Pan African University
PAU Institute of Water and Energy Sciences

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## INSTITUTE FOR WATER AND ENERGY SCIENCES
## (including CLIMATE CHANGE)

# Master Dissertation

Submitted in partial fulfillment of the requirements for the master's degree
in

Energy Policy

Presented by

***Emaediong Udeme UMOEKA***

**THE IMPACT OF INNOVATION ON RENEWABLE ENERGY CONSUMPTION IN NIGERIA**

***Defended on 04/09/2019 Before the Following Committee:***

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## DECLARATION

I, Umoeka, Emaediong Udeme, hereby declare that this thesis titled "The Impact of Innovation on Renewable Energy Consumption" is original and has not by any means been submitted in part or full for any other degree of this University or any other University. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

12/09/2019

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## DEDICATION

To Mr/ Mrs. Udeme John Umoeka

## ACKNOWLEDGEMENT

I am very grateful to God Almighty, who has made it possible for me to live to see such advancement in life and still trusting Him for more. I sincerely appreciate my parents, Mr/Mrs Udeme John Umoeka and siblings (Udeme (Jnr), Odudu-Abasi and Emem-Abasi) who have constantly been my pillar of support. To all my uncles, aunties and cousins, I thank you all immensely.

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## LIST OF ABBREVIATIONS

$CO_2$: Carbon dioxide Emission

GDP: Gross Domestic Product

REC: Renewable Energy Consumption

INNO: Innovation

TO: Trade Openness

OR: Oil Rent

REAP: Renewable Electricity Action Programme

REMP: Renewable Energy Master Plan

NREEEP: National Renewable Energy and Energy Efficiency

Policy LHP: Large Hydro-power

MW: Megawatt

KW: Kilowatt

MSW: Municipal Solid Waste

CAD: Centralized Anaerobic Digestion

NAPRI: National Animal Production Research Institute

FCT: Federal Capital Territory

RE: Renewable Energy

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# ABSTRACT

*This study investigates the impact of innovation on renewable energy consumption in Nigeria using a time series data of 1996Q1- 2017Q4. The data on renewable energy consumption, GDP, innovation, carbon dioxide emissions, trade openness and oil rent were obtained from world development indicators 2018. The impact of innovation on renewable energy consumption effect was estimated with dynamic ordinary least square model. This study employed the vector autoregressive model of Toda and Yamamoto causality test to examine the causal and long-run relationship among the variables; renewable energy, GDP, innovation, carbon dioxide emissions, trade openness and oil rent. From the study, the empirical result indicated that for objective one, GDP, Innovation and trade openness had a positive relationship with the dependent variable renewable energy consumption while, CO2 emission and Oil rent had a negative relationship with renewable energy consumption. The result of objective two indicated no causality among the variables however, there was a unidirectional causality from oil rent to renewable energy consumption and also a unidirectional causality from innovation to carbon dioxide emission. As a result of the findings the study recommends, expansionary monetary and fiscal policies to increase GDP which will in turn increase renewable energy consumption, increase investment in innovation, environmental policies like emission tax per ton of* $CO_2$ *and emission allowance should be promoted, in order to force companies to either reduce their CO2 emission or pay heavily for it, liberalized trade policies to enhance trade openness and finally government should implement market policies such as subsidy, tax holiday, low import duties on renewable energy sources in order to enhance its generation, deployment and consumption.*

# RESUME

*Cette étude examine l'impact de l'innovation sur la consommation d'énergie renouvelable au Nigeria à l'aide d'une série de données chronologiques du premier trimestre 1996 au quatrième trimestre 2017. Les données sur la consommation d'énergie renouvelable, le PIB, l'innovation, les émissions de dioxyde de carbone, l'ouverture commerciale et la rente pétrolière proviennent des indicateurs de développement mondial 2018. L'impact de l'innovation sur l'effet de la consommation d'énergie renouvelable a été estimé à l'aide du modèle dynamique des moindres carrés ordinaires. Cette étude a utilisé le modèle vectoriel autorégressif du test de causalité de Toda et Yamamamoto pour examiner la relation causale et à long terme entre les variables : énergie renouvelable, PIB, innovation, émissions de dioxyde de carbone, ouverture commerciale et rente pétrolière. Les résultats empiriques de l'étude indiquent que pour l'objectif un, le PIB, l'innovation et l'ouverture commerciale ont eu une relation positive avec la variable dépendante de la consommation d'énergie renouvelable, tandis que les émissions de CO2 et la rente pétrolière ont eu une relation négative avec la consommation d'énergie renouvelable. Le résultat de l'objectif deux n'a indiqué aucune causalité entre les variables, mais il y a eu une causalité unidirectionnelle entre la rente pétrolière et la consommation d'énergie renouvelable aussi bien qu'entre l'innovation et les émissions de dioxyde de carbone. Suite aux conclusions de l'étude, il est recommandé de promouvoir des politiques monétaires et fiscales expansionnistes visant à accroître le PIB, ce qui entraînera à son tour une augmentation de la consommation d'énergie renouvelable, une augmentation des investissements dans l'innovation, des politiques environnementales telles que la taxe sur les émissions par tonne de CO2 et les quotas d'émission afin de forcer les entreprises à réduire leurs émissions de CO2 ou à les payer fortement, une libéralisation des politiques commerciales pour accroître leur ouverture commerciale et enfin le gouvernement doit implémenter des politiques de marche telles que les  subventions, congés fiscaux et faibles droits à l'importation sur les énergies renouvelables afin de renforcer leur production, déploiement et consommatio*

# CHAPTER ONE
# INTRODUCTION

## 1.1 Background to the Study

The energy sector of Africa is crucial to its sustainable development process, yet it is deemed as being one of the most poorly developed energy systems in the world (AEO, 2014). Affordable, reliable, sustainable and modern energy for all is the goal 7 of the 17 Sustainable Development Goals because energy is crucial to economic development. The human population universally continues to grow at a very rapid rate causing a significant increase in the demand for energy. According to Sims et al (2010), following the recent increase in energy use, the demand for energy is expected to increase by 65% from 2004 to 2030. The increasing demand for energy as a result of increase in population has an important environmental implication. According to the World Bank report (2015), primary energy consumption accounted for more than 60% of carbon dioxide emissions globally therefore leading to an increase in global warming and as stated by Ristinenand Kraushaar (1998), the bulk of the energy used globally is obtained from non-renewable sources.

Contemporary literature in Africa has emphasized the need for a more sustainable energy sources which is to increase the use of renewable energy sources to effectively tackle the problem associated with the use of fossil fuel energy sources (Maji, 2015; Rafindadi and Ozturk, 2016; Ozturk and Bilgili, 2015; Adewuyi and Awodumi, 2017a,b). This is because of the benefits associated with the use of this energy sources. Renewable energy sources such as wind, biomas, hydropower and solar do not emit carbon dioxide and the quantity of this energy sources on earth is infinite yet it accounts for about 22% of the world total energy consumption (EIA, 2016). According to Bhattacharya et al (2016), this low account of renewable energy sources has further increased the growing concern by energy policymakers to increase the share of renewable energy in total energy mix.

In spite of the enormous potentials of renewable energy in Africa, solar, biomass, hydropower and wind have accounted for a small share of the world renewable energy mix. As stated by AEO, 2014, the share of electricity generation in sub- Saharan Africa as at 2012 by coal, hydro, gas, petroleum and nuclear were; 56%, 22%, 9%, 9% and 3% respectively. However, the renewable energy sources such as wind, solar, biomass and geothermal accounted for 1% which biomass from unclean wood fuel and charcoal constituted the largest share. Thus, the importance of increasing the share of renewable energy in Africa, especially wind, solar, geothermal and clean biomass cannot be over emphasized. Further-more, Waziri et al (2018) in their study stated that in West Africa, the pursuit of economic growth is done without taking its impact on the environment and future generation into consideration, due to the kind of energy sources used with other resource to produce goods and services. However, to attain sustainable development, the need for future generation must not be compromised to achieve that of the present generation.

### 1.1.1 Renewable Energy Potentials in Nigeria

Nigeria is the most populous country in the Africa at about 200million as stated by the United nation estimates of 2019. The increase in population coupled with epileptic power supply are among the many factors contributing to the need for renewable energy sources. This section shows in detail the different renewable energy sources in Nigeria and their potential

#### Hydropower

Nigeria is endowed with numerous small and large rivers and falls which is responsible for the huge potential of hydropower in the country. According to Aliyu et al (2015), large hydro power (LHP) is contributing about 30% to the present generation capacity in Nigeria, thereby making it one of the major sources of electricity generation in the country. There are three major hydropower sites in Nigeria: Kainji (760 MW), Jebba (540 MW) and Shiroro (600 MW). The fourth hydropower station is a private owned utility services company located at six different sites in Plateau state owned by the Nigerian Electricity Supply Corporation Limited (NESCO) and has a total potential of just 21 MW. In Nigeria, there exist different categories of hydropower such as large, small, mini and micro hydropower.

Technically, the exploitable hydropower capacity of the country according to Mohammed et al

(2017) is at 20,000 MW though the installed commercial capacity of hydropower in the country stands at around 2000 MW including all the small hydropower plants. By international standard, a 10 MW capacity limit of hydropower is defined to be small hydropower but in the Nigerian context, in accordance with the standard of the Energy Commission of Nigeria, capacities up to 500 kW and 1 MW are defined as micro- hydropower and mini-hydropower respectively. According to the Energy Commission of Nigeria, the large hydro potential is estimated at 11 250 MW and the small hydro potential at 3 500 MW. The figures below show the commissioned large hydropower stations in Nigeria and the small hydropower in existence in Nigeria.

**Table 0.1: Commissioned Large Hydropower Stations in Nigeria**

| LOCATION | CAPACITY (MW) | COMMISSIONED DATE | RIVER |
|---|---|---|---|
| Shiroro | 600 | 1990 | Kaduna |
| Kainji | 760 | 1968 | Niger |
| Jebba | 570 | 1984 | Niger |
| Zamfara | 100 | 2012 | Bunsuru |

**Source: Zarma IH. Hydro power resources in Nigeria (2006)**

**Table 0.2: Small Hydropower in Existence in Nigeria**

| RIVER | STATE | INSTALLED CAPACITY (MW) |
|---|---|---|
| Bagel I | Plateau | 1 |
| Bagel II | Plateau | 2 |
| Ouree | Plateau | 2 |
| Kura | Plateau | 8 |
| Lere | Plateau | 4 |
| Lere | Plateau | 4 |
| Bakalori | Sokoto | 3 |
| Tiga | Kano | 9 |

| | | |
|---|---|---|
| Total | | 30 |

**Source: ECN (2015)**

**Biomass**

There exist a variety of biomass resources in Nigeria with great opportunities for energy generation from it. These biomass resources available in Nigeria include wood fuels, by-products from crops, animal wastes and wastes arising from forestry, agricultural, municipal and industrial activities (Mohammed et al 2013; Adeoti et al, 2014; Iye and Bilsborrow, 2013). According to the study of Ogwueleke (2009), annually Nigeria generate about 25 million tonnes of municipal solid waste. It is further estimated that about 227,500 t of animal waste is generated in Nigeria daily, since 1 kg of animal waste produces about 0.03 $m^3$ biogas, then the country has the capacity to potentially produce about 6.8 million $m^3$of biogas per day from the animal waste (SERN 2014).

**Agricultural Residue**

Nigeria is a largely agrarian nation where agriculture supports basically the rural microeconomics settings. The production of agricultural residue in Nigeria is mainly dictated by ecological zones and regional agricultural activities. One of the sources of agricultural residue in Nigeria is cereal crop residue and about 80% of the country's total land is cultivable and typically supports cereal crop production (Mohammed et al 2013). Cereal crop is one of the staple foods in the country, so during the harvest season, large quantities of processing residue are generated and burnt in the farm to allow for further cultivation of the soil due to inability to utilize it for energy production.

Furthermore, these residues are used for domestic fuel by burning in traditional three-stones stoves in the rural areas or discarded as solid waste in urban area. Other agricultural biomass sources available in Nigeria are Jatropha curcas, sunflower, cassava, sugarcane and castor oil with sustainable potential for liquid biofuel production. As stated by Abila (2012), the use of biofuels enhances the potential for sustainable development in Nigeria. currently, the following biofuel companies exist in the country and they include: Alconi/Nosak (43.8 million l/year), UNIKEM (65.7 million l/year), Intercontinental Distilleries (9.1 million l/year), Dura clean (4.4 million l/year) and Allied Atlantic Distilleries Ltd. (10.9 million l/year). The Nigerian Yeast and Alcohol

Manufacturing Company is currently building a $200 million ethanol manufacturing plant with a capacity of 30 million l/year. The table below shows the energy potential of agricultural residue in Nigeria.

**Table 0.3: Energy Potential of Major Agricultural Residues in Nigeria**

| **Agricultural Crop** | **Generated Residue** | **Production Quantity $(10^3\ t)^2$** | **Crop to Residue Ratio (PRR)** | **Calculated Residue Generated** | **Energy Content (MJ/KG)** | **Energy Potential (TJ)** |
|---|---|---|---|---|---|---|
| Maize | Stalk | 7306 | 1.5 | 10,959 | 15.48 | 168,65 |
| Rice, paddy | Straw | 3219 | 1.5 | 4829 | 15.56 | 75.14 |
| Sorghum | Stalk | 4784 | 2.62 | 12,534 | 17.00 | 213.08 |
| Wheat | Stalk | 34.2 | 1.5 | 51.3 | 19.3 | 0.99 |
| Coconut | Shell | 170 | 0.6 | 102 | 10.61 | 1.08 |
| Oil palm Fruit | Empty Fruit bunch | 8500 | 1.25 | 2,125 | 15.51 | 32.96 |
| Sugarcane | Bagasse | 1414 | 0.3 | 424.3 | 13.38 | 5.68 |
| Cocoa | Stalk | 428 | 1.0 | 428 | 15.48 | 6.63 |
| Millet | | 4125 | 3.0 | 12,375 | 15.51 | 191.94 |
| **Total** | | | | | | **697.15** |

**Source: FAO statistics (2010)**

**Municipal Solid Waste**

These are waste material generated from human daily activities which contains mostly biodegradable and non-biodegradable matter. As stated by Ogwueleka (2009), the per capita municipal solid waste per day in Nigeria differs from place to place, for instance Lagos, Kano, Ibadan, Kaduna, Port-Harcourt and Onitsha solid waste stand at 0.63 kg, 0.56 kg, 0.51 kg, 0.58 kg, 0.60 kg and 0.53 kg respectively, depending on the economic activities and level of urbanization of the place. The biodegradable fraction can be treated by anaerobic digestion for biogas which can be used for cooking and electricity generation by thermo-chemical conversion in an incineration or gasification power plant. According to Mohammed et al (2013), an estimated potential of power generation from MSW in Lagos metropolis stands at about 442MW while a 35kW electricity project has been initiated in Oyo State to utilize biogas from abattoir waste generated in the area. The table below indicates the estimated power generation potential from MSW in Lagos metropolis

**Table 0.4: Estimated Power Generation Potential from MSW in Lagos Metropolis**

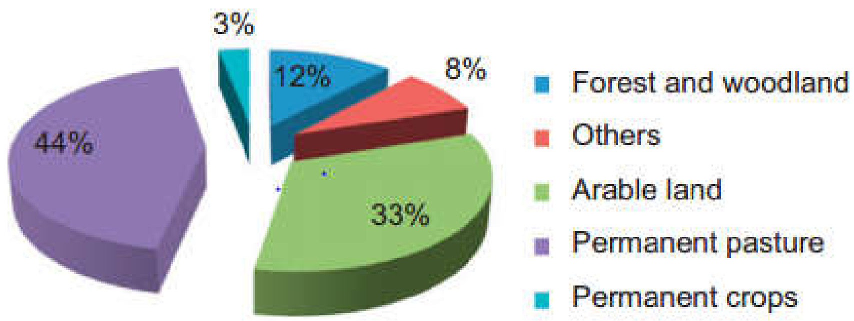
| **Local Government Area** | **Estimated Power Generation Potential (MW)** |
|---|---|
| Agege | 28.5 |
| Ajeromi-Ifelodun | 37.7 |
| Alimosho | 56.5 |
| Amuwo-Odofin | 14.5 |
| Apapa | 14.5 |
| Eti-Osa | 27.2 |
| Ifako-Ijaiye | 20.6 |
| Ikeja | 17.9 |
| Kosofe | 25.8 |
| Lagos Island | 23.8 |
| Lagos Mainland | 17.4 |
| Mushin | 36.5 |
| Ojo | 26.0 |
| Oshodi-Isolo | 31.3 |
| Somolu | 28.3 |
| Surulere | 35.2 |
| Total | 441.7 |

**Source: Motherland Nigeria (2005)**

**Forest Biomass**

Forest biomass in Nigeria stretches from north to south though the exact potential in the country is not well known due to poor record keeping of forest resource production and exploitation. The forest in the northern region of the country is made up of largely woods and shrubs while thick rain forest is found in the Southern region. According to a study conducted by motherland Nigeria (2005), it is estimated that the total land mass of the country is covered with about 12% forest and wood and 95% of the established forests in Nigeria are owned by the government. The trees, residues and charcoal derivatives are mostly utilized as combustible biomass. About 80% of the wood in developing country is used for fuel wood consumption (Sampson et al, 2005; Roda, 2002; FAO, 2003) and the usage in Africa is pegged at 90% (Maes and Verbist, 2012), indicating the over-reliance on traditional Biomass. According to Mohammed et al (2014), if the resources are utilized sustainably, the prospect for bio-electric power generation through bioenergy resources is very enormous to complement the low energy access in the country. The figure below shows that about 12% of the total land mass of Nigeria is covered with forest and wood

**Figure 0.1: Percentage Estimate of Land Use in Nigeria**




**Source: Motherland Nigeria (2005)**

**Animal Residue**

This is another source of renewable energy resource in Nigeria which consist of mainly animal dung from Cattle, pigs, goats, poultry and sheep. According to Malau-Aduli, et al (2003), most of the country's ruminant livestock especially cattle is found in the Northern region. Animal manure can also be used as a co-substrate with human waste or other wastes for biogas production especially in a centralized anaerobic digestion (CAD) facility and this seems more sustainable in the North since it has the largest share of livestock population in the nation. According to Mohammed et al (2013), Till recently, less than 10 biogas digesters have been installed including in a prison in Zaria, National Animal Production Research Institute (NAPRI), Zaria, Ojokoro/Ifelodun, Lagos and Mayflower Secondary School, Ikene, Lagos. The table below indicates the FAO statistic for animal production in Nigeria.

**Table 0.5: Livestock Production Quantity in Nigeria from 2001 to 2010**

| Year | Cattle | Pigs | Goats | Sheep | Chicken |
|---|---|---|---|---|---|
| 2001 | 15,133,400 | 5249,540 | 45,260,400 | 28,692,600 | 124,620,000 |
| 2002 | 15,148,600 | 6111,820 | 46,640,000 | 29,400,000 | 131,125,000 |
| 2003 | 15,163,700 | 5677,900 | 47,551,700 | 30,086,400 | 137,680,000 |
| 2004 | 15,700,000 | 5910,000 | 48,700,000 | 30,800,000 | 143,500,000 |
| 2005 | 15,875,300 | 6141,220 | 49,959,000 | 31,547,900 | 150,700,000 |
| 2006 | 16,065,800 | 6390,000 | 51,223,600 | 32,314,200 | 158,400,000 |
| 2007 | 16,152,700 | 6642,340 | 52,488,200 | 33,080,300 | 166,127,000 |
| 2008 | 16,293,200 | 6908,030 | 53,800,400 | 33,874,300 | 174,434,000 |
| 2009 | 16,435,000 | 7184,360 | 55,145,400 | 34,687,300 | 183,156,000 |
| 2010 | 16,578,000 | 7471,730 | 56,524,100 | 33,519,800 | 192,313,000 |

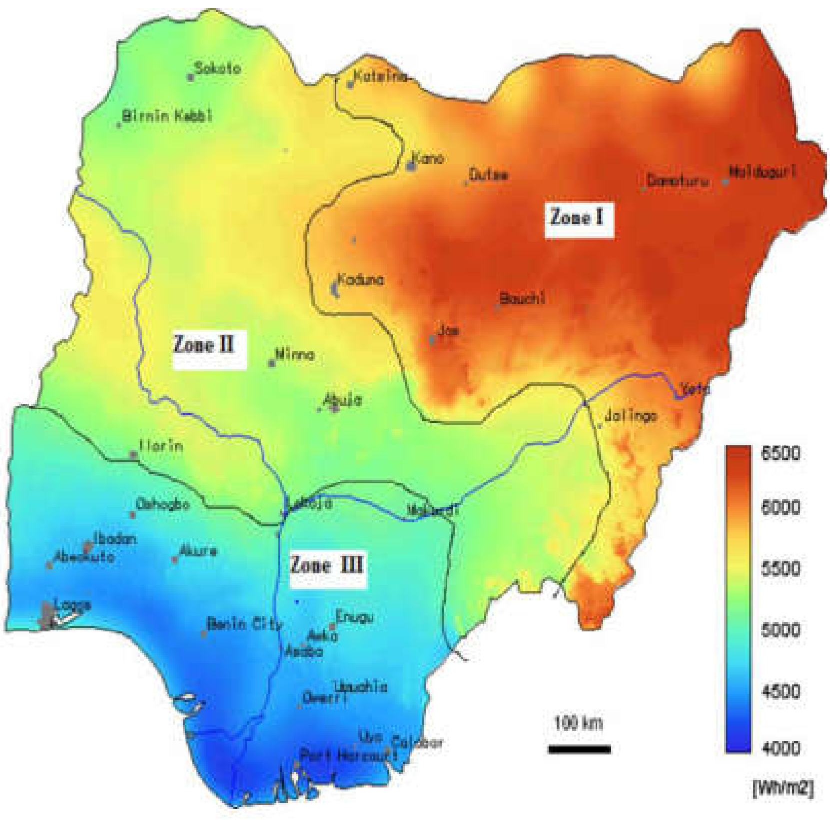
**Source: FAO (2010)**

**Solar**

As stated in the study of Ohunakin et al (2014), Nigeria is located close to the equator where sunshine is evenly distributed throughout the year. The daily average solar radiation ranges from about 12.6 MJ/m2-day in the coastal axis to about 25.2 MJ/m2- day in the far North axis, thereby having an estimated solar energy average of 6,372,613 PJ/year in the country (Energy commission of Nigeria, 2003; Ohunakin et al, 2014). According to Aliyu et al (2013), it is estimated that solar energy will increase from 1MW to 20MW in 2020 to 2030. Chineke and Ezike (2010) stated in their study that in the northern region of the country, Maiduguri shows the highest potential value of solar photovoltaic followed by Sokoto, while the Federal Capital Territory (Abuja) shows a great potential with a minimum value greater than 3000 W h/m2/day. Port-Harcourt in the southern axis showed the least potential in July but still maintains a value higher than the threshold and also the period June to August generally experiences a notable fall in potential in solar energy as a result of cloud cover due to peak rainy season.

Due to the abundance of solar energy in Nigeria as a result of the country's location in the equator, Okoro and Madueme (2006) has suggested that a systematic and harmonized financial investment in the area of solar energy research to reduce the country's over dependence on its depleting fossil reserve. In the same vein Ohunakin, et al (2014) stated that as at January 2014, there were over 60 solar projects in Nigeria which is estimated to increase in number in future. The solar radiation map of Nigeria is presented below:

**Figure 0.2: Zone Based Solar Radiation Map of Nigeria**



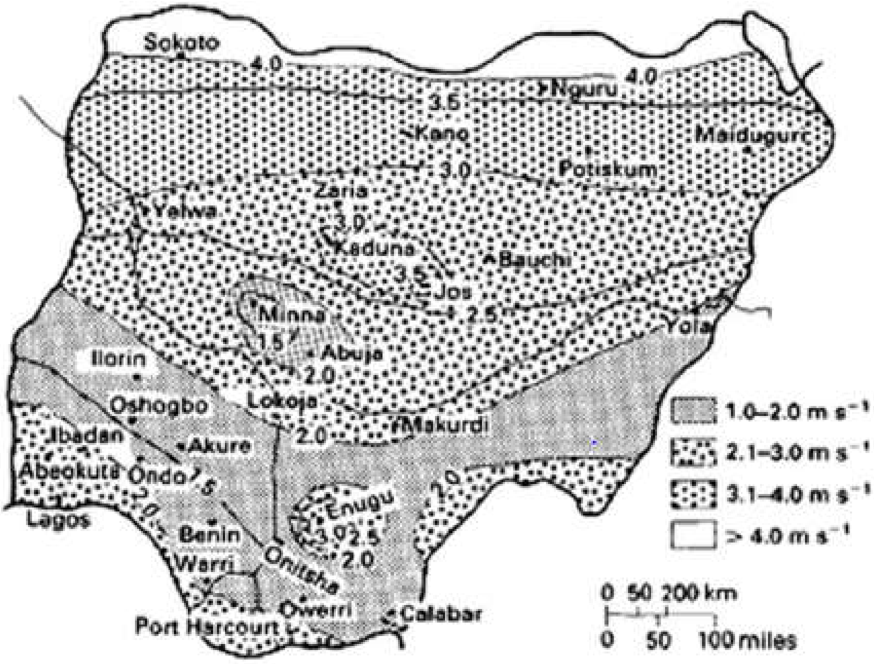

**Source: Huld et al (2005)**

**Wind**

Wind is another renewable energy resource available in Nigeria. Nationally, the annual average wind speed is at about 10m heights and ranges from 2.3 to 3.4 m/s along the coastal sites while for the semi- arid areas and highlands sites with wind peak occurring between April and August, the wind varies from 3.0-3.9 m/s (Adaramola and Oyewola, 2011; Ajayi, 2010; Ngala et al 2007). According to Salisu and Garba (2013), one of the notable wind power generation in Nigeria with a total generation capacity of 10MW is the first Nigeria wind farm of 37 wind turbines in Rimi village of Katsina state. This project is part of the agenda of the federal government of Nigeria to increase the contribution of RE to electricity generation capacity in the country. The other wind-based power generation sites are located at Sayya Gidan-Gada (Sokato state), Dan-Jawa village (Sokoto state) and Benin energy research Centre (Edo state) with generating capacities of 5KW, 0.75KW and 1KW respectively.

Although lots of windmills installed in the 1950s and 1960s which were used for pumping in the Northern part of Nigeria are no longer functioning, rehabilitated windmill for water pumping at Kadawa village (Kano state) still functions (Ajayi, 2009). According to Saddik et al (2012), the attractive sites for wind power generation in Nigeria are the coastal regions, the offshore, the inland hilly regions of the North, the mountainous terrains in the middle belt and the northern part of the country. Mohammed et al (2013), stated that though there is an enormous wind power potential in Nigeria, its utilization level in the country is still relatively low. Exploration of these potentials will help in the diversification of Nigeria's energy mix, boost electricity generation to cope with electricity demand, create employment for youths and contribute to the reduction of carbon footprint. The figure below depicts the annual mean wind speed distribution in Nigeria

**Figure 0.3: Annual Mean Wind Speed Distribution in Nigeria (isovents at 10 m height)**




**Source: Ojosu and Salawu (1990)**

**Table 0.6: Summary of the Renewable Energy Potential in Nigeria**

| Resources | | Potential | Current Utilization and Further Remarks |
|---|---|---|---|
| Large Hydropower | | 11,250 MW | 1,900 MW exploited |
| Small Hydropower (<= 30MW) | | 3,500 MW | 64.2 MW exploited |
| Biomass (non-fossil organic matter) | Agricultural Residue | 72 million hectares of Agricultural land | 91.4 million tonnes/year produced |
| | Municipal Solid Waste | 30 million tonnes per year | 18.5 million tonnes produced in 2005 and now estimated at 0.5 kg per capita per day |
| | Forest Biomas | 11 million hectares of forest and woodland | 43.4 million tonnes per year fuel wood consumption |
| | Animal Residue | 245 million assorted animals in 2001 | - |
| Solar PV | | 3.5 – 7.0 Kwh/m2/day | 15 MW dispersed solar PV installations [estimated] |
| Wind | | 2 - 4 m/s at 10 m height | Wind speeds in Nigeria range from a low 1.4 to 3.0m/s in the Southern areas, except for coastal line and 4.0 to 5.1m/s in the North. The Plateau area particularly interesting. |

**Source: ECN (2014)**

### 1.1.2 Renewable Energy Policies and Regulations in Nigeria

This section of the study focuses on the overview of policies, acts and regulations in Nigeria which are particularly relevant to the integration of renewable energy in the energy mix of Nigeria. The documents below contain the guiding policy statements for renewable energy in the country:

- Renewable Energy Policy Guidelines, 2006
- Renewable Electricity Action Programme (REAP), 2006
- National Biofuel Policy and Incentives (2007)
- Renewable Energy Master Plan (REMP). 2012
- National Renewable Energy and Energy Efficiency Policy (NREEEP), 2015

**Renewable Energy Policy Guidelines, 2006**

This is the federal government policy on electricity from renewable energy sources, issued by the Federal Ministry of Power and Steel, highlighting the government's Vision, policies and objectives for prompting the growth of renewable energy in the energy mix of Nigeria. The policy guide stipulates an expansion of renewable energy market to at least five percent of total electricity generating capacity with a minimum of 5 TWh of electric power production and the construction of renewable electricity systems to cover remote areas not connected to the national grid. Also, the guidelines emphasize on the establishment of affordable pricing mechanisms, development of innovative, cost-effective and practical measures to accelerate access to electricity services in rural areas through renewable sources.

**Renewable Electricity Action Programme, 2006**

The core objective of this REAP document is on the nation utilizing all forms of renewable energy sources for electricity generation, highlights potential gaps, technical assessments of the sources and financial implications as compared to conventional energy. The REAP gives an overview on the Renewable Energy potentials, technologies and markets and then elaborates on the development targets per technology, application and the strategies for their achievement. It further lays out the financing procedures via the Renewable Electricity Fund (REF) and other sources, looks into roles of government bodies and concludes with a risk assessment as well as structures for monitoring and evaluation. The study is relevant for mid-term on-grid renewable energy but more interesting for the rural energy supply since this was the principal application area of renewable energy at the time of writing.

**National Biofuel Policy and Incentives, 2007**

This document was issued in 2007 to support programme for biofuel, aim especially at integrating the agricultural sector of the economy with the downstream petroleum sector because biofuels would impact on the quality of petroleum products as a more environmentally friendly fuel as compared to fossil fuel-based energy source. The objective of the policy document was to develop and promote a national fuel ethanol industry using agricultural products in order to improve the export properties of automotive fossil-based fuels produced in Nigeria. The policy sets out to link the agricultural and energy sectors with the primary aim of stimulating development in the agricultural sector. The most distinct targets of the policy include a contribution of all biofuels companies with 0.25% of their revenue towards funding research into feedstock production, local technology development and improved farming practice.

**Renewable Energy Master Plan, 2012**

The REMP drafted by the Energy Commission of Nigeria and the United Nations Development Programme (UNDP) in 2005 and reviewed in 2012, expresses vision, objectives and sets out a road map for increasing the role of renewable energy in achieving sustainable development in Nigeria (ECN, 2012). According to ECN (2013), the master plan does not categorically distinguish on-grid from off-grid generation, however, it refers to integrating renewable energy into buildings, electricity grids and other distribution systems and sets a target from 42% in 2005 to 60% in 2015 and 75% by 2025. Nigeria intends to increase the supply of renewable electricity from 13% of total electricity generation in 2015 to 23% in 2025 and 36% by 2030, thereby making renewable electricity to account for about 10% of Nigeria's total energy consumption by 2025. Incentives to promote the attainment of the renewable energy target as well as grow the renewable energy market. However, the REMP has still not been signed and approved by the National Assembly to be passed into law governing the renewable energy development.

**National Renewable Energy and Energy Efficiency Policy, 2015**

The National Renewable Energy and Energy Efficiency Policy (NREEEP) was approved by the federal council to replace the REMP, outlining the policies and measures for the promotion of renewable energy and energy efficiency in Nigeria. The NREEEP as part of its objectives stipulated that the proportion of electricity generated from renewable energy sources in Nigeria, shall increase to a level that meets or exceeds the ECOWAS regional policy targets for renewable electricity generation and energy efficiency for 2020 and beyond. It recommends that an appropriate strategy should be developed to harness these potentials in order to add value to the ongoing changes in Nigeria's power sector.

### 1.1.3 Global Policies and Programmes on Renewable Energy.

This section describes various global policies and programmes of renewable energy in the world.

**ECOWAs Renewable Energy Policy (EREP)**

This ECOWAS Renewable Energy Policy was adopted in 2013, by the 43rd Ordinary Session of the ECOWAS Authority of Heads of State and Government, which held in Abuja, Nigeria. The main aim of the policy was to ensure increased use of renewable energy sources such as solar, wind, small-scale hydro and bioenergy for grid electricity supply and for the provision of access to energy services in rural areas. The EREP target for ECOWAS region is to increase the share of renewable energy in the region's overall electricity mix to 10% in 2020 and 19% in 2030. Including large hydro, the share would reach 35% in 2020 and 48% in 2030. Around 25% of the rural ECOWAS population will be served by mini-grids and stand-alone systems by 2030. Also, the policy aims at assisting the ECOWAS Member States to develop appropriate regulatory frameworks for the promotion of renewable energy technologies and services, thus reinforcing regional integration in the renewable energy sector.

**NEPAD Renewable Energy Policy**

NEPAD, being the implementing arm of the African Union and being driven by its mandate as Africa's development agency, follows two parallel practical approaches to increase energy access of the African population to clean energy sources and achieve the goals of sustainable development. The first approach focusses on accelerating the development and implementation of Africa's High Priority Renewable Energy Projects through its Initiative Renewable Energy Access Programme (REAP). The second approach is targeting Africa Mega Energy Projects both in Generation and Transmission Lines that are of regional nature and accelerate their development and implementation through the Programme for Infrastructure Development in Africa (PIDA).

Under **REAP,** NEPAD started by sourcing one to two high priority renewable energy projects from African countries, that are supported as an institution or with partners under Africa's Sustainable Energy for all Hub (SE4ALL). The PIDA's **Energy vision** is to develop efficient, reliable, affordable and environmentally friendly energy networks and to increase access to modern energy services for all Africans.

**The International Renewable Energy Agency (IRENA)**

This is an intergovernmental organization that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. As stated in the new IRENA report, Innovation is the crucial point for the diffusion of renewable energy. The report stated that factors like digitalisation and electrification will help countries make the most of low-cost renewables. It further stated that clean energy industry will have to make sure there is continual innovation so that recent falls in power generation costs continues.

## 1.2 Statement of Problem

The relevance of energy in our everyday life cannot be overemphasized because energy is a major contributor to a better livelihood thereby increasing the Gross Domestic Product of any country. As stated in the Energy Poverty Action Initiative of the World Economic Forum (IEA, 2007), the access to energy is very crucial for the improvement of the quality of life and also for economic development. According to Boes and Taylor (2003), there is a strong correlation between energy consumption and increase in the wealth of a nation. Energy is deemed as the engine room through which other sectors of the economy will develop. The amount of energy available and utilized by a country determines its development level, industrial strength and the wealth in that country. According to Ramchandra and Boucar (2011), security, climate change and public health are directly interrelated with energy.

Africa is hungry for energy, as stated by the world economic forum 2016, only about 24% of sub-Saharan Africans have access to electricity and the energy generation capacity of Africa is only 28 Gigawatts excluding South Africa; this quantity equals to that of Argentina alone. The demand is only expected to rise with increasing population, urbanization and economic productivity. As a result of small installed capacity, there is low energy consumption and access. Even those connected to a power grid experience an average of 54 days of power outage a year – that's darkness for 15% of the year. According to Okafor and Joe-Uzuegbu (2010), though Nigeria is abundantly blessed with both conventional and non-conventional energy sources, yet the country still suffers from inadequate supply of energy. Due to population boom, inevitable industrialization, rural-urban migration, more agricultural production and improving living standards, the demand for energy in Nigeria continues to increase.

According to Nwaka (2005), in the last two decades there has been a great population rise in the cities translating to an overwhelming demand on electricity. According to the united nation estimates of 2019, the current population of Nigeria is estimated at 200,416,053 million, ranking number seven in the list of countries by population and Nigeria is projected to become the 3rd. most populous country in world by 2050. As stated above, this large population compete for the little access of energy available in Nigeria therefore putting a lot of pressure on the already bad state of the energy situation in Nigeria.

In order for Nigeria to attain sustainable economic growth and social development goal in the near future, cleaner energy sources like wind, solar, biofuel, and hydropower need to be put in place. This can be done through concerted effort in both private and public sector to speed up the rate of innovation in the area of renewable energy. The role of innovation on energy is very important in not just increasing access to energy but also addressing the issue of high energy consumption resulting in the negative influence on the environment. The emphasis in recent era is inclined towards achieving sustainable development by focusing on ways in which the negative effects of business and economic operations can be reduced. The country needs to develop a technologically driven renewable energy sector that will harness the nation's resources to complement its fossil fuel consumption and guarantee energy security, thus this study seeks to investigate the impact of innovation on renewable energy consumption

### 1.3 Research Questions

- To what extent does innovation affect the renewable energy consumption in Nigeria?
- What is the causal and Long-run relationship among innovation, renewable energy consumption and economic growth in Nigeria?

### 1.4 Objectives of the Study

The study investigates the impact of innovation on renewable energy consumption in Nigeria. The specific objectives however are as follows;

- To determine the impact of innovation on the renewable energy consumption in Nigeria.
- To examine the causal and the long-run relationship among renewable energy consumption, Economic growth, innovation, carbon emission, trade Openness and oil rent in Nigeria

## 1.5 Hypothesis of the Study

- $H0_1$: There is no significant effect of innovation on the renewable energy source such as solar, hydropower and wind in Nigeria
- $H0_2$: There is no causal or long-run relationship among innovation, renewable energy consumption and economic growth in Nigeria.

## 1.6 Significance of the Study

Firstly, it will avail policy makers' further explanation and prediction on how to unlock sustainable energy through the performance indicators used in the work. Secondly, the study will open a research window that will guide further research, particularly concerning the use of innovation to unlock sustainable energy in Nigeria. Lastly, it will feed the monitoring and evaluation of the implementation of STISA and Agenda 2063 to achieve the Africa we want.

## 1.7 Scope of the Study

The focus of this study is to investigate the impact of innovation on renewable energy consumption in Nigeria covering a period of 1996Q1 to 2017Q4. Due to lack of innovation data in various country in Africa, this work will be carried out in only Nigeria. The variables used to model renewable energy consumption include; innovation, renewable energy consumption and economic growth.

## 1.8 Plan of the study

The study will be organized into five chapters. Chapter one will entail the background and objectives of the research, the second chapter will entail a review of relevant literature concerning the research topic, chapter three will present the methodology used, chapter four will present an analysis of data collected from the field and the last chapter will present major findings from the study, conclusion and recommendations.

# CHAPTER TWO

# LITERATURE REVIEW

This chapter is structured into three sections: conceptual literature, theoretical literature and empirical literature. The conceptual literature defines different concepts that are relevant to the study in order to foster a clear understanding of the terms. This is followed by a review of theories under the section of theoretical literature and the empirical literature which reviews various works carried out by other researchers on topics similar to that of this study.

## 2.1 Conceptual Literature

This section is set aside to provide definitions, understanding and appreciation of concept such as innovation and renewable energy which are the main concepts used in this study.

### Innovation

According to Schumpeter (1939), innovation is defined as any activity which leads to the setting up of a new production function. The activities were divided into several steps such as: introducing new product, introducing new method of production, opening new market and finding of appropriate sources of raw materials. Sahal (1985) and Dosi (1982), in their work viewed innovation as a cumulative process, he stated that empirically, in many areas of technical change there is a strong cumulativeness in the form of innovation avenues or technological trajectories.

In Pierre Lionnet (2003), innovation is a process in which a unique idea is developed into a stage where income is generated from it eventually. It is a dynamic social, economic and technical process which involves the synergy of people from different perspective, horizons and motivations. Fagerberg (2005), distinguished between invention and innovation by stating that invention is the occurrence of an idea while the implementation of that idea into practice is termed as innovation.

The Oslo manual has different definition of innovation. the Oslo Manual first edition which grew out of experimental innovation surveys of the 70s and 80s limited the definition of innovation mainly to manufacturing, although services were mentioned, it involved only technological product and process innovation which is the production of a product (OECD 1992: para. 239). In five years, a revised manual was implemented. The manual was revised after five to include services, which dominated GDP, though it was still about technological product and process innovation and putting of product on the market. Process innovation included production but added delivery of the resulting product to the market (OECD, 1997).

Further-more, a revision leading to the third edition of the Oslo Manual (OECD, 2005) took place from 2003 to 2005. In the OECD, 2005, Products were still goods or services, but the definition was expanded to organization and use of business practices, and market development or the finding of new markets. The result was one process, two methods, and one product to be delivered to the market. An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices workplace organization or external relations (OECD/Eurostat, 2005). This work will adopt the concept of innovation from the OECD Manual of 2018, which states that innovation is a new or improved product or process significantly increased from the unit of previous product or processes and that has been made available to potential utilizers or brought into use by the process.

**Renewable Energy.**

Renewable energy is generally defined as energy that is got from resources which are naturally replenished on human time scale. According to Akuru et al (2017), Renewable Energy is defined as the form of energy obtained primarily or indirectly from sunlight, through differential heating on the earth's surface, leading to air movement and can be replenished during the life time of an adult human. Agbongiarhuoyi (2015) stated that renewable energy can be utilized in four distinct areas such as; electricity generation, air and water heating/cooling, motor fuels, and rural electrification needs.

### 2.1.1 Types of Renewable Energy

**Solar Energy**

This form of energy depends on nuclear fusion power from the core of the sun. It is harnessed through the conversion of sunlight into electricity with the use of solar cells in solar panel. This system is called Photovoltaic system (PV) or thermal system (Basri et al 2015). Solar energy can be converted into different ways, ranging from solar water heating through solar collectors, attic cooling with solar attic fans for domestic use and the complex technologies of direct conversion of sunlight to electrical energy using mirrors and boilers or photovoltaic cells.

The sun ray conversion technologies are either of the solar thermal type mainly used for solar heating, cooling, drying, thermal power plant or of the photovoltaic type which is used for electricity generation. PV can be used to supply power to remote rural areas that are not connected to the national grid. It can also be used to power low to medium power applications such uses as communication stations, rural television and radio, streetlights, water pumping, refrigeration and powering security cameras, which require power of the order of 1–10 kW. It is also possible to generate PV power for feeding into the national grid and concentrated solar power (CSP) projects can be used for utility scale power plants larger than 20 MW capacity.

**Wind Energy**

Wind energy the form of energy that is dependent on the difference of temperature on the earth's surface due to different temperatures of the earth's surface when hit by sun rays. It can also be defined as the use of air flow through wind turbines to provide the mechanical power to turn electric generators. According to Joselin-Herbert et al (2007), in order to generate electricity from wind, the Wind turbines convert the kinetic energy of the wind to electrical energy by rotating the blades. This form of energy is limited due to the availability and the fluctuating nature of wind in some areas.

Joselin-Herbert et al (2007) observed in their study that the world technical potential of the onshore wind energy is very large at about $20{,}000\times10^9$ to $50{,}000\times10^9$kWh per year compared to the current total annual world electricity consumption of about $15{,}000\times10^9$kWh. This form of energy is used to pump water or generate electricity, though it requires extensive aerial coverage to produce a good amount of energy In determining the viability of wind as an energy source, it is important to know the greatest extent possible of the wind resources before investing in and installing a wind turbine (Anderson et al 2011). This is to prevent investing in areas with low wind velocity.

**Hydropower Energy**

Hydropower is an energy produced through the combination of potential energy and kinetic energy of flowing water to generate electricity using rotary hydro turbine. it is a form of energy that depends on gravitational potential of elevated water that was lifted from the oceans by sunlight and the energy produced from a hydro source is obtained from hydropower turbines. Run-off Rivers (ROR) are used for small hydropower while large dams are used for large hydropower. Dams are reservoirs of water to interrupt the natural flow of a river and they are constructed to impound a large volume of water. The water rotates a turbine that drives an electric generator that injects Kilowatt hours into the grid.

**Biomass Energy**

Biomass energy is an indirect form of solar energy as it comes from photosynthesis. Biomass is all biological plant and animal matter that can be used for energy production. It is derived from four main sources namely; agricultural source, forests and their derivatives, municipal solid wastes and animal dung and it is very common throughout the world. According to Bapat et al (1997), the third largest primary energy resource in the world after coal and oil is biomass. Saxena et al (2009); Lora ES and Andrade (2009), stated that biomass are compounds of nitrogen, carbon, sulfur and oxygen with significant amounts of free energy in the form of chemical bonds. This energy can be released by breaking of molecule to generate heat, which can be converted to mechanical work or electricity.

When transformed into liquid from, biomass is also used as a raw material for transport fuel. In the same vein, both food and non-food biomass can be used to produce biofuels which can take several forms, ranging from gas, liquid or solid form (Saxena et al, 2009). Biomass can be converted into electric power through the following methods: direct combustion of biomass material, gasification, pyrolysis, and anaerobic digestion.

**Geothermal Energy**

Geothermal energy originates from the original formation of the planets and from radioactive decay materials. It is a type of renewable energy generated and stored in the earth. The difference in temperature between the core of the planets and its surface known as the geothermal gradient, drives a continuous conduction of thermal energy in the form of heat from the core to the surface. This type of energy is mainly use for electricity generation and the production of heat

## 2.2 Theoretical Literature

This section is set aside to review the different theories of innovation definitions.

### 2.2.1 Theories of Innovation

**Linear Theory**

Linear model of innovation is one of the first theory of innovation advanced in the past to explain the relationship between the economy on one hand and science and technology on the other hand. Joseph Schumpeter, one of the first proponent of the theory identified three stages of innovation namely; invention, innovation and diffusion. According to Schumpeter, invention is the first manifestation of an idea, innovation is the first application of the invention in the market and diffusion is the growing of the technology throughout the market.

This diffusion process is represented by an s-shaped curve, beginning with market positioning of a technology through a slow start up, then gathers momentum and finally slowing down as a saturation level is reached (Schumpeter, 1934; (Stenzel, 2007). According to Nemet (2007), the linaer model shows that the improvement in scientific understanding determines the rate of innovation and the optimal way to increase the input of new inventions is by simply putting more resources into research and development. This is the process of technology- or supply push. However, critics argue that Schumpeter was more interested in the consequences of innovation than its causes and that none of his works "contain anything that can be identified as a theory of innovation" (Ruttan, 2001)

**Technology Push versus Demand Pull Model**

The critique of the technology-push linear model of innovation propounded an alternative called the demand-pull in 1950s and 60s. The demand-pull argument advanced that the demand for products and services is more important in stimulating innovation than advances in state of knowledge. It stated that it is actually economic factors that drive the rate and direction of innovation. According to Nemet (2007), changes in market demand create opportunities for firms to invest in innovation to satisfy unmet needs this in turn steers firm to work on finding solution to these unmet needs.

**Organizational and National Level Research Model**

Still in the 1950s and 1960s era, theoretical research broadened its perspective to include the sources of innovation. According to Xu (2007), the organizational and national level research model, focused on how to promote innovation in organizations through actual management of the research and development activities as wells as the department. Furthermore, the macro-economic understanding of innovation was examined in the work of Solow (1956). Solow estimated that the largest contribution to growth did not come from increases in labour or capital productivity, but from advances in knowledge. In the same vein Nelson (1959) and Arrow (1962) investigated the question of whether investment in knowledge lead to increase in national economic needs.

**Induced Innovation Approach.**

One of the theories of the 1970s to 1990 is the induced innovation approach. This approach analyses the change in national income on the rate and direction of technical change as a factor of production. It places emphasis on market drivers and hence demand-pull mechanisms are seen as important. According to Foxon (2003), innovation will be directed to more labour-saving technologies, if labour becomes relatively more expensive as compared to capital.

**Evolutionary Economics Approach**

This theory of innovation was built on the Schumpeterian understanding of innovation and on the ideas of bounded rationality and uncertainty. The evolutionary economic view described innovation as slow-moving and incremental, arising out of the inter-twined of different variables ranging from the economic, social, institutional and technological dimension. According to Stenzel (2007), Changes in one variable can create tensions with the others, thereby bringing about more changes and resulting in a continuous feedback loops among the different variables.

**Path Dependency Approach**

The path dependency theory which propounds the idea that innovation is as a function of the path of its development was promoted in the study of David (1985) and Author (1994). According to Cohen and Bacdayan (1994), the relationship existing between innovative learning process and routines are series of behaviour learned which involves several actors who are connected by relations of communication in the firms. This theory describes how some organizational decisions are influenced by decisions taken in the past. Significantly, path dependence explains how decisions made by firm is dependent on past decisions made, though the past circumstances may no longer be relevant.

This means that the more a particular technology is adopted, the more likely it is to be further adopted. According Foxon and Pearson (2008), expectations are shared amongst firms in an industry, thereby enhancing technological development. As stated by Kemp and Foxon, (2007), the process of mutual adaptation of the innovation and the environment in which it is produced leads to socio-technical regimes, where the institutions are the social rules and for innovation to take place there must be changes in the rules and the overcoming of inertia.

**The Chain Linked Model**

This model was propounded by Kline (1986). This model shows the interaction between research, the existing body of scientific and technological knowledge, the potential market, invention and finally the various steps in the production process. According to OECD, 1997, the model emphasizes on the importance of the continuous interaction between marketing and the design stage. Also, research is viewed as a form of problem solving instead as a source of inventive ideas. The chain-linked model integrates two types of interaction. The first refers to the processes which occurs in a firm while the second refers to the relationship between the firm and the global science and technological system which a firm operates in.

**The Innovation System Frame**

In the later part of the 20th century, different theories of innovation which reflected the complexity and interlinkage of the innovation process were propounded. The innovation system framework at the level of enterprise, national, regional and sectorial were proposed. In 1997and 2005 respectively, a guideline document known as the Oslo Manuel was developed. The Oslo manual of 1997 dealt with technological innovations while that of 2005 introduced the marketing and organizational innovations. This Oslo Manuel deals on technological product and process of innovation at the firm level. According to Speirs et al (2008), this Manuel uses the conceptual framework of the innovative system frame to classify conditions into four separate domains relating to innovative capacity. These domains are as follows:

- The Framework Conditions: this deals on the external area where the firm is operated and situated. It looks at the basic educational system, market accessibility, access to capital in the financial institutions, legislative and market accessibility
- Science and Engineering: this covers the science and technology institutions bases of the

business innovators.

- Transfer Factors: the factors affecting learning by firms and the information transmission from one firm to the other
- Innovation Dynamo: this domain talks on the propensity of the firm to innovate taking into consideration the interrelated system of factors that shape the innovative capacity of a firm.

**National Innovation Systems**

This approach was developed initially in the late 1980s in a study of the Japanese economy. The theory focuses on the individual and comparative analyses of the innovation system in various countries, across a wide range of technologies. The main idea of the national innovation system is that critical institutional drivers would be found at the national level. According to Freeman and Perez (1988), national innovation system can be defined as linkage of institutions both in the public and the private sectors whose activities and interactions initiate, modify, import and diffuse new technologies.

The national innovation systems approach to innovation theory has been developed and used extensively by the OECD (OECD, 1997 & 2002). Innovation process comprises of different actors and institutions. The interaction, flow of knowledge, funding, incentives for innovation and interlinkages between this actors and institutions are created by an institutional set-up. According to Remoe and Guinet (2002), the national innovation system model is rooted on an interactive model of innovation process that places importance on the market and non-market knowledge transactions among various component including institutions, firms and human resources.

**National Innovative Capacity**

This model was developed by Porter and it is related to the national innovation systemmode. The national innovative capacity refers to a political and economic entity of a country to produce a range of commercial relevant innovation. Porter (2002) in his study observed that despite the expenditure on research and development being common to all countries that innovative activity was concentrated in small number of countries due to biases in expenditure. This differences across countries was also noticed in Patent registrations with some regions or countries registering significantly more patents per capita than others. This location-bias is at the heart of the concept of the national innovative capacity and NIC theory has concluded that international patents provide the best proxy of innovation. According to Speirs et al., (2008), the national innovation capacity theory is underpinned by three main elements namely:

- Common Innovation Infrastructure: This is similar to the Oslo Manuel, taking into consideration the human and financial resources set aside for innovation, the policies impacting on innovation, and the economy's level of technological sophistication.
- Cluster-Specific Conditions: This element entails the geographic concentration of interconnected companies and institutions in a particular field.
- Quality of Linkages: This element focuses on the two-relationship between the common infrastructure and the industrial clusters.

**Technological Innovation Systems**

This theory is a development of the system style approach of innovation process. It is distinguished from other system theory through the basic starting point. According to Speirs et al., (2008), National innovation systems starts mainly from the notion that innovation is geographically heterogeneous while Technological Innovation System begins with technology and technological change as the starting point. In contrast to the national innovation system, in a technological innovation system, the number of actors, networks and institutions are normally smaller as compared to that of a national innovation system and this in turn reduces the complexity of this theory.

According to Hekkert and Negro (2009), the technological innovation system model, makes it possible to study the dynamic nature of an innovation process thereby making it possible to understand better what actually occurs within an innovation system. Sometimes the scope of a technology innovation system does overlap with sectoral, regional and national system scopes and the dynamic interaction of actors and knowledge flows within all these contexts remain fundamental.

### Transitions Theory

This theory is an extension of the TIS theory. It moves away from just simple incremental process of innovation to a more radical shift in the products and process. According to Gross (2008), this strand of analysis goes beyond economics and encompasses history, sociology and engineering. Technological change and the transition process can be investigated from different stand point but with the major purpose of trying to anticipate and manage future transitions. One of the examples of such review is that of Fouquet (2010), who reviewed past energy transitions by sector and service to identify features that may be useful for future transitions.

The primary determinant of energy transitions were the opportunities to produce sustainable energy services. Typically, the existence of a niche market willing to pay more for these characteristics enabled new energy sources and technologies to be refined gradually until they could compete with the incumbent energy source. Other factors cited by Fouquet (2010) as common features of successful energy transitions are: a successful learning curve leading to a decrease in costs, an S-shaped growth model of technological diffusion into a new market and the technological clusters. Foxon et al (2010), stated that three main lines of research has been developed under the transitions approach, namely: the multi-level perspective of the transition process, the strategic niche or transition management and the socio-technical scenarios.

## 2.3 Empirical Literature

This section of the work reviews various works carried out by other researchers on topics similar to that of this study

### 2.3.1 Literature Review on Innovation and Energy Consumption

Literatures such as Haseeb et al, 2017; Ekong and Akpan, 2014 and Okpiliya et al, 2016, focused mostly on how the level of innovation can be utilized in increasing energy conservation. Therefore, little attention was given to how innovations and energy consumption are related. Theoretically there is a link suggesting that innovation can have both a positive and negative effects on energy consumption. If the level of innovations focuses on the energy-efficient technologies, there will be a positive result on the level of consumption. The use of renewable energies is also critical in diversifying the dependence of a country in the process of energy consumption. Thus, in the absence of focus on efficient use of energy, the high level of innovations can enhance the country's dependence on energy consumption.

Popp (2001), utilized a time series data from 1970-1994 to study the relationship between Patent data of the United States as a proxy for innovation with the energy prices. Basing the analysis on the prices of energy-efficient innovations, the study found out that, when the level of educational quality variable is included in the analysis, both energy prices along with the level of educational quality have a positive significant relationship with the level of innovation in the country. As the two variable increases, the innovation level on the country also increases. However, when the variable of the level of educational quality is not included in the analysis, the results suggested that energy prices has a negative relationship with the level of innovations, meaning that as energy prices variable increases, the level of innovation decreases.

One other interesting study in this innovation and energy nexus is that of Herring and Roy (2007), who investigated on the interrelation between the level of innovation, energyeffectiveness, and energy consumption. Following the results of the findings of the study, they concluded that adopting energy efficient technologies in the short-run influences the level of energy consumption by reducing it, while the decrease of energy consumption is dominated by high growth and as a result, increased the level of energy consumption in long-run. In the same vein, Alfredsson (2004) in his study stated that green consumption does not bring about a positive effect to the quality of the environment.

According to the study of Berndt et al (1993), which investigated the relationship between technology and energy. This work was focused on United States, Canada, and France. It evaluated trans-log cost functions in the manufacturing industry for manufacturing industries of the countries above. The findings indicated that changes in technologies results in improved savings in both fuels consumption and electricity consumptions. Mountain et al (1989), in a similar context, analyzed Technological innovation and a changing energy mix in the manufacturing sector of

Ontario, using parametric and flexible approach. The findings of the study showed that level of technology enhanced the utilization of natural gas.

Elliott, et al (2017) adopted the distinctive approach in examining the association between energy consumption and technologies using mobile technologies primarily focusing on Samsung Galaxy Note to analyze its role in energy consumption. The researchers applied the quantitative methodology to analyze the battery consumption of Android smartphones, by gathering data from interviews, experiments and questionnaires mixed approach. From the results of the analysis, the study discovered that user practice is a significant factor to influence energy consumption of smartphone technologies.

According to Álvarez-Herránz et al (2017), in their Energy innovations-GHG emissions nexus study using a panel approach to inquire into the relationship between energy-efficient technologies with the environment in 28 OECD countries. The study analyzed how innovation contributes to reducing environmental degradation and energy intensity thus concluding that energy efficient technology has no significant effect on improving environmental quality of OECD using an annual data of 1990 to 2004. This study used public budget in energy research development and demonstration along with green-house gas emissions.

In the same vein Andreoni and Levinson (1998) inquire into how innovations in technologies, energy consumptions, growth and environmental degradation on one hand depends on the technical effect. The findings revealed that increased investment in innovation improves environmental quality thereby decreasing level of pollutions. The results further showed that higher level of income in economies resulted in higher energy consumption and declines the level of degradation through the level of innovations. This same conclusion was made in the study of Abidin and Haseeb, 2015; 2018.

Balsalobre et al (2015) also used the panel approach of 28 OECD countries from 1994-2010 to the association between energy-oriented research development and demonstration (RD and D) and energy intensity. The results of the study indicated that energy innovations reduce pollution in the environment therefore decreasing the negative effect of energy intensity. Furthermore, this study revealed that focus on energy Research development and Demonstration policies can help in reducing can level of energy intensity and improves the quality of the environment just as the reviewed work above.

The same results are reported in work of Alcantara and Duro, 2004; Dowlatabadi and Oravetz, 2005; which states that energy intensity involves higher energy consumption and therefore declines quality of the environment. Bointner (2014) studied the impact of innovation in energy industries of fourteen IEA countries. The outcome of the study showed that public research and development are positively related to the promotion of market diffusion of niche technology and in turn underlies the ability to result in a breakthrough of the respective technology.

Lastly, Li and Lin (2016) investigate the relationship of energy prices on energy technology patents in thirty provinces of China using a time series data of 1999–2013. The study applied the statistical technique of Fully Modified Ordinary Least Square in order to check the long-run coefficient of the variables. The results of the study indicated that energy prices reduce the level of energy technology patents in China.

# CHAPTER THREE

# RESEARCH METHODOLOGY

This chapter discusses the methodology adopted for the study. It is divided into five sections: Section 3.1 discusses the dataset used, 3.2 model specification, 3.3 gives an overview of the estimation techniques and procedures, section 3.4 presents the model justification, while section 3.5 shows the econometric package used in estimation

## 3.1 Data

The datasets utilized in this study comprises of secondary data from World Development Indicator 2018. The data ranges from 1996Q1 to 2017 Q4 and the variables include; Renewable energy measured by Renewable energy consumption (% of total final energy consumption), Economic growth measured by GDP Per Capita (Constant LCU), Innovation proxied by High-technology exports (% of manufactured exports), Carbon dioxide emission measured by CO2 emissions (metric tons per capita), Trade Openness measured by the sum of Exports of goods and services (% of GDP) with Imports of goods and services (% of GDP) and finally Oil rents measured by Oil rents (% of GDP)

## 3.2 Model Specification

Taking the objectives into account, we develop an empirical model in this study, that is consistent with the broader literature on renewable energy consumption. The analysis is conducted with the use of standard linear regression framework as stated below:

$Y = \alpha_i + \beta_1 X + \varepsilon_t$……………………………………………….3.1

Where Y is a vector of the dependent variable, $\alpha_i$ is the intercept, $\beta_1$ is the slope parameter, X is the vector of the independent variables and $\varepsilon_t$ is the error term with zero mean and constant variance.

The model specification is expanded as below

$REC_t = f\,(GDP_t, INNO_t, CO_{2t}, TO_t, OR_t)$………………………......3.2

Where,

REC = Renewable Energy Consumption

GDP = Gross Domestic Product per Capita

INNO = Innovation

$CO_2$ = $Co_2$ emissions per capita

TO = Trade Openness

OR = Oil Rent

### 3.2.1 Model for Objective 1.

Objective one investigates the impact of innovation on the renewable energy consumption in Nigeria. To estimate this objective, the model is econometrically specified as:

$$REC_t = X_t M' + \sum_{i=-m}^{i=m} \emptyset_i \, \Delta GDP_{t-i} + \sum_{i=-n}^{i=n} \omega_i \Delta INNO_{t-i} + \sum_{i=-j}^{i=j} \delta_i \, \Delta CO2_{t-i} +$$

$$\sum_{i=-i}^{i=l} \theta_i \, \Delta TO_{t-i} + \sum_{i=-k}^{i=k} ¥_i \, \Delta OR_{t-i} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

Where

$$M = [C, \alpha, \beta, \gamma, z \,], X = [1, GDP_t INNO_t CO2_t TO_t \; OR_t]$$

And m, n, j, L and k are the lengths of leads and lags of the regressors.

### 3.2.2 Model for Objective 2

The objective examines the causal and the long-run relationship among renewable energy consumption, Economic growth, innovation, carbon emission, trade openness and oil rent in Nigeria. This study employs the Augmented VAR model of Toda and Yamamoto (1995). To undertake the TY version of granger causality test, we estimate the following equation

$$\begin{bmatrix} REC_t \\ GDP_t \\ INNO_t \\ CO_{2t} \\ TO_t \\ OR_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} REC_{t-1} \\ GDP_{t-1} \\ INNO_{t-1} \\ CO_{2t-1} \\ TO_{t-1} \\ OR_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} REC_{t-2} \\ GDP_{t-2} \\ INNO_{t-2} \\ CO_{2t-2} \\ TO_{t-2} \\ OR_{t-2} \end{bmatrix} + A_3 \begin{bmatrix} REC_{t-3} \\ GDP_{t-3} \\ INNO_{t-3} \\ CO_{2t-3} \\ TO_{t-3} \\ OR_{t-3} \end{bmatrix} + A_4 \begin{bmatrix} REC_{t-4} \\ GDP_{t-4} \\ INNO_{t-4} \\ CO_{2t-4} \\ TO_{t-4} \\ OR_{t-4} \end{bmatrix} +$$

$$A_5 \begin{bmatrix} REC_{t-5} \\ GDP_{t-5} \\ INNO_{t-5} \\ CO_{2t-5} \\ TO_{t-5} \\ OR_{t-5} \end{bmatrix} + A_6 \begin{bmatrix} REC_{t-6} \\ GDP_{t-6} \\ INNO_{t-6} \\ CO_{2t-6} \\ TO_{t-6} \\ OR_{t-6} \end{bmatrix} + \begin{bmatrix} \varepsilon REC_t \\ \varepsilon GDP_t \\ \varepsilon INNO_t \\ \varepsilon CO_{2t} \\ \varepsilon TO_t \\ \varepsilon OR_t \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

In equation (3.4), $A_1 \ldots A_6$ are 6 x 6 matrices of co-efficient with $A_0$ being a 6 x 1 identity matrix and $\varepsilon_t$ are the error term which is assumed to have zero mean and constant variance. To test the hypothesis that REC does not granger cause INNO, we test the following hypothesis: $H_0 = \alpha_{ij}^1 = \alpha_{ij}^2 = \alpha_{ij}^3 = \alpha_{ij}^4 = \alpha_{ij}^5 = \alpha_{ij}^6 = 0$. Where, $\alpha_{ijs}$ are the coefficients of REC. Also, to test the non-causality from to INNO to REC, the following null hypothesis is tested: $H_0 = \alpha_{ji}^1 = \alpha_{ji}^2 = \alpha_{ji}^3 = \alpha_{ji}^4 = \alpha_{ji}^5 = \alpha_{ji}^6 = 0$. Where, $\alpha_{jis}$are the coefficients of INNO variable. Similar procedures are applied for testing causality between other variables in this model.

Toda and Yamamoto solve the problem of pre-testing for unit root and cointegration. It is also applied when the variables have different order of co-integration. The Toda and Yamamoto (TY) procedure uses a modified Wald test for putting restrictions on the parameters of the VAR (k) from an Augmenting VAR ($k + d^{max}$) model, where k is the lag length and $d^{max}$ is the maximum order of integration of variables. The approach which is based on Augmented VAR modeling has a Wald test statistic. This modified Wald test has asymptotic chi square ($x^2$) distribution regardless of the order of integration of the series or their co-integrating properties and it fits a standard vector autoregression model on levels of the variables. This provides information about the long causality of the series which is ignored in other method that uses first differencing.

### 3.3 Estimation Technique and Procedure.

There will be pre-estimation test of descriptive statistics, correlation matrix, unit root test and cointegration test. Depending on the result of the cointegration test, the first model will be estimated with the use of Dynamic Ordinary least square method by Stock and Watson (1993). The second model will be estimated by the use of the Augmented VAR model of Toda and Yamamoto. This approach fits a standard vector auto-regression model on levels of the variables, that give allowances for the long-run information often ignored in systems that require first differencing and prewhitenin (Clarke & Mirza, 2006). The approach developed by TY employs a modified Wald test (MWALD)for restriction on the parameters of the VAR (k) where k is the lag length of the system.

## 3.4 Model Justification

The Dynamic Ordinary least square method (DOLS) is used for the estimation of model one due to the advantages it possesses over ordinary least square method. This model solves the problem of endogeneity and autocorrelation in a regression model which the ordinary least square method cannot. Also, this model can be used even when the variables are of different order of integration that is I(1) and I(0) with possible cointegration and it is also applicable to small sample size.

The Augmented Vector Autoregressive (VAR) model of Toda and Yamamoto is used to capture objective two. This method is advantageous over other causality method of estimation due to the fact that the procedure does not require pre-testing for the cointegration properties of VAR system. Due to this the problem of biases of pretesting that weakens the traditional causality test is avoided. Another advantage of TY causality method is that the test is valid irrespective of whether the series are I(0), I(1) or I(2), non-cointegration or cointegration of any arbitrary order. Lastly, there is also no loss of information due to differencing because it estimates a VAR in levels.

## 3.5 Econometric Package

For the purpose of this study, E-views 9 is the econometric package that will be used for the estimation of the two objectives of the study

# CHAPTER FOUR

# PRESENTATION OF RESULTS AND INTERPRETATIONS

## 4.1 Presentation of the Pre-estimation Tests

This chapter will deal with some pre-estimation test, in order to ensure a good structure of the time series data, used in the analysis of this research. The pre-estimation test includes: descriptive analysis, correlation analysis, a unit root or stationary test and a cointegration test. This pre-estimation test is done to ensure that an unbiased estimator of the model is achieved and the estimation errors are minimized. This study adopted the Engle-Granger cointegration test. The cointegration test shows the evolution and the long run relationship among the variables.

### 4.1.1 Descriptive Analysis

A descriptive analysis summarizes the features of the raw data collected for estimation. It is used to describe a data set measure of central tendency and measure of variability. The measure of central tendency is taken care by the mean, median and mode while the measure of variability is captured by the maximum and minimum values, the standard deviation, Kurtosis and the skewness. However, descriptive analysis is not use for conclusion regarding the hypothesis for the model of the work

**Table 0.1: Summary Statistics of the Variables**

| | REC | GDP | INNO | CO2 | TO | OR |
|---|---|---|---|---|---|---|
| Mean | 86.16882 | 292898.1 | 2.174426 | 0.578732 | 38.58173 | 12.02105 |
| Median | 86.54212 | 293889.2 | 1.664289 | 0.582317 | 39.68605 | 12.88869 |
| Maximum | 88.83185 | 385227.6 | 13.39215 | 0.770377 | 53.27796 | 20.92307 |
| Minimum | 82.95602 | 202936.1 | 0.018100 | 0.325376 | 20.72252 | 2.803152 |
| Std. Dev. | 1.351230 | 66084.98 | 2.913367 | 0.133575 | 9.073204 | 4.933291 |
| Skewness | -0.672097 | -0.070824 | 2.882672 | -0.454248 | -0.281350 | -0.256223 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Kurtosis | 3.074330 | 1.497687 | 10.91985 | 2.394497 | 2.311425 | 2.218656 |
| Jarque-Bera | 6.645393 | 8.349034 | 351.8650 | 4.370667 | 2.899481 | 3.201365 |
| Probability | 0.036055 | 0.015383 | 0.000000 | 0.112440 | 0.234631 | 0.201759 |
| Sum | 7582.856 | 25775035 | 191.3495 | 50.92841 | 3395.192 | 1057.852 |
| Sum Sq.Dev. | 158.8466 | 3.80E+11 | 738.4306 | 1.552287 | 7162.103 | 2117.351 |
| Observations | 88 | 88 | 88 | 88 | 88 | 88 |

The table 4.1 above, shows the descriptive value of each of the variables used in this study. As indicated in the result above, we can see the average value, middle value, highest value, lowest value and the standard deviation of each of the variables. Also, the skewness, kurtosis and the probability of the Jarque-Bera which shows the distribution of the variables can be seen in the result. On the skewness statistics a value of 0 indicates a normal distribution.

The result indicates that all variables except “INNO” indicates a long-left tail because they are less than 0 while “INNO” shows a long right tail as it is greater than zero. Moving on to the Kurtosis, the value “3” indicates a normal distribution. So, the variable “REC” is normally distributed while “GDP, CO2, TO and OR” indicates a flat curve distribution because the values are less than “3” and “INNO” indicates a peaked curve distribution as the value is greater than “3”. Finally, we talk about the probability of the Jarque-Berra statistics. The probability indicates that the variables “REC, GDP and INNO” are not normally distributed while the variables “CO2, TO and OR” are normally distributed.

### 4.1.2 Correlation Test

The correlation test is used to measure the degree of association among the variables. If there is high occurrence of intercorrelation among the dependent variable in a multiple regression model, it can lead to misleading results. In the presence of high multicollinearity, the confidence interval of the coefficient tends to become very wide and the statistics tend to be small.

**Table 0.2: Correlation Matrix**

| | REC | GDP | INNO | CO2 | TO | OR |
|---|---|---|---|---|---|---|
| REC | 1.000000 | 0.373628 | 0.209066 | -0.645737 | -0.323732 | -0.302380 |
| GDP | 0.373628 | 1.000000 | -0.090470 | 0.183227 | -0.507092 | -0.375702 |
| INNO | 0.209066 | -0.090470 | 1.000000 | -0.243359 | -0.193679 | -0.069463 |
| CO2 | -0.645737 | 0.183227 | -0.243359 | 1.000000 | 0.076880 | 0.297928 |
| TO | -0.323732 | -0.507092 | -0.193679 | 0.076880 | 1.000000 | 0.624523 |
| OR | -0.302380 | -0.375702 | -0.069463 | 0.297928 | 0.624523 | 1.000000 |

The correlation values of the variables under investigation indicates evidence of no multi-collinearity among the variables. This is because all the variables are not in excess of 0.8 in absolute terms, which is in accordance with the econometric rule of thumb for multicollinearity estimation problem. This is an indication that the model has been specified correctly.

### 4.1.3 Unit Root Test

We adopted the Augmented Dickey Fuller (ADF) and the Philips Perron Test in order to test for stationarity of our variables in the model. This test is necessary to ensure that all variables estimated are stationary in order to avoid spurious result. The ADF unit root test requires homoscedastic and uncorrelated errors in the structure of the variable, while PP test generalizes the ADF procedure, allowing for less restrictive assumptions. Both tests are used to guarantee better estimation. The results of the test are presented in the table below;

**Table 0.3: Unit Root Analysis**

| | ADF | | | PP | | |
|---|---|---|---|---|---|---|
| VARIABLES | LEVEL | 1ST DIFF | DIFF. PROB | LEVEL | 1ST DIFF | DIFF. PROB |
| REC | -2.322618 | -9.137312** | 0.0000 | -2.399285 | -9.137312** | 0.0000 |
| GDP | -1.654392 | -10.19439** | 0.0000 | -1.290873 | -10.14667** | 0.0000 |
| INNO | -3.478128 | | | -4.146327 | | |
| CO2 | -1.598720 | -9.319213 | 0.0000 | -1.597001 | -9.320123** | 0.0000 |
| TO | -2.833929 | 9.144844** | 0.0000 | -2.982776 | -9.144844** | 0.0000 |
| OR | -2.586577 | -6.633708** | 0.0000 | -2.723879 | -9.138157** | 0.0000 |

**NOTE:** *, ** and *** shows the rejection of the null hypothesis of a unit root test for both ADF and PP at 1%, 5% and 10% level of significance respectively.

From the table above, the results of ADF and PP test at level and first difference indicates that, all the variables except innovation variable are stationary after the first difference in both tests. Innovation variable is stationary at level with ADF and tested PP unit root test.

### 4.1.4 Cointegration Test

This study adopted the Engle-Granger cointegration test. The cointegration test shows the evolution and the long run relationship among the variables.

**Table 0.4: Cointegration Test**

Series: REC GDP INNO CO@ TO OR01
Sample: 1995Q1- 2017Q4
Included Observations: 88
Null Hypothesis: Series are not cointegrated
Cointegrating equation deterministics: C
Automatic lags specification based on Schwarz Criterion (maxlag=11)

| Dependent | tau-statistic | Prob.* | z-statistic | Prob.* |
|---|---|---|---|---|
| REC | -2.995754 | 0.7472 | -16.28045 | 0.7586 |
| GDP | -2.399685 | 0.9280 | -10.91700 | 0.9399 |
| INNO | -4.658562 | 0.0873 | -67.35710 | 1.0000 |
| CO2 | -2.601026 | 0.8834 | -10.95386 | 0.9391 |
| TO | -3.196119 | 0.6564 | -17.57745 | 0.6986 |
| OR | -3.333142 | 0.5890 | -17.76028 | 0.6898 |

*MacKinnon (1996) p-values

From the cointegration result above, the p-values are insignificant indicating that we accept the null hypothesis that states that the series are not cointegrated, we therefore conclude that there is no cointegration in this work.

### 4.2 Results for Objective One

**Table 0.5: Dynamic ordinary least squares (DOLS)**

Dependent Variable: REC
Method: Dynamic Ordinary Least Squares (DOLS)
Sample: 1996Q1 2017Q4
Included observations: 83 after adjustments

| | Coefficient | Std. Errors | t-Statistics | Prob |
|---|---|---|---|---|
| GDP | 1.09E-05 | 2.56E-06 | 4.255541 | 0.0001 |
| INNO | 0.240902 | 0.096246 | 2.502989 | 0.0155 |
| CO2 | -7.948629 | 1.442577 | -5.510022 | 0.0000 |
| TO | 0.001132 | 0.032881 | 0.034438 | 0.9727 |
| OR | -0.003202 | 0.060127 | -0.053251 | 0.9577 |

| | | | | |
|---|---|---|---|---|
| C | 86.48746 | 1.831538 | 47.41779 | 0.0000 |

R-squared 0.829072
Adjusted R-squared 0.730460
F-statistic 10.62129

From the result of table 4.5, the variable GDP, Innovation and CO2 emission were significant at 5% level while trade openness and Oil rent were insignificant at 5%. The variables GDP, Innovation and trade openness indicated a positive relationship with the dependent variable renewable energy consumption. Indicating that an increase in the variables leads to an increase in renewable energy consumption. On the other hand, the variable CO2 emission and Oil rent registered a negative relationship with renewable energy consumption, therefore indicating that increase in those variables decreases renewable energy consumption.

## 4.3 Results for Objective Two

**Table 0.6: Causality Test**

VAR Granger Causality/Block Exogeneity Wald Tests

Date: 07/22/19 Time: 20:39
Sample: 1996Q1 2017Q4
Included observations: 80

Dependent variable: REC

| Excluded | Chi-sq | df | Prob. |
|---|---|---|---|
| GDP | 7.236178 | 8 | 0.5114 |
| INNO | 2.990909 | 8 | 0.9349 |
| CO2 | 8.357308 | 8 | 0.3994 |
| TO | 5.047482 | 8 | 0.7525 |
| OR | 17.20600 | 8 | 0.0280 |
| All | 41.22221 | 40 | 0.4169 |

Dependent variable: GDP

| Excluded | Chi-sq | df | Prob. |
|---|---|---|---|
| REC | 8.581001 | 8 | 0.3789 |

| | | | |
|---|---|---|---|
| INNO | 5.513753 | 8 | 0.7015 |
| CO2 | 12.39153 | 8 | 0.1346 |
| TO | 4.185422 | 8 | 0.8400 |
| ORR | 3.487409 | 8 | 0.9002 |
| All | 25.13733 | 40 | 0.9679 |

Dependent variable: INNO

| Excluded | Chi-sq | Df | Prob. |
|---|---|---|---|
| REC | 4.931499 | 8 | 0.7649 |
| GDP | 0.350544 | 8 | 1.0000 |
| CO2 | 4.034520 | 8 | 0.8540 |
| TO | 2.666625 | 8 | 0.9535 |
| ORR | 1.686414 | 8 | 0.9892 |
| All | 19.53423 | 40 | 0.9973 |

Dependent variable: CO2

| Excluded | Chi-sq | Df | Prob. |
|---|---|---|---|
| REC | 5.133172 | 8 | 0.7433 |
| GDP | 3.231462 | 8 | 0.9190 |
| INNO | 32.69749 | 8 | 0.0001 |
| TO | 3.108181 | 8 | 0.9274 |
| ORR | 8.577928 | 8 | 0.3791 |
| All | 55.69336 | 40 | 0.0506 |

Dependent variable: TO

| Excluded | Chi-sq | Df | Prob. |
|---|---|---|---|
| REC | 6.413969 | 8 | 0.6010 |
| GDP | 10.62476 | 8 | 0.2239 |
| INNO | 4.299653 | 8 | 0.8291 |
| CO2 | 2.515487 | 8 | 0.9610 |
| ORR | 6.665908 | 8 | 0.5731 |
| All | 26.31934 | 40 | 0.9528 |

Dependent variable: ORR

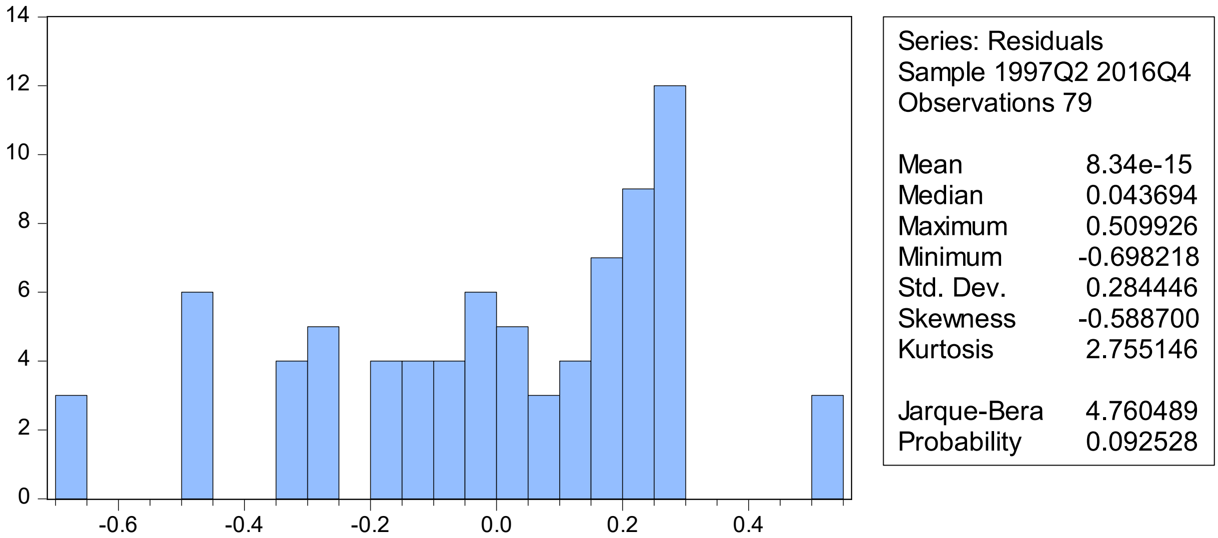
| Excluded | Chi-sq | Df | Prob. |
|---|---|---|---|
| REC | 1.418995 | 8 | 0.9940 |
| GDP | 4.293964 | 8 | 0.8297 |
| INNO | 10.72315 | 8 | 0.2179 |
| CO2 | 7.422229 | 8 | 0.4918 |
| TO | 12.47089 | 8 | 0.1314 |

| | | | |
|---|---|---|---|
| All | 52.36115 | 40 | 0.0911 |

From the result of the Toda and Yamamota causality test, there is no causality among the variables however, there is a unidirectional causality from oil rent to renewable energy consumption and also a unidirectional causality from innovation to carbon dioxide emission

## 4.4 Post Estimation Test

**Figure 0.1: Normality test**




The normal distribution result above indicates that the residual of the variable has negative skewness indicating a long-left tail, a flat curve as indicated by the Kurtosis statistics and the probability of the Jarque-Berra indicates that the curve is not normally distributed

## 4.5 Evaluation of the Research Hypothesis

The various statistical assumptions stated in Chapter One would be verified in this section having conducted the respective model estimations. The hypotheses testing would form the premise on which conclusion would be drawn and recommendations inferred since they are all tied to their respective research objectives and questions. The hypotheses which were already stated in their null form in chapter one will be restated, this time in both null and alternative forms.

**Research Hypothesis 1**

$H_0$: Innovation does not significantly impact on the Renewable Energy Consumption in Nigeria
$H_1$: Innovation significantly impacts on the Renewable Energy Consumption in Nigeria

Decision Rule: The variable innovation was found to have a significant impact on renewable energy consumption in Nigeria, as indicated in our result. Therefore, we reject the null hypothesis and conclude that Innovation significantly impacts on the Renewable Energy Consumption in Nigeria.

**Research Hypothesis 2**

$H_0$: There is no long run relationship or causal relationship among Renewable energy consumption, Gross Domestic Product, Innovation, $Co_2$ emissions, Trade openness and Oil rents in Nigeria
$H_1$: There is a long-run or causal relationship among Renewable energy consumption, Gross Domestic Product, Innovation, $Co_2$ emissions, Trade openness and Oil rents in Nigeria.

Decision Rule: The result indicated a uni-directional causality from oil rent to renewable energy consumption and from innovation to $Co_2$ emissions while the rest of the variables tested showed no causality. In the same vien, the cointegration test indicated no cointegration, meaning that there is no long-run relationship among the variables. Therefore, we do not reject the null hypothesis which states that there is no long run relationship or causal relationship among Renewable energy consumption, Gross Domestic Product, Innovation, $Co_2$ emissions, Trade openness and Oil rents in Nigeria.

# CHAPTER FIVE

# SUMMARY, RECOMMENDATION AND CONCLUSION

In this chapter; summary of the findings of the study, the conclusion and policy recommendations to promote renewable energy are presented.

## 5.1 Summary of Research Findings

This research exercise investigates the impact of innovation on renewable energy consumption in Nigeria. For effective evidence, the study employed time series data from 1996Q1 to 2017Q4. The variables used in estimation, which were obtained from World Development Indicator 2018 were: Renewable energy measured by Renewable energy consumption (% of total final energy consumption), Economic growth measured by GDP Per Capita (Constant LCU), Innovation proxied by High-technology exports (% of manufactured exports), Carbon dioxide emission measured by CO2 emissions (metric tons per capita), Trade Openness measured by the sum of Exports of goods and services (% of GDP) with Imports of goods and services (% of GDP) and finally Oil rents measured by Oil rents (% of GDP).

A descriptive statistics analysis and a correlation statistic test were conducted in order to know some characteristics of the data obtained. As a fundamental rule for the use of time series data, both Augmented Dickey Fuller test (ADF) and Philips-Perron test (PP) were employed for stationarity test. From the stationarity test result, innovation was stationary at levels in both test (ADF and PP), while renewable energy consumption, GDP per capita, carbon dioxide emission, trade openness and oil rents were stationary at first difference when estimated with ADF and PP. lastly for the pre-estimation test, a cointegration test was conducted and the result found no cointegration among the variables.

In order to estimate objective one, the Dynamic Ordinary Least Square method was employed, while the Augmented Vector Autoregressive (VAR) model of Toda and Yamamoto test was used to capture the model for objective two. The results from objective one showed that GDP, Innovation and trade openness had a positive relationship with the dependent variable renewable energy consumption while, $CO_2$ emission and Oil rent had a negative relationship with renewable energy consumption. The result of objective two indicated no causality among the variables however, there was a unidirectional causality from oil rent to renewable energy consumption and a unidirectional causality from innovation to carbon dioxide emission.

The implications of this findings to the Nigeria economy, shows that increasing gross domestic product and innovation increases renewable energy consumption. The negative relationship between co2 emission and renewable energy indicates that having a high co2 emission in Nigeria will be as a result of using other sources of energy rather than renewable energy, so government should put policies in place to reduce co2 emission thereby aiding the consumption of renewable energy. Trade openness led to increase in renewable energy consumption, this shows that Nigeria has benefitted significantly from the transfer of cleaner technologies from developed countries. So, policies to strengthen the importation of cleaner technologies should be put in place to increase the consumption of renewable energy.

Finally, on the relationship between oil rent and renewable energy consumption. This implies that an increase in oil rent decrease the consumption of renewable energy and a reduction in oil rent increases renewable energy consumption. This is due to the fact that the prices of renewable energy consumption cannot compete with that of conventional sources. So therefore, government should put policies on ground to enable the take-off of renewable energy sources, thereby making it competitive with the conventional sources

**5.2 CONCLUSION**

The benefit of renewable energy to the sustainable development of Nigeria cannot be overemphasized. Energy is needed for the functioning of virtually all sectors of the economy in the world, this is why it is deemed important to be considered as one of the sustainable development goals as goal 7 which is to ensure access to affordable, reliable, sustainable and modern energy for all. In Nigeria, access to electricity which is the most widely used form of energy is very low as the access rate is below 50% with about 70% of the population living in the rural area not having access to the grid supply electricity. This study therefore seeks ways to improve renewable energy consumption by studying renewable energy consumption and some variables such as GDP Per Capita, Innovation, Co2 emissions, Trade Openness and Oil rents. The result indicated that increasing innovation in Nigeria will therefore increase the renewable energy consumption.

## 5.3 RECOMMENDATIONS

Based on the findings of the empirical findings of the work, the following policy options are necessary to improve renewable energy consumption in Nigeria.

- GDP per Capita had a positive relationship with renewable energy consumption. This means that effective economic policies favoring economic growth and development will lead to increases in RE consumption. Government should therefore embark on expansionary monetary and fiscal policies to increase income and wealth generation by focusing on increasing innovation and productivity. This will in turn increase the renewable energy consumption of Nigeria

- The empirical study reveals that innovation is a catalyst for renewable energy consumption which means that innovation will further increase renewable energy consumption in Nigeria. Thus, increasing renewable energy consumption requires investment in technological innovations. To stimulate investment and innovation in renewable energy, policy makers need to focus not just on core climate policies but on broader investment conditions and different policies, ranging from investment and competition to trade and financial markets. If policies for broader investment environment do not make investment conditions favorable deployment and innovation of renewables technologies as well as the effectiveness of climate policies will be hindered

- In Nigeria, energy consumption has favoured fossil despite their environmental impact. Therefore, the federal government should introduce policies aimed at discouraging $CO_2$ and other Greenhouse gas emissions form electricity generation. Policies like emission tax per ton of $CO_2$ and emission allowance, should be promoted in order to force companies to either reduce their CO2 emission or pay heavily for it. This is to ensure the reduction in Co2 emission which will in turn increase renewable energy consumption as indicated empirically in this study

- Trade openness tends to increase renewable energy consumption in Nigeria. Hence, international trade activities can be promoted more extensively by the policy makers through lifting the trade barriers for environmentally sustainable goods and services in the country. This will aid the transfers and adoption of clean technologies thereby increasing renewable energy consumption.

- Given that renewable energy infrastructure is very expensive, Nigeria produces higher priced electricity from RE sources, but most consumers are not prepared to pay such a price. The cost of electricity generation from renewable energy sources are more than conventional sources, in such a way that if prices of conventional energy increases consumers still stick to the consumption of crude oil sources due to the price gap as indicated in the study. Government should therefore implement market policies such as subsidy, tax holiday, low import duties on renewable energy sources in order to enhance its generation, deployment and consumption

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# APPENDICES

## APPENDIX A

## RESULT FOR PRE-ESTIMATION TEST

### A1: Unit Root Test

Null Hypothesis: REC has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -2.322618 | 0.4172 |
| Test critical values: | 1% level | -4.066981 | |
| | 5% level | -3.462292 | |
| | 10% level | -3.157475 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(REC)
Method: Least Squares
Date: 07/16/19 Time: 10:44
Sample (adjusted): 1996Q2 2017Q4
Included observations: 87 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| REC(-1) | -0.112577 | 0.048470 | -2.322618 | 0.0226 |
| C | 9.558100 | 4.138989 | 2.309284 | 0.0234 |
| @TREND("1996Q1") | 0.003287 | 0.002601 | 1.263516 | 0.2099 |

| | | | |
|---|---|---|---|
| R-squared | 0.062994 | Mean dependent var | 0.003216 |
| Adjusted R-squared | 0.040685 | S.D. dependent var | 0.584903 |
| S.E. of regression | 0.572881 | Akaike info criterion | 1.757597 |
| Sum squared resid | 27.56818 | Schwarz criterion | 1.842628 |
| Log likelihood | -73.45546 | Hannan-Quinn criter. | 1.791836 |
| F-statistic | 2.823633 | Durbin-Watson stat | 1.907777 |
| Prob(F-statistic) | 0.065039 | | |

Null Hypothesis: D(REC) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -9.137312 | 0.0000 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(REC,2)
Method: Least Squares
Date: 07/16/19 Time: 10:46
Sample (adjusted): 1996Q3 2017Q4
Included observations: 86 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(REC(-1)) | -1.002958 | 0.109765 | -9.137312 | 0.0000 |
| C | -0.053430 | 0.131722 | -0.405628 | 0.6861 |
| @TREND("1996Q1") | 0.001274 | 0.002586 | 0.492604 | 0.6236 |

| | | | |
|---|---|---|---|
| R-squared | 0.501473 | Mean dependent var | 0.000000 |
| Adjusted R-squared | 0.489460 | S.D. dependent var | 0.832042 |
| S.E. of regression | 0.594511 | Akaike info criterion | 1.832106 |
| Sum squared resid | 29.33579 | Schwarz criterion | 1.917722 |
| Log likelihood | -75.78054 | Hannan-Quinn criter. | 1.866562 |
| F-statistic | 41.74523 | Durbin-Watson stat | 1.999998 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: REC has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -2.399285 | 0.3774 |
| Test critical values: | 1% level | -4.066981 | |
| | 5% level | -3.462292 | |
| | 10% level | -3.157475 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 0.316876 |
| HAC corrected variance (Bartlett kernel) | 0.343967 |

Phillips-Perron Test Equation
Dependent Variable: D(REC)
Method: Least Squares
Date: 07/16/19 Time: 10:46
Sample (adjusted): 1996Q2 2017Q4
Included observations: 87 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| REC(-1) | -0.112577 | 0.048470 | -2.322618 | 0.0226 |

| | | | | |
|---|---|---|---|---|
| C | 9.558100 | 4.138989 | 2.309284 | 0.0234 |
| @TREND("1996Q1") | 0.003287 | 0.002601 | 1.263516 | 0.2099 |

| | | | |
|---|---|---|---|
| R-squared | 0.062994 | Mean dependent var | 0.003216 |
| Adjusted R-squared | 0.040685 | S.D. dependent var | 0.584903 |
| S.E. of regression | 0.572881 | Akaike info criterion | 1.757597 |
| Sum squared resid | 27.56818 | Schwarz criterion | 1.842628 |
| Log likelihood | -73.45546 | Hannan-Quinn criter. | 1.791836 |
| F-statistic | 2.823633 | Durbin-Watson stat | 1.907777 |
| Prob(F-statistic) | 0.065039 | | |

Null Hypothesis: D(REC) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -9.137312 | 0.0000 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 0.341114 |
| HAC corrected variance (Bartlett kernel) | 0.341114 |

Phillips-Perron Test Equation
Dependent Variable: D(REC,2)
Method: Least Squares
Date: 07/16/19 Time: 10:48
Sample (adjusted): 1996Q3 2017Q4
Included observations: 86 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(REC(-1)) | -1.002958 | 0.109765 | -9.137312 | 0.0000 |
| C | -0.053430 | 0.131722 | -0.405628 | 0.6861 |
| @TREND("1996Q1") | 0.001274 | 0.002586 | 0.492604 | 0.6236 |

| | | | |
|---|---|---|---|
| R-squared | 0.501473 | Mean dependent var | 0.000000 |
| Adjusted R-squared | 0.489460 | S.D. dependent var | 0.832042 |
| S.E. of regression | 0.594511 | Akaike info criterion | 1.832106 |
| Sum squared resid | 29.33579 | Schwarz criterion | 1.917722 |
| Log likelihood | -75.78054 | Hannan-Quinn criter. | 1.866562 |
| F-statistic | 41.74523 | Durbin-Watson stat | 1.999998 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: GDP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 4 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -1.654392 | 0.7625 |
| Test critical values: | 1% level | -4.072415 | |
| | 5% level | -3.464865 | |
| | 10% level | -3.158974 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GDP)
Method: Least Squares
Date: 07/16/19 Time: 10:52
Sample (adjusted): 1997Q2 2017Q4
Included observations: 83 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| GDP(-1) | -0.064561 | 0.039024 | -1.654392 | 0.1022 |
| D(GDP(-1)) | 0.019204 | 0.089347 | 0.214935 | 0.8304 |
| D(GDP(-2)) | 0.011212 | 0.086980 | 0.128900 | 0.8978 |
| D(GDP(-3)) | 0.003220 | 0.084917 | 0.037916 | 0.9699 |
| D(GDP(-4)) | 0.740467 | 0.083428 | 8.875545 | 0.0000 |
| C | 12536.11 | 6624.294 | 1.892445 | 0.0622 |
| @TREND("1996Q1") | 151.0383 | 105.8870 | 1.426410 | 0.1578 |

| | | | |
|---|---|---|---|
| R-squared | 0.539885 | Mean dependent var | 1877.256 |
| Adjusted R-squared | 0.503560 | S.D. dependent var | 5703.324 |
| S.E. of regression | 4018.477 | Akaike info criterion | 19.51576 |
| Sum squared resid | 1.23E+09 | Schwarz criterion | 19.71976 |
| Log likelihood | -802.9041 | Hannan-Quinn criter. | 19.59772 |
| F-statistic | 14.86267 | Durbin-Watson stat | 2.049826 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: D(GDP) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -10.19439 | 0.0000 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GDP,2)
Method: Least Squares
Date: 07/16/19 Time: 10:53
Sample (adjusted): 1996Q3 2017Q4
Included observations: 86 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(GDP(-1)) | -1.111099 | 0.108991 | -10.19439 | 0.0000 |
| C | 2794.523 | 1272.790 | 2.195588 | 0.0309 |
| @TREND("1996Q1") | -17.31747 | 24.48712 | -0.707207 | 0.4814 |

| | | | |
|---|---|---|---|
| R-squared | 0.556008 | Mean dependent var | 0.000000 |
| Adjusted R-squared | 0.545309 | S.D. dependent var | 8346.174 |
| S.E. of regression | 5627.889 | Akaike info criterion | 20.14312 |
| Sum squared resid | 2.63E+09 | Schwarz criterion | 20.22873 |
| Log likelihood | -863.1540 | Hannan-Quinn criter. | 20.17757 |
| F-statistic | 51.97011 | Durbin-Watson stat | 2.029874 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: GDP has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 7 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -1.290873 | 0.8836 |
| Test critical values: | 1% level | -4.066981 | |
| | 5% level | -3.462292 | |
| | 10% level | -3.157475 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 30270839 |
| HAC corrected variance (Bartlett kernel) | 36379644 |

Phillips-Perron Test Equation
Dependent Variable: D(GDP)
Method: Least Squares
Date: 07/16/19 Time: 10:55
Sample (adjusted): 1996Q2 2017Q4
Included observations: 87 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| GDP(-1) | -0.044834 | 0.042898 | -1.045109 | 0.2990 |
| C | 10469.55 | 7803.606 | 1.341629 | 0.1833 |
| @TREND("1996Q1") | 100.6093 | 112.1558 | 0.897049 | 0.3723 |

| | | | |
|---|---|---|---|
| R-squared | 0.016750 | Mean dependent var | 1800.588 |

| | | | |
|---|---|---|---|
| Adjusted R-squared | -0.006660 | S.D. dependent var | 5580.726 |
| S.E. of regression | 5599.280 | Akaike info criterion | 20.13254 |
| Sum squared resid | 2.63E+09 | Schwarz criterion | 20.21757 |
| Log likelihood | -872.7654 | Hannan-Quinn criter. | 20.16678 |
| F-statistic | 0.715496 | Durbin-Watson stat | 2.149534 |
| Prob(F-statistic) | 0.491905 | | |

Null Hypothesis: D(GDP) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -10.14667 | 0.0000 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 30568260 |
| HAC corrected variance (Bartlett kernel) | 37410756 |

Phillips-Perron Test Equation
Dependent Variable: D(GDP,2)
Method: Least Squares
Date: 07/16/19 Time: 10:55
Sample (adjusted): 1996Q3 2017Q4
Included observations: 86 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(GDP(-1)) | -1.111099 | 0.108991 | -10.19439 | 0.0000 |
| C | 2794.523 | 1272.790 | 2.195588 | 0.0309 |
| @TREND("1996Q1") | -17.31747 | 24.48712 | -0.707207 | 0.4814 |

| | | | |
|---|---|---|---|
| R-squared | 0.556008 | Mean dependent var | 0.000000 |
| Adjusted R-squared | 0.545309 | S.D. dependent var | 8346.174 |
| S.E. of regression | 5627.889 | Akaike info criterion | 20.14312 |
| Sum squared resid | 2.63E+09 | Schwarz criterion | 20.22873 |
| Log likelihood | -863.1540 | Hannan-Quinn criter. | 20.17757 |
| F-statistic | 51.97011 | Durbin-Watson stat | 2.029874 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: INNO has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 4 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -3.478128 | 0.0484 |
| Test critical values: | 1% level | -4.072415 | |
| | 5% level | -3.464865 | |
| | 10% level | -3.158974 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(INNO)
Method: Least Squares
Date: 07/16/19 Time: 11:02
Sample (adjusted): 1997Q2 2017Q4
Included observations: 83 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| INNO(-1) | -0.397223 | 0.114206 | -3.478128 | 0.0008 |
| D(INNO(-1)) | 0.198061 | 0.108981 | 1.817387 | 0.0731 |
| D(INNO(-2)) | 0.198064 | 0.108981 | 1.817411 | 0.0731 |
| D(INNO(-3)) | 0.198067 | 0.108982 | 1.817435 | 0.0731 |
| D(INNO(-4)) | -0.285338 | 0.108983 | -2.618185 | 0.0107 |
| C | 1.166814 | 0.550807 | 2.118373 | 0.0374 |
| @TREND("1996Q1") | -0.005897 | 0.009001 | -0.655124 | 0.5144 |

| | | | |
|---|---|---|---|
| R-squared | 0.340624 | Mean dependent var | 0.021557 |
| Adjusted R-squared | 0.288568 | S.D. dependent var | 2.314622 |
| S.E. of regression | 1.952301 | Akaike info criterion | 4.256462 |
| Sum squared resid | 289.6725 | Schwarz criterion | 4.460461 |
| Log likelihood | -169.6432 | Hannan-Quinn criter. | 4.338417 |
| F-statistic | 6.543405 | Durbin-Watson stat | 1.920262 |
| Prob(F-statistic) | 0.000013 | | |

Null Hypothesis: D(INNO) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 7 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -5.658645 | 0.0001 |
| Test critical values: | 1% level | -4.078420 | |
| | 5% level | -3.467703 | |
| | 10% level | -3.160627 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(INNO,2)
Method: Least Squares
Date: 07/16/19 Time: 11:03
Sample (adjusted): 1998Q2 2017Q4
Included observations: 79 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(INNO(-1)) | -2.123462 | 0.375260 | -5.658645 | 0.0000 |
| D(INNO(-1),2) | 1.121658 | 0.342594 | 3.274014 | 0.0017 |
| D(INNO(-2),2) | 1.119881 | 0.306513 | 3.653615 | 0.0005 |
| D(INNO(-3),2) | 1.118129 | 0.265626 | 4.209409 | 0.0001 |
| D(INNO(-4),2) | 0.425458 | 0.217235 | 1.958513 | 0.0542 |
| D(INNO(-5),2) | 0.424245 | 0.188083 | 2.255628 | 0.0273 |
| D(INNO(-6),2) | 0.423048 | 0.153531 | 2.755456 | 0.0075 |
| D(INNO(-7),2) | 0.421865 | 0.108537 | 3.886838 | 0.0002 |
| C | 0.257764 | 0.524204 | 0.491726 | 0.6245 |
| @TREND("1996Q1") | -0.004490 | 0.009862 | -0.455348 | 0.6503 |

| | | | |
|---|---|---|---|
| R-squared | 0.687507 | Mean dependent var | 0.001184 |
| Adjusted R-squared | 0.646747 | S.D. dependent var | 3.356383 |
| S.E. of regression | 1.994870 | Akaike info criterion | 4.336858 |
| Sum squared resid | 274.5859 | Schwarz criterion | 4.636788 |
| Log likelihood | -161.3059 | Hannan-Quinn criter. | 4.457019 |
| F-statistic | 16.86720 | Durbin-Watson stat | 2.003423 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: INNO has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -4.146327 | 0.0079 |
| Test critical values: | 1% level | -4.066981 | |
| | 5% level | -3.462292 | |
| | 10% level | -3.157475 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 4.312993 |
| HAC corrected variance (Bartlett kernel) | 5.223881 |

Phillips-Perron Test Equation
Dependent Variable: D(INNO)
Method: Least Squares
Date: 07/16/19 Time: 11:04
Sample (adjusted): 1996Q2 2017Q4
Included observations: 87 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| INNO(-1) | -0.300798 | 0.077933 | -3.859691 | 0.0002 |
| C | 0.780561 | 0.496785 | 1.571225 | 0.1199 |
| @TREND("1996Q1") | -0.002795 | 0.009041 | -0.309128 | 0.7580 |

| | | | |
|---|---|---|---|
| R-squared | 0.150674 | Mean dependent var | 0.002586 |
| Adjusted R-squared | 0.130452 | S.D. dependent var | 2.266536 |
| S.E. of regression | 2.113535 | Akaike info criterion | 4.368475 |
| Sum squared resid | 375.2304 | Schwarz criterion | 4.453506 |
| Log likelihood | -187.0287 | Hannan-Quinn criter. | 4.402714 |
| F-statistic | 7.450962 | Durbin-Watson stat | 1.753022 |
| Prob(F-statistic) | 0.001050 | | |

Null Hypothesis: D(INNO) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -9.110898 | 0.0000 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 5.136928 |
| HAC corrected variance (Bartlett kernel) | 5.136928 |

Phillips-Perron Test Equation
Dependent Variable: D(INNO,2)
Method: Least Squares
Date: 07/16/19 Time: 11:14
Sample (adjusted): 1996Q3 2017Q4
Included observations: 86 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(INNO(-1)) | -1.000051 | 0.109764 | -9.110898 | 0.0000 |
| C | 0.031237 | 0.510667 | 0.061169 | 0.9514 |
| @TREND("1996Q1") | -0.000643 | 0.010022 | -0.064177 | 0.9490 |

| | | | |
|---|---|---|---|
| R-squared | 0.500025 | Mean dependent var | 1.26E-17 |
| Adjusted R-squared | 0.487978 | S.D. dependent var | 3.224167 |
| S.E. of regression | 2.307076 | Akaike info criterion | 4.544100 |
| Sum squared resid | 441.7758 | Schwarz criterion | 4.629717 |
| Log likelihood | -192.3963 | Hannan-Quinn criter. | 4.578557 |
| F-statistic | 41.50423 | Durbin-Watson stat | 2.000001 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: $CO_2$ has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -1.598720 | 0.7857 |
| Test critical values: | 1% level | -4.066981 | |
| | 5% level | -3.462292 | |
| | 10% level | -3.157475 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CO2)
Method: Least Squares
Date: 07/16/19 Time: 11:17
Sample (adjusted): 1996Q2 2017Q4
Included observations: 87 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| CO2(-1) | -0.049760 | 0.031125 | -1.598720 | 0.1136 |
| C | 0.037211 | 0.018263 | 2.037477 | 0.0447 |
| @TREND("1996Q1") | -0.000142 | 0.000165 | -0.855872 | 0.3945 |

| | | | |
|---|---|---|---|
| R-squared | 0.047005 | Mean dependent var | 0.002162 |
| Adjusted R-squared | 0.024314 | S.D. dependent var | 0.038181 |
| S.E. of regression | 0.037714 | Akaike info criterion | -3.683676 |
| Sum squared resid | 0.119480 | Schwarz criterion | -3.598645 |
| Log likelihood | 163.2399 | Hannan-Quinn criter. | -3.649436 |
| F-statistic | 2.071567 | Durbin-Watson stat | 2.003328 |
| Prob(F-statistic) | 0.132377 | | |

Null Hypothesis: D(CO2) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -9.319213 | 0.0000 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CO2,2)
Method: Least Squares
Date: 07/16/19 Time: 11:17
Sample (adjusted): 1996Q3 2017Q4
Included observations: 86 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(CO2(-1)) | -1.022333 | 0.109702 | -9.319213 | 0.0000 |
| C | 0.011867 | 0.008611 | 1.378209 | 0.1718 |
| @TREND("1996Q1") | -0.000216 | 0.000169 | -1.282745 | 0.2032 |

| | | | |
|---|---|---|---|
| R-squared | 0.511328 | Mean dependent var | 1.11E-18 |
| Adjusted R-squared | 0.499553 | S.D. dependent var | 0.054401 |
| S.E. of regression | 0.038485 | Akaike info criterion | -3.642847 |
| Sum squared resid | 0.122930 | Schwarz criterion | -3.557230 |
| Log likelihood | 159.6424 | Hannan-Quinn criter. | -3.608390 |
| F-statistic | 43.42409 | Durbin-Watson stat | 2.001715 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: CO2 has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -1.597001 | 0.7864 |
| Test critical values: | 1% level | -4.066981 | |
| | 5% level | -3.462292 | |
| | 10% level | -3.157475 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 0.001373 |
| HAC corrected variance (Bartlett kernel) | 0.001369 |

Phillips-Perron Test Equation
Dependent Variable: D(CO2)
Method: Least Squares
Date: 07/16/19 Time: 11:18
Sample (adjusted): 1996Q2 2017Q4
Included observations: 87 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| CO2(-1) | -0.049760 | 0.031125 | -1.598720 | 0.1136 |
| C | 0.037211 | 0.018263 | 2.037477 | 0.0447 |
| @TREND("1996Q1") | -0.000142 | 0.000165 | -0.855872 | 0.3945 |

| | | | |
|---|---|---|---|
| R-squared | 0.047005 | Mean dependent var | 0.002162 |
| Adjusted R-squared | 0.024314 | S.D. dependent var | 0.038181 |
| S.E. of regression | 0.037714 | Akaike info criterion | -3.683676 |
| Sum squared resid | 0.119480 | Schwarz criterion | -3.598645 |
| Log likelihood | 163.2399 | Hannan-Quinn criter. | -3.649436 |
| F-statistic | 2.071567 | Durbin-Watson stat | 2.003328 |
| Prob(F-statistic) | 0.132377 | | |

Null Hypothesis: D(CO2) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -9.320123 | 0.0000 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 0.001429 |
| HAC corrected variance (Bartlett kernel) | 0.001402 |

Phillips-Perron Test Equation
Dependent Variable: D(CO2,2)
Method: Least Squares
Date: 07/16/19 Time: 11:18
Sample (adjusted): 1996Q3 2017Q4
Included observations: 86 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(CO2(-1)) | -1.022333 | 0.109702 | -9.319213 | 0.0000 |
| C | 0.011867 | 0.008611 | 1.378209 | 0.1718 |
| @TREND("1996Q1") | -0.000216 | 0.000169 | -1.282745 | 0.2032 |

| | | | |
|---|---|---|---|
| R-squared | 0.511328 | Mean dependent var | 1.11E-18 |
| Adjusted R-squared | 0.499553 | S.D. dependent var | 0.054401 |
| S.E. of regression | 0.038485 | Akaike info criterion | -3.642847 |
| Sum squared resid | 0.122930 | Schwarz criterion | -3.557230 |
| Log likelihood | 159.6424 | Hannan-Quinn criter. | -3.608390 |
| F-statistic | 43.42409 | Durbin-Watson stat | 2.001715 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: TO has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -2.833929 | 0.1895 |
| Test critical values: | 1% level | -4.066981 | |
| | 5% level | -3.462292 | |
| | 10% level | -3.157475 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TO)
Method: Least Squares
Date: 07/16/19 Time: 11:25
Sample (adjusted): 1996Q2 2017Q4
Included observations: 87 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| TO(-1) | -0.170733 | 0.060246 | -2.833929 | 0.0058 |
| C | 8.288971 | 2.992943 | 2.769505 | 0.0069 |
| @TREND("1996Q1") | -0.041765 | 0.021535 | -1.939403 | 0.0558 |

| | | | |
|---|---|---|---|
| R-squared | 0.089443 | Mean dependent var | -0.159887 |
| Adjusted R-squared | 0.067763 | S.D. dependent var | 4.378322 |
| S.E. of regression | 4.227376 | Akaike info criterion | 5.754914 |
| Sum squared resid | 1501.139 | Schwarz criterion | 5.839945 |
| Log likelihood | -247.3388 | Hannan-Quinn criter. | 5.789154 |
| F-statistic | 4.125625 | Durbin-Watson stat | 1.855932 |
| Prob(F-statistic) | 0.019539 | | |

Null Hypothesis: D(TO) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -9.144844 | 0.0000 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TO,2)
Method: Least Squares
Date: 07/16/19 Time: 11:26
Sample (adjusted): 1996Q3 2017Q4
Included observations: 86 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(TO(-1)) | -1.003844 | 0.109772 | -9.144844 | 0.0000 |
| C | 0.223386 | 0.985609 | 0.226648 | 0.8213 |
| @TREND("1996Q1") | -0.008669 | 0.019360 | -0.447748 | 0.6555 |

| | | | |
|---|---|---|---|
| R-squared | 0.501886 | Mean dependent var | -1.53E-16 |
| Adjusted R-squared | 0.489883 | S.D. dependent var | 6.232399 |
| S.E. of regression | 4.451335 | Akaike info criterion | 5.858546 |

| | | | |
|---|---|---|---|
| Sum squared resid | 1644.594 | Schwarz criterion | 5.944163 |
| Log likelihood | -248.9175 | Hannan-Quinn criter. | 5.893003 |
| F-statistic | 41.81418 | Durbin-Watson stat | 1.999887 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: TO has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -2.982776 | 0.1430 |
| Test critical values: | 1% level | -4.066981 | |
| | 5% level | -3.462292 | |
| | 10% level | -3.157475 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 17.25447 |
| HAC corrected variance (Bartlett kernel) | 19.52757 |

Phillips-Perron Test Equation
Dependent Variable: D(TO)
Method: Least Squares
Date: 07/16/19 Time: 11:26
Sample (adjusted): 1996Q2 2017Q4
Included observations: 87 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| TO(-1) | -0.170733 | 0.060246 | -2.833929 | 0.0058 |
| C | 8.288971 | 2.992943 | 2.769505 | 0.0069 |
| @TREND("1996Q1") | -0.041765 | 0.021535 | -1.939403 | 0.0558 |

| | | | |
|---|---|---|---|
| R-squared | 0.089443 | Mean dependent var | -0.159887 |
| Adjusted R-squared | 0.067763 | S.D. dependent var | 4.378322 |
| S.E. of regression | 4.227376 | Akaike info criterion | 5.754914 |
| Sum squared resid | 1501.139 | Schwarz criterion | 5.839945 |
| Log likelihood | -247.3388 | Hannan-Quinn criter. | 5.789154 |
| F-statistic | 4.125625 | Durbin-Watson stat | 1.855932 |
| Prob(F-statistic) | 0.019539 | | |

Null Hypothesis: D(TO) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -9.144844 | 0.0000 |
| Test critical values: | 1% level | -4.068290 | |

| | | | |
|---|---|---|---|
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 19.12318 |
| HAC corrected variance (Bartlett kernel) | 19.12318 |

Phillips-Perron Test Equation
Dependent Variable: D(TO,2)
Method: Least Squares
Date: 07/16/19 Time: 11:12
Sample (adjusted): 1996Q3 2017Q4
Included observations: 86 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(TO(-1)) | -1.003844 | 0.109772 | -9.144844 | 0.0000 |
| C | 0.223386 | 0.985609 | 0.226648 | 0.8213 |
| @TREND("1996Q1") | -0.008669 | 0.019360 | -0.447748 | 0.6555 |

| | | | |
|---|---|---|---|
| R-squared | 0.501886 | Mean dependent var | -1.53E-16 |
| Adjusted R-squared | 0.489883 | S.D. dependent var | 6.232399 |
| S.E. of regression | 4.451335 | Akaike info criterion | 5.858546 |
| Sum squared resid | 1644.594 | Schwarz criterion | 5.944163 |
| Log likelihood | -248.9175 | Hannan-Quinn criter. | 5.893003 |
| F-statistic | 41.81418 | Durbin-Watson stat | 1.999887 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: OR01 has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -2.586577 | 0.2875 |
| Test critical values: | 1% level | -4.066981 | |
| | 5% level | -3.462292 | |
| | 10% level | -3.157475 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(OR01)
Method: Least Squares
Date: 07/16/19 Time: 11:29
Sample (adjusted): 1996Q2 2017Q4
Included observations: 87 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| OR01(-1) | -0.147904 | 0.057181 | -2.586577 | 0.0114 |
| C | 2.200552 | 1.033604 | 2.129008 | 0.0362 |
| @TREND("1996Q1") | -0.012385 | 0.011139 | -1.111834 | 0.2694 |

| | | | |
|---|---|---|---|
| R-squared | 0.073777 | Mean dependent var | -0.132374 |
| Adjusted R-squared | 0.051724 | S.D. dependent var | 2.429140 |
| S.E. of regression | 2.365483 | Akaike info criterion | 4.593716 |
| Sum squared resid | 470.0230 | Schwarz criterion | 4.678747 |
| Log likelihood | -196.8267 | Hannan-Quinn criter. | 4.627956 |
| F-statistic | 3.345439 | Durbin-Watson stat | 1.869091 |
| Prob(F-statistic) | 0.040000 | | |

Null Hypothesis: D(OR01) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 7 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -6.633708 | 0.0000 |
| Test critical values: | 1% level | -4.078420 | |
| | 5% level | -3.467703 | |
| | 10% level | -3.160627 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(OR01,2)
Method: Least Squares
Date: 07/16/19 Time: 11:29
Sample (adjusted): 1998Q2 2017Q4
Included observations: 79 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(OR01(-1)) | -1.717366 | 0.258885 | -6.633708 | 0.0000 |
| D(OR01(-1),2) | 0.710971 | 0.241348 | 2.945834 | 0.0044 |
| D(OR01(-2),2) | 0.704318 | 0.222516 | 3.165246 | 0.0023 |
| D(OR01(-3),2) | 0.697407 | 0.202035 | 3.451915 | 0.0010 |
| D(OR01(-4),2) | 0.564602 | 0.178371 | 3.165324 | 0.0023 |
| D(OR01(-5),2) | 0.556061 | 0.153917 | 3.612745 | 0.0006 |
| D(OR01(-6),2) | 0.547054 | 0.125198 | 4.369495 | 0.0000 |
| D(OR01(-7),2) | 0.537578 | 0.088179 | 6.096436 | 0.0000 |
| C | 0.626341 | 0.514005 | 1.218550 | 0.2272 |
| @TREND("1996Q1") | -0.015407 | 0.009736 | -1.582543 | 0.1181 |

| | | | |
|---|---|---|---|
| R-squared | 0.710021 | Mean dependent var | 0.110472 |
| Adjusted R-squared | 0.672198 | S.D. dependent var | 3.420829 |
| S.E. of regression | 1.958562 | Akaike info criterion | 4.300121 |
| Sum squared resid | 264.6815 | Schwarz criterion | 4.600051 |
| Log likelihood | -159.8548 | Hannan-Quinn criter. | 4.420282 |
| F-statistic | 18.77205 | Durbin-Watson stat | 2.066322 |
| Prob(F-statistic) | 0.000000 | | |

Null Hypothesis: OR01 has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -2.723879 | 0.2299 |
| Test critical values: | 1% level | -4.066981 | |
| | 5% level | -3.462292 | |
| | 10% level | -3.157475 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 5.402563 |
| HAC corrected variance (Bartlett kernel) | 6.063983 |

Phillips-Perron Test Equation
Dependent Variable: D(OR01)
Method: Least Squares
Date: 07/16/19 Time: 11:32
Sample (adjusted): 1996Q2 2017Q4
Included observations: 87 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| OR01(-1) | -0.147904 | 0.057181 | -2.586577 | 0.0114 |
| C | 2.200552 | 1.033604 | 2.129008 | 0.0362 |
| @TREND("1996Q1") | -0.012385 | 0.011139 | -1.111834 | 0.2694 |

| | | | |
|---|---|---|---|
| R-squared | 0.073777 | Mean dependent var | -0.132374 |
| Adjusted R-squared | 0.051724 | S.D. dependent var | 2.429140 |
| S.E. of regression | 2.365483 | Akaike info criterion | 4.593716 |
| Sum squared resid | 470.0230 | Schwarz criterion | 4.678747 |
| Log likelihood | -196.8267 | Hannan-Quinn criter. | 4.627956 |
| F-statistic | 3.345439 | Durbin-Watson stat | 1.869091 |
| Prob(F-statistic) | 0.040000 | | |

Null Hypothesis: D(OR01) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -9.138157 | 0.0000 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 5.900449 |
| HAC corrected variance (Bartlett kernel) | 5.900449 |

Phillips-Perron Test Equation
Dependent Variable: D(OR01,2)
Method: Least Squares
Date: 07/16/19 Time: 11:32
Sample (adjusted): 1996Q3 2017Q4
Included observations: 86 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(OR01(-1)) | -1.003044 | 0.109764 | -9.138157 | 0.0000 |
| C | -0.128724 | 0.547447 | -0.235135 | 0.8147 |
| @TREND("1996Q1") | -0.000126 | 0.010741 | -0.011709 | 0.9907 |

| | | | |
|---|---|---|---|
| R-squared | 0.501520 | Mean dependent var | -6.12E-17 |
| Adjusted R-squared | 0.489509 | S.D. dependent var | 3.460657 |
| S.E. of regression | 2.472593 | Akaike info criterion | 4.682673 |
| Sum squared resid | 507.4386 | Schwarz criterion | 4.768290 |
| Log likelihood | -198.3549 | Hannan-Quinn criter. | 4.717130 |
| F-statistic | 41.75316 | Durbin-Watson stat | 2.000013 |
| Prob(F-statistic) | 0.000000 | | |

## Cointegration Test

Date: 07/16/19 Time: 11:45
Series: REC GDP INNO CO2 TO OR01
Sample: 1996Q1 2017Q4
Included observations: 88
Null hypothesis: Series are not cointegrated
Cointegrating equation deterministics: C
Automatic lags specification based on Schwarz criterion (maxlag=11)

| Dependent | tau-statistic | Prob.* | z-statistic | Prob.* |
|---|---|---|---|---|
| REC | -2.995754 | 0.7472 | -16.28045 | 0.7586 |
| GDP | -2.399685 | 0.9280 | -10.91700 | 0.9399 |
| INNO | -4.658562 | 0.0873 | 67.35710 | 1.0000 |
| CO2 | -2.601026 | 0.8834 | -10.95386 | 0.9391 |
| TO | -3.196119 | 0.6564 | -17.57745 | 0.6986 |
| OR01 | -3.333142 | 0.5890 | -17.76028 | 0.6898 |

*MacKinnon (1996) p-values.

Intermediate Results:

| | REC | GDP | INNO | CO2 | TO | OR01 |
|---|---|---|---|---|---|---|
| Rho – 1 | -0.187132 | -0.125483 | -0.703143 | -0.125906 | -0.202040 | -0.204141 |
| Rho S.E. | 0.062466 | 0.052291 | 0.150936 | 0.048406 | 0.063214 | 0.061246 |
| Residual variance | 0.188838 | 4.12E+08 | 2.894296 | 0.001096 | 13.58369 | 3.847644 |
| Long-run residual variance | 0.188838 | 4.12E+08 | 4.149951 | 0.001096 | 13.58369 | 3.847644 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Number of lags | 0 | 0 | 7 | 0 | 0 | 0 |
| Number of observations | 87 | 87 | 80 | 87 | 87 | 87 |
| Number of stochastic trends** | 6 | 6 | 6 | 6 | 6 | 6 |

**Number of stochastic trends in asymptotic distribution

# APPENDIX B

# RESULT FOR MODEL ONE

## B1: Dynamic Ordinary Least Square Test

Dependent Variable: REC
Method: Dynamic Least Squares (DOLS)
Date: 07/22/19 Time: 16:52
Sample (adjusted): 1996Q4 2017Q2
Included observations: 83 after adjustments
Cointegrating equation deterministics: C
Fixed leads and lags specification (lead=2, lag=2)
Long-run variance estimate (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| GDP | 1.09E-05 | 2.56E-06 | 4.255541 | 0.0001 |
| INNO | 0.240902 | 0.096246 | 2.502989 | 0.0155 |
| CO2 | -7.948629 | 1.442577 | -5.510022 | 0.0000 |
| TO | 0.001132 | 0.032881 | 0.034438 | 0.9727 |
| OR01 | -0.003202 | 0.060127 | -0.053251 | 0.9577 |
| C | 86.84746 | 1.831538 | 47.41779 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.829072 | Mean dependent var | 86.12432 |
| Adjusted R-squared | 0.730460 | S.D. dependent var | 1.378674 |
| S.E. of regression | 0.715770 | Sum squared resid | 26.64096 |
| Long-run variance | 1.151720 | | |

# APPENDIX C

# RESULT FOR MODEL TWO

## C1: Toda and Yamamoto Causality Test

VAR Granger Causality/Block Exogeneity Wald Tests

Date: 07/22/19 Time: 20:39
Sample: 1996Q1 2017Q4
Included observations: 80

Dependent variable: REC

| Excluded | Chi-sq | df | Prob. |
|---|---|---|---|
| GDP | 7.236178 | 8 | 0.5114 |
| INNO | 2.990909 | 8 | 0.9349 |
| CO2 | 8.357308 | 8 | 0.3994 |
| TO | 5.047482 | 8 | 0.7525 |
| OR | 17.20600 | 8 | 0.0280 |
| All | 41.22221 | 40 | 0.4169 |

Dependent variable: GDP

| Excluded | Chi-sq | df | Prob. |
|---|---|---|---|
| REC | 8.581001 | 8 | 0.3789 |
| INNO | 5.513753 | 8 | 0.7015 |
| CO2 | 12.39153 | 8 | 0.1346 |
| TO | 4.185422 | 8 | 0.8400 |
| ORR | 3.487409 | 8 | 0.9002 |
| All | 25.13733 | 40 | 0.9679 |

Dependent variable: INNO

| Excluded | Chi-sq | Df | Prob. |
|---|---|---|---|
| REC | 4.931499 | 8 | 0.7649 |
| GDP | 0.350544 | 8 | 1.0000 |
| CO2 | 4.034520 | 8 | 0.8540 |
| TO | 2.666625 | 8 | 0.9535 |
| ORR | 1.686414 | 8 | 0.9892 |
| All | 19.53423 | 40 | 0.9973 |

Dependent variable: CO2

| Excluded | Chi-sq | Df | Prob. |
|---|---|---|---|

| | | | |
|---|---|---|---|
| REC | 5.133172 | 8 | 0.7433 |
| GDP | 3.231462 | 8 | 0.9190 |
| INNO | 32.69749 | 8 | 0.0001 |
| TO | 3.108181 | 8 | 0.9274 |
| ORR | 8.577928 | 8 | 0.3791 |
| All | 55.69336 | 40 | 0.0506 |

Dependent variable: TO

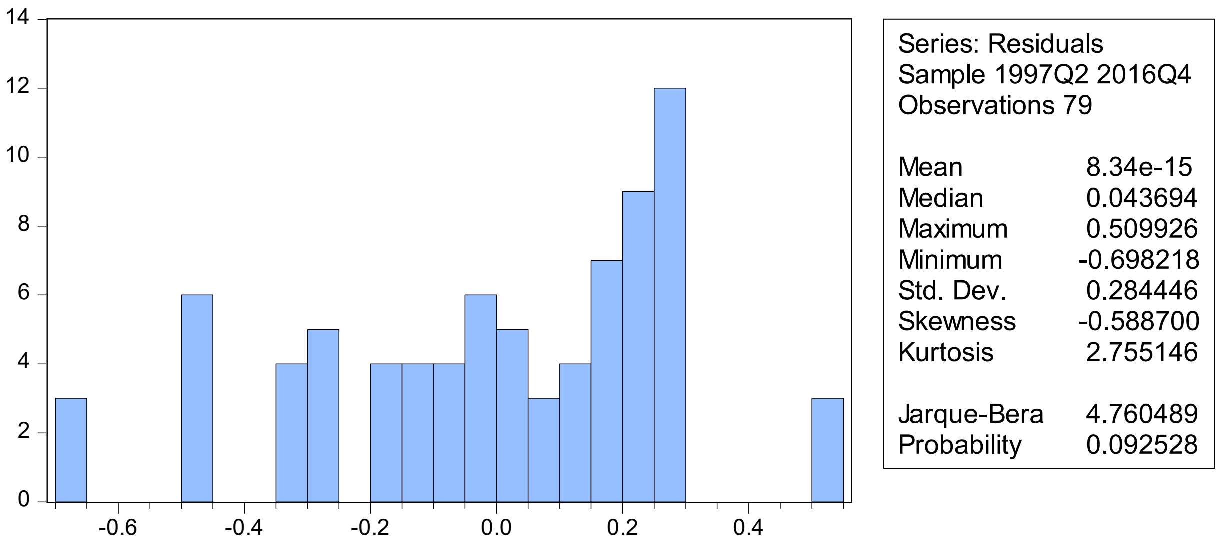
| Excluded | Chi-sq | Df | Prob. |
|---|---|---|---|
| REC | 6.413969 | 8 | 0.6010 |
| GDP | 10.62476 | 8 | 0.2239 |
| INNO | 4.299653 | 8 | 0.8291 |
| CO2 | 2.515487 | 8 | 0.9610 |
| ORR | 6.665908 | 8 | 0.5731 |
| All | 26.31934 | 40 | 0.9528 |

Dependent variable: ORR

| Excluded | Chi-sq | Df | Prob. |
|---|---|---|---|
| REC | 1.418995 | 8 | 0.9940 |
| GDP | 4.293964 | 8 | 0.8297 |
| INNO | 10.72315 | 8 | 0.2179 |
| CO2 | 7.422229 | 8 | 0.4918 |
| TO | 12.47089 | 8 | 0.1314 |
| All | 52.36115 | 40 | 0.0911 |

# APPENDIX D
# POST-ESTIMATION TEST

## D1: Normality Test



| N° | Description | Details | Cost in local currency | Exchange rate | Cost in USD | Comments |
|---|---|---|---|---|---|---|
| 1 | **Visa to Morocco** | Transportation | 980 Dinars | 118.8 | 8.2491582 | |
| | | Morocco Visa fee | 2745 Dinars (DZ) | 118.8 | 23.106061 | |
| | | Flight | 50771 Dinars (DZ) | 118.8 | 427.36532 | |
| | | Transport Casablanca-Rabat (round trip) | 838 Dirham (Morocco) | 9.35 | 89.625668 | |
| | | Hotel | 800 Dirhams (Morocco) | 9.35 | 85.561497 | |
| | | | | | | |
| **2** | **Visa to Equatorial Guinea** | Transportation to Equatorial Guinea Embassy | 100 Dirham (Morroco) | 9.35 | 10.695187 | |
| | | Equatorial Guinea Visa fee | 1000 Dirham (Morroco) | 9.35 | 106.95187 | |
| | | | | | | |
| 3 | **Equatorial Guinea Extension** | Visa extension fee | 40000 FCFA (Equatorial Guinea) | 576.9 | 34.668053 | |
| | | | | | | |
| **4** | **Transportation Tlemcen-Algiers** | Round trip 2 times | 6000 Dinars (DZ) | 118.8 | 50.505051 | |
| **5** | **Insurance** | | | | | |
| | | | | | | |
| **6** | **Internet Subscription** | Guinea | 135000 FCFA (Eq Guinea) | 576.9 | 234.00936 | |
| | | | 90000 FCFA (Eq Guinea) | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Algeria | 5000 Dinars (DZ) | | | |
| | | | | | | |
| | | | | | | |
| | | | | | 1070.7372 | |