
2016-2017	-3.0	-5.4	80.3	75.4	4.8	-20.0

Source Author's computation (2022), using data sourced from the WDI

The macroeconomic indicators for all the AOECs under review show that they are mainly driven by oil which accounts for a substantial share of foreign earnings and government revenue. Although the oil sector does dominate GDP as it does foreign earnings and government revenue, it still drives the performance of the major macroeconomic variables in these countries. For example, the fluctuating levels of GDP and other macroeconomic indicators are caused by changes in international oil prices, which result in external economic shocks. The over-reliance of these countries on oil as their economies' mainstay will continue to dictate the pace of their economic activities and various macroeconomic indicators until diversification is embraced. Furthermore, the services sector constitutes the major employer in the six AOECs described above, despite the challenge of electricity cuts, which means that businesses have to rely on generators to carry out daily activities. In addition, these countries have favourable trade balances, except Egypt, which often has a deficit trade balance. Generally, current account balances for all the countries are both negative and positive.

2.6 Prospects and Challenges in the oil sector/industry

2.6.1 Prospects

2.6.1.1 Making Oil and Gas Wealth Work for the Poor

This section analyses the challenges and prospects confronting AOECs in transforming oil resources to create economic wealth and thus improve economic growth. These countries are net oil exporters because they export more crude oil than they import, which indicates that they are oil resource endowed. They are, however, faced with the challenges of expanding access to oil and gas for the people in within their borders, which would lead to higher energy consumption. As high energy consumption has been linked to economic growth in industrialised countries, increased energy consumption in AOECs would promote economic development (Kebede et al., 2010; Saidi & Hammami, 2015; US EIA, 2017). Nevertheless, these countries are also faced with the challenge of ensuring renewable energy consumption, which has been mentioned earlier in this thesis. However, this section focusses on making oil and gas wealth work for the poor.

2.6.1.2 Oil Wealth and an Enabling Environment

This section discusses oil wealth and an enabling environment. According to Sachs and Warner (2001) and Olomola (2010), a country rich in abundant natural resources may record poorer economic performance than nations with few natural resources. Therefore, rational decisions about oil resources are vital to making natural resource wealth work and maximising the effect of crude oil on the growth of the AOECs that are still developing economies. The AfDB (2017) classifies three key interactive elements that offer a useful framework to discuss how oil wealth could improve economic growth. These elements are nature i.e. gas and oil resources; wealth i.e. human capital, institutions, infrastructure and growth; and an enabling environment i.e. civil society, power structure, accountability and governance. Experience in Africa and other countries in the world reveals that policies and investments, which apply these three elements result in positive development (see AfDB, 2017). For example, if the necessary principles of good governance, such as transparency, accountability and strengthened institutions are in place, there will be an opportunity to turn oil and gas resources into wealth in the form of human capital, institutions, infrastructure and economic growth. Economic growth will then be fed back into investment and enhanced resource utilisation and management.

2.6.2 Challenges

This section presents challenges and factors determining oil production, which affect all the oil-exporting countries in Africa since they have similar characteristics, such as a protracted military rule, a resource curse, total reliance on importation of finished and semi-finished goods, corruption, high mortality and poverty.

2.6.2.1 Weak Revenue Management

Weak revenue management may result in slow economic growth amongst oil-exporting nations (Sachs & Warner, 2001). Moreover, weak revenue management leads to weak export industries, causes low energy consumption, conflict and cyclical government expenditure (Sachs & Warner, 2005; AfDB, 2017). Therefore, there is a need to identify an appropriate revenue management framework for oil-exporting nations which would prevent revenue losses in the oil industry. The literature stresses that, revenue frameworks in the oil sector seek to indicate how much to spend and invest, and how much to spend and save, which depends on factors, such as fiscal sustainability, uncertainty surrounding oil prices and the level of petroleum resources and oil exports. Three frameworks have been recommended: the hand-to-hand rule, the permanent income rule and the bird-in-hand rule. As enumerated by the AfDB (2018), the hand-to-mouth rule entails that the government uses all revenue generated, which is usually done in nations where the size of revenue is insignificant or where development is almost non-existent. The bird-in-hand rule involves petroleum revenue, for example, being placed in petroleum bonds and invested in financial instruments whilst the government spends only the returns. The permanent income rule entails spending the discounted net revenue yearly, which is computed according to the life span of an investment project. This ensures that a permanent proportion of petroleum wealth, for instance, is spent every year henceforth, whilst the balance, which is invested in a sovereign wealth bond, continues to grow beyond the life of the project.

Another issue concerning the revenue management is the allocating of oil income to stakeholders, and some nations cannot agree with a satisfactory allocating formula. Accusations are made that the income shared with stakeholders is not reasonable and sufficient. In Nigeria, for instance, this has caused criminals to deface pipes and other facilities belonging to the refineries and kidnaping the staff of oil exploration companies. Hopkins (2008) mentions the pipeline vandalism which is the intentional damage of pipelines that move liquid oil from one point to another. Oil pipeline vandalism in the Nigeria dates to around early 1990s and has since gained momentum. For instance, according to Onuoha (2008), in 1995, seven cases of pipeline vandalism were reported, with thirty-three before the end of 1996, ninety-one cases between 1997 and 1998 and four hundred and ninety-seven cases of oil pipeline cuts between 1999 and 2005. The Port Harcourt and Warri oil paths were reported to have experienced the most damage, with the Port Harcourt axis alone recording about six hundred instances of vandalism, rising to about one thousand six hundred and fifty defaced pipelines before the end of 2006 (Onuoha, 2008). The impacts are huge in terms of human and non-human resources, not to mention the loss of income and the oil leakages that result from vandalism.

Reacting to these challenges, the Nigerian government introduced a thirteen percent derivative oil allocating formula in section 162 (2) of the 1999 Constitution as amended. It orders the payment of not less than thirteen percent of oil income to the nine oil-producing states of the federation with the purpose of reducing conflict and inspiring community development. In addition, in response to struggles and conflicts in areas with enormous oil deposits, the government created the Niger Delta Development Commission (NDDC) in 2000 to develop the oil-producing areas. Therefore, the government at federal level announced the establishment of the Niger Delta Ministry in 2008, with the NDDC becoming a parastatal under it. The ministry is charged with coordinating efforts to address infrastructural development and other oil-associated challenges, such as youth empowerment and environmental protection in the Niger Delta community.

Despite the adoption of a special sharing formula to ensure the equitable allocation of funds considering criteria, such as poverty levels and population, agitation and complaints about revenue allocated continues. Moreover, the lack of clarity on how the Nigerian government should cede the oil income to oil-producing communities makes them prone to ethnic competition and rivalry. Furthermore, improper oil income management in these communities heighten conflicts, calling for the central government to consider the demands of the states when adopting its revenue sharing formula. Therefore, the government should engage all necessary oil stakeholders and allocate reasonable compensation to them. Moreover, suitable mechanism should be adopted to manage the oil proceed prudently.

2.6.2.2 Weak Institutional Framework

Generally, AOECs are characterised by weak institutional frameworks, creating opportunities for fraud and corruption in the oil industry. According to AfDB (2017), the ministry of petroleum and cabinet's secretary, saddled with the responsibility for issuing petroleum agreements, creates room for rent-seeking behaviour and corruption on the part of state officials. Conflicts of interest are not always stated, and state interests are weakened in favour of individual interests, as the terms of negotiated petroleum agreements are used to secure personal payments and favours from oil firms (AfDB, 2017). Hence, there is a need for checks and balances in the relevant institutions. In addition, the institutional frameworks need to be strengthened to realise the full potential of the petroleum resources in various oil-exporting nations. For these frameworks to work, measures such as internal capacity advancement might be needed to administer the granting of operational licenses; impose compliance; and control the issuance, modification, renewal and suspension of licenses and permits for various undertakings and events in the oil industry.

2.6.2.3 Economic Distortion

Another major challenge facing the oil-exporting countries in Africa is the risk of the Dutch Disease, which Corden and Neary (1982) and Hamilton (2013) describe as the causal relationship between the rise in the oil industry and a fall in other sectors such as the manufacturing and agricultural industries. It shows the negative effect of oil on an economy, which gives rise to a sharp inflow of foreign currency (Egert & Leonard, 2008). This amounts to currency appreciation but makes the nation's other goods inexpensive on the export market. AU (2007) asserts that policies to prevent hyperinflation and sustain monetary dependability can lessen the risk of the Dutch Disease. Additionally, it is essential to promote non-oil sectors or strengthen connections that can be leveraged by the revenue from oil to lessen dependence on a single product.

2.6.2.4 Poor Transparency and Accountability in the Oil Industry

Poor accountability and transparency are characteristic of oil-exporting countries in Africa, which means that people are not informed about operations in the industry and proper records are not kept. This undermines the economic growth that oil income should have spurred (AfDB, 2017). Moreover, the process of licensing oil blocs lack transparency in many oil-exporting nations. It is kept confidential and sometimes used for political gain (AfDB, 2017).

Corruption continues to plague the oil sector, with public officers misappropriating and embezzling public funds. Despite anti-corruption programmes adopted by the government at various level, corruption is endemic across the AOECs (AfDB, 2017). For example, facilitation fees or bribes are paid to avoid bureaucratic bottlenecks, inefficiencies and the costs of interruptions to firms.

2.6.2.5 Continuous Exchanger Rate Volatility

According to the literature, the African oil industry is characterised by high price volatility (Iwayemi & Fowowe, 2011). Foreign currency, which is linked to the American dollar and other major currencies of the world, is volatile in the AOECs and a key challenge. Therefore, the currencies of the oil-exporting countries in Africa have constantly devalued in over time. For example, Nigeria's naira, Libya's dinar and Egypt's pound have lost almost a third of their original value when compared with the America dollar. As a result, these nations have adopted currency control measures, which hinder investment prospects.

Exchange rate volatility has a dramatic effect on net AOECs, resulting in high product prices and on-going conflict in many nations. For example, the conflict in Mozambique in 2008 was the result of the fifty percent hike in transport fares due to a sharp increase in the pump prices of petrol and diesel (AfDB, 2017). In

addition, high product prices are motives for civil unrest and uprisings in several other AOECs. The situation is even worse for poor households that rely on kerosene for cooking, lighting and other domestic tasks. Insufficient resources render it difficult to implement price smoothing and stabilisation mechanisms (AfDB, 2017). While most nations have implemented mechanisms to fairly or entirely pass on increases in international oil prices or introduce price subsidies, not all these AOECs have responded sufficiently to high oil prices.

Like the oil-importing nations, AOECs are confronted with many challenges, including management of oil wealth, technical inadequacy, a lack of institutional structure, economic distortions and environmental challenges (AfDB, 2017). Therefore, the monetary authority required to intervene in stabilising the exchange rates of the nations to ensure economic growth.

CHAPTER 3

DETERMINANTS OF ENERGY CONSUMPTION IN AFRICAN OIL EXPORTING COUNTRIES

3.1 Introduction

The relationship between energy consumption and economic growth is well documented in the energy literature (Azam et al., 2015; Wang & Wang, 2020). The role of energy in propelling sustainable economic growth is of great concern to energy economists and policymakers, especially in Africa where many countries are net African oil-exporting countries (Fuinhas & Marques, 2012; Bilgen, 2014; Dritsaki & Dritsaki, 2014).

African countries have exhibited two tendencies in energy consumption and economic growth. Firstly, the region has the lowest energy consumption per capita and the little that it consumes is dominated by dirty fuel. This fuel contributes to environmental deterioration (Kebede et al., 2010; Rennings et al., 2012). Secondly, Africa has the worst development indicators in the world, with high unemployment and poverty rates, poor access to education and health and low life expectancy (Karekezi, 2002; IEA, 2010).

A report from the World Bank shows that the global poverty rate is on the decrease across various regions of the world, except in Africa (from 278million in 1990 to 413million in 2015). The poverty rate stood at 41 percent in 2015, compared to 13 percent in other regions. In addition, 27 out of 28 of the poorest countries in the World are from SSA (World Bank, 2018). This makes it difficult for the region to attain the poverty reduction target of the MDGs (Asongu & Kodila-Tedika, 2015; Asongu et al., 2016). Moreover, Shurig (2015) maintains that only 5 percent of countries in SSA have access to electricity (IEA, 2016). This implies that per capita electricity consumption in the region is one-sixth of the world's average. In addition, the ineffective management of energy resources is another problem (Anyanwu, 2014). The governments of African countries subsidise fossil fuels, which are in high demand, at the expense of renewable energy. However, the increasing rate of fossil fuel consumption is one of the major causes of global warming due to environmental disturbance. It contributes over 75 percent of carbon dioxide (CO₂) emission (Huxster et al., 2015; Akpan & Akpan, 2012; World Bank, 2018a).

Nonetheless, fossil energy has improved humanity's standard of living, which is reflected in the positive relationship between the total primary energy produced and the average GDP per-capita (Ergun et al., 2019). However, owing to their greenhouse effect, fossil fuels need to be replaced by alternative energy sources (Smil, 2005). Sustainable growth and averting environmental change need to be achieved while

satisfying the growing energy demand. Thus, renewable energy sources should be included in a country's energy-mix (Ogbonnaya et al., 2019).

Evidence from high income countries reveals that high energy consumption correlates with high per capita income levels, whereas low energy consumption is associated with low-income countries (US EIA, 2016). For instance, energy consumption in 2017 stood at 3132.2 Mtoe in China, 753.7 Mtoe in India and 295.9 Mtoe in South Korea, with growth rates of 6.76 percent, 7.17 percent and 3.06 percent, respectively. In the same year, the energy consumption of AOECs, such as Algeria, Angola and Nigeria was 51.8 Mtoe, 7.7 Mtoe and 28.2 Mtoe, respectively, with growth rates of 1.3 percent, -0.15 percent and 0.81 percent, respectively. This shows that affordable access to adequate and dependable energy supply is a fundamental factor in the attainment of the large productivity gains that guarantee sustainable economic growth.

Despite all the efforts being made by the AOECs to improve access to energy consumption, such as the privatisation and commercialisation of energy sectors, and sustainable economic growth, it should be noted that these have not been impressive in recent times (see Karekezi & Kimani 2002; Clark et al., 2005). The inability of the AOECs to improve both their energy consumption and income levels has been blamed on inconsistent policy implementation and policymakers' failure to obtain adequate information on the factors influencing energy consumption (US EIA, 2018).

The argument is that AOECs depend on crude oil exports for most of their foreign earnings (Davidson & Sokona, 2002; Wolde-Rufael, 2006) because they are endowed with energy resources (Kebede et al., 2010; World Bank, 2016), the paradox of low energy consumption requires extensive investigation. This is especially important when these countries also have poor developmental indicators and are affected by environmental issues resulting from CO₂ emissions. Therefore, the determinants of energy consumption in AOECs need to be ascertained, which can be done by obtaining precise estimates of energy consumption to understand how they could lead to sustainable economic growth. This approach is important for two reasons. Firstly, providing definite quantitative estimates for energy consumption parameters can help in policy making. Secondly, quantitative estimates will help in forecasting future energy consumption.

The literature identifies various factors influencing energy consumption. For instance, Kolawole et al. (2017) point out that according to basic economic theory, the demand for goods and services is usually dependent on factors like their price, the income of the buyers, the price of a close substitute and other exogenous factors associated with them. **Similarly, theory of consumer behaviour asserts that consumer's decision-making is not only based upon the price of its own goods, but the price of other goods will also be considered.** Xiong, et al. (2020) and US EIA (2021) add that prices of close substitutes, like natural gas and solar, are also important factors determining energy consumption. Similarly, consumers' income and energy price are determinants of energy consumption (Atakhanova & Howie, 2007; Bohlmann & Inglesi-Lotz,

2021). Other variables influencing energy consumption, as pointed out by Samuel et al. (2013) and Sineviciene et al., (2017) include economic growth, population, foreign direct investment and industrial growth. Findings from studies are mixed and have not reached a consensus, which indicates a need for further research. The study explained in this chapter uses cross-sectional augmented autoregressive distributed lag (CS-ARDL) and cross-sectional distributed lag (CS-DL) to investigate the determinants of energy consumption in AOECs since no study to the best of our knowledge has been conducted using these methods.

The study uses macroeconomic variables from the literature, such as per capita income, trade openness and economic structure, to understand consumer reaction to these variables in the long run. This understanding might inform effective energy policies for improving not only energy consumption, in general, which is linked to economic growth, but also the use of sustainable clean energy in AOECs.

The study's novel contribution to the literature on AOECs is the use of recent panel data estimators, the CS-ARDL and CS-DL, which are robust to CD and small sample size bias. Banerjee and Carrion-i-Silvestre (2015) maintain that the power of unit root and cointegration tests may be increased by combining the information from cross-section and time dimensions. This is especially beneficial when the time dimension is limited owing to the lack of accessibility to long series of consistent time series data, which is generally the case for African countries. Our methodology controls for time dynamics, cross-sectional heterogeneity and CD. The results show that, while trade openness has a positive and significant effect on energy consumption, the effect of economic structure is negative and significant. Similarly, per capita income does not affect energy consumption. Most of these results (**economic structure and per capita income**) do not conform to theoretical expectations or some previous empirical findings, indicating that AOECs behave differently towards the determinants of energy consumption for a variety of reasons ranging from structural rigidity to the countries' inability to transition to a more efficient and growth-enhancing energy regime.

The following section of this chapter reviews the relevant literature, whilst Section 3.3 presents the theoretical framework for the study, the sources of the data and the research methodology. The empirical results are presented and discussed in Section 3.4, while the conclusion and policy recommendations are discussed in section 3.5

3.2 Literature Review

Varian's (1992) neoclassical consumption theory postulates that consumption is based on primary economic variables, influencing the demand for a commodity. According to this theory, consumption is linked to individual preferences and other factors affecting demand, such as the price of a commodity and income. Therefore, all these variables are incorporated into conventional energy demand models. Like other goods, energy is consumed primarily because of the satisfaction derived from it and its utility, for example,

in industry and household technology. Moreover, an increase in income would positively impact energy consumption, although, an increase in the price of energy would cause a consumer to consume less or seek an alternative source (see Varian, 1992).

Research on the determinants of energy consumption uses various methods (Samuel et al., 2013). For instance, Aziz et al. (2013) investigate factors driving energy demand in 16 developing countries using panel data analysis and find that price, income, economic structure and carbon-dioxide emissions have a significant positive impact on energy use.

Azam et al. (2015) employ ordinary least squares (OLS) to explore the determinants of energy consumption in Indonesia, Malaysia, and Thailand between 1980 and 2012. They find that the inflow of foreign direct investment, economic growth, trade openness and human capital development index all have a positive and statistically significant effect on energy consumption. Urbanisation has a significant positive effect on energy consumption in Indonesia and Thailand, whilst the rate of population growth has positive and statistically significant effect on energy consumption in Malaysia.

Keho (2016) investigates the drivers of energy consumption in twelve SSA countries. Bounds test cointegration is employed to test the data set for individual countries from 1970 to 2011. The research finds evidence of cointegration with industrial output, imports, income, foreign direct investment, urbanisation, population and domestic credit to the private sector. In addition, the share of the industrial sector in GDP, urbanisation, population and per capita income has a long-run relationship with energy consumption. Keho (2016) concludes that industrial output and economic/population growth were the main determinants of energy consumption in most of the countries of interest.

Using panel data analysis, Dalei (2016) investigates the drivers of energy consumption in open economies, namely China, Japan, and India. The findings of the study reveal that trade openness, GDP and carbon emissions influence energy consumption in these economies during the period under study. Kolawole et al. (2017) investigate factors that influence energy demand in 16 countries in SSA from 1980 to 2014 using the panel cointegration technique. Their results confirm income and urbanisation as major factors determining energy consumption.

Sarkodie and Adom (2018) use nonlinear iterative partial least squares (NIPALS) to examine the drivers of aggregate energy consumption in Kenya. The findings reveal that price, population density, urbanisation and renewable energy from hydro sources play a vital role in promoting energy demand. However, climate change and higher income are expected to cause an increase in alternative energy consumption. Moreover, the growth in population rate is expected to increase the consumption of alternative energy, because of the fragility of the electricity infrastructure, which is dependent on fossil fuels.

Zaharia et al. (2019) use both bibliometric analysis and panel data techniques to analyse factors determining energy consumption in the EU-28 countries between 1995 and 2014. The results from the study show that greenhouse gas emissions, GDP, population and labour growth have a positive correlation with both primary and final energy consumption. However, the increase in the female population increase, healthcare expenditure and energy taxes have a negative impact.

Fernandes and Reddy (2021) use the vector error correction model (VECM) to investigate the determinants of energy consumption in a sample of newly industrialised countries in Asia (China, India, Indonesia, Malaysia, Philippines and Thailand). The study finds that industrialisation, the exchange rate, financial development and trade openness have a significant impact on energy consumption in China. In Thailand and India, only industrialisation has an impact, whilst GDP and trade openness have a significant impact on energy consumption in Indonesia and Malaysia, respectively.

Adetola and Sunday (2021) investigate the determinants of energy consumption in Egypt using time series data from 1971 to 2017. The study adopts a wavelet coherent method for the analysis and the results reveal a positive connection between energy consumption and urbanisation at various scales and a bidirectional causal connection between the two variables. Additionally, the results show that imports are a significant determinant of energy consumption in diverse frequencies in Egypt. Moreover, evidence of bidirectional causality is found between economic growth and energy consumption, whilst gross capital formation drives energy consumption in Egypt during the period under review. The researcher concludes that policymakers in Egypt should formulate policies to ensure sustainable energy consumption.

Canh et al. (2021) integrate the influence of a shadow economy by using the stochastic impacts by regression on population, affluence and technology (STIRPAT) model for 115 countries between 1991 to 2014 to investigate the determinants of energy consumption. The study employs the system-GMM estimation technique to examine the determinants of energy consumption according to three aspects: level, intensity and renewability. The analysis of the impact of the shadow economy and the drivers of energy consumption indicates that in the global sample, a higher informal sector causes a higher level, intensity and renewability of energy consumption.

In studies in other fields, the CS-ARDL approach is used to estimate long run relationships in the empirical application of macroeconomics models (Ditzen, 2019). Using the CS-ARDL approach, Mohaddes and Raissi (2017) investigate the effect of commodity terms of trade (CTOT) volatility on economic growth in commodity-dependent countries and also assess the role of CTOT and the quality of institutions in their long-term growth performance. The results show that while CTOT volatility exerts a negative effect on economic growth, the average effect is dampened if a country has a sovereign wealth fund (SWF) and better institutional quality.

Anderson and Raissi (2018) explore the long-term effect of incessant corporate debt accumulation on the productivity growth of Italian firms and examine whether total factor productivity growth changes with the level of corporate indebtedness. The results reveal the significant negative impact of incessant corporate debt increase on total factor productivity growth and a weak indication of a threshold level of corporate debt, after which productivity expansion fall considerably. Ahmed (2020) examines the effect of business and consumer sentiment on stock market performance in the context of both advanced and emerging markets. The study reveals that for developed markets, the business sentiment has a positive impact on stock returns, covering short- and long-term time horizons, while for emerging markets, the price effect of business sentiment is short-lived. However, consumer sentiment tends to influence both market types positively, although only in the short run. Moreover, the impact of sentiment appears stronger in emerging markets than in developed countries.

According to the literature, the CS-ARDL model is used extensively because it is robust to omitted variable bias and the simultaneous determination of growth regressors. The robustness of this method is the long-run connection amongst the variables of interest, the dynamic specification of the model, which is sufficiently augmented for the regressors to become weakly exogenous, and the resulting residual, which is serially uncorrelated (Chudik et al., 2013). Moreover, CS-ARDL and CS-DL models account for cross heterogeneity, CD arising from unobserved common factors, spillover effects dynamics and feedback effects. In the current study, these models are used to investigate factors influencing energy consumption in AOECs, thereby contributing to knowledge because, as far as we are aware, oil-related studies reported in the literature do not appear to use them.

3.3 Methodology

3.3.1 Theoretical Framework

Based on the theory of consumer behaviour and the studies conducted by Mudakkar et al. (2013) and Tang & Tan (2014), a framework is designed to investigate the determinants of energy consumption. Given that the theory of consumer behaviour assumes that all consumers are rational and maximise utility and satisfaction with each unit of consumption subject to budget constraints, the energy consumption function can be written as follows:

$$EC_t = f(Y_t, P_{E,t}, P_{X,t}, H_t) \quad (1)$$

where EC_t represents energy consumption, Y_t represents the level of income, $P_{E,t}$ represents the price of energy, $P_{X,t}$ represents the price of non-energy goods and H_t represents the vector of factors influencing energy consumption. Assuming homogeneity, the specification of energy consumption can also be itemised as a function of relative price and real income of energy to non-energy goods as follows:

$$EC_t = f\left(\frac{Y_t}{P_{X,t}}, \frac{P_{E,t}}{P_{X,t}}, H_t\right) \quad (2)$$

In the energy consumption framework in equation (2), energy consumption is dependent on relative price, real income and other factors. According to the existing literature, other factors that affect energy consumption include economic structure, CO₂ emissions, population size, employment and urbanisation (see, for instance, Aziz et al., 2013; Azam et al., 2015; Esen & Bayrak, 2017; Keho, 2016; Kolawole et al., 2017; Sarkodie & Adom, 2018). Therefore, the functional relationship between energy consumption and its determinants is modified as follows:

$$EC_{i,t} = f(PERINC_{i,t}, OPEN_{i,t}, ES_{i,t})^4 \quad (3)$$

where *EC* denotes energy consumption, *PERINC* denotes per capita income, *OPEN* denotes trade openness and *ES* denotes economic structure. The empirical model of energy consumption and its determinants is written as follows:

$$\ln EC_{i,t} = \beta_0 + \beta_1 \ln PERINC_{i,t} + \beta_2 OPEN_{i,t} + \beta_3 ES_{i,t} + \varepsilon_{i,t} \quad (4)$$

where *ln* is the natural logarithm, and the error term ε is expected to be spherically distributed and white noise. The a priori expectations for the parameters in equation 4 are as follows: $\beta_1 > 0, \beta_2 > 0, \beta_3 > 0$. We expect all the explanatory variables in equation 4 to have positive relationship with energy consumption.

3.3.2 Data

The study investigates the factors influencing energy consumption in six net AOECs: Angola, Algeria, Egypt, Gabon, the Republic of the Congo and Nigeria. The choice of these countries is premised on their being producers and exporters of oil (OPEC, 2018a). The study uses annual data for the period 1980 to 2018. The sample allows the recognition of changes in variables due to various energy sector reforms to discover energy demand patterns (Shafiei et al., 2013; Kolawole et al., 2017). The dependent variable, energy consumption (EC), is proxied by total primary energy consumption in Mtoe. In line with Azam et al. (2015), the trade indicator is proxied by trade openness (OPEN), which is the ratio of the total value of imports and exports of goods and services to GDP expressed as a percentage. In addition, following Kolawole et al. (2017), economic structure (ES) is proxied by the value-added of industrial output as a

⁴ Note that several variables such as energy price, urbanisation, population size, CO₂ emissions, capital and labour were considered in our model. However, we retained the most significant variables based on tests conducted. The results are presented in Tables A-1 and A-2 of Appendix A.

percentage of GDP. This comprises the value-added of mining, manufacturing, construction, electricity, water and gas. In line with the empirical work of Kolawole et al. (2017) and Keho (2016), per-capita income (PERINC) is proxied by GDP per capita of the selected AOECs in constant 2010 US\$. This is measured as the ratio of GDP to the midyear population. Data on energy consumption are available on the US EIA (2016) website, and data on the trade openness trade, economic structure and per capita income variables are indicated by the WDI (World Bank, 2016). In addition, all the variables are expressed in natural logarithms to **minimize heteroscedacity and to convert the variables from rates and absolute terms into the same numerical structure**, except economic structure and trade openness, which are already in percentages.

3.3.3. Cross-sectional dependence test

CD may occur because of the existence of common shocks and spatial spillover effects amongst cross sections (De Hoyos & Sarafidis, 2006; Damette & Seghir, 2013) and in panel data, which may result in loss of efficiency and misleading statistics. According to Pesaran (2006), errors in CD in the panel model may lead to biased estimates⁵. Consequently, it is important to test for error in CD. To achieve this, we use Pesaran's (2004) CD tests as per the following specification:

$$CD = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N (T \hat{\rho}_{ij}^2 - 1) \rightarrow N(0,1) \quad (5)$$

where T represents the time interval, N represents the number of cross sections, and $\hat{\rho}_{ij}^2$ is the pairwise correlation coefficient between the cross-sections. In addition, the asymptotic distribution of both CD tests is standard normal ($T \rightarrow \infty$ and $N \rightarrow \infty$), and they have acceptable sample size properties. The null hypothesis for these tests is that there is cross-sectional independence in the panel model residuals.

3.3.4 Panel unit root test

Various panel unit root tests are employed in the study to test the degree of integration of the different variables. Following the presence of CD, the first-generation panel unit root tests like those conducted by Levin et al., (2002), Im, et al., (2003) and Maddala and Wu (1999), may be biased as a result of their harsh assumption of no CD in the data (O'Connell, 1998; Westerlund, 2005). Therefore, we employ a second-generation panel unit root test, Pesaran's (2007) cross sectionally augmented Im Pesaran and Shin (CIPS) test, which assumes that CD is in the form of a single unobserved common factor. Pesaran's (2007) modified version of Im et al.'s (2003) standard augmented dickey fuller (ADF) model, in conjunction with the cross-sectional averages of lagged levels and first differences of individual series, results in the cross-sectional augmented dickey-fuller (CADF) model, which is expressed as follows:

⁵ This will happen if the unobserved common factors are undeniably correlated with the regressors

$$\Delta y_{it} = \nu_i + \psi_i y_{it-1} + \varphi_i \hat{\psi}_{t-1} + \sum_{j=0}^k \varphi_{ij} \Delta \hat{y}_{it-j} + \sum_{j=0}^k \Delta y_{it-j} + \varepsilon_{it} \quad (6)$$

where $\hat{y}_{t-1} = \frac{1}{N} \sum_{i=1}^N y_{it-1}$, and $\Delta \hat{y}_t = \frac{1}{N} \sum_{i=1}^N \Delta y_{it}$

As stated above, the CIPS test statistic is calculated as the average of the CADF test statistic of cross-sections. This is specified as follows:

$$CIPS = \frac{1}{N} \sum_{i=1}^N t_i(N, T) \quad (7)$$

Where $t_i(N, T)$ denotes the CADF statistic for each i -th cross-section. Moreover, since it was likely that the dataset would suffer from CD, the null hypothesis is that a series are non-stationary. The alternative is that some of the series are stationary.

3.3.5 Panel autoregressive distributed lag method

Following Chudik and Pasaran (2013), the study explores the panel autoregressive distributed lag (P-ARDL) approach to determine the presence of long and short-run relationships between energy consumption and its determinants in AOECs. The P-ARDL methodology was chosen because of its salient advantages over conventional cointegration techniques. The advantages are as follows:

- (i) The P-ARDL framework provides for the determination of both short and long-run dynamic parameters
- (ii) It provides for diverse lagged variables, as they are allocated in the model
- (iii) The framework permits the mixture of both I(0) and I(1) data but not I(2) (Narayan, 2005; Katircioglu, 2009; Dritsakis, 2011; Rafindadi & Yosuf, 2013).

The study considers the following equation for the P-ARDL model:

$$y_{i,t} = \alpha_1 + \sum_{l=1}^p \omega_{i,l} y_{i,t-l} + \sum_{l=0}^q \beta'_{i,l} x_{i,t-l} + \varepsilon_{it} \quad (8)$$

where $i = 1, 2, \dots, N$ denotes the cross-sectional units, $t = 1, 2, 3, \dots, T$ denotes the periods, l represents the number of time lags, p denotes the lag of the dependent variable, q represents the lag of the independent variables in the equation, X_{it} represents the vector of the explanatory variables and α_1 is the fixed effect.

In line with Pesaran et al.,'s (1999) study, equation (8) is explicitly rewritten as follows:

$$\Delta y_{i,t} = \alpha_1 + \xi_i y_{i,t-1} + \theta'_i X_{i,t-1} + \sum_{l=1}^{p-1} \omega_{i,l}^* \Delta y_{i,t-l} + \sum_{l=0}^{q-1} \beta_{i,l}^{*'} \Delta x_{i,t-l} + \varepsilon_{it} \quad (9)$$

We rewrite equation (9) in error correction form to capture the highlight of the long-term relationship to accommodate the short-term adjustment. This is expressed as follows:

$$\Delta y_{i,t} = \alpha_1 + \xi_i (y_{i,t-1} - \theta_i' X_{i,t}) + \sum_{l=1}^{p-1} \omega_{i,l}^* \Delta y_{i,t-l} + \sum_{l=0}^{q-1} \beta_{i,l}^{*'} \Delta x_{i,t-l} + \varepsilon_{it} \quad (10)$$

where $\theta_i = \frac{\sum_{l=0}^{q-1} \beta_{i,l}^{*'}}{1 - \sum_{l=1}^{p-1} \beta_{i,l}}$, $\zeta_i = -(-1 \sum_{l=1}^{p-1} \beta_{i,l})$, $\omega_{il} = -\sum_{m=l+1}^p \omega_{im}$, $l = 1, 2, \dots, p-1$, and $\beta_{il} = -\sum_{m=l+1}^q \beta_{im}$, $l = 1, 2, \dots, q-1$. The term $(y_{i,t-1} - \theta_i' X_{i,t})$ denotes the error correction term, which is the long-run relationship between the dependent variables and the explanatory variables, y_{it} is the dependent variable, X_{it} is a $k \times 1$ vector of independent variables and θ_i' is a vector that contains the long-run relationships. The parameter ζ_i is the error-correcting speed of the adjustment term. If $\xi_i = 0$, then we conclude no cointegration relationship exists between the variables⁶.

According to Pesaran and Smith's (1995), Equation (10) is expressed separately for each group and computed as an average of the different coefficients. The mean group (MG) estimator allows the intercept, all the coefficients and error variance to differ across groups. Pesaran et al., (1999) propose another estimator called the pool mean group (PMG) estimator. This estimator allows the intercepts, short-run coefficients and error variances to change across groups but constrains long-run coefficients to be equal. Moreover, this estimator depends on a combination of pooling/averaging and employs a maximum likelihood method.

Chudik and Pesaran (2013) note that the correlation of unobserved common factors with regressors will lead to the P-ARDL approach being inconsistent. To overcome this, we employ the CS-ARDL, which is an extension of Pesaran's (2006) model and build on Chudik and Pesaran's (2013) model. Chudik et al. (2013) explain that this estimator supports the P-ARDL regressions with cross-sectional averages of the regressors, the dependent variable and a sufficient number of lags. The specification of CS-ARDL is expressed as follows:

$$\Delta y_{i,t} = \alpha_i + \xi_i (y_{i,t-1} - \theta_i' X_{i,t}) + \sum_{l=1}^{p-1} \omega_{i,l}^* \Delta y_{i,t-l} + \sum_{l=0}^{q-1} \beta_{i,l}^{*'} \Delta x_{i,t-l} + \sum_{l=0}^{q-1} \delta_{i,l}' \Delta \bar{\omega}_{t-l} + \varepsilon_{it} \quad (11)$$

where $\bar{\omega}_t = (\overline{\Delta y_t}, \bar{x}_t)'$, $\overline{\Delta y_t}$ and \bar{x}_t represent the simple cross-sectional averages of Δy_{it} and X_{it} , with all other variables remaining as defined in Equation (10).

Since the CS-ARDL may be subject to the small T bias, we introduce the cross-sectional distributed lag (CS-DL) estimator based on Chudik et al.,'s (2013)⁷ model. According to Chudik et al. (2013), the estimator is robust to several issues such as a unit root of regressors and its better small sample performance.

⁶ This could stand as a test for the presence of cointegration where a significant speed of adjustment contributes to cointegration between the sample variables of interest in the model.

⁷ Pros and cons of the ARDL, the CS-ARDL and the CS-DL can be retrieved from Chudik et al. (2013).

However, the CS-DL should be used in combination with others since no feedback is expected from the independent variable (see Chudik et al., 2013). Therefore, we specify CS-DL as follows:

$$y_{i,t} = \alpha_i + \theta'_i X_{i,t} + \sum_{l=0}^{q-1} \beta_{i,l} x_{i,t-l} + \sum_{l=0}^{p_{\bar{y}}} \varphi_{y,il} \bar{y}_{t-l} + \sum_{l=0}^{p_{\bar{x}}} \varphi'_{x,il} \bar{x}_{t-l} + \varepsilon_{it} \quad (12)$$

3.4 Empirical results and discussion

3.4.1 Cross-sectional dependence test results

The results of Pesaran's (2004) CD test conducted on the regression model are shown in Table 3.1 below. The null hypothesis of no correlation of the residual is rejected. This indicates that CD affects the countries under review, which justifies the use of the CS-ARDL estimator to correct this problem.

Table 3.1: Pesaran's (2004) CD test

Variable	CD-test	P-value	Corr	Abs(corr)
EC	14.75***	0.000	0.618	0.861
ES	3.22***	0.001	0.135	0.408
OPEN	2.54***	0.011	0.107	0.197
PERINC	3.95***	0.000	0.165	0.560
RESIDUALS	7.27***	0.000	0.304	0.519

Notes: Test of the null hypothesis of cross-sectional independence. *** indicates rejection at 1 percent. The residuals were generated after an estimation of the fixed effect of the dependent variables on the different determinants.

3.4.2 Panel unit root test results

CD in panel data time series constraints the consistency of first-generation panel unit root tests, which presume cross-sectional independence. Accordingly, we employ Pesaran's (2007) CIPS unit root test to determine whether our variables of interest were stationary under the assumption of CD. The null hypothesis of the CIPS test assumes that all series are non-stationary, and the alternative hypothesis is that some series are stationary. Therefore, when the CIPS statistic is larger than the critical value, the null hypothesis is rejected at the corresponding significance level. The results of the CIPS unit root test are provided in Table 3.2 below.

Table 3.2: CIPS Panel Unit Root Test

Variables	CIPS statistic	
	Level form	First difference
Model with an intercept only		
EC	-1.560**	-4.940***
ES	1.128	-3.656***
PERINC	-0.024	-4.015***
OPEN	-0.580	-4.520***
Model with an intercept and trend		
EC	-1.861**	-3.878***
ES	-0.515	-2.456***
PERINC	-2.524***	-2.514***
OPEN	-0.847	-3.699***

Note: Test of the null hypothesis of the unit root ** and *** indicate rejection of the null at 5 percent and 1 percent levels respectively.

The CIPS statistics are significant for EC at levels: I (0) with both the intercept and the intercept with trend, and for PERINC at levels I (0) with the intercept and trend only. Thus, the null hypothesis of non-stationary is rejected. Nevertheless, the rest of the variables, i.e., ES, PERINC and OPEN are nonstationary and become stationary at first difference. Given the results of the CIPS unit root test, which reveal that the variables are integrated in the order of zero and one, i.e. I (0) and I (1). We apply Pesaran and Smith's (1997;1999)⁸ P-ARDL to explore the long-run cointegration. However, none of the variables of interest is I (2), which may lead to misleading estimations (see Pesaran et al., 2001).

3.4.3 Panel autoregressive distributed lag results

The estimation results of the model (P-ARDL) for the long run and the speed of adjustment are presented in Table 3.3 below for both the MG and the PMG. Since one of the assumptions of the PMG is premised on long-run homogeneity, the MG is considered based on a rejection of poolability and the residual test. Therefore, in Model 2, the estimates indicate that in the long run, all the variables are statistically significant, except economic structure. It is observed that OPEN and PERINC have a positive long-run impact on energy consumption, while ES has a negative insignificant impact on energy consumption in AOECs during the period under study.

⁸ Notwithstanding the contradictory results on the order of integration, we ran the Westerlund's (2007) test. The result however showed that there were at least 2 cointegrating equations, indicating that there is long-run relationship between LNEC, LNPERINC, OPEN, and ES. Therefore, the null hypothesis of no cointegration was rejected. The results are presented under table A-3 of appendix A.

The OPEN estimate indicates that a 10 percent increase would lead to a 0.04 percent increase in energy consumption. This suggests that an increasing influx of trading opportunities could increase commercial activities and thus higher energy consumption. This is in line with the theory and empirical literature (Azam et al., 2015; Dalei, 2016).

The estimate indicates that a 10 percent increase in PERINC would lead to an 8.7 percent increase in energy consumption, which conforms with empirical studies and economic theory (Aziz et al., 2013; Keho, 2016; Kolawole et al., 2017). In AOECs, most energy users find it difficult to pay their bills, which leads to electricity disconnection. Therefore, an increase in income would increase their energy consumption.

The estimate indicates that ES does not influence energy consumption, which is in line with the findings of empirical studies (Kolawole et al., 2017). Zhang et al. (2017) stress that increasing industrial energy consumption is a symbol of economic development. However, the study reveals that this is not the case in the AOECs under review, the reason for which could be inadequate energy infrastructure or household poverty despite these countries being endowed with various energy resources.

In Model 2, the speed of adjustment is negative and statistically significant at the 5 percent level, signifying that in the long run, equilibrium is achievable. This indicates that 13.6 percent of the deviation of the variables from long-run equilibrium is corrected annually following a shock. Hence, it would take approximately 4 years for EC to return to the equilibrium level. These results are in line with those of Kolawole et al.'s (2017) study that reveals that a highly significant speed of adjustment indicates the presence of a stable long run relationship.

Considering the MG estimates, only PERINC was statistically significant for all the specifications at a 10 percent level. The speed of adjustment was significant and correctly signed for Models 1 and 3, signifying a correction of close to 29.4 percent every year following equilibrium for Model 1 only. Table 3 below presents the MG and PMG estimates.

Table 3.3: MG and PMG estimates

VARIABLES	1 MG-1	2 PMG-1	3 MG-2	4 PMG-2
ES	0.0102 (0.00946)	-0.000595 (0.00349)	0.0256 (0.0195)	-0.00422 (0.00280)
OPEN	-0.00188 (0.00509)	0.00373*** (0.00105)	-0.00717 (0.00727)	0.00468*** (0.000904)
PERINC	0.657 (0.528)	0.866*** (0.0764)	0.943* (0.570)	0.935*** (0.0593)
Speed of adj.	-0.294*** (0.0558)	-0.136** (0.0554)	-0.401*** (0.0838)	-0.161** (0.0787)
Constant	0.993 (0.889)	-0.0644*** (0.0244)	1.360 (0.937)	-0.140** (0.0667)
Residual(P-value)	0.000	0.000	0.000	0.000
Normality Test	0.06 [0.9700]	1.57 [0.4552]	0.84 [0.6581]	1.73 [0.4208]
Born & Breitung	0.61	0.09	1.01	0.26
Autocorrelation Test	[0.5410]	[0.9300]	[0.3130]	[0.7970]
Observations	222	222	216	216

Standard errors in (), probability value in []. *, **, *** indicates significance at 10 percent, 5 percent, and 1 percent

Given that the model stability is indispensable to infer any significance, the study interprets the diagnostic tests to ensure that the models are best linear unbiased estimator (BLUE). The results presented in Tables 3.3, 3.4, and 3.5 show that all the models are free from serial correlation and the residuals are normally distributed. This implies that the residuals of the models are random.

As stated earlier, the existence of CD may bias the MG and PMG estimates. Therefore, to overcome this problem, we estimate a CS-ARDL model up to three lags. The results are presented in Table 3.4. The coefficients of ES and OPEN differed. Evidently in Model 5, the coefficient of OPEN indicates a positive and statistically significant relationship with EC at a 10 percent level. This suggests that a 10 percent increase in OPEN would result in about a 0.02 percent increase in energy consumption. This result is similar to that of Fernandes and Reddy's (2020), who find that OPEN has a significant impact on EC in China and Malaysia. Indeed, a rise in international trade increases economic activities. This would lead to higher energy consumption in AOECs and other countries. This is consistent with Cole's (2006) and Shahbaz et al.'s (2014) results but contrary to Sbia et al.'s (2014) findings.

The coefficient of ES indicates a negative and statistically significant relationship with EC at the 10 percent level, which suggests that an increase in the contribution of the industrial sector to GDP would not substantially affect energy consumption in AOECs. A plausible explanation might be that the industrial sector of these countries is dominated by resource-based industries, mining and oil/gas exploitation, which

may not drive energy consumption the same way as manufacturing value-added. In addition, these countries are still dominated by the primary sector despite large oil and gas deposits. For example, in Nigeria, agriculture contributes 21.65 percent to GDP, while the industrial sector and oil/gas contribute 9.91 percent and 8 percent, respectively (NBS, 2018). This suggests that the economies of AOECs, as shown by Nigeria, are still driven by the primary sector with little value-added activities, which limits energy consumption.

The estimate reveals that PERINC does not have a significant effect on energy consumption in all the countries under review, which is contrary to Keho 's (2016), Kolawole et al.'s (2017) and Bohlmann and Inglesi-Lotz's (2021) findings. A probable reason might be that growth in per capita income in the AOECs is driven by oil revenue and price and not by an increase in consumption. This indicates that as the foreign earnings of these countries on oil increase, there is a tendency for households to have more income and thus increase their energy consumption. Nevertheless, the speed of adjustment for all the specified models records an interesting pattern, a correction of close to -1.04 percent occurs less than one year following disequilibrium. Table 3.4 below presents the results of the CS-ARDL.

Table 3.4: CS-ARDL

VARIABLES	5	6	7
	CS-ARDL-1	CS-ARDL-2	CS-ARDL-3
ES	-0.00504* (0.00291)	0.00133 (0.00379)	-0.0502 (0.0402)
OPEN	0.00183* (0.00103)	-0.41e-05 (0.000983)	-0.0136*** (0.00401)
PERINC	0.294 (0.188)	0.307 (0.214)	-0.415 (1.085)
Speed of adj	-1.042*** (0.101)	-1.195*** (0.135)	-1.094* (0.556)
Constant	0.0018 (0.004)	-0.0052 (0.00644)	0.00462 (0.0135)
Normality Test	3.47 [1760]	3.57 [0.1677]	6.81 [0.0532]
Born & Breitung Autocorrelation Test	4.13 [0.1270]	2.37** [0.0180]	3.18 [0.2040]
Observations	204	204	204

Standard errors in (), probability value in []. *, **, *** indicates significance at 10 percent, 5 percent and 1 percent.

The estimate of the CS-DL is presented below in Table 3.5, which shows that there is no feedback from the control variable in the models, which does not make it better than the CS-ARDL. It is evident in Table 3.5 that only PERINC is positive up to the third lag in all the specifications. However, the coefficient of ES maintains its negative effect on energy consumption. Only OPEN does not have any impact on energy consumption in all the models.

Table 3.5: Cross-sectional DL

	8	9	10
VARIABLES	CS-DL1	CS-DL2	CS-DL3
ES	-0.00679* (0.00312)	0.00092 (0.0035)	-0.00394 (0.00517)
OPEN	0.00164 (0.00104)	-0.000061 (0.00134)	-0.006778 (0.006944)
PERINC	0.38491* (0.19833)	0.61522* (0.24915)	0.911231* (0.387578)
Constant	0.00119 (0.00457)	-0.002997 (0.00510)	-0.00451 (0.00574)
Normality Test	4.21 [0.1218]	2.92 [0.2320]	3.75 [0.1537]
Born & Breitung	1.40	1.11	3.66
Autocorrelation Test	[0.1610]	[0.2660]	[0.1610]
Observations	204	204	204

Standard errors in (), probability value in []. *, **, *** indicates significance at 10 percent, 5 percent and 1 percent.

3.5 Summary and Conclusions

The empirical evidence on the determinants of energy consumption provides diverse results due to differences in the dataset, methodology and proxies. Specifically, energy consumption seems to be driven by different factors in both rich and poor economies (see Samuel et al., 2013; Keho, 2016; Fernandes & Reddy, 2021). The current study contributes to the literature by investigating the factors influencing energy consumption in AOECs during the period under review and testing whether factors driving energy consumption in these countries are sensitive to their status as net oil exporters. By using the dataset of six samples of AOECs for the period 1980 to 2018, CS-ARDL and CS-DL modelling approaches are explored to consider the time dynamics, the heterogeneity and the possible problem of CD that may occur, which most studies do not acknowledge.

Trade openness, per capita income and economic structure appear to influence energy consumption in various ways. Specifically, trade openness has a positive and significant effect on energy consumption, and this may be because the AOECs rely on energy exports for most of their foreign earnings. The effect of the economic structure is negative and significant, suggesting that these countries are unable to transform their economies despite huge oil earnings. Similarly, per capita income does not affect energy consumption, indicating that these economies are at a stage where income levels do not drive energy consumption, which may be due to structural rigidity in the energy mix. Most of these findings do not conform to both theoretical expectations and previous empirical findings. These results, therefore, indicate that AOECs may behave

differently when it comes to what drives their energy consumption for a variety of reasons ranging from structural rigidity to their inability to transition to a more efficient and growth-enhancing energy regime.

A plausible reason for why both per capita income and economic structure do not drive energy consumption may be that the sampled countries suffer from Dutch Disease. This is a concept that describes the tendency for resource wealth to stunt economic growth and value-added manufacturing (Smith, 2004). This feature may be linked to these results in two ways. Firstly, a variant of Dutch Disease common to net African oil exporters describes how a combination of poor governance and weak institution stunts economic growth and undermines the ability of these countries to transform themselves structurally despite high oil revenue. As rents from these resources are misallocated, these economies are unable to transform and modernise themselves to increase the demand for energy while the resource windfall is appropriated by the elites. This explanation has been discussed extensively by several studies (see for instance, Sala-i-Martin, 2003). Secondly, rents are not used optimally to drive the economy and change its structure, which means that these economies are unable to make the energy transition that is required to increase their demand for more energy.

Based on the results of the study, some policy recommendations can be inferred. Firstly, since the structure of the economy, which is proxied by the share of the industrial sector, stunts energy consumption, policymakers should use oil earnings to grow manufacturing sectors in these AOECs. The governments of these countries should encourage private investment from both internal and external sources, which could drive manufacturing value-added in these economies. Policymakers can kick start this process by providing an enabling environment for investors in industrial sectors to encourage investment and growth. Secondly, these countries should also accelerate the formulation and implementation of policies to stimulate the switch from fossil fuels to modern renewable energy. Moreover, as stressed by Marina et al.'s (2018) study, countries should create incentives for renewable energy consumption. Thirdly, an important finding of the current study is that per capita income does not have any impact on energy consumption, which may be due to the low level of per capita income in the sampled countries. Hence, these countries need to transform their economies to make economic growth more inclusive and driven by domestic value-added instead of exogenous income the export of primary products.

CHAPTER 4

ON THE GRANGER CAUSALITY BETWEEN ENERGY CONSUMPTION AND ECONOMIC GROWTH: THE CASE OF AFRICAN OIL EXPORTING COUNTRIES

4.1 Introduction

In the study presented in Chapter 3, the ARDL approach is used to explore the determinants of energy consumption in AOECs, which resulted in discovering that trade openness has a positive impact on energy consumption in these countries. This chapter presents the investigation of the connection between energy consumption and economic growth in AOECs, which like the determinants of energy consumption could influence policy. The study aims to ascertain whether economic growth encourages energy consumption or vice versa. Understanding the direction of causality will enable policymakers to formulate suitable policies for sustainable energy consumption and economic growth. However, as stated earlier in this thesis, if increased energy consumption leads to economic growth and poverty reduction, AOECs face the dilemma of increasing fossil fuel consumption, which is the easiest option, or providing access to clean, renewable energy, which would ensure the health of the planet but might not be in sufficient quantities for increasing consumption. Nevertheless, it remains to be seen whether energy consumption does increase economic growth because although many studies maintain this, there is also a lack of consensus about the energy-growth nexus, particularly in developing countries.

Most of the literature identifies a high rate of energy consumption as a major driver of industrialization leading to economic growth because developing countries generally change the structure of their economies from the manufacturing of primary goods to value-added products (Mensah, 2014; Qasim Alabed et al., 2021). Studies indicate a positive relationship between the average living standard of a given country and per capita energy consumption, thereby confirming that energy is an important enabler of economic development (Stern, 2010; Kebede et al., 2010; Saidi & Hammami, 2015; Mukhtarov et al., 2017).

While global data support the hypothesis that energy consumption correlates positively with per capita income, the evidence for energy-rich African countries contradicts this trend (IEA, 2010). In AOECs, per capita energy consumption has not been significantly higher than average (Kebede et al., 2010; IEA, 2014b). This may be due to huge revenues generated from the export of crude oil not being utilised to change the structure of the economies of the AOECs or increase per capita energy consumption (Aryeetey et al., 2012). Thus, the literature argues that natural resource endowed economies tend to grow more sluggishly than resource-poor economies (Sachs & Warner, 1995; Jalloh, 2013). For most AOECs, the

absurdity of the so-called “resource curse”, as manifested in slow growth and low energy consumption despite an abundance of energy resources, remains conundrum (Kolawole et al., 2017).

AOECs are prime examples of how natural resource endowment stunts economic growth, not only because these countries grow slowly like other African countries but also because their growth performance is worse than that of resource scarce African countries (Wolde-Rufael, 2005). A review of the literature on what drives the poor growth performance of resource-rich African economies has identified different probable reasons. These include, Dutch Disease whereby an increase in the growth of a particular sector causes a downturn in another, exchange rate over-valuation, rent-seeking and vulnerability to exogenous shocks (Auty, 2001).

The phenomenon of slow economic growth and low energy consumption despite an abundance of energy resources in AOECs might be explained by a quantitative determination of the causality between energy consumption and economic growth. In other words, if rapid growth in energy consumption is important enabler of economic growth in various countries, as indicated by many researchers (see Akinlo, 2008; Stern & Kander, 2012), **the question is can** AOECs use their vast energy resources to accelerate energy consumption to enable them experience rapid economic development and poverty reduction? (Wolde-Rufael, 2005; IEA, 2014). The answer to this question lies in the causal direction of the relationship of the two variables.

There is, however, another question: if AOECs were to accelerate the consumption of the fossil fuel resource with which they are the most endowed, what could they do to minimise their environmental consequences that dominate the current debate on the energy-growth nexus? (Awodumi and Adeleke, 2016; Pilatowska et al., 2020). As CO₂ emissions from the consumption of fossil fuels causes climate change (Eggoh et al., 2011; Radmehr et al., 2021), the promotion of a switch to clean, green energy is featured in the policies of countries worldwide, as highlighted by the Kyoto and Paris climate agreements. Thus, AOECs would have to include this consideration in their policies for increasing energy consumption and environmental growth if causality lies in that direction.

As stated above, although the causal connection between energy consumption and economic growth is extensively discussed in the literature, consensus has not been reached (see Ozturk, 2010; Omri, 2014). Scholars, such as Shahiduzzaman and Alam (2012) and Bhattacharya et al. (2016), amongst others, argue that energy consumption causes economic growth. However, others, including Abbasian et al. (2010) and Shahateet et al. (2014), report that causality runs from growth to energy consumption. In contrast to these two points of views, Belloumi (2009), Ezzo (2010), Menegaki and Ozturk (2013) and Cakmak (2015) observe a bi-directional causality between energy consumption and growth. However, Ozturk and Acaravci

(2010), Shahateet (2014) and Balcilar et al. (2010) report no causality at all between energy consumption and growth.

Additionally, studies have shown that the constant parameters of linear models are unable to exhibit the nonlinear behaviour of various macroeconomic indicators as they transform to their long-run equilibrium (Cheng-Lang et al., 2010; Ezzo, 2010). This claim is buttressed by Lee and Chang (2008), who argue, based on their examination of Taiwan from 1955 to 2003 using the threshold regression method, that the existence of linearity in the connection between energy consumption and economic growth may not clearly describe the precise effect of energy consumption on growth. Similarly, Chou-Wei et al. (2008) examine eight industrialised Asian economies and one developed economy and establish the presence of nonlinearity in the data, thereby indicating nonlinear Granger causality. Eggoh et al. (2010) and Lee and Chiu (2011) maintain that the absence of a cautious investigation of the occurrence of certain events like structural breaks can cause structural changes in the pattern of energy consumption, which may lead to the misspecification of the long-run properties of a dynamic system as well as insufficient estimation and testing measures. This creates an avenue for a nonlinear rather than linear connection between energy consumption and growth (Lee and Chang, 2008; Mensah, 2014). However, despite the plethora of studies employing nonlinear modelling to account for structural breaks, such as the twin energy crisis in the 1970s and the subsequent 2008/2009 financial crisis, to the best of our knowledge, no study indicates the use of this method to investigate the energy-growth nexus in AOECs.

To contribute new evidence to the literature on AOECs, **the study relies** on Omay et al.'s (2014) novel PSTRVEC technique, the application of which is missing in studies on oil-exporting countries (Mehra, 2007; Damette & Seghir, 2013), particularly AOECs, despite its ability to capture hidden details. Moreover, unlike previous studies, the study employs both linear and nonlinear unit root tests as well as cointegration tests and explore an estimator, which is robust to CD and does not suffer from endogeneity, an issue ignored in most nonlinear studies. The study tests for Granger causality between energy consumption and economic growth in a nonlinear framework, and the outcome of the study is that energy consumption and economic growth are nonlinearly cointegrated, which justifies the use of a nonlinear estimator in the study, especially as the linear tests do not reject the hypothesis of stationarity. Using the PSTRVEC model, the study finds the nonlinearities between the two variables are better explained whenever energy consumption is employed as the transition variable. The regime-wide Granger causality test indicates that in the short run, there is no causality between the two variables, which supports the short-run neutrality hypothesis. Moreover, economic growth Granger causes energy consumption in both regimes, whereas energy consumption Granger causes economic growth only while the former is growing at a faster pace in the long run. The policy implication is straightforward. Given the nature of the nexus between the two variables, reducing

energy consumption can hamper growth in the long run. This supports the use of an efficient approach whereby clean energy should be produced on a large scale to avoid consumption reduction.

The chapter focusses on the causal relationship between energy consumption and economic growth in the AOECs. It is structured as follows: Section 4.2 reviews the related theoretical and empirical frameworks. Section 4.3 discusses the econometrics framework that characterises the PSTRVEC model, the PSTRVEC model specification, the panel cointegration test (nonlinear), estimating the PSTRVEC model and the regime-wise Granger-causality tests. Section 4.4 presents the data and Section 4.5 presents the discussion of the results, while section 4.6 concludes the chapter and makes policy recommendations

4.2 Literature Review

4.2.1 Background to Theoretical Perspectives

There are two strands to the arguments about the connection between energy consumption and economic growth. The first strand is based on two opposing economic theories, which are the neo-classical growth theory and ecological economics. The former focusses on the role energy plays in the production process, while the latter is concerned with energy as a component of the universal habitat and recognizes the limits of the world's environment. According to the neo-classical approach, the quality and quantity of energy consumed and energy-related innovation are drivers of economic growth and the structural transformation of the economy. However, ecological economics does not focus on energy in terms of industrialization and economic growth, merely the relationship between economic and ecological systems (Belloumi, 2009). Many economic growth models do not include energy as factor of production. One of the reasons for this omission might be the cost constraints imposed by energy availability on economic growth before industrialization (Stern & Kander, 2012).

However, economists have extended the basic Solow growth model in an attempt to include energy as an input for production. This extension incorporates some exhaustible resources as inputs in the growth process without explicitly stating whether they are energy or non-energy resources. The extension of the Solow model provides a theoretical basis for the inclusion of energy in the production function using the process of a transition to a modern growth regime as technological changes produce a modern economy (Stern & Kander, 2012). This transition starts with the Malthusian technology whereby output depends on land input and has a decreasing return to both labour and capital. It then proceeds to the Solow technology with constant returns to capital and labour but does not face any natural resource constraints. However, as the economy is modernised and more capital flows into it, the Solow technology starts using fossil fuels in

place of land, but it still does not explicitly model energy in the production function (Hansen & Prescott, 2002).

Substituting land with fossil fuels depends on both the availability and the cost of energy in the economy because as energy becomes cheaper and more available, it will drive the economy towards modernisation and industrialisation. Furthermore, energy will become more important. The use of relatively cheap and abundant energy to drive the production process is identified as energy innovation in the theoretical literature, and it is the major driver of industrialisation and the justification of the inclusion of energy in the Solow model. However, the inclusion of energy in the Solow model requires breaking the constraints imposed by dependence on an organic economic system and a shift towards a modern growth regime (Stern & Kander, 2012).

The extension of the Solow model adds energy to production with an elasticity of substitution of less than one with capital and labour but sets the elasticity of substitution between capital and labour at unity. In addition, the model provides two indices for technological progress instead of a single index of total factor productivity. The first index is labour augmenting, while the second is energy augmenting, and the reason for this is that technological progress improves the efficiency of both labour and energy. Energy augmenting technical change includes all technically efficient production processes of obtaining more output from a given energy input without substituting capital and labour for energy or augmenting the other inputs through technological change (Stern & Kander, 2012). This leads to greater efficiency in energy use and the development of innovative energy.

Empirical evidence seems to support the importance of energy as a crucial input in the production process owing to its momentous role in propelling economic growth in both emerging and industrialised economies (see Ghali & El-Sakka, 2004; Oh & Lee, 2004; Lee & Chang, 2008). For example, Stern and Kander (2012) demonstrate how energy drives industrial growth in Sweden despite the diminishing share of energy in GDP for a century. In the same vein, numerous studies establish the importance of energy in the growth process in emerging economies (Ghali & El-Sakka, 2004; Lee & Chang, 2008; Shafiei et al. 2013; Ha et al. 2018). This indicates that the standard neoclassical growth model can be augmented to include energy as input, which can be validated empirically

The second strand of the theoretical argument is the causal connection between energy consumption and economic growth, which is still a subject of debate (Yu et al., 1985). Wolde-Rufael (2005), focusses on whether energy consumption retards or stagnates industrial growth and whether it is a variable that contributes to sustainable economic growth. These two extreme positions have spurred policymakers and economists to assess the nexus between energy consumption and economic growth and could be

summarised into four distinct hypotheses. Firstly, it is opined that low energy consumption stunts growth, which is known as the *growth hypothesis* (see, for instance, Soytaş & Sari, 2003; Shiu & Lam, 2004; Lee & Chang, 2005; Apergis & Danuletiu, 2012). According to this hypothesis, implementing the appropriate strategies for energy conservation may lead to low energy consumption, which will unfavourably affect economic growth (Behmiri & Manso, 2013). The second hypothesis, known as the *conservative hypothesis*, suggests that policies relating to energy conservation (like eliminating fossil fuels) aimed at conserving energy consumption will have limited or no impact on economic growth (see Narayan & Smyth, 2005; Souhila & Kourbali, 2012; Kalyoncu et al., 2013; Umit & Bulut, 2015). Therefore, energy conservation policies based on energy saving can be applied without hampering economic growth, since energy conservation does not affect it (Hatemi & Irandoust, 2005). The third hypothesis, known as the *feedback hypothesis*, suggests that energy consumption and economic growth are interdependent and influence each other (Zhang & Yang, 2013; Aslan et al., 2014; Ahmad et al., 2016; Wang et al., 2016). Lastly, the fourth hypothesis, the *neutrality hypothesis*, suggests that the duo (energy consumption and economic growth) do not affect each other. This is affirmed by Ozturk (2010) and Li and Leung (2012) who maintain that none of the energy preservation or energy growth policies have an adverse effect on economic growth. Considering this scenario, it would be a better idea to pay attention to policies that focus on the conservation of the ecological system by restraining the country's energy consumption, thereby increasing energy efficiency (Hatemi & Irandoust, 2005; Topolewski, 2021). Because of the diverse views on the nexus between energy consumption and economic growth, it seems pertinent to investigate empirically the causal relationship between these two variables with specific reference to AOECs to unveil energy strategies for these countries.

4.2.2 Rostow's Stages of Economic Growth

Another theoretical way to look at how energy can drive economic growth in AOECs is to link it with the Rostow's stages of economic growth and development theory and determine whether African net oil exporters have used their energy resources to drive development as proposed by the Rostow's Theory. This theory lists five stages of development, namely: (1) Traditional society; (2) Preconditions for take-off; (3) Take-off; (4) Drive to maturity; and (5) Age of high mass consumption. These stages fit the developmental trajectory of most Western economies. Successive studies (see, for instance, Rostow, 1963; Hoffmann, 1963; Rosovsky, 1965; Rumi et al. 2020) have provided empirical evidence to validate this theory for developed economies. Moreover, resource-rich economies like Australia, the United States and Canada have used their abundance of resources to drive economic development at the early stage of their development, thereby following the take-off stage of the Rostow's model as they moved towards industrialisation. This path has not been followed by most countries in Africa, especially the resource rich

economies. This paradox raises an important question. Why are African resource-rich economies not able to drive development through energy abundance?

A growing body of work has attributed this failure to resource curse. This describes a situation where resource-rich economies grow slower than the average. There are different variants of the resource curse ranging from how over-valued exchange rate stunts valued-added manufacturing and misallocated resources to how governance and institutional weakness results in the waste and plundering of resource wealth (Sala-i-Martins et al. 2003; AfDB, 2017). As for AOECs the most likely reason for their failure to drive development through resource wealth is governance and institutional weakness, which has been well-documented in these countries (see, for instance, Sala-i- Martin et al, 2003). It is, therefore, apparent that unlike other resource-rich economies, African net oil exporters have not used their abundance resources to drive industrialisation because of resource curse due to poor governance and weak institutions (Smith, 2004).

4.2.3 Review of the Empirical Literature

Guided by empirical evidence, the link between energy consumption and economic growth is extensively documented in the extant literature on energy economics to gain insight into the nexus between these two variables (Chontanawat et al., 2006; Pokharel, 2007). Therefore, this section reviews the empirical literature on the nexus between energy consumption and GNP, which can be traced to the pioneering work of Kraft and Kraft in the late 1970s, which indicates a uni-directional connection between GNP and energy consumption in the US economy from 1947 to 1974. However, the many later works report often contradictory results for both developed and developing economies (see, for instance, Asafu-Adjaye, 2000; Soytas & Sari, 2003; Mehrara, 2007; Mehadevan & Asafu-Adjaye, 2007; Balat, 2008; Wolde-Rufael & Menya, 2010; Salisu et al., 2018; Sarker et al., 2019; Azam, 2020). A reason for this might be the use of different sampled periods and countries, research methods and model specifications (Ozturk, 2010; Ma et al., 2010; Costantini & Martini, 2010). In addition, most of these studies are limited in scope concerning the application of linear models.

Most macroeconomic variables, as well as the energy-growth nexus, are affected by regime changes in economic events, changes in policy, and exogenous shocks like oil prices, which can cause structural change (Lee, 2005; Raheem & Yusuf, 2015). Therefore, studies, which use nonlinear estimators (Ocal, 2000; Lee & Chang, 2008; 2007), provide a clearer understanding of the nexus, which help policymakers to develop better energy production and consumption strategies (Mensah, 2014; Raheem and Yusuf, 2015).

A growing body of literature concentrates on developed economies using nonlinear estimators. For instance, Hamilton (2003) employs a flexible approach to investigate the nonlinear nexus between the price of oil and GDP in the US from 1949:2 to 2001:4 and finds a nonlinear relationship between a rise in the price of oil price and GDP, as opposed to a decline.

Chiou-Wei et al. (2008) use annual data from 1954 to 2006 for eight Asian countries and the US and a nonparametric statistical method is employed to account for the nonlinear feature of the data. Findings from the study indicate that Indonesia, Taiwan, the Philippines, Hong Kong, and Singapore exhibit a nonlinear causal link between energy consumption and economic growth during the period under study. Furthermore, through the use of both linear and nonlinear tests, countries, such as Thailand, the US and South Korea, are found to have no causal connection between energy and growth. Hong Kong, Indonesia, Malaysia, and Taiwan showed causality running from energy to growth. In addition, the study finds bi-directional causality for Indonesia and Malaysia and uni-directional causality for Hong Kong and Taiwan. The implication is that implementing energy conservation policies may lead to a significant adverse effect on economic growth.

Zhang (2008) examines the nexus between the price of oil and economic growth in Japan between 1957:1 and 2006:4 using the flexible nonlinear model approach initiated by Hamilton (2001) and finds that negative oil price shocks have an adverse effect on economic growth, as opposed to a positive impact. Moreover, the study confirms nonlinearity between the two variables.

Using a Markov switching exponential general autoregressive conditional heteroskedastic (EGARCH) approach, Aloui and Jammazi (2009) examine the correlation between the price of crude oil and stock markets in France, Japan and the United Kingdom (UK) from December 1987 to January 2007. Aloui and Jammazi (2009) find that a rise in the price of oil plays a crucial role in determining both the transition across regimes and stock market returns in the three countries. In a related study, Rahaman and Serletis (2010) examine the asymmetric impact of oil price shocks and monetary policy on macroeconomic activity from 1983:1 to 2008:4. The study use the smooth transition regression (STR) technique, and the results confirm that oil price volatility impacts output growth nonlinearly in the US.

Ajmi et al.'s (2013) research on the nexus between energy consumption and growth in the Group of Seven (G7) economies between 1960 and 2010 explores both Kyrtsou-Labys's (2006) and Hiemstra-Jones's (1994) nonlinear tests. The result from Kyrtsou and Labys's (2006) test suggests that there is uni-directional causality running from energy to growth for both the US and France. The test also reveals that uni-

directional causality runs from GDP to energy for Germany and from energy to GDP for France. However, Hiemstra and Jones's (1994) test shows uni-directional causality running from energy use to GDP for the UK, whilst bi-directional causality between energy use and GDP for France, Canada, the US and Japan. Ajmi et al. (2013) maintain that the policy implication of these inconsistent results, which reflect the situations of specific countries and periods, is that the energy-growth nexus should be viewed with caution.

Omay et al.'s (2014) empirical research, uses the panel smooth transition regression (PSTR) model for G7 economies from 1977 to 2007 and finds nonlinearity both in the long and short-run connections between the energy consumption and economic growth. Moreover, an increase in the consumption of energy causes a rise in the output growth rate in the short run during periods of both economic expansion and depression, and energy consumption does not Granger cause growth in the long run. In the short run, the output growth rate does not cause energy consumption during economic recessions. However, in high growth regimes, the output growth rate increases energy consumption and in the long run, output growth causes an increase in energy consumption.

Bayramoglu and Yildirim (2017), use the asymmetric ARDL bounds test approach to explore the connection between energy consumption and economic growth for the period 1973:1 to 2013:4 in the US. They find that the impact of energy consumption is asymmetric in the long term but not in the short term.

Using a dynamic panel threshold model, Qasim Alabed et al. (2021) examine the connection between energy consumption and economic growth in the Middle East and North Africa (MENA) from 1990 to 2014. They find that energy consumption positively and significantly influences economic growth in a low energy consumption regime. Conversely, it has a negative and significant effect on economic growth in a high energy consumption regime. In addition, CO₂ emissions are positively and significantly connected to economic growth in a low CO₂ emissions regime. Nonetheless, CO₂ emissions are negatively and significantly related to economic growth in a high CO₂ emissions regime. Qasim Alabed et al. (2021) conclude that effective energy policies, such as effective regulations on CO₂ emissions, would improve energy efficiency and replacing fossil fuels with clean energy sources, would reduce global warming.

Deng et al. (2021) explore the relationship between energy consumption and economic and social development in 18 cities in Henan, China between 2006 and 2018 using the extended STIRPAT model and the threshold regression method. They find that economic and social development is positively and significantly associated with total electricity consumption despite regional heterogeneity. Additionally, there is a nonlinear connection between economic and social development and urban energy consumption.

Empirical studies of low-income developing economies, especially in Africa, have different results. For instance, Esso (2010) employed Gregory and Hansen's (1996a, 1996b) approach to test threshold cointegration and the causality relationship between energy consumption and economic growth in African countries from 1970 to 2007. Esso (2010) finds that energy consumption and GDP are cointegrated in Nigeria, Ghana, Cote d'Ivoire, South Africa and Cameroon and confirms that GDP has a positive long-run relationship with energy consumption before 1988, although the impact becomes negative in Ghana and South Africa afterwards. In addition, while results confirm bi-directional causality between energy consumption and GDP for Cote d'Ivoire, uni-directional causality running from GDP to energy is affirmed for Ghana and the Democratic Republic of the Congo (DRC).

Eggoh et al. (2011) reexamine the connection between energy consumption and growth in 21 African economies between 1970 and 2006. The study adopts causality and Westerlund's (2007) panel cointegration tests for two sets of economies, namely net energy importers and exporters. The outcome of their findings establishes a long-run equilibrium correlation between energy consumption, economic growth, labour and capital for each group and the whole set of economies. It could be inferred from these findings that a reduction in energy consumption would cause a decline in growth and vice versa. In addition, the findings suggest that a rise in the consumption of energy could spur an upsurge in growth and vice versa for the two groups. However, the outcomes from Eggoh et al.'s (2011) study, most especially the case of net energy exporters, might not reflect the true picture of AOECs because most of the countries pooled together in the study have different economic structures. Moreover, net AOECs have an enormous dependency on the oil sector which accounts for more than 80 percent of their foreign exchange earnings.

In Nigeria, Ekeocha (2020) re-examine the connection between energy consumption and economic growth from 1999:1 to 2016:4 using nonlinear ARDL and an ARDL-error correction model (ECM) specification. They find a uni-directional causality running from energy consumption to economic growth. Moreover, Raheem and Yusuf (2015) investigate the nexus between energy consumption and economic growth in 12 selected African economies for the period 1980 to 2010, using both linear and nonlinear estimators, which follows Hansen's (1996) procedure of threshold autoregression. The study reveals that the linear model has a misspecification error, which confirms the nonlinear model. Furthermore, the study finds that although a low energy regime retards growth in countries, such as Sudan and South Africa, high energy consumption stimulates economic growth in Algeria, Senegal and Morocco. The only net oil-exporting economies included in the study are, Algeria, Egypt and Gabon, and Nigeria, the largest oil producer in Africa, is

excluded, which suggests that the study may not reflect the situation of all oil-exporting economies in Africa.

The empirical studies show that only a few studies on Africa examine nonlinearity between energy consumption and economic growth, which indicates a lacuna in the energy literature on AOECs because these economies are vulnerable to structural breaks. Firstly, most of these countries operate in an economic environment where energy policies are either unstable or not well-grounded, which has implications for both energy consumption and its causal relationship with economic growth (Wamukonya, 2005; Kolawole et al., 2017). In most cases, these economies tend to tackle their energy problems with inappropriate policies, which may have unintended consequences on energy consumption in these countries. Secondly, the structure of the economies of AOECs makes them vulnerable to both exogenous shocks and global financial/economic crises, which is evident in how their economic performance is defined by the boom-bust cycle of oil price fluctuations. Therefore, to understand how these economies react to structural disturbances, recent econometrics techniques need to be used. Thirdly, these economies are experiencing a transition in their energy consumption patterns, which makes them vulnerable to exogenous shocks.

The study presented in this chapter differs from the studies reviewed above, as focusses on net oil-exporting nations in Africa that depend solely on crude oil exports as their foreign exchange earnings and do not receive much attention in published empirical studies. Although AOECs are homogenous, their sources and patterns of energy consumption differ. Therefore, structural changes are likely to have differential impacts on their energy consumption with their attendant effect on economic growth. In addition, the study captures information on the nonlinear causality between energy consumption and economic growth because, as argued by Payne (2010), the information captured by linear causality tests may not be adequate to reveal the energy-growth nexus.

A few studies, such as those conducted by Lee and Chang (2008) and Ajmi et al. (2013), find nonlinear causality between energy consumption and economic growth in the context of developed economies. However, the reliability of their inferences can be questioned owing to the limitations of the techniques employed. For instance, according to Chiou-Wei et al. (2008), the techniques used may cause over rejection of the hypothesis tested despite its promising outcomes. Karanfil (2009) maintains that looking for research direction from a new perspective or employing new techniques might lead to more consistent and conclusive results. Furthermore, Karanfil (2009) stresses that the application of the same conventional methods on distinct data sets or periods will only bring more confusion to the literature. This argument is supported by Payne (2010) and Ozturk (2010) based on their reviews of empirical studies. They conclude

that new methods and approaches should be adopted to examine the connection between energy consumption and economic growth.

Yalta and Cakar (2012) recommend that future studies should embrace state-of-the-art econometrics techniques and be more focussed as well as detailed in identifying dependable information about the connection between energy consumption and economic growth, which will be possible with robust test results. Therefore, the study presented below employs a PSTRVEC model, which is new to studies on Africa, to account for nonlinear causality. Moreover, this econometrics technique allows smooth switches between the two regimes of boom and bust whilst studying each one independently (see, for instance, Omay et al., 2014; Tipoy et al., 2018) to provide information for suitable energy policies on energy consumption and economic growth in AOECs.

4.3 Econometrics Framework⁹

Following Omay et al. (2014), we estimate the PSTRVEC model for the AOECs and conducted a Granger causality test for energy consumption and economic growth. As enumerated by Terasvirta and Anderson (1992) and extended by Granger and Terasvirta (1993), there are several merits to employing the PSTRVEC model, compared with other methods used to investigate the energy-growth nexus. Firstly, it is theoretically more motivated than simple threshold and Markov regime-switching techniques, which impose an unanticipated change in constants. Secondly, the method also permits the displaying of various forms of nonlinear and asymmetric dynamics regardless of the nature of the transition function. In addition, the method allows the selection of the type of the transition function and the most appropriate switching indicator, compared to other related techniques that coerce both the switching indicator and the a priori function.

⁹These estimators were rooted in the work of Ucar and Omay (2009) and extended by Omay et al. (2014). Therefore, this section draws from the work of Omay et al. (2014).

4.4 PSTRVEC Model Specification

In line with the work of Omay et al. (2014), which is underpinned by that of Gonzalez et al. (2005), the study specifies a PSTRVEC model to study regime-wise connections between energy consumption and economic growth in AOECs as follows:

$$\begin{aligned} \Delta gdp_{it} = & v_1 + \alpha_1 ec_{it-1} + \sum_{j=1}^{p_i} \varphi_{1j} \Delta gdp_{it-j} + \sum_{j=i}^{q_1} \delta_{ij} \Delta enr_{it-j} \\ & + G(S_{it}; \gamma, c) \left[\tilde{\alpha}_1 ec_{it-1} + \sum_{j=1}^{p_i} \tilde{\varphi}_{1j} \Delta gdp_{it-j} + \sum_{j=1}^{q_i} \tilde{\delta}_{1j} \Delta enr_{it-j} \right] + \varepsilon_{1it} \end{aligned} \quad (1)$$

$$\begin{aligned} \Delta enr_{it} = & v_2 + \alpha_2 ec_{it-1} + \sum_{j=1}^{r_i} \varphi_{2j} \Delta gdp_{it-j} + \sum_{j=i}^{s_1} \delta_{2j} \Delta enr_{it-j} \\ & + G(S_{it}; \gamma, c) \left[\tilde{\alpha}_2 ec_{it-1} + \sum_{j=1}^{r_i} \tilde{\varphi}_{2j} \Delta gdp_{it-j} + \sum_{j=1}^{s_i} \tilde{\delta}_{2j} \Delta enr_{it-j} \right] + \varepsilon_{2it} \end{aligned}$$

where $i = 1, \dots, N$, and $t = 1, \dots, T$. N and T represent the cross-section and time dimensions of the panel, respectively. Moreover, gdp_{it} is real GDP together with enr_{it} (energy consumption). The variables gdp_{it} and enr_{it} are in logarithm form. Individual fixed effects are denoted by v_i , while ec_{it} represents the error term, which is estimated from equation (5) (i.e., $ec_{it} = \hat{v}_{it}$). In addition, ε_{it} indicates the error term, which is expected to be a martingale variance in terms of the vector $Z'_{it} \equiv (gdp_{it}, enr_{it})'$ up to time $t - 1$, (i.e., $E[\varepsilon_{it} | Z_{it-1}, Z_{it-2}, \dots, Z_{it-p}, \dots] = 0$). The error term is attributed to a conditional variance, which is constant, (i.e. $E[\varepsilon_t | Z_{it-1}, Z_{it-2}, \dots, Z_{it-p}, \dots] = \sigma_i^2$). Thus, the simultaneous relationship across the errors of the N equations is permitted (i.e., $covb(\zeta_{lit}, \zeta_{ljt}) \neq 0$ for $l = 1, 2$ and $i \neq j$).

Following the works of González et al. (2005) and Omay and Kan (2010), we rely on the following logistic transition function for the time series smooth transgression autoregressive (STAR) models

$$F(S_{it}; \gamma, c) = \left[1 + \exp \left(-\gamma \prod_{j=1}^m (S_{it} - c_j) \right) \right]^{-1} \text{ with } \gamma > 0 \text{ and } c_m \geq \dots \geq c_1 \geq c_0; \quad (2)$$

where $c = (c_1, \dots, c_m)'$ represents the m -dimensional vector of position parameters, and γ is the slope parameter, which indicates the smoothness of the transition between the regimes. Thus, if $m = 1$, we have

a first-order logistic transition function, where the extreme regimes conform with low and high values of s_{it} , in such a manner that the coefficients in Equation (1) transform smoothly from α_j, φ_j and δ_j to $\alpha_j + \tilde{\alpha}_j, \varphi_j + \tilde{\varphi}_j$ and $\delta_j + \tilde{\delta}_j$, respectively, as s_{it} rises. After $\gamma \rightarrow \infty$, the logistic transition function $F(s_{it}; \gamma, c)$ in the first order, changes to an indicator function $I[A]$, and takes a value of 1 when event A happens and 0 otherwise. Consequently, based on Hansen's (1999b) study, the PSTR model is reduced to two regimes.

When $m = 2$, $F(s_{it}; \gamma, c)$ equals 1 for both low and high s_{it} , which minimises at $\left(\frac{c_1+c_2}{2}\right)$. Because of this, if $\gamma \rightarrow \infty$, the PSTR is reduced to a three-regime threshold regression model. If $\gamma \rightarrow 0$, the transition function $F(s_{it}; \gamma, c)$ will reduce to a constant value and hence for any value of m , the PSTR model will collapse to a panel linear regression.

The empirical requirement method for the PSTR encompasses the following steps (Gonzalez et al., 2005; Omay & Kan, 2010; Omay et al., 2014):

1. An appropriate panel linear model should be specified for the data under review.
2. The null hypothesis of linearity should be evaluated against the alternative nonlinear smooth transition form so that if linearity is not accepted, a suitable transition variable s_{it} and the transition function's choice of $F(s_{it}; \gamma, c)$ will be selected.
3. Parameters in the chosen PSTRVEC model should be estimated.

According to Hansen (1999a,b), the existence of unknown nuisance parameters under the null hypothesis are responsible for the complexity of linearity tests. Indeed, the null hypothesis of linearity could be expressed in diverse ways. It is indicated by Omay et al.,(2014) that the equality of the parameters in both regimes could be stated as $H_0: \alpha_j = \tilde{\alpha}_j$ and $\varphi_j = \tilde{\varphi}_j$. Moreover, a specification, such as the alternative null hypothesis $H'_0: \gamma = 0$, also leads to a linear model. To control this issue, Luukkonen et al. (1988) stress that the transition function $F(s_{it}; \gamma, c)$ be replaced with an appropriate Taylor estimation. For instance, a k^{th} order Taylor estimation for the first order logistic function at about $\gamma = 0$ leads to the following equation:

$$\Delta z_{it} = \partial_i + \pi'_0 e c_{it-1} + \sum_{j=1}^{p_i} \phi_{0j} \Delta z_{it-j} + \sum_{h=1}^k \tilde{\pi}'_h s_{it}^h e c_{it} + \sum_{h=1}^k \sum_{j=1}^{p_i} \tilde{\phi}_{hj} s_{it}^h \Delta z_{it-j} + e_{it} \quad (3)$$

where $z'_{it} \equiv (gdp_{it}, enr_{it})'$ and $\partial, \pi', \phi, \tilde{\pi}$ and $\tilde{\phi}$ are functions of the parameters $\mu_i, \alpha, \varphi_j, \delta_j, \tilde{\alpha}, \tilde{\varphi}_j, \tilde{\delta}_j, \gamma$, and c_i , and e_{it} comprise the original disturbance term, ξ_{it} and the error correction term resulting from the Taylor estimation. Therefore, evaluating $H_0: \gamma = 0$ in Equation (1) is the equivalent to evaluating the null

hypothesis. $H_0: \eta_1 = \eta_2 = \eta_3 = 0$ where $\eta_i \equiv (\tilde{\pi}_i, \tilde{\phi}_i)$ in Equation (3). This test could be performed through a Lagrange multiplier (LM) type test that estimates F-distribution and is expressed as follows:

$$LM = \frac{(SSR_0 - SSR_1)/kp}{SSR_0/(TN - N - k(p + 1))} \sim F(kp, TN - N - k(p + 1)) \quad (4)$$

where SSR_0 and SSR_1 are the total of squared residuals under both hypotheses (null and alternative). In selecting the appropriate transition variable, S_{it} , LM statistics could be computed for various candidates, and the one for which the p-value of the test statistic is considered the smallest can be chosen. The next stage in the specification of a PSTR model is to select between $m = 1$ and $m = 2$. The decision rule, according to Terasvirta (1994), is based on the order of the tests in Equation (3). For instance, using the auxiliary Equation (3) with $k = 3$, the null hypothesis $H_0^*: \eta_1 = \eta_2 = \eta_3 = 0$ is formulated. If the null is not accepted, $H_{03}^*: \eta_3 = 0$ is tested, then $H_{02}^*: \eta_2 = 0 | \eta_3 = 0$ and $H_{01}^*: \eta_1 = 0 | \eta_2 = \eta_3 = 0$. Ordinary F tests are used to test the hypotheses, represented by F3, F2, and F1 respectively. Following the decision rule, if the p-value equivalent to F2 is the smallest, then an exponential transition function is chosen, but if it is otherwise, a first-order logistic function should be considered.

4.4.1 Panel Cointegration Test (nonlinear)

In the study, we specify the following connection between energy consumption and economic growth:

$$y_{i,t} = \alpha_i + \beta_i X_{i,t} + u_{i,t} \quad (5)$$

where $y_{i,t}$ and $X_{i,t}$ represent the observable I (1) variables. In addition, $\beta = (\beta_1, \dots, \beta_m)$ denotes the parameters to be estimated, while $u_{i,t}$ denotes the stochastic term. Furthermore, $y_{i,t}$ represents a scalar, $X_{i,t} = (x_{1,t}, x_{2,t}, \dots, x_{m,t})$ denotes an $(m \times 1)$ vector and lastly, α_i represents the fixed effect/heterogeneous intercept. If there is an $(n \times 1)$ vector, $Z'_{i,t} \equiv (y_{i,t}, X'_{i,t})$ is created as $(z_{i,t} = z_{t-1} + \varepsilon_{i,t})$, where $\varepsilon_{i,t}$ denotes independent and identically distributed (i.i.d) variables including mean zero, the positive definite variance-covariance matrix Σ and $E|\varepsilon_{i,t}|^s < \infty$ for some $s > 4$.

The stochastic term $u_{i,t}$ in Equation (5) is assumed to be trend stationary, hence, the vector $z_{i,t}$ is expected to be co-integrated. In addition, according to Engle and Granger (1987), $u_{i,t}$ is referred to as equilibrium error. In the study, $u_{i,t}$ is treated as a nonlinear model:

$$u_{i,t} = \gamma_i u_{i,t-1} + \phi_i u_{i,t-1} F(u_{i,t}, \theta_i) + \xi_{i,t} \quad (6)$$

where $\xi_{i,t}$ denotes a zero-mean error, with $F(u_{i,t}, \theta_i)$ representing a smooth transition function of $u_{i,t-1}$. According to Kapetanios et al., (2006), imposing $F(u_{i,t}, \theta_i) = 0$ or $F(u_{i,t}, \theta_i) = -\gamma_i \mu'_i$, where μ'_i denotes

the vector of level parameters, should result in a traditional linear cointegration equation. In addition, following the studies of Kapetanios et al. (2003, 2006), Ucar and Omay (2009) and Maki (2010) on nonlinear cointegration, we surmise that the function of transition $F(u_{i,t}, \theta_i)$ is exponential.¹⁰

$$F(u_{i,t}, \theta_i) = 1 - \exp[-\theta_i u_{i,t-1}^2] \quad (7)$$

where if $u_{i,t}$ denotes a stochastic mean zero, then together with $\theta_i \geq 0$, the function of transition $F(u_{i,t}, \theta_i)$ is restricted between zero and one and symmetrically U-shaped around zero. Therefore, the parameter θ_i decides the haste of the transition between the two extreme values of the transition function $F(u_{i,t}, \theta_i)$. The exponential transition function permits adjustment to the long-run equilibrium irrespective of the size of the disequilibrium. Substituting Equation (7) in (6) and re-parameterising the resultant equation obtains the following regression model:

$$\Delta u_{i,t} = \varphi_i u_{i,t-1} + \psi_i u_{i,t-1} [1 - \exp\{-\theta_i u_{i,t-1}^2\}] + \varepsilon_{i,t} \quad (8)$$

where, assuming $\theta_i > 0$, the next step is to ascertain the speed of mean reversion. Supposing $\varphi_i \geq 0$, this procedure might display unit root or combustible behaviour for small values of $u_{i,t-1}^2$. Nevertheless, assuming the deviations from the equilibrium are adequately huge, for big values of $u_{i,t-1}^2$, it would have steady dynamics, and for this reason, it would be geometrically ergodic and indicate that $\varphi_i + \psi_i < 0$.¹¹

Applying $\varphi_i = 0$, would indicate that $u_{i,t}$ comes after a unit root process in the middle regime. In addition, this would permit a likely serial relationship of the error term in Equation (8). Hence, the following regression model would be obtained:

$$\Delta u_{i,t} = \psi_i u_{i,t-1} [1 - \exp\{-\theta_i u_{i,t-1}^2\}] + \sum_{j=1}^p \rho_{ij} \Delta u_{i,t-j} + \varepsilon_{i,t} \quad (9)$$

The cointegration test could be built on a definite parameter θ_i , where the null hypothesis of no cointegration is zero and, according to the alternative hypothesis, is positive. However, direct testing of the null hypothesis is not feasible, given that ψ_i is not recognised in a null hypothesis. In line with Luukkonen et al.'s (1988) study, the transition function in Equation (7) could be replaced with its first-order Taylor estimation, which could be consistent with the null hypothesis, and result in the following regression model:

$$\Delta u_{i,t} = \delta_i u_{i,t-1}^3 + \sum_{j=1}^{p_i} \rho_{ij} \Delta u_{i,t-j} + e_{i,t} \quad (10)$$

¹⁰ Both the second order logistic as well as the exponential functions provide an increase in the same additional regression for the assessment of cointegration (see Kapetanios et al., 2003; 2006).

¹¹ The ergodicity of such nonlinear procedures is explained by Kapetanios et al.(2003); Ucar and Omay (2009)

where $e_{i,t}$ contains the initial shocks $\varepsilon_{i,j}$ in Equation (9), including the error term from Taylor's approximation. This model makes room for the distinct lag order p_i for each unit in the Equation (10). Therefore, the null hypothesis (no cointegration) and the alternative (cointegration) could be expressed as follows:

$$H_0: \delta_i = 0, \text{ for all } i, \text{ (which indicates no cointegration)}$$

$$H_o: \delta_i < 0, \text{ for some } i, \text{ (indicating nonlinear cointegration)}$$

Empirically, a few augmentation terms could be chosen in the supplementary regression in Equation (10), employing any appropriate lag selection technique. The cointegration test could be estimated using a standard statistical average of individual cointegration tests covering the entire panel (Ucar & Omay, 2009). In line with Kapetanios et al., (2003) and Ucar and Omay (2009), the test for the cointegration of the i -th individual is the t-statistics for evaluating $\delta_i = 0$ in Equation (10), which is defined as follows:

$$t_{i,NL} = \frac{\Delta u_i' M_t u_{i,-1}^3}{\hat{G}_{i,NL} (u_{i,-1}' M_t u_{i,-1})^{3/2}} \quad (11)$$

where $\hat{G}_{i,NL}^2$ is the consistent estimator such that $\hat{G}_{i,NL}^2 = \frac{\Delta U_i' M_t u_i}{T-1}$, $M_t = I_T - \tau_T (\tau_T' \tau_T)^{-1} \tau_T'$ with $\Delta u_i = (\Delta u_{i-1}, \Delta u_{i-2}, \dots, \Delta u_{i-T})'$ and $\tau_T = (1, 1, \dots, 1)$. In addition, at the satisfaction of the non-variance property and the presence of moments, the normal standardisation of the \bar{t}_{NL} statistic is attained as follows:

$$\bar{K}_{NL} = \frac{\sqrt{N}(\bar{t}_{NL} - E(t_{i,NL}))}{\sqrt{\text{var}(t_{i,NL})}} \quad (12)$$

where $\bar{t}_{NL} = N^{-1} \sum_{i=1}^N t_{NL}$, $E(t_{i,NL})$ and $\text{var}(t_{i,NL})$ are the anticipated value and variance of the $t_{i,NL}$ statistic indicated in Equation (11).

Amongst the common problems experienced in panel regression is the existence of CD. This may arise, according to Omay and Kan (2010), from spatial correlations, omitted global variables, spillover effects and common unnoticed shocks, for example. In addition, the existence of correlated errors from individuals drives the conventional unit root and cointegration testing method that is valid in panel data analysis. The evaluation of the performance of the restricted sample from the obtainable tests indicates that all tests experience serious size falsifications when panel members are cointegrated (see Banerjee et al., 2004). However, tests, which are built on the regression equation together with unobserved and/or observed features as the supplementary regressors, are expected to control this issue, and thus we take cognisance of the studies of Moon et al. (2004), Pesaran (2007), Bai et al. (2009) and Omay and Kan (2010).

Bootstrap-based tests can be used to accomplish decent sized properties (see Maddala & Wu, 1999; Chang, 2004; Ucar & Omay, 2009). Thus, before employing the testing method, the existence of CD must be taken into consideration, for instance, by adopting the test technique suggested by Pesaran (2004). This can be expressed as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left[\sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \right] \quad (13)$$

In Equation (13), $\hat{\rho}_{ij}$ represents the estimated coefficient for the correlation between the error terms of i and j .

As in Ucar and Omay's (2009) study, the sieve bootstrap technique is used to overcome the possible problem of CD. After recognising the cointegration and the long-run connection between the variables, we estimate the panel error correction (PEC) model. We follow Omay et al.'s (2014) example and use a PSTRVEC model to observe a regime-wise relationship between energy consumption and economic growth in AOECs. The justification for this is that not only is the modification to the long-run equilibrium level unaffected but also the dynamic interdependence between the variables, which might be nonlinear.

4.4.2 Estimating PSTRVEC models and regime-wise Granger-causality tests

After the selection of the transition variable and the form of the transition function, the PSTRVEC model is assessed by exploring a suitable nonlinear least squared estimator. The optimum algorithm is unburdened using starting values that are relatively good. When the values of the parameters γ and c in the transition function are fixed, we have the linear parameters, $\mu_i, \alpha, \varphi_j, \delta_j, \tilde{\alpha}, \tilde{\varphi}_j, \tilde{\delta}_j$, in the PSTRVEC model, and hence it is estimated using the least squares. For a nonlinear least square, an appropriate way of obtaining logical starting values is to conduct a two-dimensional grid exploration over the parameters γ and c and choose those values that reduce the panel sum for the squared residuals.

Estimating panel regression models is often associated with the problem of CD. In Equation (1), we permit a simultaneous relationship across the errors of the equations in the model, (*i.e.* $cov(\zeta_{lit}, \zeta_{ljt}) \neq 0$ for $l = 1, 2$ and $i \neq j$). The problem of CD may probably be serious in the case of oil-exporting countries owing to the links between the sampled economies. To overcome the issue of CD, we follow Omay et al. (2014) and solve the energy and growth equations for all sampled economies and instantaneously employ a nonlinear generalised least squares (GLS) estimator iteratively. Moreover, in the same manner, we rectify the issue of endogeneity bias.

As indicated by Li (2006) and Omay et al. (2014), Granger causality test can be performed separately for each regime by selecting transition variables, such as the growth rate of energy consumption and the logistic

transition function (first order). The null hypothesis (no Granger causality) is expressed for both low and high growth as stated in Table 4.1 below:

Table 4.1: Granger causality tests

Energy consumption does not Granger cause economic growth during periods of low growth. (i.e., economic growth < some threshold value) in the short run	$H_0: \delta_1 = 0$
Energy consumption does not Granger cause economic growth during periods of low growth (i.e., economic growth < some threshold value) in the long run	$H_0: \alpha_1 = 0$ and/or $H_0: \alpha_1 = \delta_1 = 0$
Energy consumption does not Granger cause economic growth during periods of high growth (i.e., economic growth > some threshold value) in the short run	$H_0: \delta_1 = \hat{\delta}_1 = 0$
Energy consumption does not Granger cause economic growth during periods of high growth (i.e., economic growth > some threshold value) in the long run	$H_0: \alpha_1 = \hat{\alpha}_1 = 0$ and/or $H_0: \alpha_1 = \hat{\alpha}_1 = \delta_1 = \hat{\delta}_1 = 0$
Economic growth does not Granger cause energy consumption during periods of low growth (i.e., when economic growth < some threshold value) in the short run	$H_0: \varphi_2 = 0$
Economic growth does not Granger cause energy consumption during periods of low growth (i.e., economic growth < some threshold value) in the long run	$H_0: \alpha_2 = 0$ and/or $H_0: \alpha_2 = \varphi_1 = 0$
Economic growth does not Granger cause energy consumption during periods of high growth periods (i.e., economic growth > some threshold value) in the short run	$H_0: \varphi_2 = \hat{\varphi}_2 = 0$
Economic growth does not Granger cause energy consumption during periods of high growth periods (i.e., economic growth > some threshold value) in the long run	$H_0: \alpha_2 = \hat{\alpha}_2 = 0$ and or $H_0: \alpha_2 = \hat{\alpha}_2 = \varphi_2 = \hat{\varphi}_2 = 0$

Source: Author's adaptation from Omay et al. (2014)

4.4.3 Data

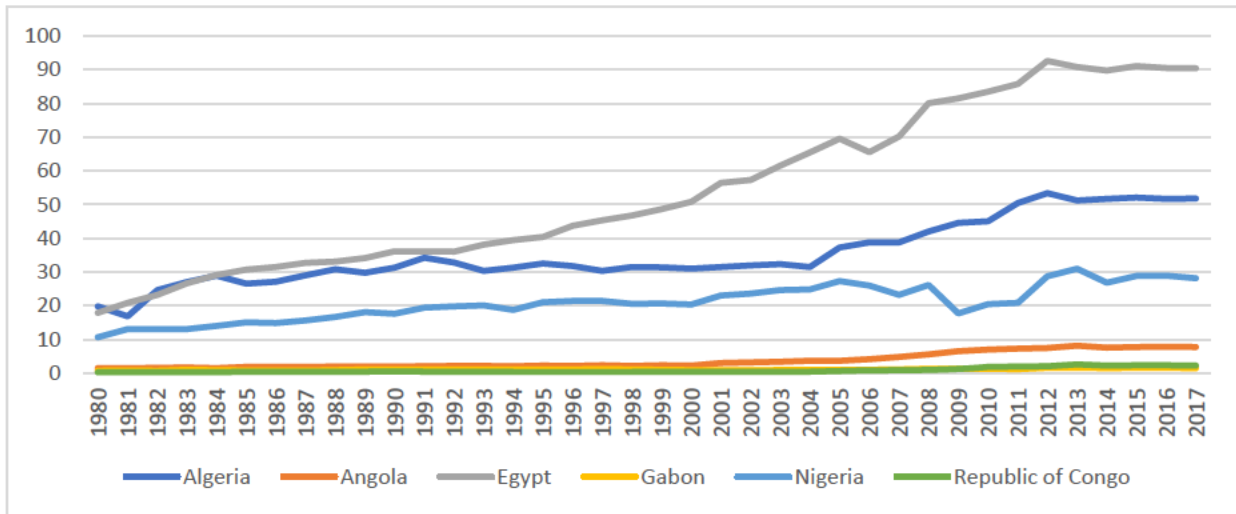
Banerjee and Silvestre (2015) explain the importance of using panel data techniques to increase the power of testing for unit roots and cointegration. This is particularly relevant when the time dimension is

constrained because of the unavailability of a long series of dependable time series data. Thus, we favour the use of panel data over cross-sectional or time-series data in the study, which uses panel data for six net AOECs¹² for the period 1980-2017. The setting of the sample period and the selection of the countries are premised on the availability of data and the period being long enough to account for any reforms in the energy sectors of the AOECs. Aligning with the research of Mehrara (2007), Damette and Seghir (2013) and Omay et al. (2014), the total primary energy consumption in million tonnes of oil equivalent (Mtoe) is a proxy for energy consumption. Primary energy consumption comprises energy consumed from its direct source. The data is available from the US EIA (2018) website. In the study, the real GDP, which is expressed as the value of all goods and services produced at constant general prices for each country yearly, with 2010 as the base year for all the AOECs under review, is adopted as a proxy for economic growth. The study includes this variable to examine the impact of energy consumed on the total output of the AOECs' economies in line with Ouedraogo's (2013) study. The data on the real GDP variable are available on the World Bank Development Indicators website (World Bank, n.d.). Both energy consumption and real GDP variables are expressed in natural logarithms, **to minimise heteroscedacity and to convert the variables from rates and absolute terms into the same numerical structure.**

Figures 4.1 and 4.2 below describe the relationship between energy consumption and real GDP. The figures reveal that while energy consumption shows an increasing trend, the movement of real GDP is relatively flat and does not align with the growing trend of energy consumption. The scatter plots in Figure 4.3 below show the relationship between the real GDP and the energy consumption of the countries under review. The relationship depicted in the graphs represents the co-movement of the two variables. The scatter plots reveal that the relationship between the variables differs across countries. The relationship between real GDP and energy consumption in Algeria, Angola, Egypt, Nigeria and the Republic of the Congo is positive. However, the graph shows that the relationship in Egypt is close to perfect. In other words, there is an almost one-to-one relationship between the real GDP and energy consumption in Egypt. The relationship between the variables is more positive in Algeria than it is in Angola, Nigeria and the Republic of the Congo. In addition, there is almost no relationship between real GDP and energy variables in the Republic of the Congo. However, in Gabon, the relationship between real GDP and energy is negative. **The reason for no correlation between energy consumption and real GDP in Angola, Gabon and the Republic of the Congo could be link to high consumption of fossil fuel energy sources in these countries. This can further be affirmed in the figures 2.4, 2.6 and 2.8.**

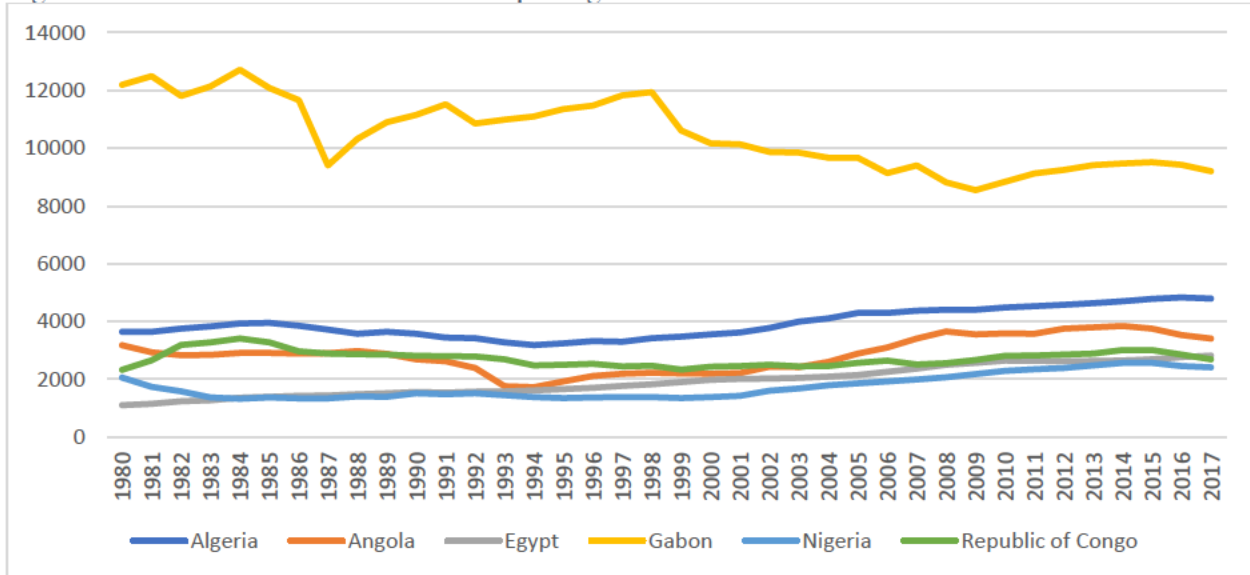
¹² The selected countries were; Algeria, Angola, Egypt, Gabon, the Republic of the Congo and Nigeria (Libya and Sudan were left out owing to the paucity of data). The selected countries represent the bulk of oil production on the Africa continent based on the Organization of Petroleum Exporting Countries benchmark classification index of 2017.

Figure 4.1: Energy Consumption in six African Oil Exporting Countries



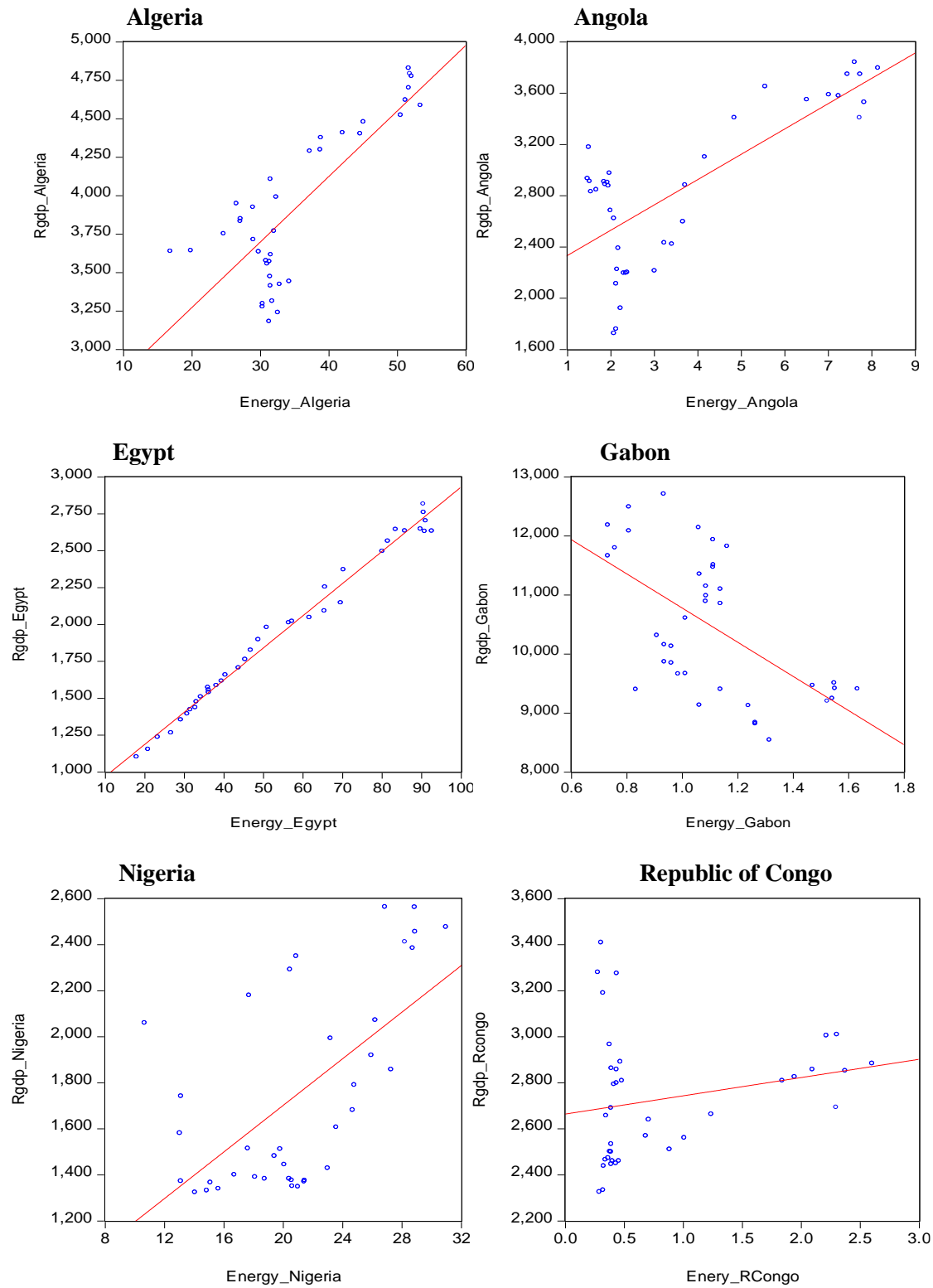
Source: Author's Computation (2022)

Figure 4.2: Real GDP in six African Oil Exporting Countries



Source: Author's Computation (2022).

Figure 4.3: Relationship between the real GDP and the energy consumption in six AOECs



Source: Author's Computation (2022)

4.5 Empirical Results and Discussion

We start by testing the existence of unit roots in our variables of interest. The first and prime step of the investigation of the connection between energy consumption and economic growth requires that all the variables are integrated of the same order, notably, I(1). Linear Im-Pesaran-Shin (IPS) tests were conducted in line with those used by Im et al. (2003), and the nonlinear Ucar and Omay (UO) tests are performed in line with those used by Ucar and Omay (2009)¹³. The results of the IPS tests suggest that both variables (energy consumption and economic growth) have a unit root. However, the UO tests indicate that the variables have a unit root only for the intercept specification. Therefore, we treat these two variables as having a unit root. The next step is to conduct tests for cointegration. The empirical results are presented in Table 4.2 below.

Table 4.2: Linear and nonlinear panel unit root tests

Variables	IPS Test				UO Test			
	Intercept		Intercept & Trend		Intercept		Intercept & Trend	
	W – stat	t – stat	W – stat	t – stat	W – stat	t – stat	W – stat	t – stat
Gdp	0.762	-1.231	-1.400	-2.632	1.572	-1.539	-1.889***	-2.551***
Enr	0.496	-1.346	-0.892	-2.461	1.099	-1.981	-1.977***	-2.457***

Note: The “***” represents rejection of the null hypothesis of unit root at 1percent employing bootstrap p-value, at a maximum of 12 lags.

We first estimate a fixed-effects model with two selected variables of interest. The results are stated below (with the t-statistics in parentheses).

$$gdp_{i,t} = -0.1729enr_{i,t} \\ (-7.558)$$

$$enr_{i,t} = -1.3426gdp_{i,t} \\ (-7.558)$$

In the regression models, both energy consumption and economic growth are negative and significant. Next, we draw out the residuals from these equations to perform the linear and nonlinear cointegration tests. Moreover, we perform the Pesaran (2004) CD test on the residuals and obtain a test statistic of 5.3402 with a p-value of (0.00), thereby rejecting the null hypothesis of cross-sectional independence. Following this outcome, we compute the p-values of the cointegration tests, using the bootstrap technique. While the linear

¹³ We employed both IPS and UO tests based on the expectations that the entities in the panel were cross sectionally independent.

test is built on Pedroni's (1999) cointegration test, the nonlinear test is built on Equation (8). The results are provided in Table 4.3 below.

Table 4.3: Linear and nonlinear cointegration tests

	Linear Test		Nonlinear Test	
	W – stat	t – stat	W – stat	t – stat
$\mu_{i,t} = gdp_{i,t} + 0.1729enr_{i,t}$	-0.517	-0.973	0.977**	-0.721**
$\mu_{i,t} = enr_{i,t} + 1.3426gdp_{i,t}$	-0.545	1.918	0.987**	2.056**

** denotes significance at the 5 percent level using bootstrapped p-values, at a maximum of 4 lags with 800 bootstraps.

The linear tests fail to reject the null hypothesis of no cointegration in the two models. However, the nonlinear cointegration test rejects it. These results prove the superiority of nonlinear tests over their counterparts because, based on linear tests, we would conclude that the variables are not cointegrated. Omay et al. (2014) caution against the low power and size properties of linear tests. Thus, energy consumption and economic growth are nonlinearly cointegrated in the study. Next, we estimate the nonlinear panel regression model. The first step to be taken is to estimate a linear panel vector error-correction (PVEC) model and test for linearity. The results are presented below (with the t-statistics in parentheses):

$$\Delta gdp_{i,t} = \nu_1 - 0.008ect_{i,t-1} + 0.348\Delta gdp_{i,t-1} + 0.065\Delta enr_{i,t-1}$$

(-2.535) (5.869) (2.174)

$$\Delta enr_{i,t} = \nu_2 - 0.0007ect_{i,t-1} - 0.106\Delta enr_{i,t-1} + 0.132\Delta gdp_{i,t-1}$$

(0.369) (-1.583) (0.983)

In both models, the error correction terms appear negative and at the same time significant. The growth equation, for instance, suggests that a rise in the consumption of energy has a significant positive effect on economic growth in the short run. Likewise, the energy equation suggests that, a rise in growth rate has an insignificant effect on the consumption of energy in the short run. Next, we test for linearity using the PVEC model. This is done individually for both equations, with energy consumption, economic growth and error terms employed as transition variables. If energy consumption is chosen as the transition variable, this means that nonlinearities between economic growth and energy consumption will be described by the rate of change in energy consumption. If economic growth is chosen as the transition variable, this will indicate that the nonlinearities are elucidated by the business cycle phases. If the error term is chosen, then

the variances from equilibrium will be accountable for the nonlinearities. The selection of the transition variable is based on the variable that strongly rejected linearity. The results of the tests are provided below in Table 4.4.

Table 4.4: Results of linearity tests

Model	Transition Variables		
	$\Delta enr_{i,t-2}$	$\Delta gdp_{i,t-2}$	$ect_{i,t-2}$
	F-Test	F-Test	F-Test
GDP	26.110***	75.370***	22.730***
ENR	108.800***	2.325	6.811***

Linearity test against a PSTR specification, *** denotes significance at 1percent level.

From the estimations, the strongest rejection occurs when economic growth is employed as a threshold variable in the economic growth equation. However, the strongest rejection also occurs when energy consumption is used as the threshold variable in the energy consumption equation. To come to a decision, we employ energy consumption as the threshold variable because its test statistic (108.800) is larger than the one for economic growth (75.37). Next, the form of the transition function was determined. Building on Equation (12), Building on equation (12), $m = 2$ is selected only if F_2 records the strongest rejection of the null hypothesis, and $m = 1$ is selected for other alternatives. The different F-tests are presented in Table 4.5 below.

Table 4.5: Selection of transition

	F_1	F_2	F_3
	F-test	F-test	F-test
GDP	26.110***	13.060***	8.701***
ENR	108.800***	53.900***	35.620***

*** denotes the significance at 1 percent level

All three tests strongly reject the null hypothesis. However, for both models, F_1 strongly rejects the null hypothesis. Therefore, the logistic transition function with $m = 1$ is the most suitable function. The results imply the existence of one threshold and two extreme regimes.

The PSTRVEC model is estimated by employing the nonlinear GLS estimator iteratively to prevent probable CD and produce an estimate with the maximum likelihood. To hasten the process of estimation,

values for the slope of the transition function (γ) and the threshold (c) are obtained by employing a grid-search method. The results are presented as follows:

$$\begin{aligned} \Delta gdp_{i,t} &= \nu_1 - 0.002ect_{i,t-1} + 0.085\Delta gdp_{i,t-1} + 0.076\Delta enr_{i,t-1} \\ &\quad (-0.240) \quad (1.723) \quad (0.591) \\ &+ [0.365ect_{i,t-1} - 0.066\Delta gdp_{i,t-1} - 0.013\Delta enr_{i,t-1}] \cdot G(s_{i,t-1}; \gamma, c), \\ &\quad (5.162) \quad (-1.362) \quad (-1.326) \\ \Delta enr_{i,t} &= \nu_2 - 0.049ect_{i,t-1} - 0.128\Delta gdp_{i,t-1} - 0.122\Delta enr_{i,t-1} \\ &\quad (-2.819) \quad (-1.150) \quad (-0.699) \\ &+ [0.315ect_{i,t-1} + 0.045\Delta gdp_{i,t-1} + 0.085\Delta enr_{i,t-1}] \cdot G(s_{i,t-1}; \gamma, c) \\ &\quad (5.290) \quad (0.378) \quad (2.323) \\ G(\Delta enr_{i,t-1}; \gamma, c) &= \left(1 + \exp \left(\underset{(0.805)}{-11.101} (\Delta enr_{i,t-1} - \underset{(8.356)}{0.033}) \right) \right)^{-1} \end{aligned}$$

As discussed earlier, the regime change in the PSTRVEC model was built on the transition function $G(\Delta enr_{i,t}; \gamma, c)$. The threshold value c is evaluated to be 3.3 percent. In the same vein, while Regime I occurs when the growth rates of energy are lower than the threshold, Regime II correlates with higher growth rates. Given our change of the log of energy consumption and the sign on the threshold, Regime I corresponds to an increase in energy consumption. The estimated $\gamma = 11.101$ indicates that there is a smooth transition between the two regimes.

Considering the estimates from the PSTRVEC model and first taking into account the growth equation, in the low growth regime, when energy consumption is decreasing and is denoted as $G(\Delta enr_{i,t}; \gamma, c) \approx 0$, the evaluated coefficient of the error term is -0.002 and statistically insignificant. This result indicates that economic growth does not revert to deviations from a long-run equilibrium level in low growth regimes. Furthermore, the evaluated coefficient of the lagged energy consumption is 0.076 and statistically insignificant. In expansionary periods, when energy consumption is increasing and is represented as $G(\Delta enr_{i,t}; \gamma, c) \approx 1$, the evaluated coefficient of the error term is 0.363 (= -0.002+0.365) and statistically significant. Similarly, the estimated coefficient of the lagged energy consumption is 0.063 (= 0.076-0.013), indicating that the impact of energy consumption on growth rate falls moderately in high growth regimes.

We now consider the energy equation. The evaluated coefficient of the error term is -0.049 and is statistically significant, indicating that energy consumption responds to a deviation from long-run equilibrium in low growth regimes. The magnitude is smaller, suggesting that about 4.9 percent of the disequilibrium in the short run is corrected in the long run. Moreover, the estimated coefficient of the output is -0.128, but not significant in low growth regimes. This suggests that a fall in economic growth at a 10 percent level of significance decreases energy consumption by 12.8 percent in the short run when there is an increase in economic growth. The estimated coefficient of the error correction becomes positive (-0.049 + 0.315=0.266) and statistically significant in expansionary periods. This indicates that there is no adjustment to deviation from long-run equilibrium. For economic growth, it turns negative (-0.083), but the estimate is not significant. Again, a decrease in economic growth does not increase energy consumption in expansionary periods (high growth regimes).

We now conduct the regime-wise Granger causality test. According to Omay et al. (2014), the test is carried out by focusing on the lagged explanatory variable for short-run causality and by focusing on the speed of adjustment for long-run causality. In addition, we perform a joint test of the error term and lagged explanatory variables for the stronger form of Granger causality. The different tests are carried out for Regime I, $G(\Delta nr_{i,t}; \gamma, c) \approx 0$ and for Regime II, $G(\Delta nr_{i,t}; \gamma, c) \approx 1$ separately. The outcomes of the tests are presented in Table 4.6 below.

Table 4.6: Regime-wise Causality Tests

Dependent Variables				
Source of causation	Δ GDP		Δ ENR	
	Low growth regime	High growth regime	Low growth regime	High growth regime
Short run				
Δ ENR	1.32	0.89		
Δ GDP			0.35	1.39
Long-run				
ECT	0.06	15.05***	7.95***	22.04***
Joint (short and long run)				
ECT / Δ ENR	0.69	21.68***		
ECT / Δ GDP			7.32***	12.96***

***, **, * denotes respectively the significance at 1 percent, 5 percent, and 10 percent levels

The results of the short-run Granger causality tests in both low and high growth regimes indicate that neither energy consumption nor economic growth Granger causes each other. This supports the neutrality hypothesis, suggesting the same as the conservation hypothesis. Any decrease in energy consumption does not have an impact on economic growth and vice versa. The plausible reason for these results might be that these economies are in the first stages of development, in which the production process is still on conventional technological approaches (see Telatar, 2014). The results are inconsistent with those of Omay et al. (2014) whereby in the short run, energy consumption Granger causes economic growth both in recessionary and expansionary regimes. Moreover, in Omay et al.'s (2014) study, economic growth does not Granger cause energy consumption in recessionary regimes but does in expansionary regimes. Omay et al.'s (2015) study of developing countries also contradicted our results in the short run by indicating bi-directional Granger causality in both regimes (recessionary and expansionary), which corroborates the feedback hypothesis, suggesting that both energy consumption and economic growth are mutually determined and affected.

Considering our results of the long-run estimates, we can infer that energy consumption Granger causes economic growth only in a high growth regime, which suggests that conserving energy consumption would

slow down economic performance. Evidence consistent with ours is provided by Bayramoglu and Yildirim's (2017) study of the US, Ekeocha's (2020) investigation of Nigeria and Qasim Alabed et al.'s (2021) research on the MENA region. However, our findings contradict those of Esso (2010), who maintains that in the five countries in Africa, which were not energy-dependent economies before 1988, the implementation of an energy conservation strategy will not hamper economic growth. Perhaps, differences in sample periods, the estimation approach adopted and the choice of proxy variables for energy consumption and economic growth could explain this inconsistency.

Our study finds that economic growth Granger-causes energy consumption in the long run in both low and high growth regimes. These results are similar to those of Kraft and Kraft (1978), who find a uni-directional causality from economic growth to energy in the US. In addition, Kraft and Kraft (1978) concur with other studies' results, such as those of Soytas and Sari (2006) in Germany, Al-Iriani (2006) in 6 countries of the Gulf Cooperation Council (GCC), Mahadevan and Asafu-Adjaye (2007) in net energy importing developed economies and net energy exporting developing economies and Mehrara (2007) in 11 oil-exporting countries. Ozturk's (2010) study of a panel of 51 countries, categorised according to their income level, finds that only lower income countries exhibit uni-directional causality running from economic growth to energy consumption, which is in line with our results. Furthermore, Omay et al.'s (2015) empirical research on 8 developing countries (Azerbaijan, Bulgaria, Kazakhstan, Latvia, Lithuania, Romania, the Russian Federation and Turkey) reveals results similar to ours, as did Topolewski's (2021) study. Moreover, in our study, the joint test, which combines both the short and long-run causality tests, supports the long run result. However, this evidence differs from that of Omay et al. (2014) whereby the joint causality test indicates that the effect of energy consumption on economic growth stems from short run results.

4.6 Summary and Conclusions

A large and growing body of empirical literature examines how to explore better ways of understanding the correlation between energy consumption and economic growth, which can drive optimal energy policy. In the study explained above, to contribute to the literature, we examine the causal connection between energy consumption and economic growth in a sample of six net AOECs: Algeria, Angola, Egypt, Gabon, the Republic of the Congo, and Nigeria from 1980 to 2017, using a PSTRVEC model. Thus, the short and long-run connection between the two fundamentals within a nonlinear framework is modelled to remedy CD and Granger causality tests are run.

The estimate of the nonlinear PSTRVEC model with two extreme regimes corresponding to periods of low and high energy consumption clearly describes the energy-growth nexus. In the short run, energy consumption does not drive economic growth in the sampled countries, especially when the economic

growth rate is very low (a low regime). This result fits into our theoretical framework, which proposes that energy consumption is likely to drive economic growth through the transition to innovative energy consumption, although in a low growth regime it may not drive energy consumption. Moreover, as our sampled countries are not industrialised, energy consumption may have a limited impact on economic growth, as the study results suggest that there is no significant decrease in energy consumption when growth is very low. In addition, energy consumption does not influence economic growth when the latter is falling, which suggests that AOECs should strive to maintain a high growth regime for energy consumption to drive economic growth.

The Granger causality tests, which are carried out individually for the high and low growth regimes, show that in the short run, neither energy consumption nor economic growth affects each other in both regimes, suggesting that the neutrality hypothesis is valid in this situation. This reveals that in the short run, the connection between energy consumption and economic growth is not sensitive to economic growth and vice versa in both regimes. In the long run, energy consumption stimulates economic growth in a high growth regime but, not in a low growth regime. In this regard, conservative policies on energy consumption may have a negative impact on economic growth. This implies that energy consumption has a significant effect on economic growth, and an increase in energy consumption causes a rise in output in a high growth regime. However, in a low growth regime, energy consumption has an insignificant effect on economic growth in AOECs. Nevertheless, economic growth spurs energy consumption in both regimes, which supports the conservation hypothesis. As restrictive energy policies do not have any negative effect on growth parameters, in this case, application of conservative energy policies combined with sustainable economic strategies will possibly be more beneficial. This implies that economic growth is driven by an increase in energy consumption in the AOECs and is sustained over a long period.

Our results provide some insights into how AOECs can use their energy abundance to drive economic development and structural change using the classical Rostow's stages of economic development. Moreover, the results have shown that energy consumption does not drive economic growth when the latter is expanding sluggishly or not at all. This implies that for these countries to drive maximum benefits from their resource wealth they need to use it to drive their transition to industrialisation at a level that appropriates Rostow's stages of development. They need to transform themselves structurally to reach the take-off stage where they can increase their investment and start a process of self-sustaining and self-generating economic growth. As our results imply, high growth rates need to be sustained over a long period before it can lead to both industrialisation and the total transformation of the economy. This transformation will also show how the economy makes the energy transition as it embraces industrialisation and makes the transition from underdevelopment to modern economy.

The study results suggest that AOECs that are already experiencing economic growth should formulate long-term policies to stimulate energy consumption to ensure further development. Policies to improve energy consumption and consider the environment should add more renewable sources to the energy mix, thereby using increasing the use of efficient technology, affordable and sustainable energy. In AOECs experiencing low economic growth, policies for stimulating investment in the various sectors of the economy might lead to increased energy consumption in the long run, which would in turn improve economic growth. However, for AOECs to have an effective energy policy, they should develop their institutions, thereby improving their ability to manage energy and monitor the implementation of policies. Furthermore, AOECs should have a policy of collaboration whereby they share best practices and experiences in the utilisation of energy resources, energy management and the development of energy technology, which will ultimately increase energy consumption and economic growth.

CHAPTER 5

OIL PRICE SHOCKS, ENERGY CONSUMPTION AND ECONOMIC GROWTH IN AFRICAN OIL EXPORTING COUNTRIES

5.1 Introduction

In Chapter 3, key macroeconomic variables that influence energy consumption are examined. The findings reveal that trade openness has a positive and significant relationship with energy consumption. In Chapter 4, the direction of causality between energy consumption and economic growth is investigated. In this chapter, the relationship between oil price shocks, energy consumption and economic growth, which has policy implications, is studied.

Empirical evidence has shown that developing countries require increasing energy stock to keep pace with the expansion of their economies (see for instance, Cantore et al, 2016) because, as indicated by the results of the study explained in Chapter 4, in countries that are already experiencing growth, increasing energy consumption, by stimulating industry, for example, leads to further economic growth in the long run (Stern & Kander, 2010; Esen & Bayrak, 2017; Li et al., 2019). However, oil price is subject of shocks. These shocks could affect the rate of energy consumption, income and economic growth in oil exporting countries.

The price of crude oil tends to fluctuate unexpectedly, which is a problem experienced since the 1970s (see Baumeister and Kilian, 2016; Herrera et al., 2019). Historically, oil prices are driven by demand, which is affected by factors, such as an increase in the precautionary demand for crude oil and the demand for, industrial commodities (Kilian and Park, 2009; Zhao et al., 2016), and supply, which is affected by factors, such as production disruptions, disasters and increased production costs (Kilian & Park, 2009). A crude oil price shock, which is a sudden increase in cost often accompanied by a decrease in supply affects energy consumption in that consumers stop buying or shift to other forms of energy.

The impact of the price of oil on economic activities is recognised in the literature (see Hamilton, 1983; Kilian & Vigfusson, 2011; Timilsina, 2015). Oil prices are a major predictor of income and economic growth in oil exporting countries. However, oil price shocks have a detrimental effect on economic growth (Kilian, 2008), which leads to consumers shifting to energy alternatives and government measures to mitigate the negative consequences (Jbir & Zouari-Ghorbel, 2009). AOECs are particularly affected by oil price shocks since oil is a major source of revenues¹⁴. These revenues form a large part of their budgets. Therefore, oil price shocks have performed impacts on these economies. Several episodes of oil price shocks and a corresponding slow-down in economic growth have been recorded in Africa's oil exporting countries. For instance, the very recent experience of oil price shocks between 2015-2017, plunged the

¹⁴ For instance, 80 percent of Nigeria's export is crude oil

Nigerian economy into a recession with annual GDP growth slowing down to -1.6 percent and 0.8 percent in 2016 and 2017, respectively (World Bank, 2019). Similarly, following the global oil price shock of 2015, Angola¹⁵ experienced a recession in 2016, 2017 and 2018 with GDP growth rates of -2.5 percent, -0.1 percent, and -2.0 percent respectively (World Bank, 2019). These statistics reveal that oil price shocks could result in substantial detrimental effect on growth and economic activities of AOECs.

The literature on the relationship between oil price and economic growth lacks consensus (see for instance, Akira, 2012; Kurihara, 2015), and empirical analysis of the interactions between oil price shocks, energy consumption and economic growth is scant. The available studies either focus on energy consumption and economic growth or oil price shocks and economic growth. Hence, empirical work on the interaction between oil price shocks, energy consumption and economic growth would provide some insights. Additionally, several existing studies on oil price shocks and economic growth focus on developing countries but do not take into account the peculiarities of AOECs, which could influence their findings. Furthermore, these studies use methods, such as vector autoregressive models (VARs) and structural vector autoregressive models (SVARs) to examine the effect of oil price shocks on energy consumption or oil price shocks on economic growth. However, a VAR is sizable, as it estimates a large number of parameters, which may have an impact on the impulse response functions that may be imprecise. To circumvent this, the study described in this chapter uses a Bayesian structural vector autoregressive model (BSVAR), which allows the incorporation of prior belief in the estimation, thereby leading to a reduction of parameters by shrinking unnecessary deeper lags. Thus, the impulse response estimation tends to be more precise.

The study contributes to knowledge by empirically investigating the effects of oil price shocks on energy consumption and economic growth nexus in AOECs using the BSVAR estimating technique. Studies show that the effect of oil prices on the economies of many net oil importing countries is largely different in the case of net AOECs (see, for instance, Wesseh & Lin, 2017; Taghizadah-Hesary et al. 2019). The current study focusses on six net AOECs using time series from 1980 to 2018. As these countries are both exporters of crude oil and importers of refined products, the effect of oil price shocks may vary amongst them across time and space.

Following this introduction, the remainder of this chapter is organised as follows. Section 5.2 presents the review of literature relevant to the study. In Section 5.3, the methodological framework of the BSVAR, the estimation procedure, the selection of the variables and the sources of the data are presented. The results

¹⁵ Second largest producer of crude oil in Africa after Nigeria

and the discussion of the findings are provided in Section 5.4, while the summary and conclusions are in Section 5.5.

5.2 Literature Review

The relationship between oil price shocks and macroeconomic performance has received considerable attention in the literature since the article by Hamilton (1983). Thereafter, the empirical literature on this theme has produced diverse evidence. While some studies conclude that oil price shocks have a significant effect on macroeconomic behaviour, others are of the opinion that the effect of oil price shocks on the economy is not significant. Findings of earlier studies largely depend on whether an economy is a net oil exporting or net oil importing country. Studies, such as those of Moshiri and Banihashem (2012), Ftiti et al (2014) and Rotimi and Ngalawa (2017), focus on oil exporting countries. However, the studies conducted by Zhang (2008), Wesseh and Lin (2018) and Gershon et al (2019) centre on oil-importing countries.

Moshiri and Banihashem (2012) investigate the asymmetric effects of oil price shocks on the economic growth from 1970 to 2009 of six OPEC oil exporting countries using VAR model and find that a decrease in oil prices leads to revenue cuts and the stagnation of the economy. Moreover, an increase in oil prices increases revenue but does not generate sustainable economic growth. Ftiti et al (2016) adopt Priestley and Tong's (1973) frequency approach to assessing the impact of oil prices on the economic growth of the four major OPEC countries (the United Arab Emirates, Kuwait, Saudi Arabia and Venezuela) between 3 September 2000 and 3 December 2010. Oil prices are observed to have a significant impact on economic growth in the countries of interest, especially during a downturn in the global business cycle. Sadeghi (2017) examines the effect of government size on how output responds to oil price shocks in 28 oil-exporting countries from 1990 to 2016. The results suggest that positive oil price shocks accompanied by an increase in government size lead to a larger output. Using panel VAR, Rotimi and Ngalawa (2017) examine the processes of the transmission of the effect of oil price shocks on economic performance through the monetary policy in AOECs between 1980 and 2015. The result indicates that oil price shocks have a large impact on the economic performance of AOECs and the process of transmission is through monetary policy. Using a PSTR model, Alimi and Aflouk (2017) confirm that the relationship between oil price shocks and economic growth in Gulf Corporation Council (GCC) economies from 1980 to 2015 is not linear, as it is affected by the threshold effect in GCC economies, and the effect of oil price shocks is greater below the threshold level.

Some studies have explored the oil price shocks and economic growth nexus for African oil importing countries. Following the non-linear estimation procedure developed by Hamilton (2001) and using quarterly data from 1957Q1 to 2006Q4, Zhang (2008) finds that a negative oil price shock has a greater impact on

growth than a positive one, which confirms the existence of non-linearity between oil price shocks and economic growth in Japan. Gershon et al. (2019) utilise VAR model to investigate the implications of oil price shocks on developing net oil importing countries between 1980 and 2015. The results show that an oil price increase would temporarily increase GDP per capita in the short run for the selected countries. Focusing on Liberia, a small open net oil-importing economy, from 1980 to 2015 using unrestricted VAR model, Wesseh and Lin (2018) show that between January 1996 and June 2017, a rise in the price of oil stimulates GDP. Using VAR, Wen et al (2018) find that oil price shocks have a positive effect on China's short-run economic growth, although, in the long run, monetary policy shocks affect the relationship between crude oil price shocks and economic growth.

Cross and Nguyen (2017) employ time varying Bayesian vector autoregressive (BVAR) model to assess the oil price shocks-GDP nexus in China between 1992Q1 and 2015Q3. The study reveals that the impact of oil price shocks on the country's output is temporal. Nevertheless, oil supply shocks generate a negative effect on China's GDP growth, while oil demand shocks have a positive effect. Using a VAR model, Cunado et al. (2015) show that the type of oil price shocks determines responses to Asian economic activities and inflation from 1997Q2 to 2014Q3. While oil supply shocks have a limited impact on Asian economic activities, globally-driven oil demand shocks have significant impact.

Several studies, such as Menegaki and Ozturk (2013), Shahateet (2014) and Cakmak (2015) have empirically assessed the relationship between energy consumption and economic growth to test the energy-growth hypothesis. Apergis and Payne (2009) employ a heterogenous panel cointegration test and ECM to examine the energy-growth nexus in 11 countries of the commonwealth of independent states (CIS) between 1991 and 2005. The result shows unidirectional causality from energy consumption to economic growth in the short-run and bi-directional causality from energy consumption to economic growth in the long-run. Hence, the feedback hypothesis between energy and economic growth is confirmed.

By categorising selected African countries into net oil exporters and net oil importers, Eggoh et al. (2011) find a long run relationship between energy consumption and growth for the two groups of countries from 1970 to 2006. Further evidence shows that increasing energy consumption increases economic growth and vice-versa. Using a system generalised method of moments (GMM) to analyse data on selected African countries between 1971 and 2017, Lawal et al. (2020) reveal a significant positive relationship between electricity consumption and economic growth. The stimulating effect is evident after a threshold level of 0.48 percent. Using Bayer and Hanck's (2013) joining co-integration approach, Pesaran et al.'s (2001) bounds test and Kripfganz and Schneider's (2018) critical values and approximate p-values, Bekun et al. (2019) explore the relationship between energy consumption and economic growth in South Africa between

1960 and 2016, while considering carbon dioxide emission. The result supports a long run relationship between the variables and one way causality from energy use to economic growth. Which validates the energy-led growth hypothesis.

By bifurcating energy into renewable and non-renewable sources, Kahia et al. (2016) establish a long run relationship between GDP and both renewable and non-renewable energy consumption from 1980 to 2012 in MENA net oil-exporting countries. Evidence from the PEC model indicates a unidirectional causality from economic growth to renewable energy consumption in the short run. However, in the long run, the result shows bidirectional causality. To study a sample of 38 top renewable energy consuming countries from 1991 to 2012, Bhattacharya et al. (2016) employ heterogeneous panel estimation techniques. The results indicate that renewable energy consumption has a positive and significant impact on economic growth.

A few studies have assessed the link between oil price shocks and energy consumption. For instance, Agbanike et al. (2019), who use the ARDL approach to examine the interaction between oil price, energy consumption and carbon dioxide emission in Venezuela between 1971 and 2013. Their result reveals that an increase in crude oil prices increases energy consumption, which in turn increases carbon dioxide emissions with a negative effect on economic growth. Using data for developed countries covering the period 1971 to 2006, Lee and Chiu (2011) analyse the short and long run relationship between oil prices, nuclear energy consumption and economic growth. The panel cointegration result shows that oil prices have a positive and long run effect on nuclear energy consumption. In addition, a unidirectional causality running from oil price to economic growth to nuclear energy consumption is found. However, using the Toda-Yamamoto long-causality test method, Payne (2012) shows no causal relationship between oil prices, renewable energy consumption and real GDP in the US from 1949 to 2009.

The literature review reveals **that there are differ results**. This is owing to different datasets, methodologies and periods. The study unfolded in this chapter contributes to the debate by analysing oil price shocks and their impact on the energy consumption and economic growth of AOECs.

5.3 Research Methodology

Using a BSVAR, the current study analyses the impact of oil price shocks on energy consumption and economic growth in a sample of six net AOECs, which depend on crude oil for earnings and thus are vulnerable to oil price shocks in terms of energy consumption and economic growth (World Bank, 2018b). According to Cushman and Zha (1997) and Kim and Roubini (2000), BSVAR, which is an extension of VAR and SVAR, allows the analysis of a multivariate relationship among variables (see Sims & Zha, 1998; Waggoner & Zha, 2003). In addition, the model allows the creation of diverse lags, as the impact of oil

price shocks might not be felt immediately and involves the use of the datasets of each selected country and, a time series data estimation.

Furthermore, SVAR model allows the incorporation of theories, unlike other models that maybe atheoretical in nature. The model built is therefore structural. The SVAR technique is used by many researchers, including those conducting oil-related studies (see Berkelmans, 2005; Elbourne, 2008; Ncube & Ndou, 2011). Omolade and Ngalawa (2014) use the technique to explore whether the exchange rate regime matters in the monetary policy transmission mechanism and the growth of the manufacturing sector in Libya and Nigeria. Ahmed and Wadud (2011) employ the model to examine the role of oil price shocks in macroeconomic activities and the monetary responses of the Malaysian economy. Kose and Baimaganbetov (2015) employ the model when investigating the asymmetric impact of price shocks on Kazakhstan's macroeconomic dynamics. Sek and Lim (2016) use the SVAR model to examine the effect of oil price shocks on the domestic inflation of groups of oil importing and exporting countries. Chiweza and Aye (2018) utilise to assess the effects of oil price uncertainty on economic activities in South Africa. Algaheed (2020) uses SVAR to test the effects of symmetric oil price shocks on the government expenditure-real exchange rate nexus in a Saudi Arabian oil-based economy. In addition, empirical literature linked to banking and finance use the model (see, for instance, De Graeve and Karas, 2010).

Although SVARs and VARs are commonly used, they tend to be overparameterized due to the number of lags that can be large. For example, a VAR with 2 variables and 2 lags will have 10 parameters. This is sizable and has an impact on the degrees of freedom. As a consequence, the IRFs and forecasts from a VAR can be imprecise, especially in large models (Blake and Mumtaz, 2012). The Bayesian technique allows to avoid this by using shrinkage. Indeed, with a BVAR, it is possible to decrease the impact of further lags, reducing by the same token, the number of parameters to be estimated. The BVAR allows the obtention of impulse response functions that are more precise.

The BVAR combines a prior, stemming from the researcher belief prior seeing the data, and the likelihood. Thus, the researcher updated his prior belief with the likelihood of the data to obtain a posterior. This process, from the Bayes' rule, can be written as:

$$P(\beta, \sigma^2 | Y_t) = \frac{P(Y_t | \beta, \sigma^2) P(\beta, \sigma^2)}{P(Y)}$$

where $P(Y_t | \beta, \sigma^2)$ represents the likelihood of the data, $P(\beta, \sigma^2)$ is the prior, $P(Y)$ the marginal density of the data and $P(\beta, \sigma^2 | Y_t)$ the posterior. Y_t, β and σ^2 represent the data, the estimated parameters and the

variance respectively. To conduct inference, given that the marginal density of the data is constant, the above rule can be rewritten as:

$$P(\beta, \sigma^2 | Y_t) \propto P(Y_t | \beta, \sigma^2) P(\beta, \sigma^2)$$

This formula indicates that the posterior is proportional to the prior multiplied by the likelihood.

The current study uses a BSVAR to investigate the effects of oil price shocks on energy consumption and economic growth in AOECs. This has not been done, to the best of our knowledge. Various studies have used both VAR and SVAR. Mahmud (2009) employs SVAR model to analyse oil price shocks and monetary aggregates in Nigeria economy. Farzanegan and Markwardt (2009) use VAR to investigate the impact of oil price shocks in Iran. Ahmed and Wadud (2011) use the SVAR to examine the effect of oil price shocks on macroeconomic activities and corresponding monetary responses in Malaysia. Akinyele and Ekpo (2013) employ VAR to investigate the connection between oil price shocks and macroeconomic performance in Nigeria. Khan and Ahmed (2014) utilise the SVAR model to explore the macroeconomic effects of oil and food price shocks in Pakistan. Hoang et al., (2019) use SVAR model to investigate the interaction between energy consumption and oil shocks in the US. Ajayi et al. (2019) employ VAR to assess the effect of oil price shocks on energy consumption in Nigeria. Liu et al., (2020) utilise SVAR to examine the effects of oil price shocks on macroeconomic fluctuations in China. Yildiz et al., (2021) explore the use of SVAR technique to investigate the effect of oil price shocks on the South African economy.

5.3.1 A Structural Vector Autoregressive Model with Block Exogeneity

To estimate our model, we use a SVAR with oil price being exogenous. The reason is that the AOECs in the study are small enough to affect global oil prices. After omitting constant terms, a standard SVAR can be expressed as:

$$Ax_t = \sum_{l=1}^p B_l x_{t-l} + \varepsilon_t, \quad (1)$$

where x_t denotes an $n \times 1$ column vector of endogenous variables at time t . A and B_l are $n \times n$ parameter matrices, ε_t denotes an $n \times 1$ column vector of structural disturbances, p denotes the lag length and $t = 1, \dots, T$, where T represents the sample size. The structural disturbances have zero mean and are both serially as well as mutually uncorrelated. For the sake of clarity, we rewrite Equation 1 in the following matrix notation:

$$Ax_t = Fz_t + \varepsilon_t, \quad (2)$$

where $z_t = [x_{t-1} \dots x_{t-p}]'$ and $F = [B_1 \dots B_p]$. Here z_t represents the $np \times 1$ column vector of all lagged variables and F denotes the $n \times np$ matrix of all lagged coefficients. Given the block exogeneity assumption, we can rewrite the SVAR estimate in Equation (2) as follows:

$$\begin{pmatrix} A_{11} & 0 & 0 \\ A_{21} & A_{22} & 0 \\ A_{31} & A_{32} & A_{33} \end{pmatrix} \begin{pmatrix} x_{1t} \\ x_{2t} \\ x_{3t} \end{pmatrix} = \begin{pmatrix} F_{11} & 0 & 0 \\ F_{21} & F_{22} & 0 \\ F_{31} & F_{32} & F_{33} \end{pmatrix} \begin{pmatrix} x_{1t-1} \\ x_{2t-1} \\ x_{3t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{pmatrix} \quad (3)$$

where x_1 , x_2 and x_3 represent respectively oil price (OP), energy consumption (EC) and economic growth (GDP). The ordering of the variables is simple. OP is the first variable as it is exogenous. This means that it is affected only by its own lags. EC is the second variable and GDP is the last one. All our variables entered the estimation at first difference given that they are not stationary¹⁶.

5.3.2 Bayesian Approach to Imposing Restrictions and Estimation

Following the identification scheme explained in the previous subsection, we allow simultaneous interactions in the contemporaneous connection between the variables of interest. The higher degree of simultaneous interaction makes our structural model less restrictive and hence builds on the existing SVAR models as exemplified by Cushman and Zha (1997) and Kim and Roubini (2000). In addition, a total of 3 zero restrictions on the contemporaneous-coefficient matrix, A , would exactly identify the model more, realistically than would any recursive VAR model and some SVAR models that have a lower degree of simultaneous interaction.

Owing to the high degree of simultaneous interaction in our over-identified SVAR model, the shape of the posterior density of the parameters tends to be non-Gaussian. Because of this, the widely used importance sampling method of obtaining finite-sample inferences becomes inefficient, as identified by Leeper et al. (1996) and Zha (1999). Following Waggoner and Zha (2003), who highlight how the use of the importance sampling method in a simultaneously interacted over-identified models results in misleading inferences. Hence, we do not use the existing importance sampling method used by Cushman and Zha (1997) and Kim and Roubini (2000).

To avoid the problem experienced due to the simultaneity involved in our over-identified SVAR model, we estimate the model using the Bayesian Gibbs sampling technique used by Waggoner and Zha (2003), who incorporate prior information into the VAR, as suggested by Sims and Zha (1998). The advantage of this approach is that it delivers precise statistical inferences with a high degree of simultaneous interactions

¹⁶ The unit root test for the different variables can be found in appendix A-5.

amongst the contemporaneous variables for models with restricted variance-covariance matrices of the residuals and those with restrictions on lagged coefficients.

We apply the Gibbs sampling technique to our SVAR model. We assume a_i to be the i th row of the contemporaneous-coefficient matrix, A , and f_i to be the i th row of the lagged-coefficient matrix, F , defined Equation (2), where $1 \leq i \leq n$. We let ϕ_i be any $n \times n$ matrix of rank q_i and R_i be any $k \times k$ matrix of rank r_i . Hence, the linear restrictions on the contemporaneous-coefficient matrix, F , can be summarised as follows:

$$\phi_i a_i = 0, i = 1, \dots, n \quad (5)$$

$$R_i f_i = 0, i = 1, \dots, n \quad (6)$$

Following Waggoner and Zha (2003), we assume that there are non-degenerate solutions to the above problems. Furthermore, we define an $n \times q_i$ matrix U_i the columns of which form an orthonormal basis for the null space of ϕ_i , and a $k \times r_i$ matrix V_i the columns of which form an orthonormal basis for the null space R_i . Therefore, a_i and f_i , which, respectively, are the rows of A and F , will satisfy the identifying restrictions (5) and (6) if, and only if, there are a $q_i \times 1$ vector g_i and a $r_i \times 1$ vector h_i such that

$$a_i = U_i g_i, \quad (7)$$

$$f_i = V_i h_i \quad (8)$$

Our model becomes much easier to estimate by forming priors on the elements of g_i and h_i , because the original parameters of a_i and f_i can be easily recovered through the linear transformation of U_i and V_i . Waggoner and Zha (2003) establish that using this method, simulations can be carried out on an equation-by-equation basis, which vastly reduces the computational burden of the problem. To obtain the finite-sample inferences of g_i and h_i , and their functions, i.e., impulse response, it is, therefore, compulsory to simulate the joint posterior distribution of g_i and h_i . To do this simulation, we follow Waggoner and Zha's (2003) two-step Gibbs sampling method¹⁷. Firstly, we simulate draws of g_i from its marginal posterior distribution, and also, given each draw of g_i , we simulate h_i from the conditional posterior distribution of h_i . Secondly, the simulation requires draws from the multivariate normal distribution. Hence, the first step is straightforward, owing to the restrictions preventing over-identifying being imposed on the contemporaneous-coefficient matrix, A , which restrict the reduced-form covariance matrix, Σ .

¹⁷ For comprehensive explanation of the algebra as well as the algorithm. See Waggoner and Zha (2003).

5.3.3 Data, Sources of Data and Measurement of variables

The study relies on annual time series data from 1980 to 2018 for the six-developing oil-exporting countries. The period represents major oil price shocks due to events, such as the 1997 Asian financial crisis, the 2000 interest rate reduction resulting in a bust in the housing market and construction industries, the 2007/2008 global financial crisis and the 2014 fall in oil price triggering a disparity, which might have affected the energy consumption and economic growth of AOECs. The preference for the oil price shock, energy consumption and economic growth variables inspired by the research conducted by Jimenez-Rodriguez and Sanchez (2005), Mehrara and Mohaghegh (2011), Ftiti et al., (2016) and Ajayi et al., (2019). The choice of data start and cut-off **dates for the study is subject to the availability of the selected data from their sources** (WDI; US EIA, 2018).

5.3.3.1 Brief Description of Variables

(a) Crude Oil Prices

The oil price is the cost in US dollars per barrel of crude oil in the global oil market. This study uses the price of Brent crude oil, which is a benchmark for oil in a wider market, such as the Middle East, Europe and Africa (OPEC, 2018) and comprises different blends, such as Brent Sweet Light Crude, Oseberg crude and Forties crude. Based on IMF (2010), Ftiti et al. (2019) affirm that the Brent crude oil index accounts for about 65 percent of the daily global oil production. We treat the oil price variable in the model as exogenous because it is externally determined. It is added to the model because oil price variations may account for fluctuations in energy consumption and economic growth in energy-dependent economies like AOECs.

(b) Energy Consumption

Energy consumption is proxied by the total primary energy consumption in Mtoe. Bhattacharyya (2011) describes primary energy consumption as a measure of the total domestic demand for it is finally used as electricity, petrol or coal briquettes, for example. The inclusion of this variable in the study is to assess the impact of oil price shocks on the total primary energy consumed in AOECs in line with Ajayi et al.'s (2019) study and to understand its link to economic growth and reduction of poverty through jobs creation, for example.

(c) Economic Growth

In our study, economic growth is proxied by real GDP, which is the yearly value of the goods and services produced by an AOECs economy under review in a specific period and adjusted for inflation with 2010 as the base year. Following the works of Jimenez-Rodriguez et al., (2004), Gadea et al., (2016) and Ftiti et al.

(2016), the study incorporates this variable to examine the effect of the exogenous oil price shock variable on it.

5.4 Estimation and Empirical Findings

Our study analyses the impact of oil price shocks on energy consumption and economic growth. We next present the IRFs obtained following a BSVAR.

5.4.1 Impulse Response Functions Analysis

In this section, we present the IRFs results following the BSVAR estimation. They are shown in Figure 5.1 to 5.18 below for each country.

5.4.1.1 IRF Analysis in Algeria

In figure 5.1, the energy consumption shock has positive and significant effect on output growth. This implies that as energy growth increases, output growth is enhanced in Algeria. The IRF further revealed that the response of output growth to positive variation in energy consumption consistently falls and tends towards the equilibrium. However, the shock does not impact oil price. In figure 5.2, the economic growth shock impacts negatively on energy consumption. The implication of this is that output growth reduces energy consumption in this economy. In figure 5.3, the effect of oil price shocks in Algeria reflects positive change in output growth. However, these effects on energy consumption are mixed. It was initially negative and there after remains positive. The significant effect of this shock on the two variables are momentary and dies out after the first 6years of the horizon.

Figure 5.1: Energy Consumption Shocks (Algeria)

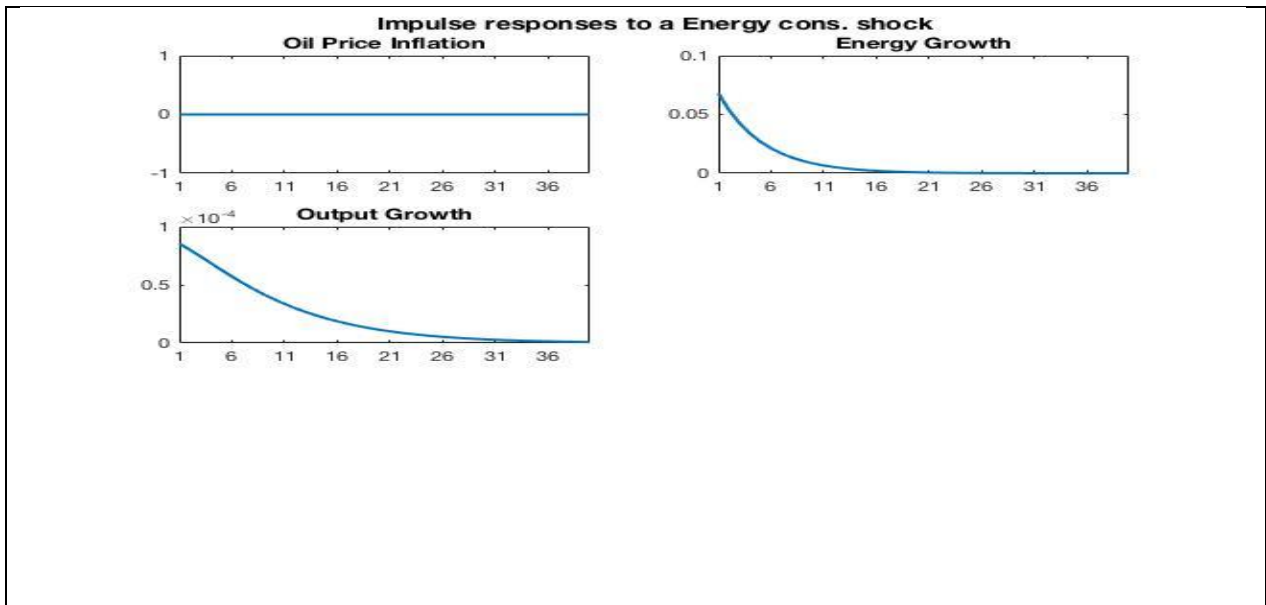


Figure 5.2: Economic Growth Shocks (Algeria)

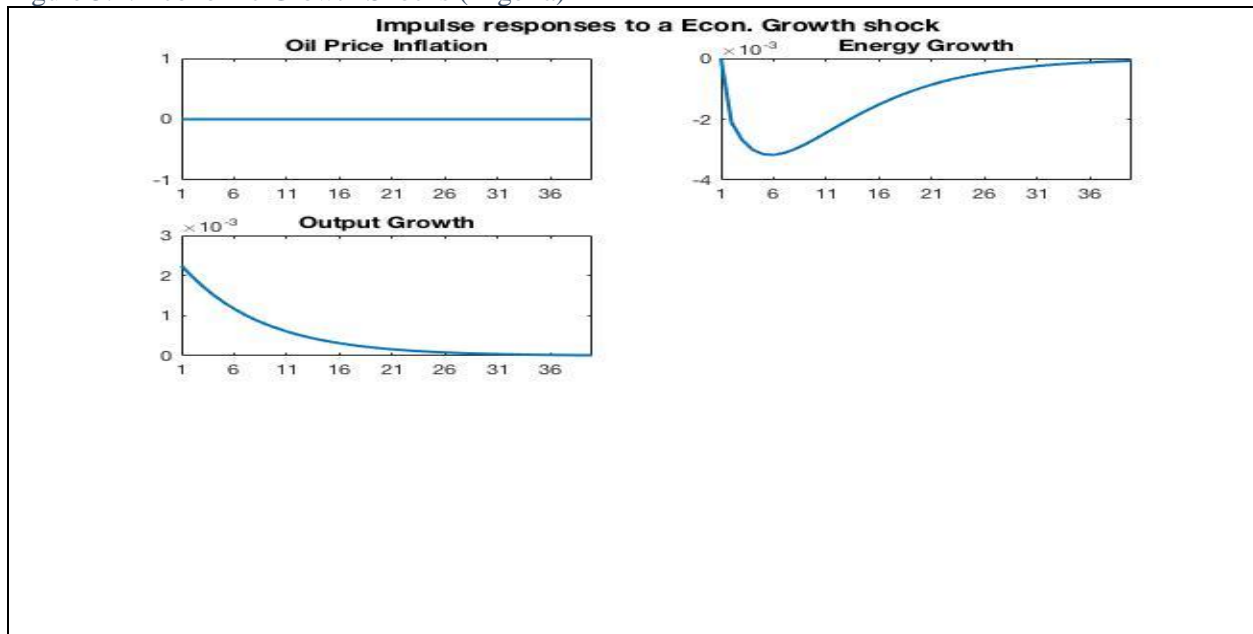
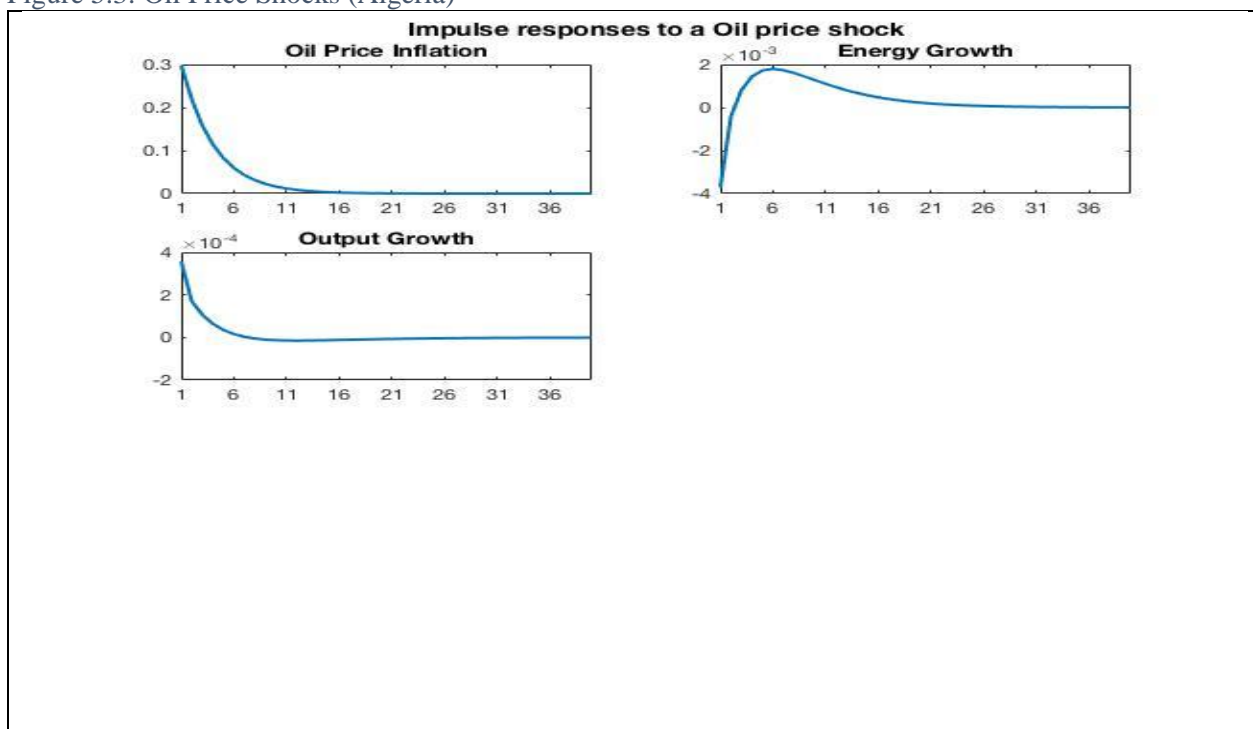


Figure 5.3: Oil Price Shocks (Algeria)



5.4.1.2 IRF Analysis in Angola

Unlike Algeria, the response of output growth to one percent standard deviation in energy consumption shock is significantly negative in Angola (see figure 5.4). **However, this negative impact dies out after 26 years of the horizon.** This indicates the existence of inverse relationship between energy consumption and economic growth in Angola. This may not be unconnected with the structure of the economy. Similar to the result obtained in Algeria, energy consumption shock does not impact the oil price. Also, considered in the estimate is the IRF of oil price and energy consumption to economic growth shock in Angola. The shock significantly and positively affects the energy growth but does not affect the global oil price in the country. This implies that energy consumption increases relative to positive variations in economic growth. **The positive effect on energy consumption is more elongated than on output growth. That is, the impact dies out after 18 years and 30 years on output growth and energy consumption respectively (see figure 5.5).** Furthermore, the oil price shock in Angola depicts a direct relationship with output growth, whereas it shows a mixed effect on energy growth (see figure 5.6). The IRF of the energy growth was initially negative and there after remains positive. This implies that oil price variations significantly affect both energy growth and output growth. **The effect of oil price shocks on output growth declines consistently and returns to the equilibrium after 20 years.**

Figure 5.4: Energy Consumption Shocks (Angola)

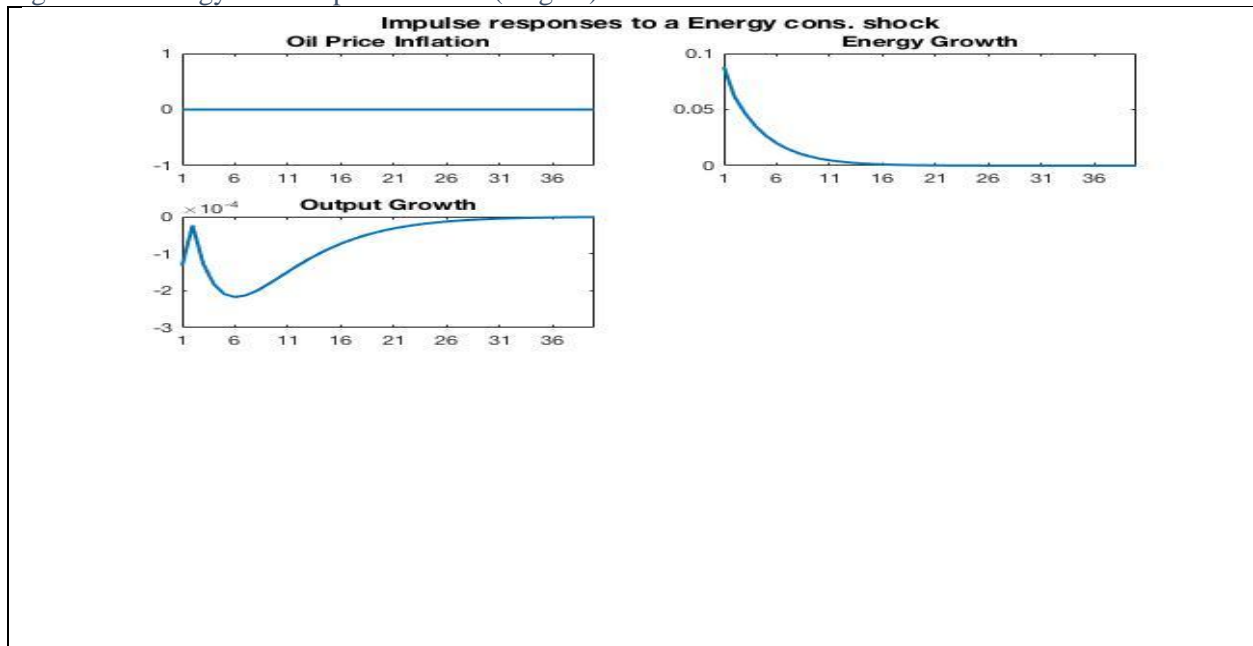


Figure 5.5: Economic Growth Shocks (Angola)

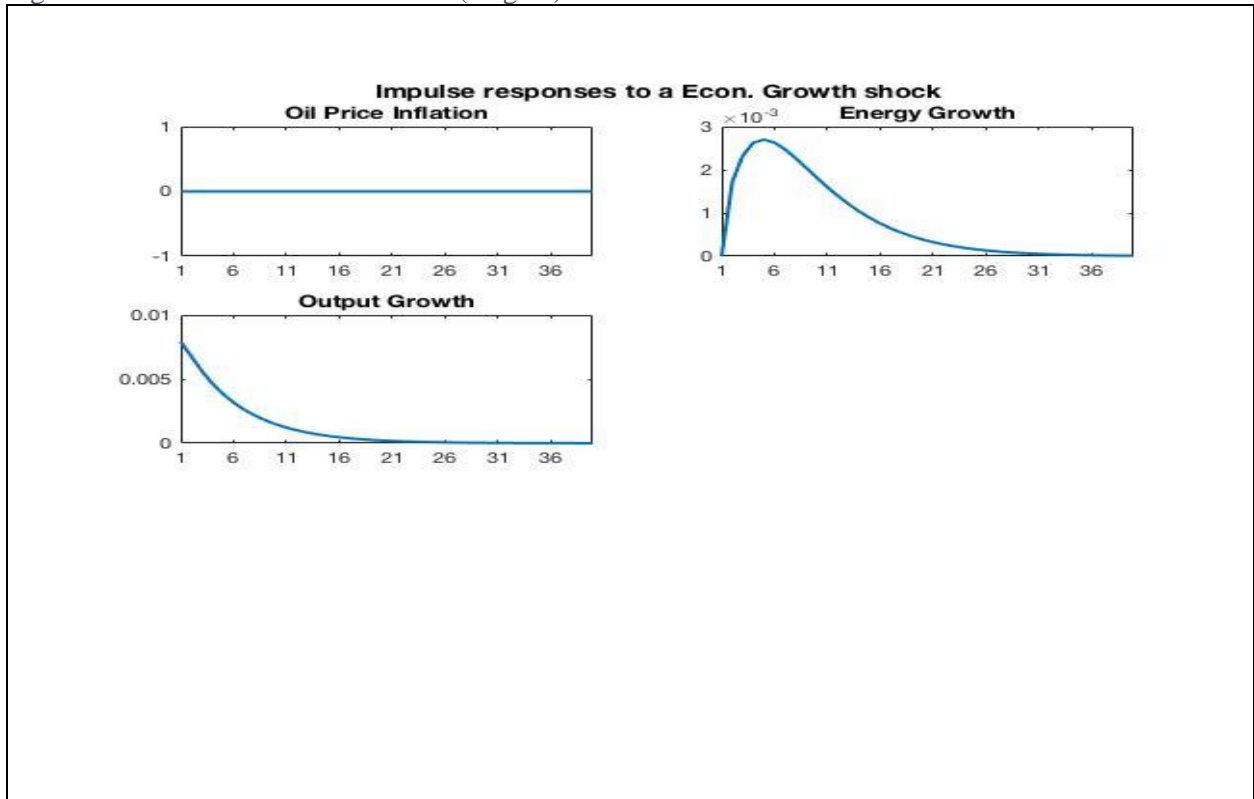
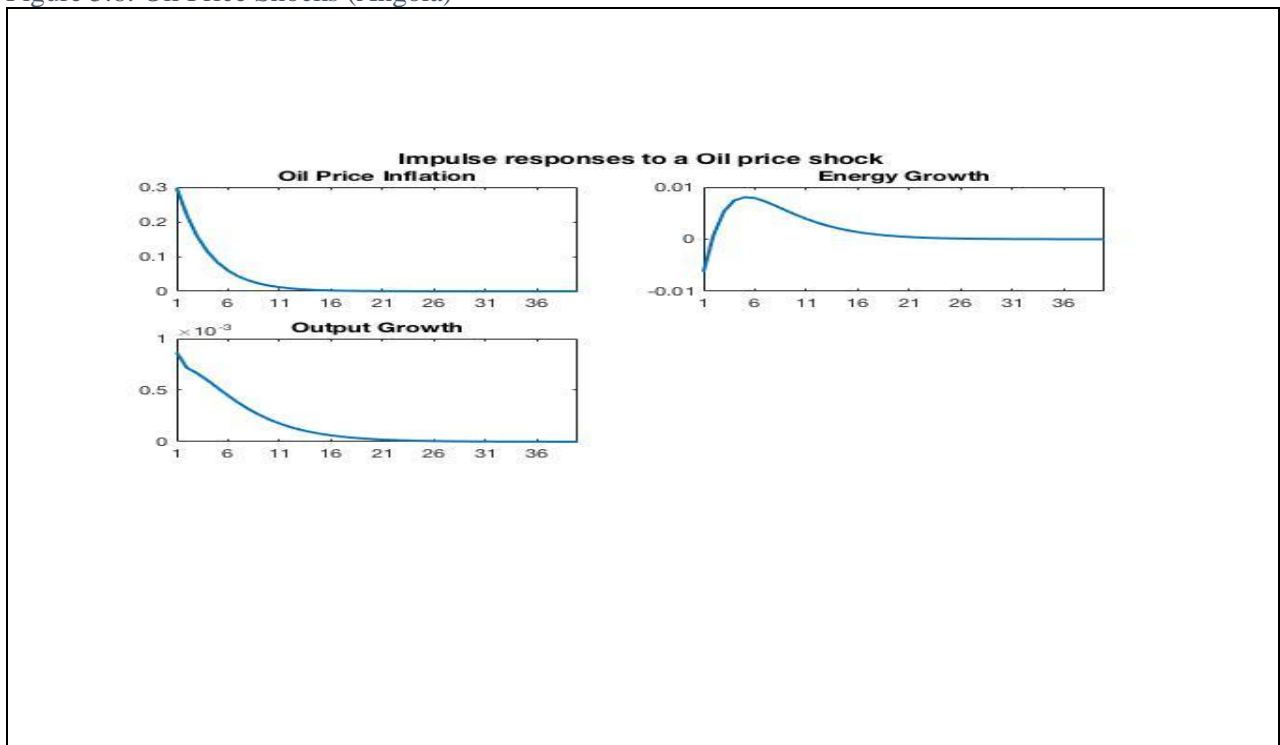


Figure 5.6: Oil Price Shocks (Angola)



5.4.1.3 IRF Analysis in Egypt

In Egypt, the response of output growth to the shock of energy consumption is relatively inverse (see figure 5.7). This is contrary to what is obtained in the Republic of the Congo's economy where the relationship was direct. **The indirect relationship may not be unconnected with high consumption of fossil fuel energy sources in this country.** The shock of economic growth in Egypt (see figure 5.8) suggests positive and significant impact on energy growth. The implication of this is that as economic growth increases, energy consumption is enhanced. **The magnitude of the effects is above 3 percent in the 8th year but dies out subsequently to the equilibrium after 35 years.** In figure 5.9, the variables of output growth and energy consumption are significantly influenced by the shock of oil price in the country. **However, these effects on the two variables are significantly pronounced within the first 6 years and thereafter returned to the equilibrium**

Figure 5.7: Energy Consumption Shocks (Egypt)

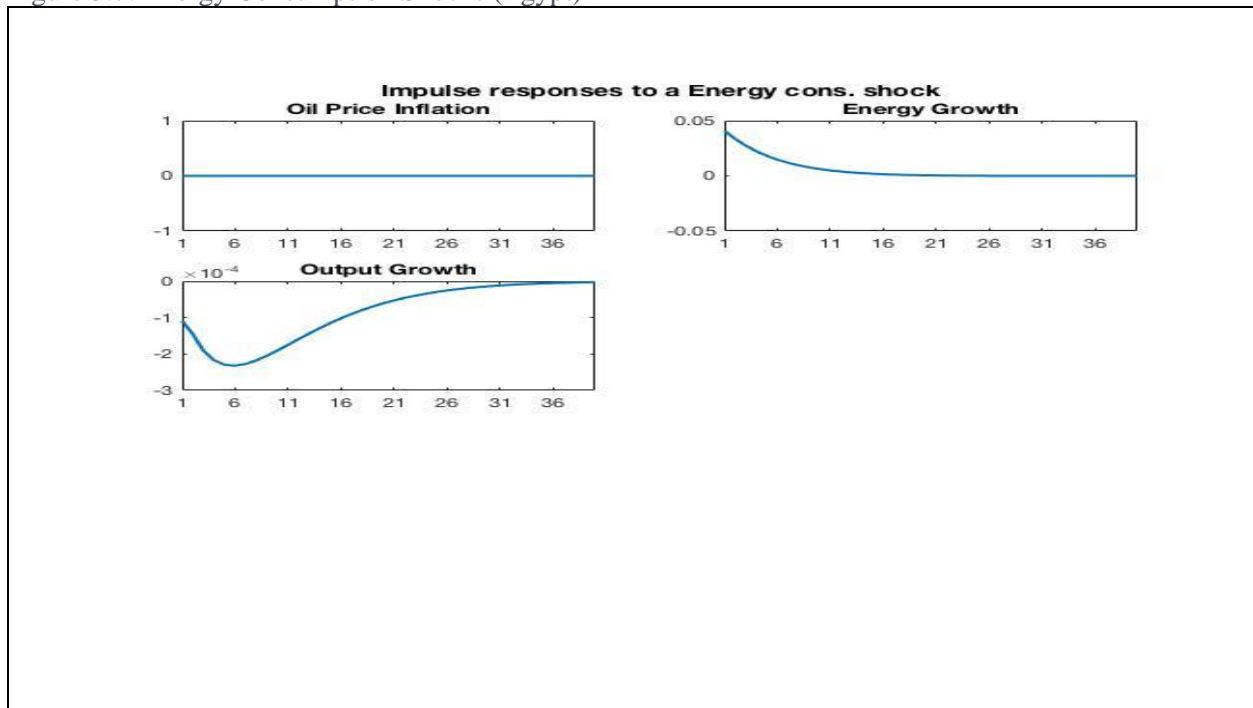


Figure 5.8: Economic Growth Shocks (Egypt)

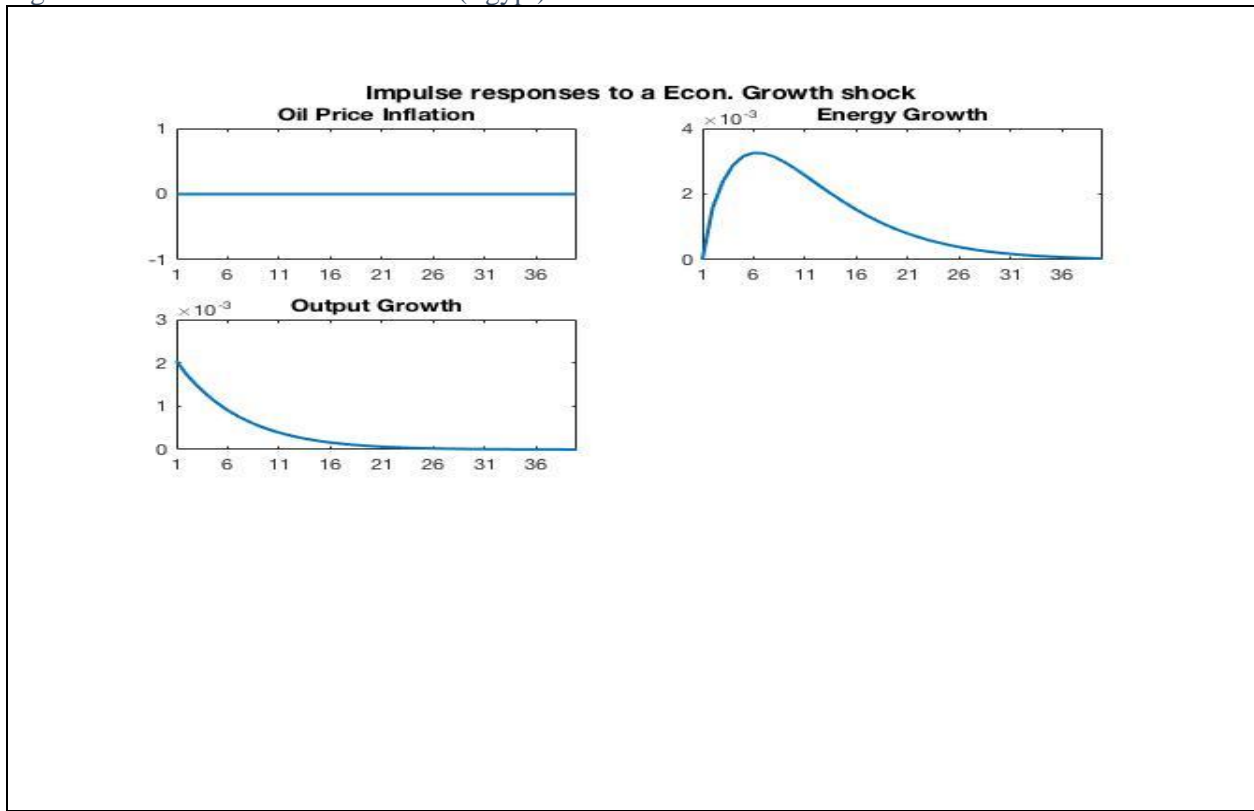
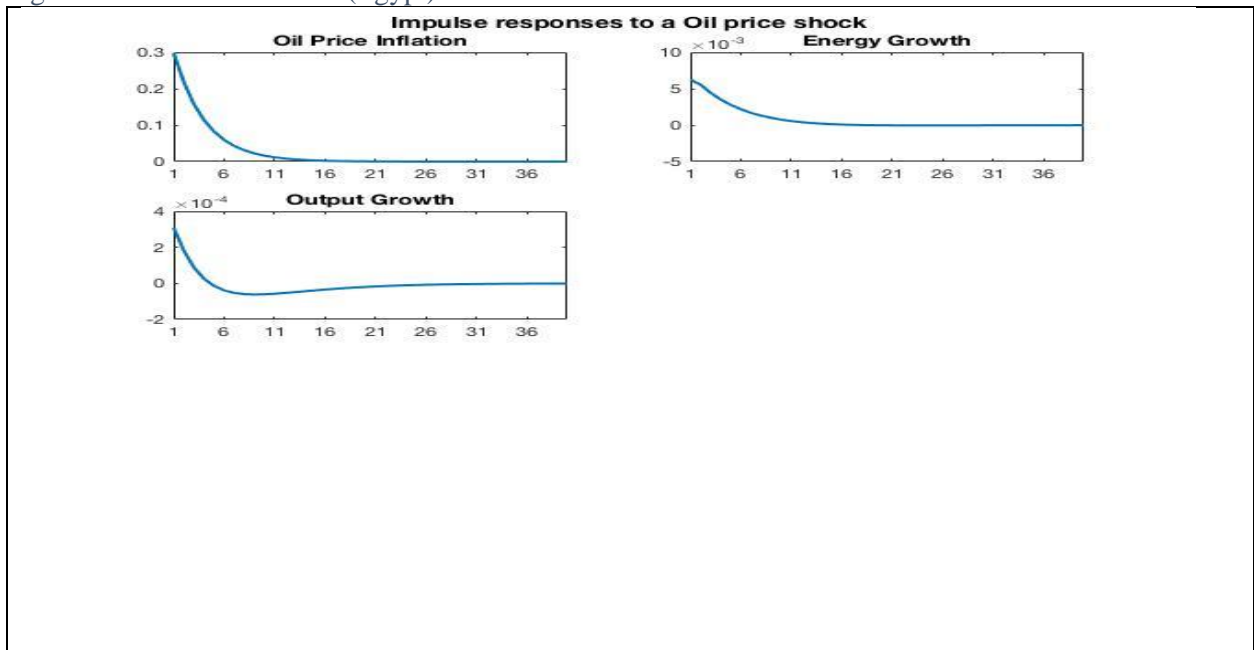


Figure 5.9: Oil Price Shocks (Egypt)



5.4.1.4 IRF Analysis in Gabon

In Gabon, the effect of energy consumption shock reflects positive change in output growth (see Figure 5.10). This implies that positive variations in output growth emanate from positive changes in energy consumption. **The positive increase is about 0.8 percent in the 6th year and thereafter returned to the equilibrium after 15 years of the shock.** However, the shock has no effect on the oil price, as IRF remains horizontal. This suggests that the global variable of oil price cannot be influenced by the domestic variable of energy consumption in Gabon, which is similar to what is obtained in other countries in this study. In figure 5.11, the response of energy consumption to one standard deviation in economic growth is significantly negative. This indirect relationship implies that increase in the output growth in Gabon subsequently leads to decrease in energy consumption. This may be due to a paradigm shift in the use of fossil fuels to an alternative energy source. Also included in the estimate is the IRF of energy growth and output growth to the shock of oil price (see figure 5.12). The response of output growth to the shock is significantly negative, while that of the energy growth is mixed with a variance of about 10 percent by the 5th year. The IRFs of both energy growth and output growth demonstrate a hump shape and thereafter return to the equilibrium. This implies that the oil price shock has a momentary effect on energy growth and output growth.

Figure 5.10: Energy Consumption Shocks (Gabon)

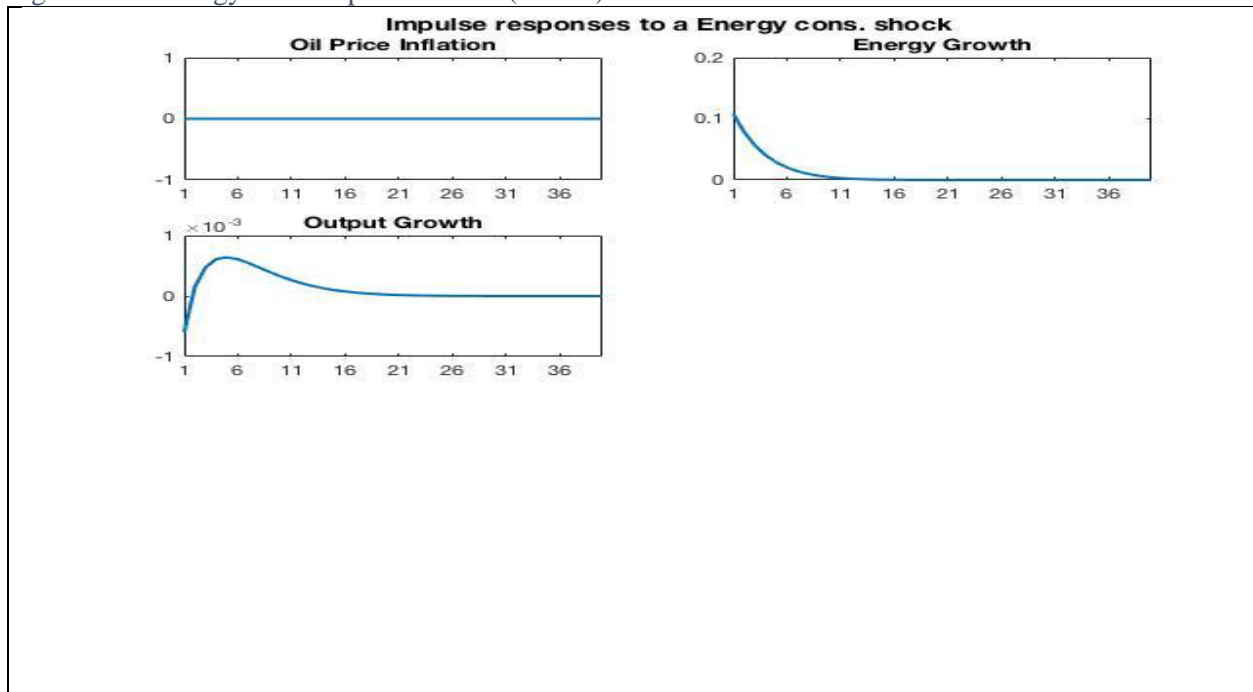


Figure 5.11: Economic Growth Shocks (Gabon)

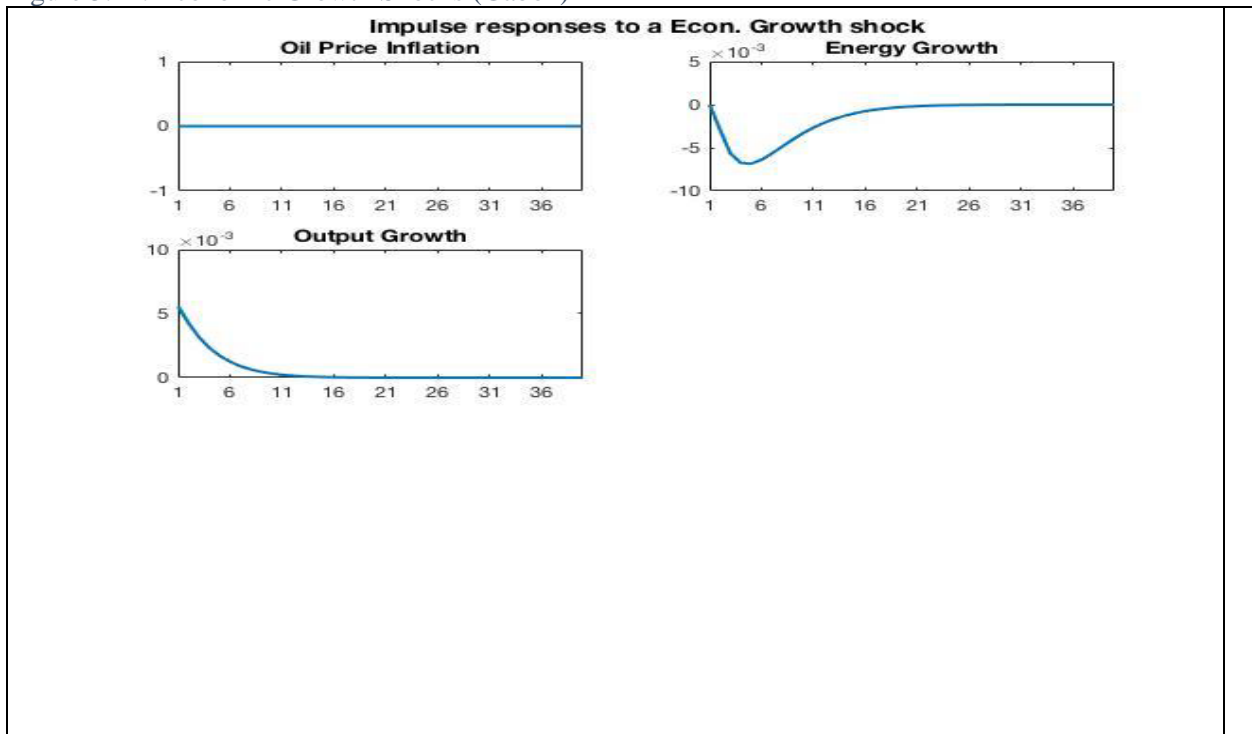
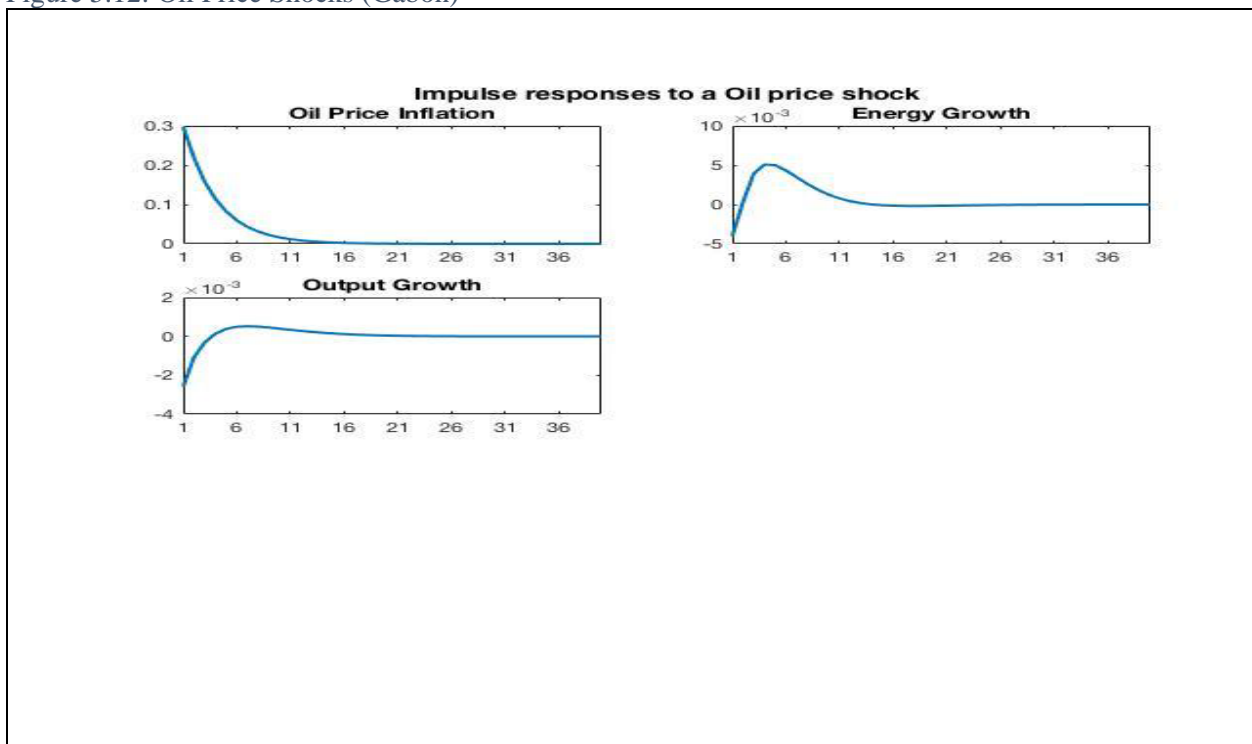


Figure 5.12: Oil Price Shocks (Gabon)



5.4.1.5 IRF Analysis in Nigeria

The IRFs in figures 5.13, 5.14 and 5.15 are the responses of the selected variables to the shock of energy consumption, economic growth and oil price in Nigeria within the period of the study. The result of the estimate suggests that output growth reacts negatively to the shock of energy consumption. **The estimate further suggests that the impact dies out after the 6th year and return to the equilibrium** (figure 5.13). Similar to the results obtained from other AOECs, the positive variation in the energy consumption in Nigeria, impacts no influence on oil price. Also, in the estimate, the response of energy consumption to one percent standard deviation in economic growth is significantly positive (see figure 5.14). The result shows that energy consumption in Nigeria reacts positively to the shock from growth dynamics. Therefore, in a bid for economic stability, energy consumption abruptly falls to return to the equilibrium **after 36 years of the horizon**. This further affirmed a strong association existing between economic growth and energy consumption. The implication is that increasing economic growth enhances economic activities, which increases the energy demand. However, this finding contradicts some related empirical research on the relationship between economic growth and energy consumption (see for instance, Sharma, 2010; Shahbaz et al., 2013; Mberek et al., 2014; Smiech & Papiez, 2014; Azam et al., 2015; Ozturk & Al-Mulali, 2015; Kasman & Duman, 2015; Antonakakis et al., 2017), whose studies affirmed the existence of mixed (positive and negative) relationship. Lastly, in figure 5.15, the IRFs of the energy growth and output growth denote significant and positive relationship to the shock of oil price. This implies that variations in the oil price in Nigeria has direct influence on the energy growth and output growth. **The energy consumption reverted to the equilibrium after the 5th year of the horizon, while the output growth dies out and returned to the equilibrium at the 31st year of the shock.**

Figure 5.13: Energy Consumption Shocks (Nigeria)

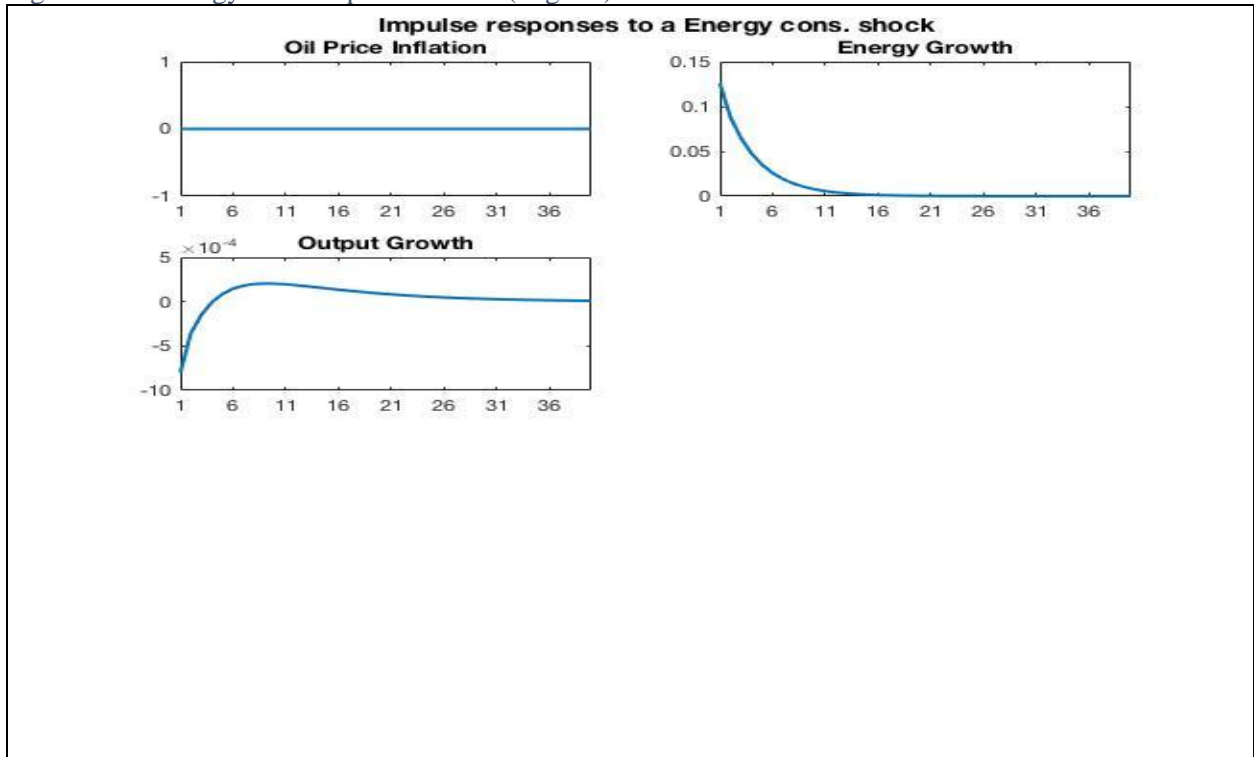


Figure 5.14: Economic Growth Shocks (Nigeria)

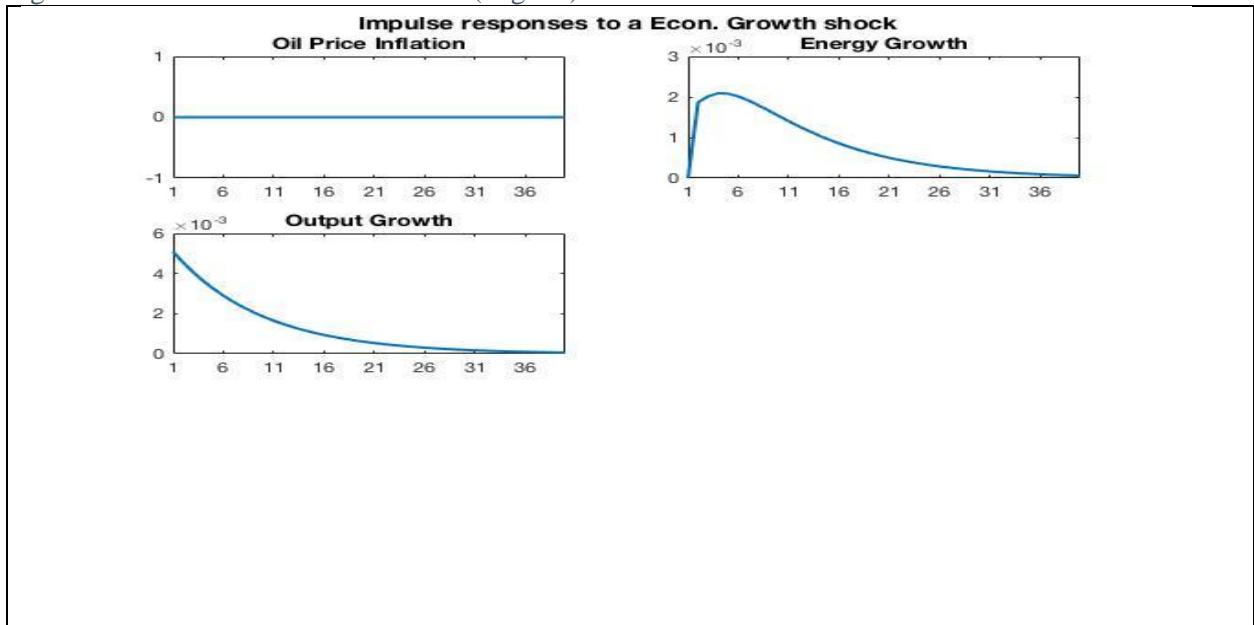
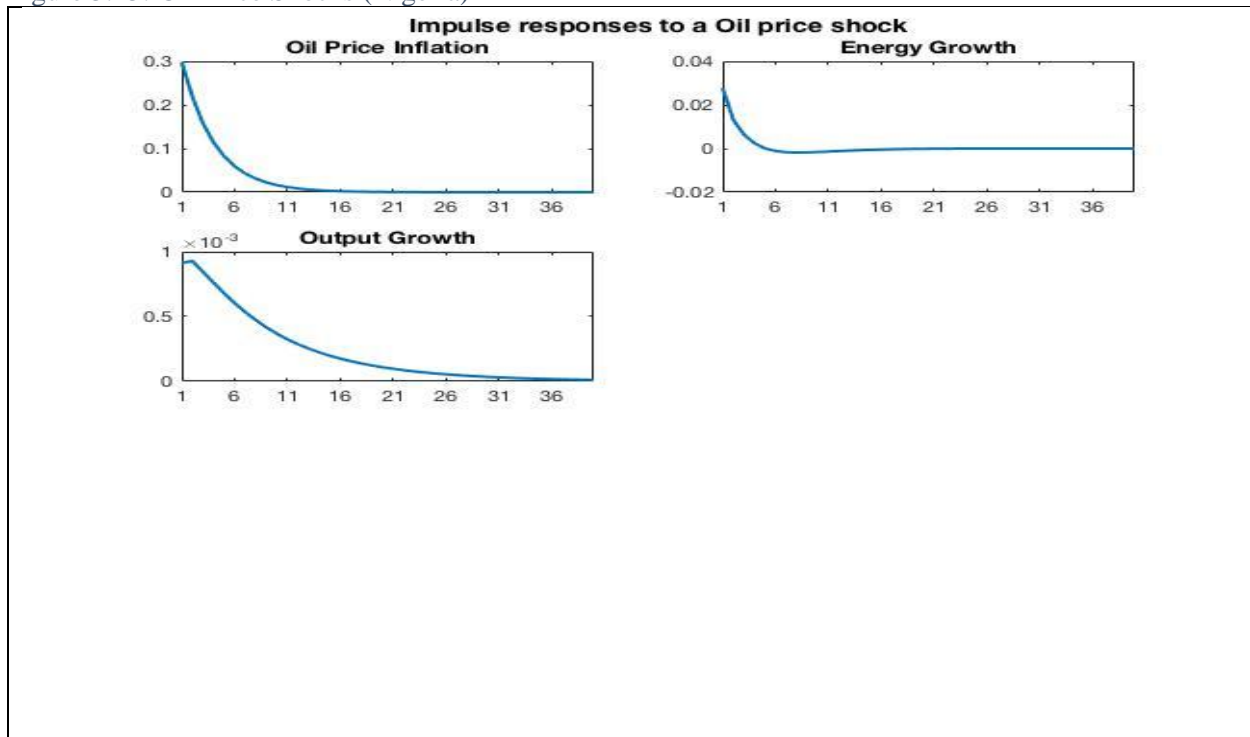


Figure 5.15: Oil Price Shocks (Nigeria)



5.4.1.6 IRF Analysis in the Republic of the Congo

In figures 5.16, 5.17 and 5.18, all the variables demonstrate positive relationship to the shock of energy consumption, growth and oil price respectively in the Republic of the Congo. The unexpected increase in energy consumption has a contemporaneous positive effect on output growth but declines to the equilibrium after 12 years (see figure 5.16). Similarly, the shock of economic growth (see figure 5.17) **impacts positive and significant effect on energy consumption to an average degree of 4 percent at the 5th year**. In the same vein, **the effect is also positive on the output growth but dies out at the 20th year**. Furthermore, the shock of oil price (see figure 5.18) suggests direct relationship with energy growth and output growth. Generally, the response of oil price to the shock of other variables indicates no effect. This implies that the variations in the internal variables (energy and output growth) will have no effect on the external variable of oil price.

Figure 5.16: Energy Consumption Shocks (the Republic of the Congo)

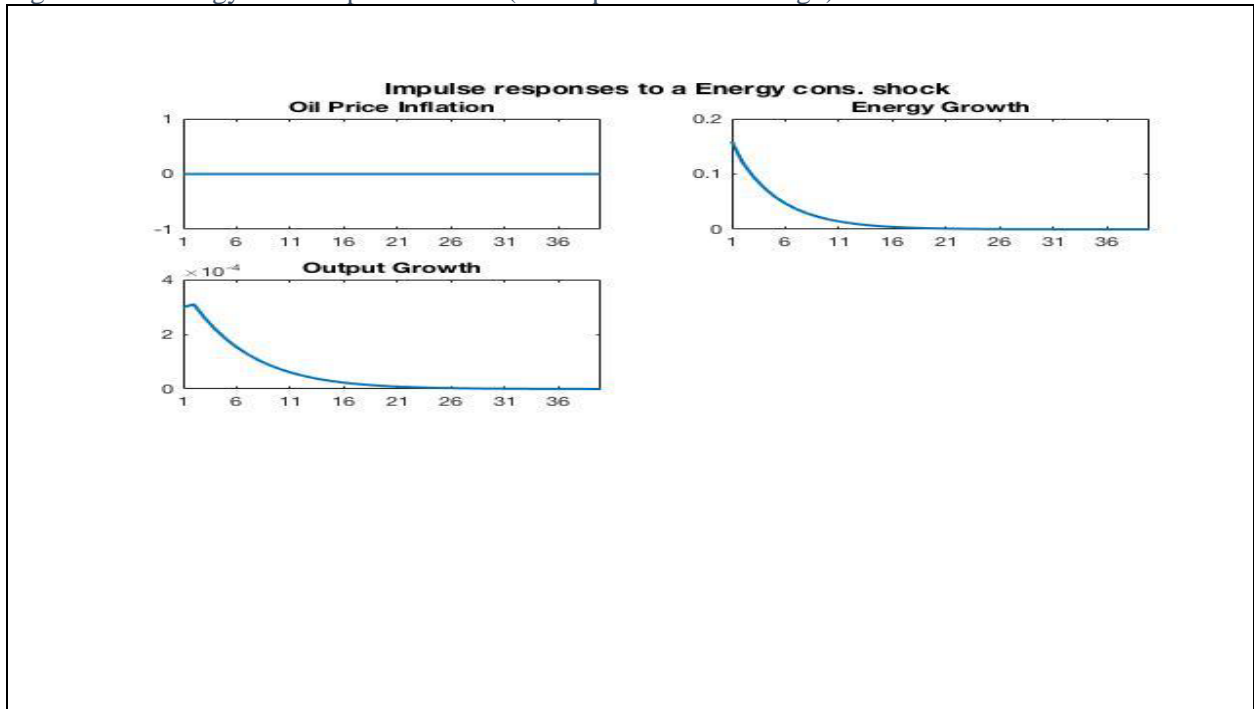


Figure 5:17: Economic Growth Shocks (the Republic of the Congo)

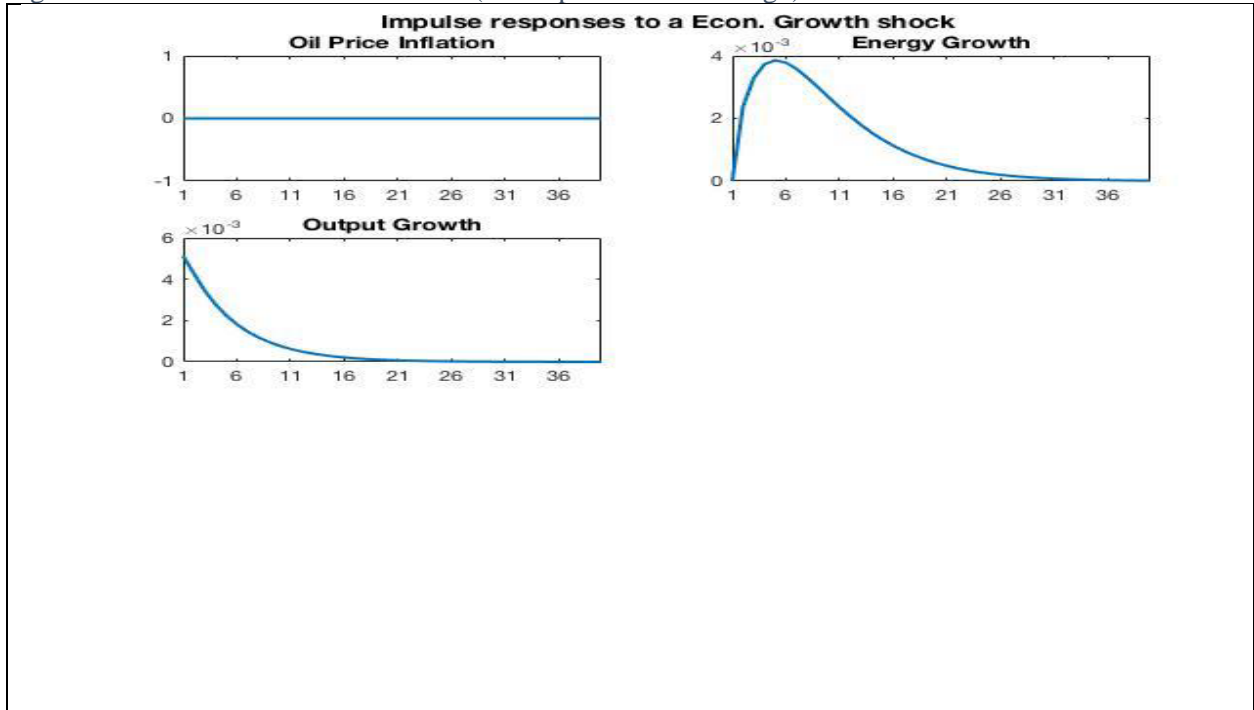
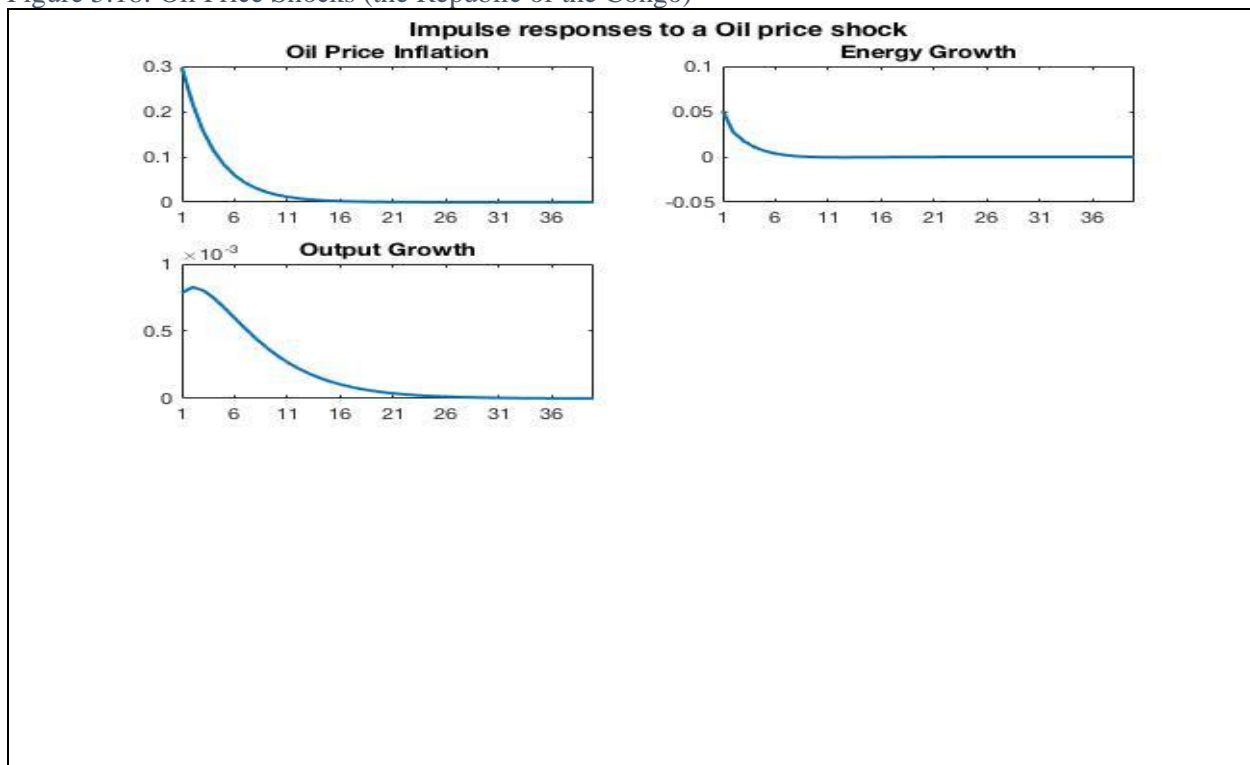


Figure 5:18: Oil Price Shocks (the Republic of the Congo)



5.4.2 Summary and Comparative Analysis of Results

Generally, in all the six selected AOECs, the variations of the variables of energy growth and output growth does not influence the oil price. This implies that the external variable cannot be significantly influenced by the domestic variables. This may be adduced to the fact that these countries do not have the power to autonomously influence the global oil price.

The positive impact of the energy consumption shock on economic growth is experienced in Algeria, the Republic of the Congo and Gabon. This may be due to the structure of the economy. This result is similar to the findings of Lee and Chiu (2011) carried out in developed countries and Sharma (2010) in 66 countries in Asia and the Pacific Islands and is further corroborated by Apergis and Payne's (2011), who submitted that energy consumption variables have a positive impact on economic growth. Conversely, the impact is negative in Angola, Egypt and Nigeria. This inverse relationship corresponds to the findings of Hague's (2021) study in GCC countries that the relationship between oil price shocks and energy consumption is positive.

Also, the positive impact of the economic growth shock on energy consumption is experienced in Angola, the Republic of the Congo, Egypt and Nigeria. This result validates Kamin and Rogers' (2000) finding that, when economic growth increases, economic activities also increase. This is likened to Eltony and Al-

Awadi's (2001) study of Kuwait, economic growth explains variations in variables in an oil-exporting country. Similar results are revealed by Boye (2001) in Ecuador, Farzanegan and Markwadt (2009) in Iran and Berument et al. (2010) in oil-exporting nations.

Furthermore, the shock of oil price produces dis-similar results in different countries of the AOECs. The positive impact of the oil price shock on energy consumption is noticed in the Republic of the Congo, Egypt and Nigeria. The result of our study supports the findings of Stern and Cleveland (2004), who emphasise that there is a strong association between oil-exporting nations' economic growth and oil prices. In a different scenario, Algeria, Angola and Gabon experienced mixed effects of both positive and negative impacts of oil price shock on energy consumption. This corresponds to the findings of Hague's (2021) study in GCC countries that the relationship between oil price shocks and energy consumption is positive.

There is direct impact between oil price shock and economic growth in Algeria, Angola, the Republic of the Congo, Egypt and Nigeria. This is contrary to the findings of Bohi (1991) and Bernanke et al. (1997), that find inverse relationship between the variables. The shock of oil price increase having inverse relationship with economic growth, which may be due to various macroeconomic factors such as economic downturns observed following oil price shocks caused by a mixture of the direct impact of the shocks themselves and the monetary reactions to them. The pronounced negative impact of oil price increase in an economy could be largely due to the close relationship between the control of oil price increases and economic downturns. Conventionally, "Price elasticity of demand" is usually associated with negative impacts and there is always a proportional fall in demand arising from a proportional increase in the input of a factor like oil price (Ghalayin 2011). An oil price hike will certainly reduce oil demand and subsequently lead to a reduction in economic growth. In other words, a rise in the oil price leads to a hike in the general price level and a slowing down of economic activities with attendant effects on economic growth. The exceptional case of Gabon, having a negative impact of oil price on growth conforms to the findings of Zhang (2008) and Sarwar et al. (2017) in member countries of the Organisation for Economic Co-operation and Development (OECD) that oil price volatility simultaneously decreases the economic growth. These results are further buttressed by the variance decomposition.

5.4.3 Variance Decomposition

Variance decomposition reveals the degree of information that each of the variables contributes to the other variables in a VAR framework. According to Raghavan and Silvapulle (2008), variance decomposition is the ratio of a shock to a variable, which is associated with either its innovations or those innovations related to other dependent variables during the diverse forecasted periods of a fitted model. Furthermore, variance decomposition is utilised to help the interpretation of our BSVAR as it has been fitted. It is explored to

ascertain how much of the forecast error variance of each of the fundamentals can be elucidated by the exogenous shocks experienced by the variables of interest. Variance decomposition accounts for the information about the ratio of the movement in a sequential way that relates to the shocks in the variable by itself and other recognized shocks (Adarov, 2019). Tables 5.1-5.2 below present the variance decomposition for each of the variables of interest. Table 5.1 below presents the variance decomposition for EC. It shows the significance of each structural innovation in the variations of EC.

Table 5.1: Variance Decomposition of Energy Consumption (EC)

Countries	Oil price	EC	GDP
Algeria	0.0028952	0.9886	0.008502
Angola	0.025807	0.97081	0.0033849
Egypt	0.023228	0.95626	0.020513
Gabon	0.0051021	0.98374	0.011158
Nigeria	0.03008	0.96864	0.0012754
Congo	0.056102	0.94212	0.001776

Source: Author's computation (2022), using data sourced from the US EIA

Table 5.1 above shows that GDP shocks in Algeria, Angola, Egypt, Gabon, Nigeria and the Republic of Congo, account for 0.8 percent, 0.3 percent, 2 percent, 1.1 percent, 0.1 percent and 0.1 percent of the variations in EC, respectively. The contribution of oil price to EC is 0.2 percent in Algeria to 2.5 percent in Angola, 2.3 percent in Egypt, 0.5 percent in Gabon, 3 percent in Nigeria and 5.6 percent in the Republic of the Congo. In brief, the results show that very little share of the variation in EC is attributed to GDP, while the major contributions to energy variance is due to oil prices across all the countries.

As shown in Table 5.2 below, besides GDP shocks, GDP fluctuations are slightly attributed to oil price shocks at about 0.7 percent in Algeria, 1.4 percent in Angola, 1 percent in Egypt, 11.4 percent in Gabon, 3.7 percent in Nigeria and 5.1 percent in the Republic of the Congo.

Table 5.2: Variance Decomposition of Economic Growth

Countries	Oil price	EC	GDP
Algeria	0.0078359	0.0020016	0.99016
Angola	0.01411	0.0018687	0.98402
Egypt	0.010872	0.035177	0.95395
Gabon	0.11454	0.032532	0.85292
Nigeria	0.037997	0.0090372	0.95297
Congo	0.051219	0.0049088	0.94387

Source: Author's computation (2022), using data sourced from the US EIA

The contribution of EC to GDP is 0.2 percent in Algeria, 0.1 percent in Angola and 3.5 percent in Egypt. It decreases to 3.2 percent in Gabon, 0.9 percent in Nigeria and 0.4 percent in the Republic of the Congo. Generally, the major contributor to the variance decomposition of GDP is oil price except in Gabon and

Congo where energy consumption explains the main variance. The economic structure of these countries might have accounted for this difference.

5.5 Summary and Conclusions

The study estimates a three-variable BSVAR model to investigate the short-run connection between oil prices and two macroeconomic variables to establish the potential processes and mechanisms through which oil price shocks affect economic growth and energy consumption in AOECs. The study uses annual data for the period spanning 1980 to 2018 to construct this model with short-run restrictions to the variables. The variables considered in the study include economic growth and energy consumption. Oil prices are treated as an exogenous variable while other variables are endogenous. The study reveals that oil price shocks have a positive impact on the energy consumption and economic growth of all six AOECs. The impact on economic growth is positive but relatively short-lived in Algeria, Angola, Gabon, Nigeria and Congo but not in Egypt. Energy consumption shocks have a positive effect on oil prices in Angola, Egypt and the Republic of the Congo, while the relationship is inverse in Gabon. Algeria produces mixed results with both positive and negative impacts. Energy consumption has a positive impact on the economic growth of these countries, except in Algeria where the effect is negative. Economic growth shocks have a positive effect on oil price and energy consumption in all six AOECs. These results are corroborated by the variance decompositions presented in Table 5.1 and 5.2. Based on the results revealed, we can some recommendations policymakers for the diversification of the nations' exports reducing their dependence on the petroleum trade and non-oil products. Diversification would lessen the effect of external shocks. However, the restoration of political stability and security is a precondition for economic diversification.

CHAPTER 6

SUMMARY, CONCLUSION, RECOMMENDATIONS AND AREAS FOR FURTHER RESEARCH

6.1 Summary and Conclusions

This study examines three distinct but interconnected topics connecting to the energy consumption and economic growth in AOECs (Algeria, Angola, Egypt, Gabon, the Republic of the Congo and Nigeria) from 1980-2018. The six chapters comprise three sections. The first section encompasses Chapters 1 and 2, which present the motivation and justification for the study on energy consumption and economic growth of the AOECs. The second section comprises Chapters 3-5.

In Chapter 3, to investigate the determinants of energy consumption (trade openness, economic structure and per capita income), we employ the CS-ARDL and CS-DL modelling approaches that are robust to CD and small sample size bias. Using annual data for the period spanning 1980-2018, the models account for time dynamics, heterogeneity and CD because countries may share the same characteristics. We construct a unit root test based on the second-generation test that controls for CD. We use the ARDL technique developed by Pesaran and Smith (1995), as extended by Pesaran, Shin and Smith (1997) to evaluate the likelihood of a long-run cointegration relationship, due to the uncertainty of the degree of integration of the variables used in the study. In line with the existence of CD after conducting the Pesaran's (2004) test, versions of the dynamic common correlated effects (dynamic CCE) estimator built by Chudik and Pesaran (2013), the CS-ARDL and the CS-DL estimating techniques, which are robust to small sample bias, are applied. The results indicate that while trade openness has a positive and significant effect on energy consumption, the effect of economic structure is negative and significant. Similarly, per capita income does not affect energy consumption. These findings did not conform to both theoretical expectations and some previous empirical findings. These results, therefore, indicate that AOECs may behave differently when it comes to what drives energy consumption for a variety of reasons ranging from structural rigidity to their inability to transition to a more efficient and growth-enhancing energy regime.

In Chapter 4, the study investigates the energy-growth nexus. A PSTRVEC model is developed using energy and growth time-series data from the AOECs. Since the application is missing in AOECs, we employ both linear and nonlinear unit roots as well as cointegration tests and explore an estimator that is robust to CD and does not suffer from endogeneity, an issue overlooked in most nonlinear studies. Moreover, we test for Granger causality between energy consumption and economic growth in a nonlinear framework to confirm whether there is existence of nonlinearity between the two fundamentals. Our

findings show that energy consumption and economic growth are nonlinearly cointegrated. This finding motivates the use of a nonlinear estimator in the study, especially as linear tests do not reject the hypothesis of stationarity. Using the nonlinear PSTRVEC model, we find that the nonlinearities between the two variables are better explained whenever energy consumption is employed as the transition variable. The regime-wide Granger causality test that we conduct indicates that, in the short run, there is no causality between the two variables. This finding supports the neutrality hypothesis in the short run. Moreover, economic growth Granger causes energy consumption in both regimes, whereas energy consumption Granger causes economic growth only while the former is growing at a faster pace in the long run.

Chapter 5 presents the study on oil price shocks, energy consumption shocks and economic growth shocks in AOECs employing the BSVAR model and annual data from 1980 to 2018. The study reveals that oil price shocks have a positive impact on the energy consumption and economic growth of all six AOECs. The domestic variables of energy growth and output growth does not impact oil price, being an external variable. On the other hand, variations of oil price show significant effect on other macroeconomic variables under consideration. The effect of oil price on energy consumption is positive in the Republic of the Congo, Egypt and Nigeria, whereas it exerts mixed effect on same variable in Algeria, Angola and Gabon. This shows that variations in price of oil varies from country to country. The positive variations of the energy consumption impact positive influence on economic growth in Algeria, the Republic of the Congo and Gabon, while it is an inverse relationship in Angola, Egypt and Nigeria. Also, the estimate further reveals that the shock of economic growth leads to positive change in energy consumption in Angola, the Republic of the Congo, Egypt and Nigeria, but significantly negative in Algeria and Gabon. These results are corroborated by the variance decomposition in Tables 5.1 and 5.2 in Chapter 5. Based on the results revealed, we can make some recommendations to policymakers for the diversification of the nations' exports by reducing their dependence on the petroleum trade and exporting non-oil products.

6.2 Recommendations

Since the structure of the economy, proxied by the share of the industrial sector, stunts energy consumption in AOECs, policymakers should use oil earnings to grow manufacturing sectors. Moreover, the governments of AOECs should encourage private investment from both internal and external sources, which can help to drive manufacturing value-added in these economies. These countries should identify those sectors that can improve domestic manufacturing value-added for both export and local consumption as a strategy for the diversification of their economies. Policymakers can kick start this process by providing an enabling environment for investors in industrial sectors to encourage investment and growth. AOECs should accelerate the implementation of policies that create incentives to stimulate the switch from fossil

fuels to modern renewable energy. As stressed by Marina et al.'s (2018), countries that encourage the use of renewable energy increase energy consumption. An important finding of the study is that in AOECs per capita income does not have any impact on energy consumption, which may be due to the low level of per capita income in the sampled countries. Hence, these countries need to transform their economies to make economic growth more inclusive, driven by domestic value-added and not exogenous income from the export of primary products.

It is recommended that AOECs enhance economic growth by improving energy consumption through a transition to innovative energy consumption. Therefore, since AOECs are endowed with both renewable and fossil fuels energy resources, they could implement an energy policy of shifting from fossil fuels to efficient renewable energy, which might ensure affordable and increased energy consumption. This shift should be supported by an inclusive framework to stimulate the participation of independent investors. In addition, for AOECs to have an effective energy policy, they should strengthen their institutions, improve their ability to manage energy and monitor the implementation of the policy. Furthermore, AOECs should have a policy of collaboration whereby they share best practices and experiences in the utilisation of energy resources, energy management and the development of energy technology, which will increase energy consumption and economic growth.

It is recommended to policymakers in AOECs to diversify the nations' exports by reducing their dependence on the petroleum trade and enhance the exportation of non-oil products. Diversification would lessen the effect of external shocks. However, the restoration of political stability and security is a precondition for economic diversification. Moreover, AOECs should create a suitable fiscal motivation to inspire the use of renewable energies as an alternative to fossil fuels that dominate these economies. Innovation subsidies are specifically important because neglecting a polluting technology for a green technology still requires important investments, particularly in net oil exporting countries. This will certainly improve the quantity of renewable energy relative to the aggregate energy consumed in these economies. Furthermore, AOECs should improve the use of renewable energies by encouraging both regionally and intercontinentally integrated markets for renewable energy technologies. The intent of which is to achieve economies of scale that entice private sector investments, which would eventually increase economic growth.

6.3 Areas for Further Research

There is a need to keep pushing the frontier of knowledge on the relationship between energy consumption and economic growth. A puzzling finding from the study is the negative relationship between per capita income and energy consumption in AOECs. More quantitative evidence of this relationship beyond offering

plausible reasons is needed. Using a new dataset on the energy mix and the level of informality with the economy may answer the question of whether households transition from fossil fuel to renewable energy as per capita income increases.

Our study investigates connection between energy consumption and economic growth in a sample of six net AOECs using the PSTRVEC model, which provides results that could benefit policymaking and contribute to the discourse on the usefulness of the techniques in empirical research to which other studies attest too. However, the topic should be explored further by accounting for the consumption of different types of non-renewable and renewable resources and their relationship with economic growth using a PSTRVEC model.

Similarly, the use of Dynamic Stochastic General Equilibrium (DSGE) for the estimation of oil price shocks in AOECs would create room for comparative analysis. Moreover, future studies could use the Factor-Augmented Vector Autoregressive (FAVAR) technique adopted by Aastveit (2014), Kucukefe (2019) and Akkoc et al. (2021) to perform a related study as an alternative to the BSVAR model, as it allows for the inclusion of more variables without essentially running out of degrees of freedom.

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APPENDIX

Appendix A

Table A-1: CS-ARDL

VARIABLES	5 CS-ARDL-1	6 CS-ARDL-2	7 CS-ARDL-3
CAPITAL	-0.000797 (0.000864)	-0.001183 (0.002341)	-0.00614 (0.00581)
URBAN	-0.11198* (0.650087)	-0.183538* (0.103616)	-0.137744 (0.09887)
LABOUR	-0.02151 (0.092303)	-0.09813 (0.113513)	-0.198474 (0.244928)
Speed of adj	-1.033*** (0.135)	-1.443*** (0.1601)	-2.47755*** (0.746199)
Constant	-0.00498 (0.0476)	0.11427 (0.10346)	-0.13538 (1.3713)
Observations	204	204	204

Standard errors in parentheses. *, **, *** indicates significance at 10 percent, 5 percent and 1 percent.

Table A-2: Cross-sectional DL

VARIABLES	8 CS-DL1	9 CS-DL2	10 CS-DL3
CAPITAL	0.00109 (0.00074)	-0.00027 (0.00277)	-0.00450 (0.00454)
URBAN	0.00595 (0.03537)	-0.02797 (0.04544)	-0.03146 (0.12201)
LABOUR	0.02792 (0.08207)	-0.02161 (0.10843)	0.07155 (0.25416)
Constant	0.00237 (0.03058)	0.01783 (0.04153)	0.05240 (0.05667)
Observations	204	204	204

Standard errors in parentheses. *, **, *** indicates significance at 10 percent, 5 percent and 1 percent.

Table A-3: Westerlund (2007) Cointegration Test

Statistics	Non Value	Constant Value	Constant and Trend Value
Gt	-3.99***	-3.226***	-3.924***
Ga	-10.141*	-7.592	-11.021
Pt	-6.722*	-6.619**	-9.916***
Pa	-6.817	-5.981	-8.612

Test of null of no cointegration

A-4:
 Algeria
 Model Structural Form
 Regime 1:const=1

	dlnoilp	dlnenr	dlnrgdp
Constant	0.0071182	0.00039334	2.7764e-05
Dlnoilp	1	0.012477	-0.0012123
Dlnenr	0	1	-0.0012554
Dlnrgdp	0	0	1
dlnoilp(-1)	0.73535	0.018768	-0.0013889
dlnenr(-1)	0	0.79336	-0.00092345
dlnrgdp(-1)	0	-0.93578	0.88345
dlnoilp(-2)	-0.0094612	-0.0032483	0.00023351
dlnenr(-2)	0	-0.00014424	3.3448e-06
dlnrgdp(-2)	0	0.37784	-0.0050793
shock_stdev	0.29773	0.068007	0.0022475

Angola
 Model Structural Form
 Regime 1:const=1

	dlnoilp	dlnenr	dlnrgdp
Constant	0.0071182	0.010901	0.00012622
Dlnoilp	1	0.021076	-0.0028815
Dlnenr	0	1	0.0015116
Dlnrgdp	0	0	1
dlnoilp(-1)	0.73535	0.032594	-0.0021686
dlnenr(-1)	0	0.70026	0.0020913
dlnrgdp(-1)	0	0.21699	0.86031
dlnoilp(-2)	-0.0094612	0.0035853	0.00027787
dlnenr(-2)	0	0.040633	-0.0019127
dlnrgdp(-2)	0	-0.043391	-0.027273
shock_stdev	0.29773	0.088212	0.0078911

Egypt
 Model Structural Form
 Regime 1:const=1

	dlnoilp	dlnenr	dlnrgdp
Constant	0.0071182	0.0035631	0.00045844
Dlnoilp	1	-0.020967	-0.0010976
Dlnenr	0	1	0.0026715
Dlnrgdp	0	0	1
dlnoilp(-1)	0.73535	-0.014896	-0.0010471
dlnenr(-1)	0	0.82769	0.00091719
dlnrgdp(-1)	0	0.76895	0.84979
dlnoilp(-2)	-0.0094612	-0.00089554	-6.074e-06
dlnenr(-2)	0	-0.0076242	-0.00058989
dlnrgdp(-2)	0	-0.12238	0.0050078
shock_stdev	0.29773	0.040815	0.0020425

Gabon
 Model Structural Form
 Regime 1:const=1

	dlnoilp	dlnenr	dlrngdp
Constant	0.0071182	0.0054913	-0.00016113
Dlnoilp	1	0.013459	0.0087573
Dlnenr	0	1	0.0055325
Dlrngdp	0	0	1
dlnoilp(-1)	0.73535	0.016171	0.0095403
dlnenr(-1)	0	0.72478	0.0096821
dlrngdp(-1)	0	-0.51578	0.7627
dlnoilp(-2)	-0.0094612	0.0036748	-0.00071778
dlnenr(-2)	0	-0.0026486	-0.00091717
dlrngdp(-2)	0	-0.24011	-0.015687
shock_stdev	0.29773	0.1079	0.0055962

Nigeria
 Model Structural Form
 Regime 1:const=1

	dlnoilp	dlnenr	dlrngdp
Constant	0.0071182	0.0054505	0.00024704
Dlnoilp	1	-0.093349	-0.0036553
Dlnenr	0	1	0.0063593
Dlrngdp	0	0	1
dlnoilp(-1)	0.73535	-0.090671	-0.0027171
dlnenr(-1)	0	0.7007	0.0073376
dlrngdp(-1)	0	0.36663	0.89691
dlnoilp(-2)	-0.0094612	0.0048547	-2.9306e-05
dlnenr(-2)	0	0.025175	-0.000532
dlrngdp(-2)	0	-0.18866	-0.0034609
shock_stdev	0.29773	0.1258	0.0050867

Congo
 Model Structural Form
 Regime 1:const=1

	Dlnoilp	dlnenr	dlrngdp
Constant	0.0071182	0.011567	-0.00047897
Dlnoilp	1	-0.17094	-0.0023145
Dlnenr	0	1	-0.0018741
Dlrngdp	0	0	1
dlnoilp(-1)	0.73535	-0.16493	-0.0011094
dlnenr(-1)	0	0.76096	-0.0010426
dlrngdp(-1)	0	0.46473	0.83258
dlnoilp(-2)	-0.0094612	0.014637	6.1429e-05
dlnenr(-2)	0	0.020659	-0.00027537
dlrngdp(-2)	0	-0.099655	-0.020832
shock_stdev	0.29773	0.15921	0.0051264

A-5: Unit Root Test

ADF Tests

Variable	Constant	Constant & Trend	None
lnoilp	-0.945	-2.282	0.224

PP Tests

lnoilp	-1.138	-2.161	0.049
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Algeria

ADF Tests

Variable	Constant	Constant & Trend	None
lngdp	-0.750	-3.008	0.422
lnec	0.350	-1.751	1.697

PP Tests

Variable	Constant	Constant & Trend	None
lngdp	-0.156	-1.261	1.231
lnec	-1.384	-2.519	2.273

Angola

ADF Tests

Variable	Constant	Constant & Trend	None
lngdp	-1.271	-1.814	0.182
lnec	-0.397	-1.569	1.126

PP Tests

Variable	Constant	Constant & Trend	None
lngdp	-1.225	-1.750	0.087
lnec	0.162	-1.739	2.912

Egypt

ADF Tests

Variable	Constant	Constant & Trend	None
lngdp	-0.564	-2.261	3.244
lnec	-0.649	-1.705	1.820

PP Tests

Variable	Constant	Constant & Trend	None
lngdp	-1.698	-2.598	5.790
lnec	-2.874**	-3.115	3.958

** denotes statistical sign at 5 percent

Gabon

ADF Tests

Variable	Constant	Constant & Trend	None
lngdp	-1.608	-1.856	-1.584
lnec	-0.725	-1.788	-0.348

PP Tests

Variable	Constant	Constant & Trend	None
lngdp	-1.481	-2.792	-1.035
lnec	-1.491	-2.594	-1.042

Nigeria

ADF Tests

Variable	Constant	Constant & Trend	None
lngdp	-0.517	-1.531	-1.559
lnec	-1.611	-2.567	1.701

PP Tests

Variable	Constant	Constant & Trend	None
lngdp	-0.742	-4.011**	-0.285
lnec	-2.311	-3.666**	1.675

** denotes statistical sign at 5%

Congo

ADF Tests

Variable	Constant	Constant & Trend	None
lngdp	-2.510	-1.960	-0.872
lnec	-1.002	-1.814	-1.542

PP Tests

Variable	Constant	Constant & Trend	None
lngdp	-2.503	-2.741	0.331
lnec	0.182	-1.222	-1.078