Energy, Economic Growth and Pollution Mitigation

Ada Chigozie Akadiri

Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Economics

Eastern Mediterranean University
August 2021
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Ali Hakan Ulusoy
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy in Economics.

Prof. Dr. Mehmet Balcılar
Chair, Department of Economics

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Doctor of Philosophy in Economics.

Prof. Dr. Hasan Güngör
Supervisor

Examining Committee

1. Prof. Dr. Alper Aslan
2. Prof. Dr. Mustafa Besim
3. Prof. Dr. Hasan Güngör
4. Prof. Dr. İlhan Öztürk
5. Prof. Dr. Sevin Uğural

ABSTRACT

The first part of this thesis examines the contribution of natural gas consumption in the real GDP of Saudi Arabia using long-span and recent time series data over the period 1968-2016 in a multivariate framework which incorporates total trade as an additional variable. Using the Autoregressive Distributed Lag method of cointegration, we found a long-run cointegration equilibrium relationship between NGC, total trade, and real GDP, with a positive significant relationship among the variables. By applying the Toda and Yamamoto method to Granger causality testing, we found a one-sided causality running from NGC to real GDP; while between real GDP and trade, NGC and total trade and total trade and real GDP are without a feedback. From our empirical results, we suggest that natural gas conservation policy would hurt the demand for natural gas, hinder total trade, and thus, retard domestic output in the long-run. However, in the near future, it is possible for the Saudi Arabian government to meet energy needs and enhance total trade by adopting renewable energy alternatives to natural gas. Results, however, upon which the policy implications are inferred should be applied with caution as they may not be feasible enough to justify the adoption of unappealing energy policy choice for Saudi Arabia.

The second part of this dissertation, confirms the existence of a positive and significant long-run nexus among environmental sustainability, renewable energy consumption and economic growth in the EU-28 countries for the period of 1995-2015. Using Dumitrescu and Hurlin (2012) Granger non-causality in heterogeneous panel, the result shows a long-run bidirectional causal relationship among renewable energy consumption, economic growth and other growth determinants. In addition, empirical results indicates real gross fixed capital formation, carbon emissions and other environmental factors are principal determinants of long-run growth in the EU. Based on these results, we infer that the exploitation of renewable energy sources in the EU-28 countries is a reliable pathway toward environmental pollution mitigation. Consequently, achieving sustainable development goals (SDGs) by the year 2030 through renewable energy consumption and carbon emission mitigation is very much achievable in the EU-28 countries, and should also be adopted by all countries as an effective global policy.

Keywords: Natural Gas Consumption, Total Trade, Economic Growth, ARDL Approach, Granger Causality, Economic Sustainability; Pollution Mitigation; European Union; CO_2 Emissions, Energy Policy.

ÖZ

Bu tezin ilk bölümü, doğal gaz tüketiminin Suudi Arabistan'ın reel GSYİH'sine katkısını, toplam ticareti ek bir değişken olarak içeren çok değişkenli bir çerçevede 1968-2016 dönemi için uzun vadeli ve yakın zaman serisi verilerini kullanarak incelemektedir. Otoregresif Dağıtılmış Gecikme eşbütünleşme yöntemini kullanarak, değişkenler arasında pozitif anlamlı bir ilişki ile NGC, toplam ticaret ve reel GSYİH arasında uzun vadeli bir eşbütünleşme dengesi ilişkisi bulduk. Toda ve Yamamoto yöntemini Granger nedensellik testine uygulayarak, NGC'den gerçek GSYİH'ya uzanan tek taraflı bir nedensellik bulduk; reel GSYİH ile ticaret arasında iken, NGC ile toplam ticaret ve toplam ticaret ile reel GSYİH arasında bir geri besleme yoktur. Ampirik sonuçlarımızdan, doğal gaz koruma politikasının doğal gaz talebine zarar vereceğini, toplam ticareti engelleyeceğini ve böylece uzun vadede yurtiçi üretimi geciktireceğini öne sürüyoruz. Ancak yakın gelecekte Suudi Arabistan hükümetinin doğal gaza yenilenebilir enerji alternatiflerini benimseyerek enerji ihtiyaçlarını karşılaması ve toplam ticareti geliştirmesi mümkün. Bununla birlikte, politika çıkarımlarının çıkarıldığı sonuçlar, Suudi Arabistan için çekici olmayan enerji politikası seçiminin benimsenmesini haklı çıkarmak için yeterince uygulanabilir olmayabileceklerinden dikkatli bir şekilde uygulanmalıdır.

Bu tezin ikinci bölümü, 1995-2015 dönemi için AB-28 ülkelerinde çevresel sürdürülebilirlik, yenilenebilir enerji tüketimi ve ekonomik büyüme arasında uzun vadeli pozitif ve önemli bir ilişkinin varlığını doğrulamaktadır. Heterojen panelde Dumitrescu ve Hurlin (2012) Granger nedenselliksizliği kullanan sonuç, yenilenebilir enerji tüketimi, ekonomik büyüme ve diğer büyüme belirleyicileri arasında uzun dönemli çift yönlü bir nedensel ilişki olduğunu göstermektedir. Ek olarak, ampirik sonuçlar, gerçek gayri safi sabit sermaye oluşumunun, karbon emisyonlarının ve diğer çevresel faktörlerin AB'de uzun vadeli büyümenin temel belirleyicileri olduğunu göstermektedir. Bu sonuçlara dayanarak, AB-28 ülkelerinde yenilenebilir enerji kaynaklarının kullanımının çevre kirliliğinin azaltılmasına yönelik güvenilir bir yol olduğu sonucuna varıyoruz. Sonuç olarak, yenilenebilir enerji tüketimi ve karbon emisyonunun azaltılması yoluyla 2030 yılına kadar sürdürülebilir kalkınma hedeflerine (SKH'ler) ulaşmak, AB-28 ülkelerinde büyük ölçüde başarılabilir ve tüm ülkeler tarafından etkin bir küresel politika olarak benimsenmelidir.

Anahtar Kelimeler: Doğal Gaz Tüketimi, Toplam Ticaret, Ekonomik Büyüme, ARDL Yaklaşımı, Granger Nedenselliği, Ekonomik Sürdürülebilirlik; Kirliliğin Azaltılması; Avrupa Birliği; CO2 Emisyonları, Enerji Politikası.

DEDICATION

TO GOD ALMIGHTY

ACKNOWLEDGMENT

The success of this work would not have been possible without the help of the Most High God whom I'm forever grateful to.

My gratitude goes to my Supervisor Prof. Dr. Hasan Güngör whose unending support and encouragement led to the success of this work. To my highly remarkable examining committee members Prof. Dr. Alper Aslan, Prof. Dr. İlhan Öztürk, Prof. Dr. Sevin Uğural and Prof. Dr. Mustafa Besim your contributions and suggestions for improvement are of mean value and these I seek to acknowledge. Many thanks also goes to the Chair of the Department of Economics Prof. Dr. Mehmet Balcılar.

My most sincere appreciation goes to my parents Late Mr. V.I. Maduaka. & Mrs. Cecilia Maduaka. You have set me on this path and got me this far through your love and encouragement for this I remain grateful. My siblings Ekene, Ugo, and Pamela for your love and encouragements all the way, I love you all.

To my world JEMIMA I am forever grateful to God for making you a part of me. Your laughter and constant joy keeps me going even in the toughest of time.

The support provided by Dr. Seyi Saint Akadiri, Asst. Prof. Dr. Alola Andrew Adewale, Asst. Prof. Dr. Gizem Uzuner, Asst. Prof. Dr. Festus Victor Bekun and Asst. Prof. Dr. Kayode Eluwole will forever remain evergreen in my memory: to my friends Tobi M.G., Lucy A., Tunde E., I love you all and I look forward to a wonderful future for you all. It is my utmost prayer that the Almighty God rewards each and every one of you.

TABLE OF CONTENTS

ABSTRACT iii

ÖZ v

DEDICATION vii

ACKNOWLEDGMENT viii

LIST OF TABLES xi

LIST OF FIGURES xii

LIST OF ABBREVIATIONS xiii

1 INTRODUCTION 1

1.1 An Overview of the Study 1

2 THE ROLE OF NATURAL GAS CONSUMPTION IN SAUDI ARABIA'S OUTPUT AND ITS IMPLICATION FOR TRADE AND ENVIRONMENTAL QUALITY 9

2.1 Introduction 9

2.2 Literature Review 15

2.3 Research Data and Methodology 21

2.3.1 Data Source and the Model 21

2.3.2 ARDL Approach 22

2.3.3 T-Y Granger Causality Testing Approach 24

2.3.4 Brown, Durbin and Evans Approach to Stability Test 26

2.4 Empirical Results and Discussions 27

2.5 Conclusion and Policy Implications 33

3 RENEWABLE ENERGY CONSUMPTION IN EU-28 COUNTRIES: POLICY TOWARD POLLUTION MITIGATION AND ECONOMIC SUSTAINABILITY 38

3.1 Introduction 38

3.2 Literature Review 41

3.3 EU Renewable for Global 3.3 EU Renewable Energy Outlook: Indication for Global Environmental Sustainability 44

3.4 Data and Empirical Models 48

3.4.1 Data 48

3.4.2 Empirical Models 50

3.4.3 Panel Granger Causality Test Approach 55

3.5 Empirical Results and Discussion 56

3.5.1 Granger Causality Results 61

3.6 Conclusion and Policy Implications 63

4 CONCLUSION 66

4.1 An overview of Conclusion 66

REFERENCES 70

LIST OF TABLES

Table 2.1: Time Series Unit Root Test Results.. 27

Table 2.2: VAR Selection Criteria and Cointegration Results 299

Table 2.3: ECM-ARDL Estimation Results 299

Table 2.4: Diagnostic Tests.. 30

Table 2.5: TY (1995) Granger Causality Test Results.. 31

Table 3.1: Sources of Renewable Energy Technology and Volume of Consumption in EU-28 Countries 45

Table 3.2: Share of EU-28 Member States' RES Share of Total RE Usage and Projection for 2020.. 47

Table 3.3: Summary Statistics of the Variables 49

Table 3.4: Pearson Correlation Results... 499

Table 3.5: Panel Unit Root Test Results 52

Table 3.6: Panel Cointegration Test... 53

Table 3.7: Regression for FMOLS Model 57

Table 3.8: PMG, MG, DFE Estimators of the ARDL (1,1) Economic Growth Equation…………………………………………..……………………………...59

Table 3.9: Dumitrescu and Hurlin (2012) Panel Granger Causality Results 62

LIST OF FIGURES

Figure 2.1: Graphical Plots of LNNGC, LNTRADE and LNRGDP......................... 22

Figure 2.2: Graphical Plot of CUSUM and CUSUSQ of Recursive Residuals……..33

LIST OF ABBREVIATIONS

ADF	Augmented Dickey and Fuller
ARDL	Autoregressive Distributed Lag
DFE	Dynamic Fixed Effect
EEA	European Environmental Agency
EG	Economic Growth
EU	European Union
FMOLS	Fully ModifiedOrdinaryLeast Square
MG	Mean Group
NGC	Natural Gas Consumption
PMG	Pooled Mean Group
RED	Renewable Energy Directive
RGDP	Real Gross Domestic Product
TT	Total Trade
VECM	Vector Error Correction Model
WDI	World Development Indicators

Chapter 1

INTRODUCTION

1.1 An Overview of the Study

As countries evolve, they take steps towards achieving a sustainable economy and the environment. The demand for energy has increased over the last two decades, especially for natural gas, oil, and electricity, among other sources. Renewable energy has been targeted by countries as a means of supplying the energy they need, extending energy consumption to more people, and achieving economic growth.

The research work by Kraft and Kraft (1978) for the United States on the relation between energy use and economic growth paved the way for a slew of other studies in a variety of countries and groups of countries. (Apergis and Payne, 2009; Baranzini et al., 2013; Ghosh, 2010; Stern, 1993; Wolde-Rufael, 2005; Yuan et al., 2007). The debate over this subject is still raging in the energy economic growth literature, with many energy practitioners and government officials focusing on the outcomes, specifically because it has been found that economies with higher energy output and demand have a higher per capita income (Owusu and Asumadu, 2016).

Energy comes from the word “energeia” in Greek. We usually see energy as the ability to produce heat from various direct sunlight methods, which happens to be the most significant source of energy needed for a healthy existence, even though most economies now use other sources of energy such as geothermal, natural gas and nuclear intensively with the increased population. According to (Bhattacharyya, 2011; Berberoğlu, 1982), the power of a system of objects or substances to work is described as energy. It is seen as a major factor that guides the world and global politics with states aiming at generating the energy required for renewable energy in order to bring it to a greater number of people for the achievement of economic growth.

Economic growth in an economy means a rise in a country's gross demand, whereby the inclusion of financial value to the economy helps improve labor productivity. The Solow Growth Model being an exogenous economic growth model examines over time, the changes in the amount of demand in an economy as a result of population changes. Based on the basic Solow growth model (Solow, 1956), a firm relationship between savings rate and income per capita exists, with a negative relationship existing with the population growth.

The classical growth theory assumes that the economic growth of a country decreases with an increasing population and constrained resources. Such assumption is due to the acceptance of classical growth theory economist who believes that a brief rise in Real GDP per person unavoidably leads to a population outburst which would therefore restrain a nation's resources there upon reducing real GDP, and as such the economic growth of the country begins to get slow. However the classical growth model overlooks the importance of efficient technological innovation in the continuous operation of an economy, being that technological advancements can help mitigate declining returns.

Based on the endogenous growth theory, economic growth is produced internally in the economy that is, by endogenous forces rather than exogenous forces. Endogenous growth theory was developed as a counter-argument to neoclassical growth theory, which argues that external forces such as technological change, among other things, are the primary drivers of economic growth, posing the issue of how income disparities between developed and developing countries could continue if physical resources, such as infrastructure, yields low returns.

Both models emphasizes on technological advancement but the Neoclassical states that sustainable growth rate is a function of population growth, labor share of income and technology but also says productivity growth that is (GDP per capital growth) is driven only by the improvement of technology. Paul Romer, an economist, proposed that technological progress is not always an end-product of autonomous research advancement, demonstrating that government programs, such as R&D spending and intellectual property rules, aided in the development of endogenous creativity and sustained economic growth.

Endogenous growth analysts believe that productivity gains are linked to faster innovation and higher human capital investments. Hence result in campaigning for government and private sector agencies in other to promote creativity and also provide resources for individuals and companies to be more innovative, such as R&D funding and intellectual property rights.

Since most oil-producing countries' reserves are being drained, some developed and developing economies are considering natural gas as a viable option because it emits less CO_2 than other fossil fuels. Governments and policymakers are exploring sound energy policy options to encourage the use of NG over other fossil fuels with the viability of renewable energy sources in the search to reduce global warming through the Kyoto Protocol in Paris.

This dissertation augments the ongoing debate on energy policy as regards the use of NG as a CO2 mitigation alternative, raising the need for the research into the role of NGC in the EG system, especially in Saudi Arabia and although current studies on the importance of energy consumption in economic growth is wide the studies on the role of natural gas consumption in economic growth are relatively limited.

This dissertation also expands the NGC-EG literature associated with Saudi Arabia by incorporating Total Trade in a consistent context using the ARDL method for co-integration testing and the Toda-Yamamoto approach for Granger causality testing, with a long and recent time series data, to establish a divergence in literature which this thesis tries to fill by trying to see how NGC in combination with TT affects the EG phase seeing Saudi Arabia is the world's leading oil exporter and energy resource manufacturer. Hence checking to see if an increase or decrease in natural gas consumption would have a significant impact on the economy’s growth or not, and its efficiency on the quality of the region's environments both in the short-term and long-term.

Saudi Arabia appears to be a fascinating country to research on, especially in terms of NGC-EG relationships, considering their impressive NG ability and usage. Saudi Arabia has emerged as a vital global economic force, a powerful regional power, and the world's largest oil producer since the discovery of oil in 1944.

According to the World Energy Council report (2016) Saudi Arabia's aggregate proved NG reserves was about 8488.9 billion cubic meters (bcm) in 2004 which put the country on the world list as the 6th most proved natural gas reserves on the globe and 3rd in the Middle East. In the same year, Saudi Arabia produced 102.4bcm of NG, which crowned the country 8th largest NG producers on the globe (WEC, 2016). This record marked the 5th straight year of improving in NG production. In Saudi Arabia, emphasis is upon enhancing domestic production of NG in order to meet their local energy demand. In addition, in 2014, the economy consumed 108.2bcm NG, which is 40.7% of their primary energy consumption which has made the country the 5thlargest NG consumer in the world.

Saudi Arabia has been a close partner to a number of European countries and despite their cultural, political, and economic differences, the Co-operation Agreement signed in 1988 between the European Economic Community and the countries that make up the Charter of the GCC (Gulf Cooperation Council) with Saudi Arabia having a special position in the Gulf–EU relationship among the seven Gulf countries and an official dialogue established between Saudi Arabia and the EU; with Trade, security, environment, energy resources, aviation, and political ties being topics of discussion between the EU and the GCC.

Based on the current findings, governments and policymakers in Saudi Arabia must implement appropriate energy policies to ensure energy efficiency and renewable energy sources, including increased investment in R&D to aid in the exploration of other renewable energy sources to buffer high demand for natural gas without slowing the economy's growth, in order to meet rising energy demand. As a result, renewable energy sources have emerged as the most realistic energy choice for satisfying current generation's growing energy demand without risking future generation's energy requirements. This leads to our next study on renewable energy usage in EU-28 nations, as well as measures aimed at pollution reduction and economic sustainability, given the EU's determination to keep the importation of emissions to a minimum.

The next chapter of this dissertation focuses on the deliberate initiative geared towards lowering CO2 emissions and a constant transitioning from conventional energy sources to renewable sources within the 28 member states of the European Union. Presently, the sources of renewable energy seems to be the most appropriate energy source to reach the rising demand for energy without missing the energy demand for future generations, whereby consuming more renewable energy, the EU is determined to limit its dependence on fossil fuel imports.

The European Council and the European Union Parliament approved of recent the renewable energy directive (RED) targets for 2020, with the RED policy playing a significant role in strengthening the European Union's energy infrastructure to ensure renewable energy sources accounts for 18 percent of the overall final consumption in 2018, with a target of 20 percent by 2020 and at least 32 percent by 2030 with the numbers being dependent on the use of energy in all of its forms in all three major sectors: heating and cooling, power, and transportation.

The Kyoto Protocol’s first contribution cycle of 2008-2012, completed by EU-28 being a signatory to the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is based on the (European Commission’s Progress Report, 2016). According to the survey, the commission (and member states) is on track to meet their 2020 GHG emission reduction deadline, which corresponds to the Kyoto Protocol's second commitment duration of 2013-2020.

However, to accomplish these specified objectives, a thorough understanding of the long-run equilibrium effects as well as the advantages of renewable energy in fostering and maintaining economic growth is essential, with the specifications for attaining this objective being sectoral goals for transportation, temperature regulation and electricity, proposed energy policy initiatives for integrating different types of renewable energies, and the use of corporate mechanisms in implementing joint support systems and joint projects among member states

This dissertation augments the literature review by trying to compare its findings to those of Apergis and Payne (2009a, 2009b, 2010a, 2010b) who carried out a contextual studies on Central America, Organization for Economic Co-operation and Development (OECD), Commonwealth of Independent States (CIS), and most recently, Eurasian countries over the period 1992-2007 using multivariate panel data model and also based on the neutrality hypothesis stated by Menegaki (2011) which argues that renewable energy is used unevenly and insufficiently across the EU-27 countries from 1997 to 2007.

This thesis uses a broader and more modern panel dataset that spans the years 1995 to 2015 for all EU-28 countries, to understand the impacts of long-run equilibrium and the importance of renewable energy in stimulating and sustaining the growth of the economy by using the EU-28 countries as a case study with Real GDP being proxy for economic growth, renewable energy consumption (REN) as energy obtained from various renewable sources such as geothermal heat, rain, waves, tides and sunlight with the inclusion of two commonly used control variables in the RE-EG literature that are found to be significant determinants of growth such as carbon emissions (CO_2) and real gross fixed capital formation (RGFCF) to see their effect in the growth of the EU either in the short or long-term.

The purpose of this thesis being in line with the objectives laid by the European Union within the 2020 European Strategy focuses on lowering the primary consumption of energy in order to achieve a constant part of the renewable energy in the final energy consumption by looking at the nexus between Europe's pooled mean group (PMG), mean group (MG), and the dynamic fixed effect (DFE) approach as a unique way of measuring the short and long-term relationships between renewable energy and the economic growth in a dynamic panel framework which would also report the level of adjustment that reveals how quickly or slowly the EU-28 countries approach or diverge from the steady state long-term environmental sustainability route.

Finally, in a stylized fashion, the last section harmonizes the main conclusions and provides a blue print for the investigated case study and all key stakeholders in tackling the impact of these macroeconomic variables in both the present and future generation to come on environment.

Chapter 2

THE ROLE OF NATURAL GAS CONSUMPTION IN SAUDI ARABIA'S OUTPUT AND ITS IMPLICATION FOR TRADE AND ENVIRONMENTAL QUALITY

2.1 Introduction

Natural gas (NG)is an essential nonrenewable energy source for the production of electricity, and it also serves as a raw material for industrial sector in the developed, emerging and developing economies of the world (Apergis and Payne, 2010).Oil reserves in most of the oil producing countries are being exhausted, hence, the possibility of a feasible alternative like natural gas is being considered in some developed and developing economies since it produces less CO_2 compared to other fossil fuels.

In the quest to mitigate global warming via Kyoto Protocol in Paris, governments and policymakers are considering sound energy policy alternatives to promote the use of NG over other fossil fuels with the feasibility of renewable energy sources. The ongoing debate on energy policy on the use of NG as an alternative means to mitigate CO2 raises the question of research on the role of NGC in the process of economic growth (EG), especially in Saudi Arabia. Although, existing studies on the role of energy consumption (EC) in EG is vast, the studies on the role of NGC in EG are relatively limited.

Saudi Arabia appears to be an interesting country to study, especially in terms of NGC-EG relationships given their remarkable NG potential and utilization. According to the World Energy Council report (2016) Saudi Arabia aggregate proved NG reserves was about 8488.9bcm in 2004. This put the country on the world list, the 6th most proved natural gas reserves on the globe and 3rd in the Middle East. In the same year, Saudi Arabia produced 102.4bcm of NG, which crowned the country 8th largest NG producers on the globe (WEC, 2016). This record marked the 5th straight year of improving in NG production.

In Saudi Arabia, emphasis is upon enhancing domestic production of NG in order to meet their local energy demand. In addition, in 2014, the economy consumed 108.2bcm NG, which is 40.7% of their primary energy consumption. This has made the country the 5th largest NG consumer in the world. NGC in Saudi Arabia has been on the rise over the years, and it has continued to play a major role in their energy policy mix. (WEC, 2016).

The role of NGC in economic growth has received growing attention among researchers recently; although, there seems to be few studies on the topic with conflicting policy implications. One major reason behind the conflicting conclusions is because previous studies on the NGC-EG nexus employ bivariate models to evaluate the presence of dynamic causal nexus among the sampled variables.

The use of a bivariate model has argued to generate inconsistent and/or biased estimates (Lutkepohl, 1982) due to non-inclusion of significant variables that might exercise an influence on the NGC-EG nexus. Non-inclusion of relevant variables in empirical studies would make policy implication inferences from such findings unreliable (Lutkepohl, 1982).By implication, such bivariate models with omitted variables would produce spurious estimators and unreliable dynamic Granger causality relationships.

On the other hand, with the use of a sound and more accurate econometrics method, using appropriate macroeconomic variables in a multivariate model with the use of sound and more reliable econometrics approach would provide robust empirical results. Consequently, the recent studies of Apergis and Payne (2010), Kum, Ocal and Aslam (2012), employed one or more control variables (export, import, capital, trade and/or labor) for ceteris paribus analysis.

This study is an addition to the NGC-EG literature in the following ways: First, studies that examine NGC, trade and EG in the same model tend not to focus on Saudi Arabia. The few studies associated with Saudi Arabia only examine the nexus between EC, CO_2 and EG (Alkhathlan and Javid, 2013; Alshehry and Belloumi, 2015). Alkhathlan and Javid (2013) in their analysis examine the nexus between EG, CO_2 and EC at various (aggregate and disaggregate) levels via the ARDL approach over the period 1980-2011.

Empirical findings suggest that a direct relationship exists between CO_2 and real income per capita. According to them, this result is evidence that, there is an increasing relationship between CO_2 and EG in the extensive model, and between oil and electricity consumption in the disaggregated model. In addition, results show an inverse and significant estimated coefficient for CO_2 in the NGC model in the short- and long-term. They were of the opinion that to reduce CO_2, Saudi Arabian economy must switch from oil consumption to gas. In addition, they advocated for electricity, since it emits lessCO_2 than other energy sources.

Alshehry and Belloumi (2015), on the other hand, examined the causal nexus between EC, EG and energy price (EP) in Saudi Arabia. This study focuses on the demand side using Johansen multivariate cointegration method and employ CO_2 as additional variable, over the period 1971-2010. The results of their analysis indicates there is at least a long-term nexus between EC, energy prices, CO2 and EG. In addition, they found a long-run one-sided causality between EC and EG and CO_2, two-sided causality between CO_2 and EG, and a long-run one-sided causality between EP to EG and CO_2. From their analysis, EP appears to be the most significant factor in explaining variations in EG. They concluded that policy towards reducing EC and CO_2might not reduce significantly Saudi's economic growth. Thus, they advocated for energy sources such solar and wind power as an alternative energy source to fossil fuel and to mitigate CO_2.

There are no clear studies for Saudi Arabia that have explored the contribution of NGC and TT to EG in a coherent framework to the best of our knowledge, using the ARDL approach in testing for co-integration and the Toda-Yamamoto approach for Granger causality testing, while using a long and more recent time series of data. This creates a gap in literature this study tries to fill.

The ARDL generates short- and long-run coefficients in a dynamic time series framework and also produces speed of adjustment. The adjustment coefficient shows how very fast or slow the Saudi Arabia is converging and/or diverging towards or from the steady state environmental sustainability path in the long-run. ARDL estimations are robust either the variable(s) are stationary at level, first difference or partially integrated I (0), I (1), mixed). It also performs better in testing cointegration in time series analysis.

In addition, in time series, we use Toda and Yamamoto (1995) approach of non-Granger causality testing as this method is argued to cause a robust statistical causality test compared to conventional approaches that failed to adjust between time series data for possible non-stationary properties and co-movement. It is often used where rank requirements for time series are not met and stationary properties are unknown, until the order of data integration is the same with the lag period chosen for the model.

Second, this study examines the role of NGC in Saudi Arabia’s output in a multivariate framework, employing TT as an additional variable. We seek to examine how NGC combined with TT influences the EG process. This study incorporates trade as an additional variable since Saudi Arabia is the world's top oil exporter and producer of energy resources, this paper incorporates trade as an additional variable; thus, inclusion of TT in NGC-EG nexus appears as an addition to energy literature.

In addition, according to Lutkepohl (1982), absence of a causality relationship in a bivariate model does arise due to omission of relevant variables. Finally, following the studies of Destek and Okumus (2017), Destek (2016), Solarin and Shahbaz (2015), Shahbaz *et al* (2014), Shahbaz *et al* (2013), Kum *et al* (2012), Lim and Yoo (2012), Apergis and Payne (2010) and Lee (2005), the magnitude and sign of the individual coefficients is analyzed in accordance with NGC-EG nexus.

The contribution of this study is of manifold: First, there are no particular studies for Saudi Arabia that has examined the contribution of NGC and TT on EG in a coherent structure, using ARDL testing approach for co-integration and Toda-Yamamoto approach for Granger causality testing, while using a long and more recent time series data. Second, this study examines the role of NGC in Saudi Arabia's output in a multivariate framework, employing TT as an additional variable.

Saudi Arabia is the world's top oil exporter and producer of energy resources; thus, inclusion of TT in NGC-EG nexus appears as an addition to energy literature. Third, the results revealed that NGC and TT are significant determinants of real GDP as they enhance economic growth of the sampled country. In addition, empirical findings indicate a one-sided dynamic Granger causality between NGC and EG, whereas there is a relationship of non-Granger causality between natural gas consumption and total trade, and between total trade and real GDP.

The one-sided long-run causality relationship between NGC and EG means Saudi Arabia is a natural gas dependent economy. Thus, implementation of natural-gas conservation policy in order to mitigate global warming as being suggested in energy policy literature would hinder the demand for natural gas, affect total trade and slow-down Saudi Arabia's economic performance in the long-run.

In summary, this study explores the impact of the production of natural gas consumption in Saudi Arabia. We investigate whether increasing or decreasing natural gas consumption has a significant impact on economic growth and, as a result, the quality of the region's environments in the short and long term. For comprehensive empirical analysis, we employ total trade, since Saudi Arabia is the world's top oil exporter and producer of energy resources; thus, inclusion of TT in NGC-EG nexus appears as an addition to energy literature.

Using ARDL approach for short- and long-run estimation coefficients and co-integration testing alongside Toda and Yamamoto non-Granger causality test, we found that, natural gas consumption and total trade play a positive and significant role in Saudi Arabia's output in the long-run with no significant impact in the short-run. Results also show that, economic and energy policies are in tune with the trade policies, and thus policymakers should focus more on natural gas consumption and its attendant effect on environmental quality and economic growth for both the present and future generations.

2.2 Literature Review

There is an extensive study on the nexus between NGC and EG. This previous studies can be grouped in four divisions. They are discussed as follows:

The first group of researchers are Nasiru and Kabara (2016), Ziramba (2015), Lim and Yoo (2012) and Isik (2010) who employed bivariate econometrics framework to explore the claimed relationships.

Isik (2010) in his study, investigated the role of NGC in EG by employing ARDL model between the periods of 1977-2008 for Turkey where he found that a direct relationship exists between EG and NGC in the short- and long-term. For example, Lim and Yoo (2012) examined the direction of causality between EG and NGC using quarterly frequency data between the periods of 1991 to 2008 for Korea and found a two-sided causality between NGC and EG.

Nasiru and Kabara (2016) examined the causality nexus between NGC and EG in Nigeria between the period 1980-2014 using the Johansen's maximum likelihood cointegration method and standard Granger causality tests. The empirical results reveals NGC has a long equilibrium nexus with EG, while, Granger causality test revealed one-sided causality from EG to NGC.

Similarly, Furuoka (2016) in their analysis for China and Japan, which are the two largest natural gas consumers in Asia, over the periods 1980-2012 via ARDL estimators. Results showed that China Japan share common features in terms of NGC-EG nexus, with the presence of long-run cointegration between the variables. Regarding causality, results showed one-sided causality from NGC to EC in China, while two-sided causality between NGC and EG in Japan with attendant policy implications. This is consistent with the studies of Molele and Ncanywa (2018) and Naser (2017).

The second group of studies investigated causal nexus between EG and NGC, where they employ as an additional variables, which include; labor, capital or both. Apergis and Payne (2010) examined the nexus between domestic investments, labor force, real GDP and NGC using a macro panel data via multivariate model between the periods of 1992–2005. They evaluated cointegration test, and found a long-run nexus and two-sided causality between EG and NGC.

Kum*et al* (2012) on the other hand, investigated the nexus between capital, NGC and EG for the G-7 nations between the periods 1970 – 2008. Their empirical analysis showed conflicting outcomes regarding the direction of causality for the paneled countries. Alam, Ahmed and Begum (2017) examines the causal link between energy demand (ED) and EG in Bangladesh between the periods 1980 – 2011, using Maximum Entropy Bootstrap in a multivariate production function study with their empirical results revealing a one-sided causality between EG to ED, which implies that, in Bangladesh, conservative policy is not the right energy policy tool.

Rafindadi and Ozturk (2015) empirically investigate the nexus between NGC, capital, labor, economic growth and exports in Malaysia over the periods 1971-2012. The study employ dual structural break unit root techniques, Johansen and Bayer-Hanck co-integration and ARDL bounds testing approach. Results revealed a one-sided causality from NGC to EC. Labor, capital and exports are reported to significantly contribute to EG. They advocated for adequate exploitation of natural gas reserves and joint effort to promote the development of human capital in the sampled region.

In the same vein, Asafu-Adjaye, Byrne and Alvarez (2016) using Pooled Mean Group (PMG) estimator approach that incorporate capital, fossil fuels and non-fossil fuels in a panel study for 53 nations between the periods 1990-2012. They concluded that real income is not adequate to promote environmental quality. Thus, policymakers were encouraged to create an enabling environment that would enhance increased investment in renewable energy.

The third group of studies in their analysis on the nexus among NGC and EC, employed trade and/or gross fixed capital formation (GFCF) as a control variable Shahbaz*et al* (2013) in their analysis highlighted the need to incorporate trade indicators in evaluating the nexus between NGC, labor, real GDP and capital for

Pakistan. They found that, export, labor, real capital and NGC stimulate growth, and a two-sided causality nexus between NGC and EC for the sampled country.

Farhani *et al* (2014), on the other hand, investigated the impact of real GFCF, trade, NGC on EG of Tunisia between the periods 1980–2010. Using ARDL testing approach for cointegration with Toda-Yamamoto approach for Granger causality testing is necessary. This is consistent with the study of Solarin and Shahbaz (2015) where they examined the role of trade openness, foreign direct investment, and capital formation on economic growth and natural gas consumption in Malaysia.

Ozturk and Al-Malali (2015) examines the nexus between NGC and EG in a panel study that incorporate as an additional variables, total labor force, trade openness and GFCF as drivers of the GDP growth between the periods 1980-2012. Findings showed the existence of a cointegration nexus between GDP growth and NGC in the long-run. NGC was reported to positively influence GDP growth in the long-run, while result shows two-sided causality nexus between NGC and GDP growth. The study advocated for energy savings technologies for the sampled countries (Solarin&Ozturk2016).

Destek (2016) examined the nexus between NGC and the growth in GDP for a panel of 26 OECD nations, using a multivariate production model that incorporate GFCF and trade openness (TOP) between the periods 1991-2003. Empirical result shows that NGC, GFCF, TOP and GDP growth are co-integrated in the long-run. Also, they discovered that NGC positively impact on GDP growth with a one-sided causality in the short-run and two-sided causality in the long-run. This is consistent with the results of Tamba (2017), Krarti, and Dubey (2018).

On the other hand, Akadiri and Akadiri (2019) in their recent study, examined the role of NGC on domestic output of Iran over the period 1980 to 2013 in a multivariate model that incorporates real GFCF as an additional variable. Their empirical results showed a one-sided causality from EG to NGC and from real GFCF to NGC, while from NGC to EG and from NGC to real GFCF, all were without a feedback in the long-run

The fourth group of studies employed several disaggregated forms of energy and variables, such as oil, electricity, coal among others. Yu and Choi (1985) in their analysis found a one-sided causal nexus among NGC and EG for United Kingdom and non-Granger causality nexus between the variables for United States.

Lee and Chang (2005) and Yang (2000) for Taiwan found no cointegration nexus but a one-sided causality between the variables, while Aqeel and Butt (2001) reported no cointegration and Granger causality nexus between NGC and EG for Pakistan, which corresponds with the work of Fatai et al (2004) for Australia and New Zealand.

Zamani (2007) for Iran, found a two-sided causal nexus between EG and NGC in the long-term. Asghar (2008) for selected Southern Asian countries using ECM and TY approach reported mixed outcomes. Reynolds and Kolodziej (2008) in their analysis for former Soviet Union, found a one-sided causality between EG and NGC. Sari, Ewing and Soytas (2008) argued that ARDL models are suitable for cointegration analysis even with small samples. They found a one-sided causality between NGC to employment and industrial production for the United States.

Khan and Ahmad (2009) for Pakistan found that NGC negatively responds to prices changes and EG in short-run, while NGC exhibit positive impact in the long-run. Ighodaro (2010) for Nigeria, using ECM model and Johansen for cointegration test, found a one-sided causality between NGC and EG in the long-run, while Payne (2011) for the United States, using TY Granger causality techniques also reported a one-sided causality between EG and NGC.

In conclusion, Bildirici and Bakirtas (2014) in their analysis examined the causality link between coal, oil consumption, coal and economic growth, using ARDL approach over the periods 1980-2011 for South Africa, Turkey, China, India, Russian and Brazil. Results reveal a two-sided causality connection between oil consumption and economic growth for the sampled countries. Furthermore, empirical data for Turkey, Russia, and Brazil reveal a two-sided causality connection between NGC and economic growth.They advocated for strategic planning for the sample countries.

These findings are consistent with the works of Molele and Ncanywa (2018) and Gokmenoglu and Kaakeh (2018). Mensah, Marbuah and Amoah (2016) on the impact of disaggregated energy consumption components, such as natural gas, electricity, oil, biomass, kerosene liquefied petroleum gas (LPG) in Ghana found that income, prices, economic institutions and urbanization significantly causes economic growth. They advocated for LPG in order to reduce unintended and spillover impact of non-renewable energy sources on the nation.

Destek and Okumus (2017) in their analysis examined disaggregated impact on energy consumption such as oil, coal and natural gas on economic growth in Great Seven (7) nations, using panel bootstrap causality method. Empirical result reveals that, oil consumption predicts growth in United States, Japan, Italy and Germany, while growth predicts oil consumption in UK and Germany. NGC was found to predict EG in the UK, US, Japan and Italy respectively. The study concludes that, NGC limiting policies would be harmful for the countries that are NGC driven. This is consistent with the studies of Tiba and Omri, (2017) and Margues and Fuinhas, (2018).

2.3 Research Data and Methodology

2.3.1 Data Source and the Model

Improving on the existing literature of Destek and Okumus (2017), Destek (2016), Solarin and Shahbaz (2015), Shahbaz*et al* (2014), Shahbaz*et al* (2013), Kum *et al* (2012), Lim and Yoo (2012), Apergis and Payne (2010) and Lee (2005) among others, this study examined in a multivariate framework, the role of NGC in EG by incorporating TT as an additional variable. Annual frequency and current data over the periods of 1968–2016were sourced from the Statistical Review of World Energy (BP) and World Bank Development Indicators (WDI) for Saudi Arabia. The implicit function and logarithm linear specifications for the study are given in Eq. (1) and (2):

$$RGDP_t = f\left(NGC_t, Trade_t\right) \quad (1)$$

$$\ln RGDP_t = \beta_0 + \beta_1 \ln NGC_t + \beta_2 \ln Trade_t + \varepsilon_t \quad (2)$$

where, RGDP denote the real GDP measured in constant 2010 billion US$, NGC indicate the NGC measured dry natural gas in billion cubic meters while TRADE denotes the total sum of trade obtained by adding total exports and total imports measures in constant 2010 billion US$.

In addition, $\ln RGDP_t$ represent the logarithm (natural log) of real GDP, $\ln NGC_t$ denote the log of NGC while $\ln Trade_t$ is the log of aggregate trade. β_0 Is the intercept term, β_1 and β_2 are slope parameters for NGC and TT, while ε_t is the stochastic term presumed to be independently identically distributed (iid). The slope parameters β_1 and β_2 are expected to be greater than zero (0), i.e., β_1 and $\beta_2 > 0$. It is expected that, the more the NG consumed, the higher the EG, and the higher the level of TT, thus, the higher would be the EG and vice versa. Figure 1 also display the graphical plot of the series under observation.

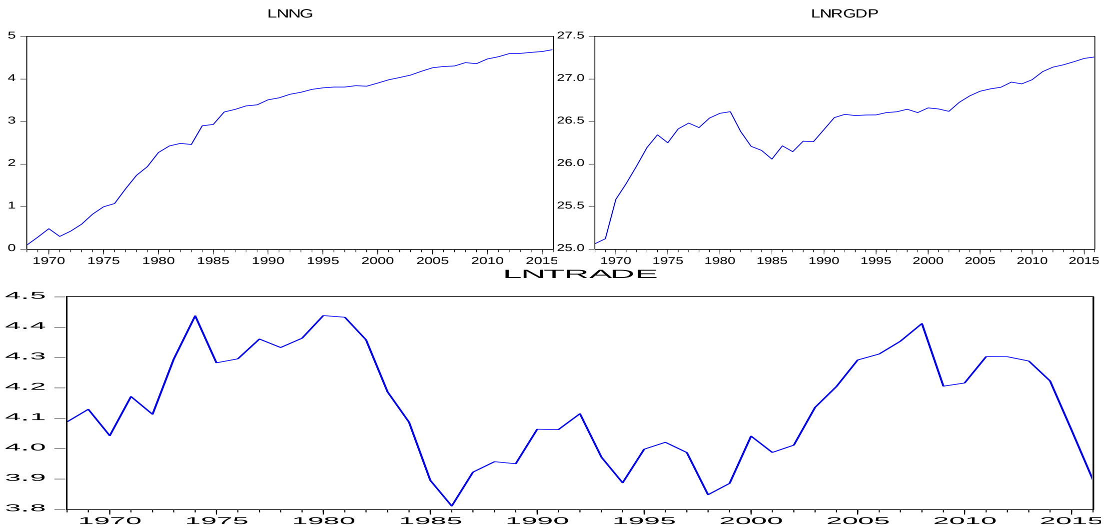

Figure 2.1: Graphical Plots of LNNGC, LNTRADE and LNRGDP

2.3.2 ARDL Approach

Over the last three decades, various econometric methods have been employed to examine production function framework. In term of univariate co-integration methods, we have among others Engle and Granger (1987), co-integration regression techniques as proposed by Phillip and Hansen (1990) FMOLS and DOLS techniques initially advanced by Saikkonen (1991) and improved upon by Stock and Watson (1993). With regards to multivariate co-integration techniques, there are various methods which includes Johansen (1988) followed by Johansen and Juselius (1990) and the improved version of Johansen (1995) built on the assumption of maximum likelihood co-integration method.

Pesaran, Shin and Smith (2001) recently developed single co-integration method, popularly known in empirical literature as ARDL, a short-run and long-run co-integration test, which has been widely accepted and used in analyzing empirically. This method of co-integration has a higher merit when correlated with different conventional co-integration method. It views the issue of endogeneity building on the limitation related with the Engle and Granger (1987) approach.

The ARDL approach also provides short-and long-term parameter estimates in a single model. This can be applied even if the variables under observation are fully stabilized at $I(0)$,$I(1)$, or both. The unrestricted error correction model specified in Eq. (2) is estimated with $\ln RGDP_t$ for Saudi Arabia:

$$\Delta \ln RGDP = \phi_0 + \sum_{i=1}^{p} \theta_1 \Delta \ln RDGDP_{t-1} + \sum_{j=0}^{q} \theta_2 \Delta \ln NGC_{t-j} + \sum_{m=0}^{r} \theta_3 \Delta \ln Trade_{t-m} + \lambda ECT_{t-1} + \varepsilon_t \qquad (3)$$

For Eq. (3), joint test, with the null of no cointegration against its alternative is stated as follows:

$$H_o : \alpha_i = o; \forall i = 4-6$$

$$H_1 : \alpha_i \neq o; \forall i = 4-6$$

This co-integration technique demands estimating F-tests using ARDL models selected using appropriate lag length selection criteria, such as the SIC and AIC. The AIC with a lag duration of 2 was chosen for this investigation. Furthermore, for the specified ARDL models, a generic ECM model must be carried out for Eq. (3) specified as below:

$$\Delta \ln RGDP = \phi_0 + \sum_{i=1}^{p} \theta_1 \Delta \ln RDGDP_{t-1} + \sum_{j=0}^{q} \theta_2 \Delta \ln NGC_{t-j} + \sum_{m=0}^{r} \theta_3 \Delta \ln Trade_{t-m} + \lambda ECT_{t-1} + \varepsilon_t \qquad (4)$$

Where Δ denotes the first difference, λ denote the ECM parameter, ECT_{t-1} represent the residuals derived from the Eq. (2), while ε_t denote the random term presumed to be normally distributed and uncorrelated with zero mean i.e. homoscedastic.

For our current study, we conduct robustness check or the ARDL co-integration test results using the best possible co-integration test of Johansen and Juselius (1990). A quick insight into this is given as:

$$Y_t = A + \sum_{n=1}^{p} \Gamma_n Y_{t-1} + \eta_t \tag{5}$$

Where, A represent a constant terms (vector), Γ denotes the matrix coefficient, *p* denotes the lag order, η_t denotes the residual matrix and $Y_t = \left(\ln RGDP, \ln NGC, \ln Trade\right)$ denotes a vector of endogenous of the *I* (1).

With regards to Eq. (5), every single variable are regarded as endogenous. Thus, the co-integrating order was estimated through the trace and maximum Eigen-value test statistics. The lag length, however, of the unrestricted VAR framework specified in Eq. (5) depends on minimizing FPE, AIC, SIC, HQ and optimizing the criteria for LR information respectively.

2.3.3 T-Y Granger Causality Testing Approach

According to Pesaran *et al* (1999) VECM is usually evaluated to conduct Granger causality test. This technique is performed alongside the Engle and Granger (1987) two steps co-integration method in studying the existence of a short-and long-term dynamic causal nexus. The initial step produces the long-term parameter estimates as shown in Eq. (2) to derive residuals deviated from equilibrium, while the subsequent step generates parameter estimates associated with the short-run adjustment popularly referred to as the speed of adjustment. Eq. below are employed in combination with the causality estimations:

$$\begin{pmatrix} \Delta \ln RGDP_t \\ \Delta \ln NGC_t \\ \Delta \ln Trade_t \end{pmatrix} = \begin{pmatrix} \mathrm{B}_{10} \\ \mathrm{B}_{20} \\ \mathrm{B}_{30} \end{pmatrix} + \sum_{a=1}^{q} \begin{pmatrix} \mathrm{B}_{11,a}^{1} & \mathrm{B}_{12,a}^{1} & \mathrm{B}_{13,a}^{1} \\ \mathrm{B}_{21,a}^{1} & \mathrm{B}_{22,a}^{1} & \mathrm{B}_{23,a}^{1} \\ \mathrm{B}_{31,a}^{1} & \mathrm{B}_{32,a}^{1} & \mathrm{B}_{33,a}^{1} \end{pmatrix} \times \begin{pmatrix} \Delta \ln RGDP_{t-a} \\ \Delta \ln NGC_{t-a} \\ \Delta \ln Trade_{t-a} \end{pmatrix} + \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \end{pmatrix} \times ECT_{t-1} + \begin{pmatrix} \mu_{1,t} \\ \mu_{2,t} \\ \mu_{3,t} \end{pmatrix} \quad (6)$$

Where $\mathrm{B}_j \left(j = 1-3 \right)$ denotes fixed country effect, $a \left(a = 1,...,q \right)$ represent the optimal lag length selected via AIC, ECT_{t-1} denote the estimated lagged ECT derived from the long-term nexus specified in Eq. (2) and estimated through Eq. (6), $\gamma_j \left(j = 1-3 \right)$ denoted the speed of adjustment coefficient, while $\mu_{j,t} \left(j = 1-3 \right)$ represent the stochastic term presumed independently identically distributed $\left(iid \right)$. Contrary to Eq. (4), the entire ECT specified in Eq. (6) is computed using similar lag length obtained via unrestricted VAR structure.

This study, rather, employs Granger non-causality tests as suggested by TY (1995) using Modified Wald statistic (MWALDs) method. The TY Granger non-causality approach has been evaluated and found to produce a more robust causality test than the conventional Granger causality test that does not account for feasible non-stationarity and/or co-integration among the time series variables when examining causality relationships.

According to Ziramba (2009) this approach necessitates the specification of $q_{\max}$, which denotes the maximum order of integration of the variables in the model defined. However, the primary model for the causality test has been deliberately over-fitted with a supplementary lags ($q_{\max}$). Thus, the new VAR order is $p = q + q_{\max}$, where q denote the optimal lag order. This is done, to establish that, the conventional t-statistics have standard asymptotic distributions for Granger causality test. This approach uses Modified WALD test statistics for limitations on the constant of $\text{VAR}(q)$ where p is the length in the model. When calculating VAR $(q+q_{\max})$, MWALD test statistics includes an asymptotic chi-square distribution.

In order to estimate a TY (1995) type of Granger non-causality test, this study specifies the NGC-EC model in the below VAR framework. By applying the method of apparently unrelated regression, this model is estimated (SUR).

$$\begin{pmatrix} \Delta\ln RGDP_t \\ \Delta\ln NGC_t \\ \Delta\ln Trade_t \end{pmatrix} = \begin{pmatrix} \text{B}_{10} \\ \text{B}_{20} \\ \text{B}_{30} \end{pmatrix} + \sum_{a=1}^{q} \begin{pmatrix} \text{B}^1_{11,a} & \text{B}^1_{12,a} & \text{B}^1_{13,a} \\ \text{B}^1_{21,a} & \text{B}^1_{22,a} & \text{B}^1_{23,a} \\ \text{B}^1_{31,a} & \text{B}^1_{32,a} & \text{B}^1_{33,a} \end{pmatrix} \times \begin{pmatrix} \Delta\ln RGDP_{t-a} \\ \Delta\ln NGC_{t-a} \\ \Delta\ln Trade_{t-a} \end{pmatrix} + \sum_{c=q+1}^{q_{\max}} \begin{pmatrix} \text{B}^1_{11,c} & \text{B}^1_{12,c} & \text{B}^1_{13,c} \\ \text{B}^1_{21,c} & \text{B}^1_{22,c} & \text{B}^1_{23,c} \\ \text{B}^1_{31,c} & \text{B}^1_{32,c} & \text{B}^1_{33,c} \end{pmatrix} \times \begin{pmatrix} \Delta\ln RGDP_{t-a} \\ \Delta\ln NGC_{t-a} \\ \Delta\ln Trade_{t-a} \end{pmatrix} + \begin{pmatrix} \mu_{1,t} \\ \mu_{2,t} \\ \mu_{3,t} \end{pmatrix} \quad (7)$$

The TY (1995) type of non-Granger causality test is superior to others, since TY approach does not necessitate specific information about the integration order of the variables under observation. According to TY (1995) this method can be employed when variables of interest are non-stationary and/or rank specification are not fulfilled, provided the integration order of the series is not above the selected lag length of the model.

2.3.4 Brown, Durbin and Evans Approach to Stability Test

It has been stated that the existence of a cointegration relationship does not sufficiently mean overtime, in empirical studies, the estimated (see Bahmani-Oskooee and Chomsisengphet, 2002). In empirical studies, the stability of the estimated coefficients (regression estimations) are examined via several confirmatory test, such as Chow (1960), Brown, Durbin and Evans (1975) as well as the (1999) test. The (Chow) former test shows a priori expectation of the possible regime switches (structural breaks) within the coverage period. While the later (Hansen and Johansen), necessitate that, series must be integrated at first order $I(1)$ and exhibit long-term constancy parameter, while failing to putting into consideration the short-term dynamic and/or adjustment of the model.

This study employs the Brown *et al* (1975) stability test approach known as cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) built on recursive regression residuals. This stability test takes into account, the short- and long-term dynamics via residuals. These tests statistics are improved recursively and graphed alongside the breakpoints of the model. Provided the plot of these statistics is within the critical values of ($p< 0.05$) significance level, it is presumed that the estimated coefficients of regression estimation are stable.

2.4 Empirical Results and Discussions

Table 1 reports the stationarity results for the variables under observation, which were conducted via two forms of time series-based unit root tests. The study employs the Augmented Dickey and Fuller (1979) and the Zivot and Andrew (1992) unit root testing approach.

Since the conventional ADF unit root tests are not suitable for testing stationarity properties of a time series data that are usually prone to regime switches (structural break), the Zivot and Andrew (ZA) unit root test approach which considers endogenous structural break. ZA unit root test approach has been widely regarded as being the most appropriate to examine integration order in a time series analysis. This indicate the sampled variables are integrated at $I(1)$ at ($p< 0.01$).

Table 2.1: Time Series Unit Root Test Results

Method	Form	RGDP	NGC	TRADE
ADF (tu)	Level	-0.395(0.901)	-3.319(1.000)	-2.101(0.224)
	Δ	-3.709**(0.031)	-2.967**(0.045)	-4.551***(0.001)
ADF (tŧ)	Level	-2.995 (0.148)	-3.978**(0.019)	-1.934 (0.614)
	Δ	-4.452***(0.006)	-4.575***(0.004)	-9.137***(0.000)
ZA	Level	-3.51	-3.363	-2.534
	Break	-2002	-2000	-1987
ZA	Δ	-6.748***	-5.226***	-6.217***
	Break	-1983	-1985	-1987
Order		I(1)	I(1)	I(1)

The break dates obtained (between the 1980s and 2000s) appears to be significant to Saudi Arabia economy. Within the 2000s periods, increased oil prices were experienced which enabled the government to embark on post budget surpluses. At the same time, the government was able to enhance spending on infrastructure development, education, training and wages (Tripp and North, 2009).

Over this period, the parastatal giant Saudi Aramco produced about 95 percent of the oil on behalf of the government, with the other 5% produced by others as of 2002. The country (Saudi Arabia) was majorly a subsistence economy as late as 1930s.

In the course of the 1973 oil shocks, Saudi Arabia's economy began to grow steadily and experienced an economy boom during the 1980s (Tripp and North, 2009). Furthermore, during the mid-80s, the oil price was slashed from40US$ to5US$ per barrel, which led to Saudi Arabia massive foreign debt. Interestingly, starting from 2002 to mid-2008, Saudi Arabia oil prices soared. This enabled the Saudi Arabian government and policymakers to report budget surpluses, and at the same time enhance spending (Tripp and North, 2003).

Examining the prevailing integration properties for the series, the ARDL framework for equation (3) was estimated as follows: First, the study affirms the long-run cointegration interconnection of equation (2) by selecting the suitable information criterion. The maximum lag length used in estimating the VAR was gotten from the independent vector autoregressive model.

Table 2A reports the results for the choice of optimal lag length. Using the optimal lag length, we reportthe co-integration results via Johansen trace statistic and maximum Eigen-value suggested by Johansen (1988) and improved upon by Reinsel and Ahn (1992). Based on these results, we obtained evidence in support of at least two co-integration vectors at (p< 0.01), (p< 0.05) and (p< 0.10) level of significance.

Table 2.2: A.VAR Selection Criteria and Cointegration Results

Lag order	LogL	LR	FPE	AIC	SIC	HQ
0	44.702	NA	0.001	2.028	-2.147	2.074
1	135.313	329.39	1.06	-5.247	-4.774*	-5.069*
2	147.236	20.294*	9.390*	-8.180*	-4.545	-5.06
Johansen test (2B)						
No of CE(s)	Eigen-value	Trace stat.	Prob.	Max-Eigen	Prob.	
None*	0.361	39.785***	0.002	21.056*	0.051	
At most 1*	0.237	18.728**	0.015	12.766*	0.085	
At most 2*	0.119	5.962**	0.014	5.962**	0.014	

Table 2.3: ECM-ARDL Estimation Results

Regressors	Coefficient	p-Value	Regressors	Coefficient	p-Value
ΔlnNGC	0.028	0.254	lnNGC	0.157**	0.048
ΔlnTrade	0.157	0.164	lnTrade	0.852**	0.044
Constant	4.193**	0.012	Constant	22.718***	0
R^2=0.950	F=281.20***	0			
ECT_{t-1}.	-0.185***	0.001			
	(-3.291)				

Second, we estimated equation (2) to derive the short- and long-term parameter coefficients for Saudi Arabia using the ARDL model displayed in Table 3. The estimation results reported in Table 3 reveals NGC exhibits positive influence on real GDP in the long-run. Specifically, the percent rise in the consumption of natural gas contributes to a long-term increase in real GDP of 0.157 percent at ($p < 0.01$) significance level. However, it appears NGC has no short-run shock on real GDP at all significance levels.

Similarly, total trade has no impact on real GDP of Saudi Arabia in the short-run. Empirical results reveals, a per cent increase in TT will cause real GDP to increase by 0.852% in the long-run, at ($p < 0.05$) level of significance. These findings resonate with the results of Farhani's *et al* (2014) for Tunisia, Lim and Yoo (2012) for Korea, Kum*et al* (2012) for G-7 countries, Apergis and Payne (2010) panel analysis of 67 countries, Narayan and Smyth (2008) for G-7 countries and Lee (2005) for 18 developing countries respectively.

Also, the time series diagnostic tests presented in Table 4 reveals the study model is appropriate and reliable, since it passed test for heteroscedasticity (ARCH), normality, functional form (i.e. model stability test reported in figure 2) and serial correlation. The high value of the coefficient of determination ($R^2 = 0.950 \rightarrow 1$) of the ECM-ARDL estimation outcomes indicate that, the speed of adjustment of the ARDL is significantly good in the short-term, finally, the F-statistic ratio of joint significance is significant statistically at $p < 0.000$) level for all variables under surveillance.

Table 2.4: Diagnostic Tests

Test	Coefficient	p-Value
ARCH	2.359	0.105
NORM	1.359	0.506
AR	8.985	0.181

Having confirmed at least two co integrating vectors among the series, the Granger causality test was estimated for equation (7) such that only 2 long-run equilibrium relationship was obtained with an ECT as reported in Table 2B and Table 3. The results are determined in Table 5 using the TY (1995) method of the non-Granger causality test. The MWALD statistics is Results show that natural gas consumption Granger cause real GDP at (p< 0.05) significance level. This reveals that natural gas consumption has predictive power over real GDP in the sampled country. As a result, there seems to be a one-sided causal relationship between natural gas consumption and real GDP.

These empirical results resonate with Johansen and Juselius (1990) conventional Granger causality test. The findings show that natural gas usage and Saudi Arabia's real GDP per capita have a long-term relationship.The findings support the existence of a long-term relationship between Saudi Arabia's natural gas usage and real GDP per capita.In the case of Saudi Arabia, this is in line with the findings of Alkhathlan and Javid (2013) and Alshehry and Belloumi (2015).

Table 2.5: TY (1995) Granger Causality Test Results

Null Hypothesis:	Mwald Statistics	P-Values	Causality	Remark
RGDP←NGC	0.559	0.454	No	Not reject
NGC → RGDP	3.672**	0.025	Yes	Reject
NGC ≠> Trade	1.199	0.273	No	Not reject
Trade ≠> NGC	1.505	0.219	No	Not reject

RGDP ≠> Trade	0.559	0.454	No	Not reject
Trade ≠> RGDP	0.327	0.567	No	Not reject

Furthermore, empirical data reveal a non-Granger causation connection between NGC and TT, as well as between real GDP and TT, indicating that these series have no predictive potential over one another. In the instance of Saudi Arabia, this suggests a neutrality hypothesis between the series.

The non-Granger causation between total trade and natural gas consumption, as well as total trade and real GDP, is similar to Ziramba's findings (2009). This provides evidence in support of natural trade and total trade-economic growth neutrality hypotheses in the case of Saudi Arabia.

Also from the findings of Mounir and Atef (2020), the non-Granger causality between trade and real GDP might be due to different proxies used for total trade, different periods, different methodology employed, as well as the fact that economic policies in different nations differ, which cannot be captured by methodologies using longitudinal data.

These results are to be expected, given that oil exports account for a significant portion of all Saudi Arabia’s exports, and oil exports are associated with filthy and damaging operations. Also, these findings imply that Saudi Arabia should import items from its trade partners that are less polluting, with effective environmental restrictions being implemented in Saudi Arabia to decrease pollution.

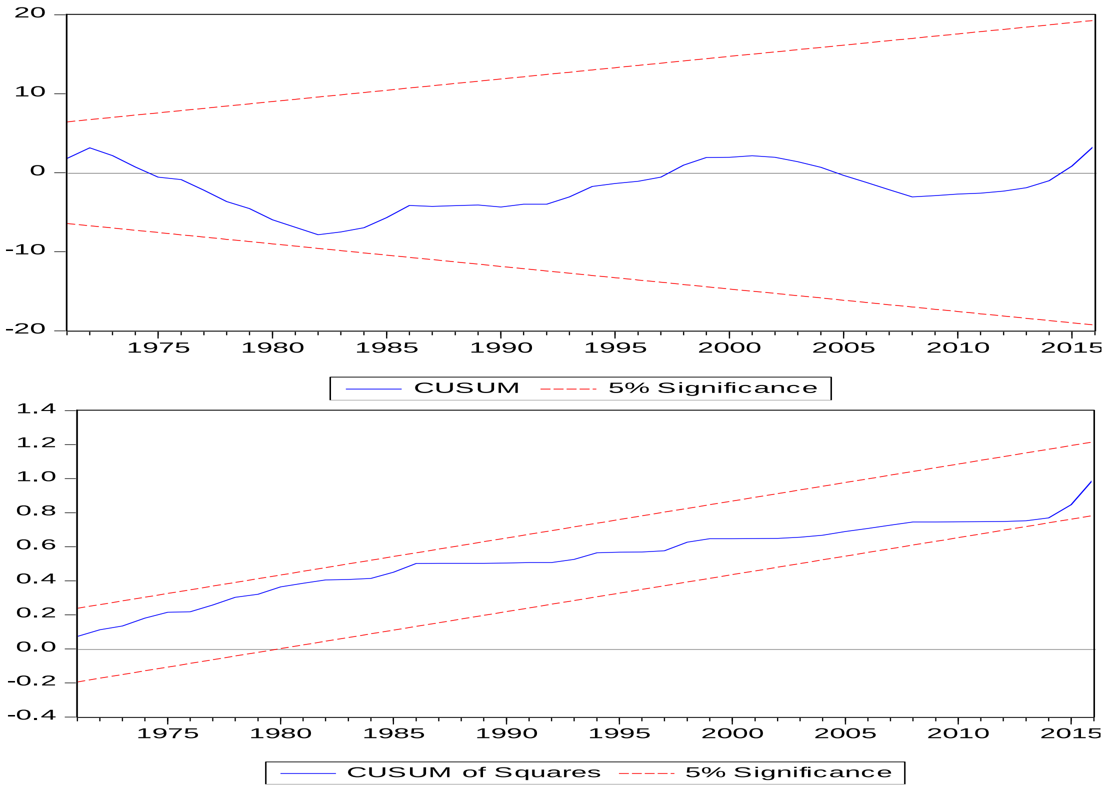

Figure 2.2: Graphical Plot of CUSUM and CUSUSQ of Recursive Residuals.

The Akaike Information Criterion (AIC) based ECM of equation (3) is chosen to conduct Brown *et al* (1975) type of stable tests. Figure 2 depicts the plotted graphs of the stability tests. The test statistics fall inside the critical limits at (p 0.05) significance level, indicating that all parameter estimations in the ECM are stable, as seen in the graphs.

By implication, the defined output model is suitable for policy decision-making in a way that influences policy changes in terms of the explanatory variables, considering that the parameter estimates in the model are sound and appear to go along with a stable structure over the study coverage period, according to Shahbaz et al (2013).

2.5 Conclusion and Policy Implications

This study looks at the dynamic relationship between NGC, TT, and EG in Saudi Arabia from 1968 to 2016 by examining the short and long-run elasticity role of

NGC and TT as explanatory factors in the amount of economic growth by looking at the equilibrium long-term connection with real GDP as the dependent variable.The empirical evidence support the existence of a cointegration connection between the variables.

Natural gas being the cleanest-burning fossil fuel, helps to improve the environment by lowering air pollution and greenhouse gas emissions across Saudi Arabia. It emits half as much carbon dioxide as coal and a considerably lesser percentage of other air pollutants. Our findings reveals, the more natural gas is being consumed the more the decrease in environmental pollution.

Furthermore, the findings indicated that natural gas consumption and total trade are important predictors of real GDP since they boost the selected country's economic growth. We found evidence in support of the NGC and EG feedback relationship. Empirical results show a one-sided dynamic Granger causality between EG and NGC, while non-Granger causality relationship exist between natural gas consumption and total trade and between total trade and real GDP. These results lend support to NGC-TT, and total trade-real per income neutrality hypotheses in Saudi Arabia.

The empirical results are suggestive whereby the one-sided long-run causality relationship between NGC and EG reveals Saudi Arabia to be a natural gas dependent economy. Both NGC and TT are critical to the country's long-term economic growth, and enacting natural-gas conservation policies to mitigate global warming, as proposed in the energy policy literature, would neither harm natural-gas demand or total trade demand in the short-run.

This policy appears to be a feasible emission reduction policy in the short-run in Saudi Arabia since NGC predicts real per capita GDP. Given Saudi Arabia's reliance on natural gas, our empirical findings show that natural gas conservation policies will curb demand, slow overall trade, and limit domestic productivity in the long term. However, the Saudi Arabian government may be able to fulfill its energy demands and increase overall trade in the near future by embracing renewable energy alternatives to natural gas.

To meet the growing energy demand, government and policy makers in this region must put in place proper energy policies to ensure energy efficiency and renewable energy source through increase investment in R&D that would help in exploring other renewable energy sources to cushion high demand for natural gas without slowing down the economy growth process.

Renewable energy sources appear to be the most suitable energy alternative that would meet the increasing energy demand of this present generation without undermining energy demand of future generations. (Apergis and Payne, 2010; Omer, 2010). Sustainable renewable energy sources such as solar energy, geothermal energy and wind energy among others.

Sustainability is one basic merit of renewable energy sources couple with the fact that renewable energy sources will never run out (Isik, Kasimati and Ongan, 2017a, b; Adewuyi and Awodunmi, 2017). This differs from fossil fuels, such as coal, natural gas, and oil, which are non-renewable energy source, and they contribute largely to global warming.

Renewable energy sources on the other hand, generate clean energy since they emit no or less CO_2 emissions (non-pollutant) and do not contribute to global warming and greenhouse effects (see Isik, Dogru and Turk, 2018). In addition, renewable energy facilities are known to generally use less maintenance than conventional generators.

In addition, results from causality show neutrality hypotheses between natural gas consumption and total trade and between economic growth and total trade. These findings imply that increase/decrease in natural gas consumption/economic growth may not at all time imply increase and/or decrease in total trade, and vice versa.

This is an indication that the economic and energy policies of Saudi Arabia are in tune with the laid down domestic and international trade policies, hence macroeconomic objectives of the region. Government and policy makers in this area are therefore urged to pay more attention to the relationship between increased consumption of natural gas and economic development in terms of the environmental effects, as excessive consumption of natural gas might affect the environmental quality of the region for immediate and future generations.

Based on our empirical findings, it appears that natural gas and crude oil would remain as prevalent energy sources for a longer period in Saudi Arabia. However, it is projected that technologies that enhances sustainable energy and secure the future from greenhouse gas emissions and environmental pollution such as renewable energy sources will surface and dominate the economy in the very near future.

Lastly, since the government is set to launch a bid for a new renewable energy tender, it is expedient for future research in this field to examine the possible interaction between fossil fuels and renewable energy sources and their impact on economy of Saudi Arabia in the long-term.

Chapter 3

RENEWABLE ENERGY CONSUMPTION IN EU-28 COUNTRIES: POLICY TOWARD POLLUTION MITIGATION AND ECONOMIC SUSTAINABILITY

3.1 Introduction

Of recent, the relationship between economic growth and renewable energy, alongside other growth key determinants, has been a topic of discussion among policymakers and researchers (see Asafu-Adjaye, 2000; Sari and Soytas, 2004; Ewing, Mahadevan and Asafu-Adjaye, 2007; Sari and Soytas, 2007; Sadorsky, 2009a, 2009b; Apergis and Payne, 2010a, 2010b; Apergis et al., 2010; Bartleet and Gounder, 2010; Marques, Fuinhas and Manso, 2010; Menyah and Wolde-Rufael, 2010; Menegaki, 2011; Atasoy, 2017; Dogan and Aslan, 2017; Paramati, Mo and Gupta,2017). Throughout the world, governments, politicians, private organizations and individuals have come to recognize the important contributions of renewables in the development of job opportunities and thus the sustainability of economic growth.

For instance, The European Union has a tendency to reduce its reliance on imports of fossil fuels by consuming more renewable energy, thus making its energy production and use more sustainable for both the economies of the bloc countries and the environment concerned. In addition, the curiosity of environmentalist and other researchers has continued to unveil further studies into non-economic drivers of the environment like immigration, healthcare, and other similar determinants (Alola, 2019a & b; Alola et al., 2019; Bekun, Alola & Sarkodie, 2019; Akadiri et al., 2019).

The Renewable Energy Directive (RED) objectives for 2020 were recently accepted by the European Council and the European Union Parliament. This RED program establishes progressive goals for its members with the ultimate objective being to have a 20 percent renewable energy contribution in the final energy consumption mix by 2020.Sectorial targets for transportation, temperature control and electricity, planned energy policy measures for combining various types of renewable technologies, and the use of corporate mechanisms to enforce joint support schemes and joint projects among member states are some of the specifics for achieving this goal.

However, to achieve these stated goals, it is crucial to have a clear understanding of the long-run equilibrium impacts and benefits of renewable energy in promoting and sustaining economic growth. It is on this premise that our current study seeks to contribute to the recent and ongoing debate on renewable energy-economic growth relationship, using the EU-28 countries as a case study. However, unlike the existing research that focuses solely on the causal relationship between macroeconomic variables, this research not only explores the causal relationship, but also investigates whether there is a long-term relationship between the variables of concern and their effect across Europe on environmental sustainability.

Unlike previous research, this study focuses on the long-term environmental sustainability of renewable energy use and economic growth in the EU-28. Using an autoregressive distributed lag (ARDL) model framework, we estimate a dynamic panel growth model. We build a panel of 28 European Union member countries for the period 1995-2015, which is used in the specification of an error correction model set up within an ARDL framework and estimated via three alternative approaches—the pooled mean group (PMG), the mean group (MG) and the dynamic fixed effect (DFE) techniques. The use of these estimation techniques is suitable when working with homogeneous/heterogeneous panels.

The macro panel data in our study is evaluated for stationarity and cointegration. Our data show that EU-28 nations are convergent on a long-term environmental sustainability path in terms of renewable energy, with renewable energy usage and economic development being strongly positively associated. Our findings are in line with Sadorsky's (2009a) findings for G7 nations and Apergis and Payne's (2010b) findings for Eurasian countries.

Following existing related studies and the aforementioned motivation, the contribution of this study is in three-fold; (i) this research is the first study to investigate the relationship between Europe's pooled mean group (PMG), mean group (MG) and dynamic fixed effect (DFE) techniques.

In a complex panel setting, we employ a relatively new and unique method of assessing short and long-term relationships between renewable energy and economic development that also reports the speed of adjustment which shows how fast or slow the EU-28 countries are converging towards or diverging from the steady state long-run environmental sustainability path. (ii) Results show that renewables are costly, therefore would impact on the real income per capita, due to its capital cost in the short-run (iii) unlike the neutrality hypothesis reported by Menegaki (2011) which claims that there is uneven and insufficient exploitation of renewable energy across the EU-27 countries over the period 1997-2007, our study employs a larger and more recent panel dataset which covers the period 1995-2015 for all the EU-28 countries.

Based on our updated panel dataset for the EU-28 countries and estimation techniques employed, we see the renewable energy and economic development to have a long-run bidirectional dynamic causality. This reveals that the exploitation of renewable energy across Europe is an effective means of attaining sustainable mitigation of environmental pollution and risks, which indicates that the region is now moving towards an environmental sustainability path. Our results are indicative and provide valuable insight for the corresponding renewable energy-growth policy decision making across Europe.

The study layout is as follows; section-2 gives an overview of the previous studies and the state of renewable energy in EU-28 countries, section-3 introduces the data and empirical models used, section-4 presents and discusses the empirical results, while section-5 is the concluding part.

3.2 Literature Review

Previous studies have discussed and provided an insight into the environmental and renewable energy-economic growth relationship. For instance, Using Pedroni (2004) panel cointegration regression approaches, Sadorsky (2009a) investigates the relationship between renewable energy use, CO2 emissions, and oil prices in G7 nations from 1980 to 2005.The author finds that the variables have a long-run equilibrium connection. CO2 emissions and real GDP per capita are the most important drivers of renewable energy use, according to empirical findings whereas oil prices have a little negative influence on renewable energy consumption.The application of modified Granger causality tests establishes unidirectional causality between nuclear energy and CO2 emissions, with no causal link between CO2 emissions and renewable energy.

They opine that renewable energy consumption is still in its infancy since it has no major impact on emissions reduction. Also, Apergis and Payne (2009a, 2009b, 2010a, 2010b) carry out contextual studies on Central America, Organization for Economic Co-operation and Development (OECD), Commonwealth of Independent States (CIS), and most recently, Using a multivariate panel data model, they established a bidirectional causality between economic development and renewable energy in both the short and long term for Eurasian nations from 1992 to 2007. Additionally, Marques et al. (2010) examine the motivation for the adoption of renewable energy within the European countries, using fixed effect vector decomposition panel data methodology over the period 1990-2006. The empirical findings reveal that CO_2 emissions and traditional energy sources prevent renewable energy distribution.

In addition, Menegaki (2011) uses a multivariate panel model to examine the link between economic development and renewable energy in 27 European nations from 1997 to 2007. The author includes in the model additional variables such as employment, GHG emissions, and final energy consumption. Because the empirical findings show no indication of a causal relationship between renewable energy use and economic development, the author concludes that the neutrality hypothesis holds true in the nations studied. This is suggested to be due to biased and inadequate utilization of the renewable energy sources across Europe.

Similarly, Ocal and Aslan (2013) used Autoregressive Distributed Lag (ARDL) and Johansen cointegration techniques to explore the Granger causation link between renewable energy use and economic development in Turkey.The study's empirical findings are contradictory, and there is no agreement on the direction of causality between economic development and renewable energy usage.

Lin and Moubarak (2014) looked at the long-term link between economic growth and renewable energy in China in a similar research.The empirical findings demonstrate a long-run bidirectional causality between economic growth and renewable energy consumption, which is consistent with Shahbaz et al (2015) study, which found that renewable energy, labor, and capital all contribute significantly to Pakistan's economic growth.

Moreover, the recent studies by Alola et al (2019a) importantly reveal the effect of immigration on the environmental condition of the EU largest states. The EU largest states (Germany, France and the United Kingdom) have all been confronted with the socio-economic challenges associated with the inflow of migrants on one hand and other migrant classifications on the other hand.

In addition, Alola (2019a, b) respectively hints on the significant impact of healthcare policy and immigration policy in the United States. While both studies posit recent evidence of immigration-environment nexus, it importantly provides information on the pertinent challenge of immigration and the healthcare system with fresh evidence.

By considering a different perspective, The Environmental Kuznets Curve (EKC) hypothesis was used by Akadiri et al 2019 to investigate the possible impact of globalization on the environment for tourist destination states. Akadiri et al (2019) validates the globalization-tourism-induced EKC theory by showing a beneficial effect of globalization and income on carbon emissions.

3.3 EU Renewable for Global 3.3 EU Renewable Energy Outlook: Indication for Global Environmental Sustainability

Globally, and specifically among the 28 member states of the European Union, there has been conscious effort directed towards reducing CO_2 emissions and consistent switching from traditional energy sources to renewable sources. A handful of renewable energy sources (RES) are currently being explored through innovative technologies across Europe (World Energy Resources, 2016).

Information provided in the reports of the European Environmental Agency (EEA), Euro-stat and the National Renewable Energy Action Plan (NREAP) as indicated in Table-6 affirm the rapidly increasing trend in the consumption of renewable energy in the EU-28 countries.

In mid-2010, the EU-28 member states submitted the NREAP that was adopted as the indicative supranational path to meet the renewable energy source target for 2020. The guidelines contained in the document were subsequently updated as interim trajectories noted in REN21 (2016) and the Renewable Energy Directive (EEA, 2017). Renewable energy is mainly consumed in three major renewable energy market sectors in the EU, namely; renewable electricity, renewable temperature control (heating and cooling) and transportation.

Table 3.1: Sources of Renewable Energy Technology and Volume of Consumption in EU-28 Countries

Source of Technology Growth	RES consumption 2015 (Kilotonnes)	RES consumption NREAPs 2020	Compound annual meet NREAP for 2020(%)
Hydropower	29858	31786	1
Onshore wind	20843	30303	8
Solid biomass	85396	94346	9
Solar photovoltaic	8669	7062	-2
Biogas	8279	10601	12
Offshore wind	3784	11740	27
Geothermal	1244	3589	35
Concentrated solar power	469	1633	23
Bio-liquids	740	5512	77
Tidal, wave& ocean energy	41	559	54
Solar thermal	2004	6455	22
RE from Heat pump	9697	12289	7
Biodiesels	11427	20920	11
Bio-gasoline	2622	7324	18
Other biofuels	168	746	32
Compliant biofuels	13239	28989	14
All biofuels	14217	28990	39

The EU-28, as a party to the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), completed the Kyoto Protocol's first commitment period, which ran from 2008 to 2012. (European Commission’s Progress Report, 2016).It is indicated in the report that the commission (and the member states) is firmly on course to attain its 2020 target for reducing GHG emissions, which is the Kyoto Protocol's second commitment period of 2013-2020. The regional body (EU-28) and individual constituent nations have implemented several policies that include 2001/77/EC and 2009/28/EC (The 2001/77/EC and

2009/28/EC are European commission directives in 2001 and 2009 respectively that are both aimed at promoting the use of energy from renewable source) to endorse the move towards achieving the above set of objectives and explicitly to encourage the use of energy from renewable sources. This aligns with the French government's recent announcement that gasoline and diesel car sales would be banned or phased out by 2040as part of ambitious and far-reaching efforts to wean the country's economy from fossil fuels, and as such, meeting its targets under the Paris climate accord.

The reports made available through the World Economic Forum (2017) and EEA (2017) indicate the progression of renewable energy consumption for 2015 and projection for 2020 among the EU-28 member countries. Evidence from these reports as indicated in Table-7 confirm that eleven (11) of the members states (countries with negative point target in Table-7) have attained the 2020 targets in time.

Table 3.2: Share of EU-28 Member States' RES Share of Total RE Usage and Projection for 2020

EU-28 member states	Share of total renewable energy			Real GDP per capita growth	
	2015(%)	2020(%)	Points	2015(%)	2020(%)
			Off/On target		
Sweden	53.9	49	-4.9	2.99	3.16
Latvia	37.6	40	2.4	3.56	8.19
Finland	39.3	38	-1.3	-0.06	4.68
Austria	33	34	1	-0.11	3.94
Denmark	30.8	30	-0.8	0.89	5.32
Croatia	29	20	-9	2.48	5.92
Portugal	28	31	3	2.02	4.2
Estonia	28.6	25	-3.6	1.38	8.19
Romania	24.8	24	-0.8	4.43	8.14
Lithuania	25.8	23	-2.8	2.74	7.17
Slovenia	22	25	3	2.24	5.13
Bulgaria	18.2	16	-2.2	4.28	6.73
Italy	17.5	17	-0.5	0.88	3.63
Spain	16.2	20	3.8	3.28	5.05
Greece	15.4	18	2.6	0.44	6.02
France	15.2	23	7.8	0.62	4.46
Germany	14.6	18	3.4	0.84	4.1
Czech Republic	15.1	13	-2.1	4.33	1.57
Slovakia	12.9	14	1.1	3.73	6.54
Poland	11.8	15	3.2	3.91	7.48
Hungary	14.5	13	-1.5	3.39	4.62
Cyprus	9.4	13	3.6	2.26	4.25
Ireland	9.2	16	6.8	24.66	4.55
Belgium	7.9	13	5.1	0.89	3.84
United Kingdom	8.2	15	6.8	1.39	5.82
Netherlands	5.8	14	8.2	0.6	5.3
Malta	5	10	5	6.31	6.44
Luxemburg	5	11	6	1.58	4.7

The EU has just established a new set of GHG emission reduction, energy efficiency, and renewable energy objectives to be fulfilled by 2030. Policies designed to achieve these goals are required of all member nations. In June 2018, the European Commission (EC), the Council of Ministers, and the European Parliament reached an agreement on policy, whereby the European Union now has a clear direction on its energy and climate targets for 2030.

These targets, among others include; first, the achievement of 40 percent mitigation in domestic GHG emissions, with binding yearly GHG emission mitigation targets for EU-28 member states over the period 2021- 2030, second, an imperative target to increase the proportion of renewable energy sources in the EU-28member states to about 32 percent of total final energy consumption by 2030, and third, a symptomatic target of about 32.5 percent increase in energy efficiency in 2030 at EU level (EEA, 2018).

3.4 Data and Empirical Models

3.4.1 Data

For the empirical estimations, we construct a panel dataset of 28 European Union countries (countries as presented in Table 6 and 7) over the period 1995-2015from the World Bank database. The study coverage was restricted to the specified time span due to unavailability of longer historical data. The variables employed in this study are reviewed as follows.

The real GDP (RGDP) being a dependent variable and serving as a proxy for economic growth, and estimated in constant US dollars in 2010. The energy obtained from renewable sources such as geothermal heat, waves, rain, tides and sunlight is seen to be Renewable energy consumption (REN) which are naturally replenished on human timescale and have been proven to generate negligible amounts of GHGs. Renewable energy consumption is evaluated as a percentage of energy's total final consumption.

Also included in our evaluation are two mostly used control variables in the renewable energy-economic growth literature such as; carbon emissions (CO_2) and real gross fixed capital formation (RGFCF). These variables have been found to be significant determinants of growth (see Sadorsky, 2009a; Apergis and Payne, 2010b) we see the descriptive statistics for the variables reported in table 8.

Table 3.3: Summary Statistics of the Variables

	LNRGDP	LNREN	LNCO2	LNGFCF
Mean	10.065	2.245	2.001	24.403
Median	10.202	2.327	2.014	24.595
Maximum	11.625	3.974	3.211	27.325
Minimum	8.231	-2.438	0.986	20.812
Std. Dev.	0.735	1.040	0.394	1.606
Skewness	-0.385	-1.033	0.255	-0.031
Kurtosis	2.436	4.855	3.252	2.169
Jarque-Bera	22.004***	186.3708***	7.845993**	16.775***
Probability	0.000	0.000	0.019	0.000
Sum	5838.175	1302.320	1161.001	14153.77
Sum Sq. Dev.	312.865	627.369	90.253	1495.171
Observations	580	580	580	580

Table 3.4: Pearson Correlation Results

Variables	LNRGDP	LNREN	LNCO2	LNGFCF
LNRGDP	1			

LNREN	0.185	1		
t-stat	4.543	----		
p-Value	0	----		
LNCO2	0.564	0.412	1	
t-stat	16.436	10.893	----	
p-Value	0	0	----	
LNGFCF	0.496	0.052	0.16	1
t-stat	13.743	1.258	3.917	----
p-Value	0	0.008	0.001	----

Table 9 report the Pearson correlation estimates that show the linear relationship amidst the panel series under consideration. Results as shown in Table 9, reveals a significant linear nexus between renewable energy consumption and economic growth, between CO_2 emissions and economic growth, gross fixed capital formation and economic growth, CO_2 emissions and renewable energy consumption, gross fixed capital formation and renewable energy consumption and between gross fixed capital formation and CO_2 emissions respectively.

In addition, results show a weak linear relationship (less than 0.60) between the panel series. Also we see in table 9 that in the fitted model, no one-to-one linear nexus (or perfect collinearity), so no traces of multicollinearity between the series of panels.

In the context of the study, there is no basis for comparing the correlation of carbon emission and renewable energy with carbon emission and Gross Fixed Capital Formation (GFCF). However, the positive and high correlation between carbon emission and renewable energy could be associated with the importance of energy use in economic growth as well as the lack of net zero impact of renewable energy sources in the EU.

Although the increase in renewable energy share since 2005 have yielded a decline in gaseous compound, yet, renewable energy sources are not necessarily zero impact. This is because increased power generation from waste and the intensive utilization of biomass energy from many EU are also responsible for more emissions such as the particulate matter (PM) and other emission-related compounds. (European Environment Agency, 2021; Reuters, 2021).

3.4.2 Empirical Models

Improving on the work of Menegaki (2011) and following other existing studies in renewable energy-economic growth literature such as Apergis and Payne (2010a, 2010b) and Marques et al. (2010), we employ a multivariate framework in examining the long-run relationship between renewable energy consumption and real GDP by incorporating carbon emissions (as a proxy for energy use) and real gross fixed capital formation as additional determinants of economic growth and renewable energy consumption. The specified model for the study is as follows:

$$RGDP_{i,t} = f\left(REN_{i,t}, \mathrm{CO}_{2i,t}, RGFCF_{i,t}\right) \quad (1)$$

Following Pesaran et al. (1999), within the popular Autoregressive Distributed Lag (ARDL: p,q) paradigm, the analysis begins with the following economic growth model integrating the lagged dependent variable and lagged explanatory variables.

$$\ln RGDP_{i,t} = \alpha_i + \sum_{j=1}^{p} \delta_{i,j} \ln RGDP_{i,t-j} + \sum_{j=0}^{q} \gamma_{i,j} Z_{i,t-j} + \varepsilon_{i.t} \quad (2)$$

Where, $Z_{i,t} = \left(\ln REN_{i,t}, \ln\mathrm{CO}_{2i,t}, \ln RGFCF_{i,t}\right)$

In equation-3, for $i = 1, 2, ..., N$ and $t = 1, 2, ..., T$, the vector $Z_{i,t}$ is a vector of the explanatory 4variables of interest and the control variables that are generally employed in energy-growth empirical analyses. While α_i is the country-level fixed effects; $\delta_{i,j}$ represents the coefficient of the lagged $\ln RGDP_{i,t}$ and $\gamma_{i,j}$ represents the coefficients of the lagged independent variables.

The ARDL cointegration technique is generally employed amongst researchers due to its unique econometric merits when related to other conventional cointegration methods. The approach reports short-run and long-run parameter estimates individually in a separate model and also takes into consideration endogeneity problems. No matter the integration order of the variables or model, the cointegration approach is applicable, i.e., whether $I(0)$, $I(1)$ or partly integrated. Panel unit tests as purposed by Choi (2001) and Im et al. (2003) are expressed in Table-10.

From the results, we see the main variables to be stationary at first difference and non-stationary at levels. As a result, we conclude that the variables are integrated at first order, i.e. (1). The stationarity or integration order of our variables necessitates further cointegration test based on consistency of the regressors. This is done to complement the ARDL test of cointegration.

As a sensitivity or robustness check, Pedroni (2004) utilized the panel cointegration test with the null hypothesis of no cointegration in heterogeneous panels and long-run coefficients estimate. The co-integrating vectors were estimated for heterogeneous cointegrated panel as advanced by Pedroni (2001) using Fully Modified Ordinary Least Square (FMOLS) estimation approach. This approach allows efficient and consistent estimation of cointegration vectors. It also addresses any issue that arises from the endogenous nature of regressors and in terms of integration and cointegration properties, clearly spells out the time series properties of the variable.

Table 3.5: Panel Unit Root Test Results

	Im-Pesaran-Shin (IPS) test		Fisher-type (Fisher) test	
Variables	Level	First Difference	Level	First Difference
lnRGDP	5.031 (1.000)	-7.234*** (0.000)	28.458 (0.999)	146.123*** (0.000)
lnREN	0.417 (0.661)	-12.721*** (0.000)	57.949 (0.403)	244.050*** (0.000)
lnCO2	2.501 (0.993)	-13.800*** (0.000)	54.654 (0.525)	261.291*** (0.000)
lnGFCF	2.895 (0.998)	-9.077*** (0.000)	46.770 (0.805)	169.652*** (0.000)

The cointegration test results revealed in Tables-11 explains the existence of a long-run cointegration equilibrium connection between the variables of interest at a ($p <$ 0.01) significance level.

Table 3.6: Panel Cointegration Test

Weighted	Coefficients	Prob.	Coefficients	Prob.
Alternative hypothesis: common AR Coefs. (within-dimension)				
Panel rho-Statistic	3.789	0.999	4.115	1
Panel PP-Statistic	-6.439***	0	-5.792***	0
Panel ADF-Statistic	-6.083***	0	-5.592***	0
Alternative hypothesis: individual AR Coefs. (between-dimension)				
Group rho-Statistic	5.817	1		
Group PP-Statistic	-9.571***	0		
Group ADF-Statistic	-7.113***	0		

By translating equation-2 into the error correction term (ECT), the specified ARDL specification may be carried out as follows:

$$\Delta \ln RGDP_{i,t} = \phi_i \ln RGDP_{i,t-1} - \theta_i Z_{i,t} + \sum_{j=1}^{p-1} \delta_{i,j}^{*} \Delta \ln RGDP_{i,t-j} + \sum_{j=0}^{q-1} \gamma_{i,j}^{*} \Delta Z_{i,t-j} + \varepsilon_{i,t} \quad (3)$$

Where,

$$\phi_i = -\left(1 - \sum_{j=1}^{p} \delta_{i,j}\right), \theta_i = -\frac{\sum_{j=0}^{q} \gamma_{i,j}}{\left(1 - \sum_{j=1}^{p} \delta_{i,j}\right)} = -\frac{\sum_{j=0}^{q} \gamma_{i,j}}{\phi_i}, \delta_{i,j}^{*} = -\sum_{d=j+1}^{p} \delta_{i,d} \text{ and}$$

$$\gamma_{i,j}^{*} = -\sum_{d=j+1}^{q} \gamma_{i,d}$$

The former part of equation-4, $\phi_i(\ln RGDP_{i,t-1} - \theta_i Z_{i,t})$,represents the speed of adjustment in the level of growth to deviation from the long-run equilibrium level with the independent variables, while the latter part represents the short-run dynamics of economic growth. The vector parameter θ_i is the coefficient of the independent variables in estimating the long-run growth, while the parameter coefficient ϕ_i captures the error-correcting speed of adjustment term. Meanwhile, if the error-correcting speed of adjustment term is less than zero $(\phi_i < 0)$, the growth model provides evidence in support of a long-run relationship between $\ln RGDP_{i,t}$ and the explanatory variables (determinants of dependent variables).

The greater the absolute value of the adjustment speed (ϕ_i), the faster the convergence rate of the model from the short-run deviation path to the long-run equilibrium path, and vice versa. On the other hand, if the error-correcting speed of adjustment term is greater or equal to zero $\left(\phi_i \geq 0\right)$, this shows the absence of a stable relation in the long-run between the dependent variable and its determinants.

The speed of adjustment and the long-run coefficients parameter estimations are therefore the primary attractions in our empirical estimation in order to fulfill the study aim.

In applying ARDL models, $p = q = 1$ is mostly specified. This model specification is mostly used in literature that employ ARDL frameworks to carry out empirical investigations (see Bassanini and Scarpetta, 2002; Martínez-Zarzoso and Bengochea-Morancho, 2004; Frank, 2009; Xing, 2012). This paper proposes a paradigm in which p=q=1. As a result, assuming ARDL (1, 1) I equation-3, we may deduce the equation below:

$$\ln RGDP_{i,t} = \alpha_i + \delta_i \ln RGDP_{i,t-1} + \gamma_{i,0} Z_{i,t} + \gamma_{i,1} Z_{i,t-1} + \varepsilon_{i,t} \quad (4)$$

Thus, we can now reformulate equation-4 in the following error correction model (ECM):

$$\Delta \ln RGDP_{i,t} = \phi_i \left(\ln RGDP_{i,t-1} - \theta_{0.1} - \theta_i Z_{i,t}\right) - \gamma_{i,1} \Delta Z_{i.t} + \varepsilon_{i,t} \quad (5)$$

Where $\phi_i = -\left(1 - \delta_i\right)$, $\theta_i = -\dfrac{\gamma_{i,0} + \gamma_{i,1}}{\phi_i}$ and $\theta_{0,i} = -\dfrac{\alpha_i}{\theta_i}$

In order to estimate equation-5, the following estimators are employed: The Mean Group estimator, the Pooled Mean Group estimator and the Dynamic Fixed-Effect estimator. When both and T are big, the MG estimator does not impose limitations, and it also does not enforce limits.

The MG estimator, on the other hand, is sensitive to outliers and sample size, particularly when the temporal dimension (T) is short, even though the cross-section (N) is high (Blackburne and Frank, 2007).The DFE estimator, on the other hand, assumes homogeneity across cross-sections in both short- and long-run coefficients while ignoring the constant term (intercept).Pesaran et al. (1999) proposed the PMG estimator as a comparison estimator between the MG and DFE estimators.

Although the PMG estimator implies that long-run coefficients are homogenous, other slope coefficients can vary among cross-sections.When the long-run slope coefficient's heterogeneity assumption is verified, the PMG estimator becomes inconclusive. When the homogeneity assumption is met, the PMG estimator becomes more robust, consistent, and efficient than the MG estimate.

The Pooled Mean Group (PMG) estimator and the Dynamic Fixed-Effect (DFE) estimator, according to Pesaran and Smith (1995), have certain complimentary properties. According to Pesaran et al (1999), the PMG estimator is more robust and accurate when dealing with lag orders and outliers. Hausman tests are used to choose the most appropriate of these estimators.

3.4.3 Panel Granger Causality Test Approach

We apply the Dumitrescu and Hurlin (2012) Granger causality test for heterogeneous non-causality. This test is applicable except when $T = N$. It is developed on the vector autoregressive model (VAR) and is resilient even when cross-sectional dependence is present. The asymptotic and semi-asymptotic distributions are both included in this test. When T exceeds N, the asymptotic distribution is used, and when N exceeds T, the semi-asymptotic distribution is used. The linear model specification is as follows:

$$y_{it} = \sum_{k=1}^{K} \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t} \tag{6}$$

Where K is the lag duration, $\gamma_i^{(k)}$ denotes the autoregressive parameter, while $\beta_i^{(k)}$ denotes the regression coefficient that might vary between groups. The causality test is normally distributed and takes heterogeneity into account. With heterogeneous models, the homogenous non-stationary hypothesis (HNC) is utilized to estimate causal relationships. Under the test, the null and alternative hypotheses for HNC are specified as follows:

$H_0 : \beta_i = 0 \ \forall_i = 1,.....N$

$H_1 : \beta_i = 0 \ \forall_i = 1,.....N_1$

$\beta_i \neq 0 \ \forall_i = N_1 + 1, N_1 + 2,....N$

Where N_1 shows the unknown parameter, that satisfies the condition $0 \le N_1 / N < 1$. In any situation, the ratio of N_1 / N should be inevitably less than 1.If $N_1 / N = 1$ implies no causality across cross-sections. This indicates a failure to reject the null of HNC. However, if $N_1 / N = 0$ it shows a causal nexus in the macro panel.

3.5 Empirical Results and Discussion

Given that the macro panel data share common integration properties, i.e. $I(1)$,coupled with the fact that the existence of a long-run cointegration relationship between the variables has been confirmed at ($p < 0.01$) level of significance (Tables-10, 11 and 12), we proceed with empirical estimations. Table-13 shows the PMG, MG and DFE estimation outcomes forequation-5, which are the study's main estimation results.

For each technique, we show the long-run coefficients, the speed of adjustment coefficient, and the short-run coefficients. The long-run coefficients of renewable energy consumption are positive and statistically significant, at ($p< 0.01$) and ($p< 0.05$) levelsas shown in the first row of Table-13 in the PMG and DFE estimations, but statistically insignificant in the MG estimation.

To determine the most appropriate estimation result for the long-run nexus between economic growth and renewable energy consumption, pairwise comparisons are carried out, first between the MG and PMG estimators, and then between the MG and DFE estimators. These comparisons are conducted with the aid of Hausman tests that estimate the supplementary homogeneity restrictions enforced by the PMG and DFE estimators relative to the MG estimator respectively.

Table 3.7: Regression for FMOLS Model

Variables/Models	lnRGDP = *f* (lnREN. lnCO2, lnGFCF)	
LnREN	0.132***	(3.171)
lnCO2	1.151***	(10.498)
LnGFCF	0.304***	(27.407)
N	552	
Long run variance	0.897	

As discussed earlier, the dynamic fixed effect and pooled mean group estimators are more efficient and consistent than the mean group estimator, under the null hypothesis that homogeneity restrictions hold. The Hausman test statistics reported in Table-13 as 5.02 with a corresponding probability value of 1.700 when MG and

PMG estimators are compared, and 0.00 with a corresponding probability value of 1.000 when the MG and DFE estimators are compared.

We infer that the PMG and DFE estimators are more efficient and appropriate than the MG estimator based on the Hausman test findings, because we could not reject the null hypothesis in both situations.Consequently, since the PMG and DFE have been taken as the preferred model specifications, then the findings recorded in Table-13 indicate that the consumption of renewable energy has a positive and statistically important long-term effect on the EU-28 countries' economic development.

The Hausman test results also suggest that regardless of the disparities in several characteristics among EU countries (for instance, environmental resources, climate change, economic policies, developmental levels, GDP per capita, etc.), the proposition of slope homogeneity across EU countries cannot be rejected statistically. Simply put, EU countries seem to have a similar long-term relationship between consumption of renewable energy, economic growth and other determinants.

The above-mentioned advantages of the PMG and DFE models are an indication that equally informs on the appropriateness of the Autoregressive Distributed Lag (ARDL). The ARDL is considered appropriate because it models variables with either *I(0)* or *I(1)* or both. Also, the model suitably provides state-wide cross-sectional short-run information in addition to the panel long-run and short-run estimates.

Furthermore, across all estimations, the estimated speed of adjustment coefficient shown in Table-13 is negative and statistically significant at the ($p<0.01$) level. This shows the convergence of relationship between inflation and economic growth, as well as the presence of a long-run equilibrium connection.We find that the DFE adjustment coefficient of -0.088 is the lowest, followed by the PMG adjustment coefficient of -0.065, and the MG with the highest adjustment coefficient of -0.195, out of the three estimates of the short-run speed of adjustment coefficients.

These results indicate that a deviation from the long-run equilibrium level of real GDP in a year is corrected by 6% to 8%annually.Furthermore, the presence of a stable long-run equilibrium connection between economic growth and its causes is confirmed by a substantial adjustment coefficient.For the record, the absolute values of our speed of adjustment coefficients from the PMG, MG, and DFE estimators are not significantly different from the estimations in Apergis and Payne (2010b), which vary between 11% and 14%. This indicates that the speed of adjustment or convergence in EU countries is similar to that of the Eurasian countries.

Table 3.8: PMG, MG and DFE Estimates of the ARDL (1,1) Economic Growth Equation

Regressors	PMG	MG	DFE
Long-run coefficients			
LnREN	0.071*** (0.000)	-0.138 (0.555)	0.049** (0.043)
lnCO2	0.595*** (0.000)	-0.388 (0.411)	0.125 (0.401)
lnGFCF	0.356*** (0.000)	0.632** (0.000)	0.493*** (0.000)
Adjustment coefficient (ECM)	-0.065*** (0.000)	-0.195*** (0.000)	-0.088*** (0.000)
Short-run coefficients			
Constant	0.036** (0.031)	-0.199 (0.580)	-0.188** (0.065)
ΔlnREN	-0.008*** (0.003)	-0.017(0.336)	-0.013* (0.095)

ΔlnCO2	0.073***(0.000)	0.041*** (0.007)	0.104*** (0.000)
ΔlnGFCF	0.246***(0.000)	0.099*** (0.000)	0.158*** (0.000)
No. of EU countries	28	28	28
No. of observations	552	552	552
Hausman test	MG VS PMG		MG VS DFE
Chi2(3)	5.02		0
Prob. > chi2	1.7		1

A quantitative evaluation of the renewable energy-economic growth relationship on the basis of the superior PMG and DFE estimation techniques shows that 1% increase in renewable energy consumption will increase economic growth by 0.071% and 0.049% in the long-run, while1% increase in renewable energy consumption will decrease economic growth (real income per capita) by 0.008% and 0.013% in the short-run.

The cost impact of renewable energy sources across the EU-28 nations may be attributed to the negative impact of renewable energy usage on economic growth. Renewable energy sources are cost effective; thus, it will be theoretically and empirically to assume that, installation of these forms (renewables) of energy sources would have an inverse impact on any economy that intends to switch from non-renewables to renewables, for sound and clean environment, most especially in the short-run.

When compared to the 0.195% indicated by Apergis and Payne for Eurasia, the influence of renewable energy usage on economic development appears to be minimal (2010b).This sort of analysis shows that the link between renewable energy and economic development can vary significantly between countries. Other long-run results in Table-12 include positive and statistically significant coefficients for real gross fixed capital formation in both models at ($p<0.01$) level of significance. This affirms the crucial role real gross fixed capital formation plays in the growth of EU countries. This is in line with Apergis and Payne's (2010b) conclusion that a ($p<0.01$) rise in real capital formation improves real GDP by 0.225% in their assessment of the influence of real gross fixed capital formation on Eurasian nations' growth.

Real gross fixed capital formation seems to play a more significant role in the long-run (0.356% and 0.493%) and in the short-run (0.246% and 0.158%) in both the PMG and DFE growth models for the EU than it does in the models for Eurasian countries. The coefficient of carbon emissions (energy use) is positive and statistically significant at a($p< 0.01$) significance level both in the long-run (0.595%) and (0.125) and short-run (0.073%) and (0.104%) in both the PMG and DFE growth models for the EU-28 countries.

Table-12 reports possible long-run equilibrium robustness check. We estimate cointegrating vectors using Fully Modified Ordinary Least Square (FMOLS) estimation approach for heterogeneous co-integrated panel as advanced by Pedroni (2001). This approach allows efficient and consistent estimation of co-integrating vectors. It also accounts for the endogeneity of regressors' issue and considers the time-series features of the variables in terms of integration and co-integration properties, as well as maintaining the consistency of long-run connections.

3.5.1 Granger Causality Results

To complement the ARDL estimation results, Granger causality tests are conducted using the approach, and the results reported in Table-14. The Wald statistic's statistical significance denotes a bidirectional causal link between real GDP and renewable energy consumption (Apergis and Payne, 2010b), as well as a bidirectional causal association between real GDP and real gross fixed capital formation (Apergis and Payne, 2010a), a bidirectional causal relationship between real GDP and carbon emissions (Ang, 2007; Halicioglu, 2009).

Bidirectional causality suggests a long-term interdependence in the EU-28 countries between real GDP and consumption of renewable energy and other growth determinants. This is in stark contrast to Menegaki's (2011) results, which claim that there is no causal link between renewable energy consumption and economic development in Europe and conclude that the assumptions of neutrality are true in the area. Our findings provide evidence to support the unidirectional causality between tourism and carbon emissions.

Table 3.9: Dumitrescu and Hurlin (2012) Panel Granger Causality Results:

Null hypothesis	Wald-stat	P-value	Causality	Direction
lnRGDP→ lnREN	4.941***	0	Yes	
lnREN → lnRGDP	3.790***	0	Yes	bidirectional
lnRGDP → lnCO2	4.705***	0	Yes	
lnCO2 → lnRGDP	4.305***	0	Yes	bidirectional
lnRGDP→ lnGFCF	0.209***	0	Yes	
lnGFCF→ lnRGDP	3.171***	0	Yes	bidirectional
lnREN → lnCO2	2.807***	0	Yes	
lnCO2 → lnREN	5.969***	0	Yes	bidirectional
lnREN → lnGFCF	0.027***	0	Yes	
lnGFCF → lnREN	2.760***	0	Yes	Bidirectional
lnCO2 →lnGFCF	0.077***	0	Yes	
lnGFCF → lnCO2	4.114***	0	Yes	bidirectional

3.6 Conclusion and Policy Implications

This study examines the long-term link between renewable energy consumption and economic growth for a panel of 28 European Union (EU-28) nations from 1995 to 2015. The report also discusses the environmental effect of mitigating carbon emissions to achieve sustainable economic development. The study reveals a substantial positive long-run equilibrium link between renewable energy consumption and economic growth in the EU-28 nations by analyzing the error correction model of an autoregressive distributed lag (ARDL) dynamic panel framework. This finding is consistent and robust in terms of model specifications, estimation techniques and choice of variables.

Furthermore, by comparing our findings to those of Apergis and Payne (2010b), the following conclusions may be drawn: first, Eurasian nations are approaching the long-run equilibrium growth path quicker than European Union countries in terms of renewable energy.Secondly, renewable energy has a higher beneficial influence on economic growth in Eurasian nations than in EU-28 countries. Third, the EU-28 nations' positive impact on real gross fixed capital creation is larger than that of Eurasian countries.Finally, the findings suggest that the use of renewable energy has a short-term negative impact on economic growth in the EU-28 nations.

Also, evidence for a feedback hypothesis is provided by the bidirectional causal link between renewable energy usage and economic development.Evidence of a bidirectional causal relationship between renewable energy use and economic development indicates that the region is currently heading toward environmental sustainability, and this conclusion is consistent with Sadorsky's (2009a) research of the G7 countries and Apergis and Payne (2009a, 2010b) for Central America and Eurasia, but in sharp contrast with that of Menegaki (2011) for Europe.

Growing the use of renewable energy sources would deter the consumption of fossil fuels, thus mitigating carbon emissions. Governments and policymakers in the EU region must also adopt effective economic and energy policies to promote marketability and the production of renewable energies in order to achieve the region's environmental sustainability. As posited by Apergis and Payne (2010a), subsidies and/or tax credits on renewable energy production and consumption, introduction of renewable energy portfolio principles among others could serve as useful policy tools.

Interestingly, the result of the current study is in line with the recently adopted and revised energy transition and efficiency policies of the EU (European Commission, 2019).As a result, this study recommends that the Renewable Energy Directive (EU) 2018/2001, the Energy Efficiency Directive (EU) 2018/2002, the Governance Regulation (EU) 2018/1999, and the Energy Performance of Building Directive be implemented in a proactive manner.

The implementation of the aforementioned regulations across the EU states will not only help to achieve long-term energy efficiency goals, but it will also help to create jobs, improve health, and provide platforms for innovation, all of which will contribute to the 2030 Sustainable Development Goals (SDGs).

Renewable energy as a complement or alternative for non-renewable energy sources for a clean and sustainable environment has a cost (capital cost) on economic growth and performance, which should be kept in mind by governments and policymakers in developed, developing, and emerging economies.

From the global perspective, the adoption of corporate mechanism especially toward optimizing the use of renewable energy for economic growth stimulation and sustainability is encouraged. In doing so, the global drive toward attaining the SDGs by 2030 will become realizable rather than remain a mere aspiration.

Chapter 4

CONCLUSION

4.1 An overview of Conclusion

This dissertation seeks to examine the effect of energy consumption (natural gas and renewable energy) sources on the growth of the economy and its environmental implications. As previously stated, there has been a rise in demand for energy use in the last two decades, especially for natural gas, oil, and electricity, among other sources, with countries focusing on renewable energy to meet their energy needs, extend energy usage to more people, and achieve economic growth.

The ongoing energy policy debate on the use of NG as an alternative means of mitigating CO_2, raises the research question on the role of natural gas consumption (NGC) in economic growth (EG) process, especially in Saudi Arabia. Using a multivariate framework this thesis examines the role of NGC in Saudi Arabia with the inclusion of total trade, and also checks if an increase or decrease in NGC would have an effect on the economy's growth and environment both in the short and long term.

The empirical result shows a one-sided long-run causality relationship between NGC and EG proving Saudi Arabia to be a natural gas dependent economy. NGC and TT both appear to play an important role in the long-run economic growth process of the nation which means that from our empirical results, it appears implementing natural-gas conservation policy in order to mitigate global warming as being suggested in energy policy literature would not hurt the demand for natural gas or total trade in the short-run.

Natural-gas conservation policy as a means of reducing environmental pollution through carbon emissions appears to be a feasible emissions reduction policy in the short-term in Saudi Arabia since NGC predicts her real per capita GDP and given Saudi Arabia's reliance on natural gas, our empirical findings imply that natural gas conservation policies will limit demand, slow overall trade, and curb domestic output in the long-run.

However, the Saudi Arabian government may be able to fulfill its energy demands and increase overall trade in the near future by embracing renewable energy alternatives to natural gas.This is significant because, in order to satisfy the economy's growing demand for energy, governments and policymakers in the region must implement ambitious energy policies that ensure energy efficiency and the supply of renewable energy by increasing R&D expenditure, which would help explore other renewable energy sources to cushion the high demand for natural gas without slowing the growth phase of the economy.

The next chapter reveals that the increased use of renewable energy will reduce the use of fossil fuels thereby limiting carbon emissions. The hypothesis feedback is supported by the bidirectional causal relationship between renewable energy consumption and economic growth.

The evidence supporting a bidirectional causal relationship between renewable energy consumption and economic growth indicates that the country is on its path to becoming a regional leader in environmental sustainability. This result is in line with Sadorsky's (2009a) findings for the G7 nations, as well as Apergis and Payne's (2009a, 2010b) findings for Central America and Eurasia, but not with Menegaki's (2011) findings for Europe.

The study shows that the long-term equilibrium between renewable energy use and economic growth in the EU-28 nations is substantially positive, using a panel of 28 European countries to evaluate the long-run connection between renewable energy use and economic growth. The result gotten from the PMG, MG, DFE reveals the long-run coefficient of renewable energy consumption are positive and statistically significant at 1% and 5% level in PMG and DFE but statistically insignificant in the MG estimation.

Based on previous studies such as Apergis and Payne (2010b), we see that in terms of renewable energy, Eurasian countries converge faster than the European Union countries towards the long-term growth direction of equilibrium, for Eurasian nations, the positive effect of renewable energy on economic development is greater than that of the EU-28 countries. Lastly, the positive influence of real gross fixed capital growth is far higher for the EU-28 countries than it is for the Eurasian countries, implying that renewable energy has a short-term negative impact on the EU-28 countries' economic growth.

As a result, adopting suitable economic and energy policies/regulations, the EU member countries will not only help to achieve long-term energy consumption goals, but it would also help to increase the availability of job opportunities, health improvement and a good start-up for innovation and thus drive the Sustainable Development Goals (SDGs) for 2030 to a large extent.

Finally renewable energy as a supplement or replacement for non-renewable energy sources for a safe and sustainable world has a cost (capital cost) on economy’sgrowth and efficiency, which should be kept in mind by governments and policymaker

REFERENCES

Acemoglu, D. (2012). Introduction to economic growth. *Journal of economic theory*, *147*(2), 545-550.

Adewuyi, A. O., &Awodumi, O. B. (2017). Renewable and non-renewable energy-growth-emissions linkages: Review of emerging trends with policy implications. *Renewable and Sustainable Energy Reviews*, 69, 275-291.

Akadiri, S. S. & Akadiri, A C. (2020). Interaction between CO2 emissions, energy consumption and economic growth in the Middle East: Panel causality evidence. *International Journal of Energy Technology and Policy*16 (2), 105-118.

Akadiri, S. S., Bekun, V. F., Taheri, E., & Akadiri, A C. (2019). Carbon emissions, energy consumption and economic growth: A causality evidence. International Journal of Energy Technology and Policy15 (2-3), 320-336.

Akadiri, S. S. & Akadiri, A C. (2019). The role of natural gas consumption in economic growth. Strategic Planning for Energy and the Environment.

Akadiri, A. C., Saint Akadiri, S., &Gungor, H. (2019). The role of natural gas consumption in Saudi Arabia's output and its implication for trade and environmental quality. *Energy Policy*, *129*, 230-238.

Alola, A. A. (2019a). Carbon emissions and the trilemma of trade policy, migration policy and health care in the US. *Carbon Management*, 1-10.

Alola, A. A., Yalçiner, K., Alola, U. V., & Saint Akadiri, S. (2019). The role of renewable energy, immigration and real income in environmental sustainability target. Evidence from Europe largest states. *Science of The Total Environment*.

Alshehry, A. S., & Belloumi, M. (2015). Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. Renewable and Sustainable Energy Reviews, 41, 237-247.

Alam, M. J., Ahmed, M., & Begum, I. A. (2017). Nexus between non-renewable energy demand and economic growth in Bangladesh: Application of Maximum Entropy Bootstrap approach. Renewable and Sustainable Energy Reviews, 72, 399-406.

Alkhathlan, K., &Javid, M. (2013). Energy consumption, carbon emissions and economic growth in Saudi Arabia: An aggregate and disaggregate analysis. Energy Policy, 62, 1525-1532.

Ang, J. B. (2007). CO2 emissions, energy consumption, and output in France. *Energy Policy*, *35*(10), 4772-4778.

Apergis, N. and Payne, J. E. (2009a). Energy consumption and economic growth in Central America: evidence from a panel cointegration and error correction model. *Energy Economics, 31*(2), 211-216.

Apergis, N. and Payne, J. E. (2009b). Energy consumption and economic growth: evidence from the Commonwealth of Independent States. *Energy Economics*, *31*(5), 641-647.

Apergis, N. and Payne, J. E. (2010a). Renewable energy consumption and economic growth: evidence from a panel of OECD countries. *Energy policy*, *38*(1), 656-660.

Apergis, N. and Payne, J. E. (2010b). Renewable energy consumption and growth in Eurasia. *Energy Economics*, 32.6(2010): 1392-1397.

Apergis, N., Payne, J. E., Menyah, K. and Wolde-Rufael, Y. (2010). On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. *Ecological Economics, 69*(11), 2255-2260.

Apergis, N., & Payne, J. E. (2010). Natural gas consumption and economic growth: a panel investigation of 67 countries. Applied Energy, 87(8), 2759-2763.

Aqeel, A., & Butt, M. S. (2001). The relationship between energy consumption and economic growth in Pakistan. Asia-Pacific Development Journal, 8(2), 101-110.

Asafu-Adjaye, J., Byrne, D., & Alvarez, M. (2016). Economic growth, fossil fuel and non-fossil consumption: A Pooled Mean Group analysis using proxies for capital. *Energy Economics*, *60,* 345-356.

Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. *Energy economics*, *22*(6), 615-625.

Atasoy, B. S. (2017). Testing the environmental Kuznets curve hypothesis across the US: Evidence from panel mean group estimators. *Renewable and Sustainable Energy Reviews*, *77*, 731-747.

Bahmani-Oskooee, M., &Chomsisengphet, S. (2002). Stability of M2 money demand function in industrial countries. Applied Economics, 34(16), 2075-2083.

Baranzini, A., Weber, S., Bareit, M., & Mathys, N. A. (2013). The causal relationship between energy use and economic growth in Switzerland. Energy Economics, 36, 464-470.

Bartleet, M. and Gounder, R. (2010). Energy consumption and economic growth in New Zealand: Results of trivariate and multivariate models. *Energy Policy*, *38*(7), 3508-3517.

Bassanini, A. and Scarpetta, S. (2002). Does human capital matter for growth in OECD countries? A pooled mean-group approach. *Economics letters*, *74*(3), 399-405.

Bhattacharyya, S. C. (2011). Energy demand management. In Energy Economics (pp. 135-160). Springer, London.

Bayer, C., & Hanck, C. (2013). Combining non-cointegration tests. *Journal of Time Series Analysis*, *34*(1), 83-95.

Bekun, F. V., Alola, A. A., &Sarkodie, S. A. (2019). Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. *Science of The Total Environment*, *657*, 1023-1029.

Bekun, F. V., Emir, F., &Sarkodie, S. A. (2019). Another look at the relationship between energy consumption, carbon dioxide emissions, and economic growth in South Africa. *Science of The Total Environment*, *655*, 759-765.

Blackburne, E. F. and Frank, M. W. (2007). Estimation of nonstationary heterogeneous panels. *Stata Journal*, *7*(2), 197.

Bowden, N. and Payne, J. E. (2010). Sectoral analysis of the causal relationship between renewable and non-renewable energy consumption and real output in the US. *Energy Sources, Part B: Economics, Planning, and Policy*, *5*(4), 400-408.

British Petroleum, (2018). https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/co2-emissions.html. (Accessed 28 March 2019).

Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for testing the constancy of regression relationships over time. Journal of the Royal Statistical Society. Series B (Methodological), 149-192.

Bildirici, M. E., & Bakirtas, T. (2014). The relationship among oil, natural gas and coal consumption and economic growth in BRICTS (Brazil, Russian, India, China, Turkey and South Africa) countries. *Energy*, *65*, 134-144.

Chow, G. C. (1960). Tests of equality between sets of coefficients in two linear regressions. Econometrica: Journal of the Econometric Society, 591-605.

Choi, I. (2001). Unit root tests for panel data. *Journal of international money and Finance*, *20*(2), 249-272.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. Journal of the American statistical association, 74(366a), 427-431.

Dogan, E. and Aslan, A. (2017). Exploring the relationship among CO2 emissions, real GDP, energy consumption and tourism in the EU and candidate countries: Evidence from panel models robust to heterogeneity and cross-sectional dependence. *Renewable and Sustainable Energy Reviews*, *77*, 239-245.

Doornik, J. A. (1995). Testing general restrictions on the cointegrating space. Nuffield College, Oxford, UK. Mimeo.

Destek, M. A. (2016). Natural gas consumption and economic growth: Panel evidence from OECD countries. Energy, 114, 1007-1015.

Destek, M. A., &Okumus, I. (2017). Disaggregated energy consumption and economic growth in G-7 countries. Energy Sources, Part B: Economics, Planning, and Policy, 12(9), 808-814.

Dumitrescu, E. I. and Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling*, *29*(4), 1450-1460.

Emir, F., &Bekun, F. V. (2018). Energy intensity, carbon emissions, renewable energy, and economic growth nexus: new insights from Romania. *Energy & Environment*, 0958305X18793108.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. Econometrica: journal of the Econometric Society, 251-276.

European Commission. (2016). EU's progress report. Implementing the Paris Agreement Progress of the EU towards the at least -40% target. https://ec.europa.eu/clima/policies/strategies/progress_en.

European Environment Agency. (2021). Renewable energy in Europe: key for climate objectives, but air pollution needs attention. https://www.eea.europa.eu/themes/energy/renewable-energy/renewable-energy-in-europe-key.

European Commission. (2019). New Renewables, Energy Efficiency and Government Legislation comes into force on 24 December 2018. https://ec.europa.eu/info/news/new-renewables-energy-efficiency-and-governance-legislation-comes-force-24-december-2018-2018-dec-21_en.

European Environmental Agency. (2017). Recent growth and knock-on effects. *No. 3(2017)*.https://www.eea.europa.eu/publications/renewable-energy-in-europe-2017.

European Environmental Agency. (2018).https://www.eea.europa.eu/themes/energy.

Ewing, B. T., Sari, R. and Soytas, U. (2007). Disaggregate energy consumption and industrial output in the United States. *Energy Policy*, *35*(2), 1274-1281.

Furuoka, F. (2016). Natural gas consumption and economic development in China and Japan: An empirical examination of the Asian context. *Renewable and Sustainable Energy Reviews*, *56*, 100-115.

Farhani and Sahbi (2012) Tests of Parameters Instability: Theoretical Study and Empirical Analysis on Two Types of Models (Arma Model and Market Model) (2012). International Journal of Economics and Financial Issues (IJEFI),Vol. 2, No. 3, pp. 246-266, 2012. Available at SSRN: https://ssrn.com/abstract=2104126

Farhani, S., Shahbaz, M., Arouri, M., &Teulon, F. (2014). The role of natural gas consumption and trade in Tunisia's output. Energy Policy, 66, 677-684.

Fatai, K., Oxley, L., &Scrimgeour, F. G. (2004). Modelling the causal relationship between energy consumption and GDP in New Zealand, Australia, India, Indonesia, The Philippines and Thailand. Mathematics and Computers in Simulation, 64(3-4), 431-445.

Frank, M. W. (2009). Inequality and growth in the United States: Evidence from a new state-level panel of income inequality measures. *Economic Inquiry*, *47*(1), 55-68.

Ghosh, T., L. (2010). Shedding light on the global distribution of economic activity. The Open Geography Journal, 3(1).

Hansen, H., & Johansen, S. (1999). Some tests for parameter constancy in cointegrated VAR-models. The Econometrics Journal, 2(2), 306-333.

Holtz-Eakin, D. and Selden, T. M. (1995). Stoking the fires? CO2 emissions and economic growth. *Journal of Public Economics*, *57*(1), 85-101.

Im, K. S., Pesaran, M. H. and Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, *115*(1), 53-74.

Işik, C. (2010). Natural gas consumption and economic growth in Turkey: a bound test approach. Energy Systems, 1(4), 441-456.

Isik, C., Dogru, T., & Turk, E. S. (2018). A nexus of linear and non-linear relationships between tourism demand, renewable energy consumption, and economic growth: Theory and evidence. International Journal of Tourism Research, 20(1), 38-49.

Işik, C., Kasımatı, E., &Ongan, S. (2017). Analyzing the causalities between economic growth, financial development, international trade, tourism expenditure and/on the CO2 emissions in Greece. Energy Sources, Part B: Economics, Planning, and Policy, 12(7), 665-673.

Işik, C., & Radulescu, M. (2017). Investigation of the relationship between renewable energy, tourism receipts and economic growth in Europe. Statistika: Statistics and Economy Journal, 97(2), 85-94.

Ighodaro, C. A. (2010). Co-integration and causality relationship between energy consumption and economic growth: Further empirical evidence for Nigeria. Journal of Business Economics and Management, 11(1), 97-111.

Johansen, S. (1988). Statistical analysis of cointegration vectors. Journal of economic dynamics and control, 12(2-3), 231-254.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. Oxford Bulletin of Economics and statistics, 52(2), 169-210.

Kum, H., Ocal, O., & Aslan, A. (2012). The relationship among natural gas energy consumption, capital and economic growth: Bootstrap-corrected causality tests from G-7 countries. Renewable and Sustainable Energy Reviews, 16(5), 2361-2365.

Khan, M. A., & Ahmad, U. (2008). Energy demand in Pakistan: a disaggregate analysis. The Pakistan Development Review, 437-455.

Krarti, M., & Dubey, K. (2018). Review analysis of economic and environmental benefits of improving energy efficiency for UAE building stock. *Renewable and Sustainable Energy Reviews, 82*,

Kraft, J., & Kraft, A. (1978). On the relationship between energy and GNP. The Journal of Energy and Development, 401-403. 14-24.

Lee, J., &Strazicich, M. C. (2003). Minimum Lagrange multiplier unit root test with two structural breaks. *Review of economics and statistics*, *85*(4), 1082-1089.

Lee, C. C., & Chang, C. P. (2005). Structural breaks, energy consumption, and economic growth revisited: evidence from Taiwan. Energy Economics, 27(6), 857-872.

Lee, C. C. (2005). Energy consumption and GDP in developing countries: a cointegrated panel analysis. Energy economics, 27(3), 415-427.

Lee, J. W. and Brahmasrene, T. (2013). Investigating the influence of tourism on economic growth and carbon emissions: Evidence from panel analysis of the European Union. *Tourism Management*, *38*, 69-76.

Lin, B. and Moubarak, M. (2014). Renewable energy consumption–Economic growth nexus for China. *Renewable and Sustainable Energy Reviews*, *40*, 111-117.

Lim, H. J., &Yoo, S. H. (2012). Natural gas consumption and economic growth in Korea: a causality analysis. Energy Sources, Part B: Economics, Planning, and Policy, 7(2), 169-176.

Lütkepohl, H. (2006). Structural vector autoregressive analysis for cointegrated variables. *AllgemeinesStatistischesArchiv*, *90*(1), 75-88.

Lütkepohl, H. (1982). Non-causality due to omitted variables. Journal of Econometrics, 19(2-3), 367-378.

Lütkepohl, H., &Poskitt, D. S. (1991). Estimating orthogonal impulse responses via vector autoregressive models. Econometric Theory, 7(4), 487-496.

Mahadevan, R. and Asafu-Adjaye, J. (2007). Energy consumption, economic growth and prices: a reassessment using panel VECM for developed and developing countries. *Energy Policy*, *35*(4), 2481-2490.

Marques, A. C., Fuinhas, J. A. and Manso, J. P. (2010). Motivations driving renewable energy in European countries: A panel data approach. *Energy policy*, *38*(11), 6877-6885.

Martínez-Zarzoso, I. and Bengochea-Morancho, A. (2004). Pooled mean group estimation of an environmental Kuznets curve for CO2. *Economics Letters, 82*(1), 121-126.

Marques, A. C., &Fuinhas, J. A. (2018). On the Dynamics of Renewable Energy Consumption (Aggregated and Disaggregated) and Economic Growth: An Approach by Energy Sources. In *The Economics and Econometrics of the Energy-Growth Nexus* (pp. 77-112).

Menegaki, A. N. (2011). Growth and renewable energy in Europe: a random effect model with evidence for neutrality hypothesis. *Energy Economics*, *33*(2), 257-263.

Menyah, K. and Wolde-Rufael, Y. (2010). CO2 emissions, nuclear energy, renewable energy and economic growth in the US. *Energy Policy, 38*(6), 2911-2915.

Molele, S. B., &Ncanywa, T. (2018). Resolving the energy-growth nexus in South Africa. *Journal of Economic and Financial Sciences, 11*(1), 8.

Mensah, J. T., Marbuah, G., &Amoah, A. (2016). Energy demand in Ghana: A disaggregated analysis. *Renewable and Sustainable Energy Reviews, 53*, 924-935.

Naser, H. (2017). On the cointegration and causality between oil market, nuclear energy consumption, and economic growth: evidence from developed countries. *Energy, Ecology and Environment*, *2*(3), 182-197.

Narayan, P. K., & Smyth, R. (2008). Energy consumption and real GDP in G7 countries: new evidence from panel cointegration with structural breaks. Energy Economics, 30(5), 2331-2341.

Ocal, O. and Aslan, A. (2013). Renewable energy consumption–economic growth nexus in Turkey. *Renewable and Sustainable Energy Reviews*, *28*, 494-499.

Omer, A. M. (2010). Environmental and socio-economic aspects of possible development in renewable energy use. Journal of Agricultural Extension and Rural Development, 2(1), 001-021.

Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Engineering, 3(1), 1167990.

Ozturk, I., & Al-Mulali, U. (2015). Natural gas consumption and economic growth nexus: Panel data analysis for GCC countries. *Renewable and Sustainable Energy Reviews*, *51*, 998-1003.

Paul M. Romer (1994). The origins of endogenous growth. Journal of Economic Perspectives, Volume 8, Number 1-Winter 1994 Pages 3-22

Paramati, S. R., Mo, D. and Gupta, R. (2017). The effects of stock market growth and renewable energy use on CO_2 emissions: Evidence from G20 countries. *Energy Economics*, *66*, 360-371.

Payne, J. E. (2009). On the dynamics of energy consumption and output in the US. *Applied Energy*, *86*(4), 575-577.

Pedroni, P. (2001). Fully modified OLS for heterogeneous cointegrated panels. In *Nonstationary panels, panel cointegration, and dynamic panels* (pp. 93-130). Emerald Group Publishing Limited.

Pedroni, P. (2004). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric theory*, *20*(3), 597-625.

Pesaran, M. H. and Smith, R. (1995). Estimating long-run relationships from dynamic heterogeneous panels. *Journal of econometrics*, *68*(1), 79-113.

Pesaran, M. H., Shin, Y. and Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association*, *94*(446), 621-634.

Phillips, P. C., & Hansen, B. E. (1990). Statistical inference in instrumental variables regression with I(1) processes. The Review of Economic Studies, 57(1), 99-125.

Phillips, P. C., &Perron, P. (1988). Testing for a unit root in time series regression. Biometrika, 335-346.

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American Statistical Association, 94(446), 621-634.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of applied econometrics, 16(3), 289-326.

Payne, J. E. (2011). US disaggregate fossil fuel consumption and real GDP: an empirical note. Energy Sources, Part B: Economics, Planning, and Policy, 6(1), 63-68.

Rahul Goswami, (2021). Oil and gas regulation in Saudi Arabia: Overviewhttps://uk.practicallaw.thomsonreuters.com/w-019-2522?transitionType=

Reynolds, D. B., & Kolodziej, M. (2008). Former Soviet Union oil production and GDP decline: Granger causality and the multi-cycle Hubbert curve. Energy Economics, 30(2), 271-289.

Reuters. (2021). Shift to renewable energy eases key environmental burdens, EU says. https://www.reuters.com/article/us-energy-eu-renewables/shift-to-renewable-energy-eases-key-environmental-burdens-eu-says-idUSKBN29N09W.

REN21. (2016). Renewables 2016 Global Status Report, Paris, REN21 Secretariat and Washington, DC. World-watch Institute. http://www.ren21.net/about-ren21/annual-reports/.

Reinsel, G. C., &Ahn, S. K. (1992). Vector autoregressive models with unit roots and reduced rank structure: estimation likelihood ratio test, and forecasting. Journal of Time Series Analysis, 13(4), 353-375.

Riza R., Shida R. H. & Samira S. (2021). Renewable energy consumption, CO2 emissions, and economic growth nexus: A simultaneity spatial modeling analysis of EU countries. Structural Change and Economic Dynamics volume 57, pages 13-27.

Rafindadi, A. A., &Ozturk, I. (2015). Natural gas consumption and economic growth nexus: Is the 10th Malaysian plan attainable within the limits of its resource?. *Renewable and Sustainable Energy Reviews*, *49*, 1221-1232.

Sabiha S. G. (2019). Saudi Arabia's relations with the EU and its perception of EU policies in MENA. Middle East and North Africa Studies.

Shahbaz, M., Uddin, G. S., Rehman, I. U., & Imran, K. (2014). Industrialization, electricity consumption and CO2 emissions in Bangladesh. *Renewable and Sustainable Energy Reviews*, *31*, 575-586.

Shahbaz, M., Ozturk, I., Afza, T., & Ali, A. (2013). Revisiting the environmental Kuznets curve in a global economy. *Renewable and Sustainable Energy Reviews*, *25*, 494-502.

Sari, R., Ewing, B. T., &Soytas, U. (2008). The relationship between disaggregate energy consumption and industrial production in the United States: an ARDL approach. Energy Economics, 30(5), 2302-2313.

Saikkonen, P. (1991). Asymptotically efficient estimation of cointegration regressions. Econometric theory, 7(01), 1-21.

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., &Leitão, N. C. (2013a). Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia. Renewable and Sustainable Energy Reviews, 25, 109-121.

Shahbaz, M., Khan, S., & Tahir, M. I. (2013b). The dynamic links between energy consumption, economic growth, financial development and trade in China: fresh evidence from multivariate framework analysis. Energy economics, 40, 8-21.

Solarin, S. A., &Shahbaz, M. (2015). Natural gas consumption and economic growth: The role of foreign direct investment, capital formation and trade openness in Malaysia. Renewable and sustainable energy reviews, 42, 835-845.

Shahbaz, M., Arouri, M., &Teulon, F. (2014). Short-and long-run relationships between natural gas consumption and economic growth: Evidence from Pakistan. Economic Modelling, 41, 219-226.

Saidi, K., Rahman, M. M., & Amamri, M. (2017). The causal nexus between economic growth and energy consumption: New evidence from global panel of 53 countries. *Sustainable cities and society*, *33*, 45-56.

Solarin, S. A., & Ozturk, I. (2016). The relationship between natural gas consumption and economic growth in OPEC members. *Renewable and Sustainable Energy Reviews*, *58*, 1348-1356.

Stern, D. I. (1993). Energy and economic growth in the USA: a multivariate approach. Energy economics, 15(2), 137-150.

Tamba, J. G. (2017). Energy consumption, economic growth, and CO2 emissions: Evidence from Cameroon. *Energy Sources, Part B: Economics, Planning, and Policy*, *12*(9), 779-785.

Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. Journal of econometrics, 66(1), 225-250.

Tugcu, C. T. (2014). Tourism and economic growth nexus revisited: A panel causality analysis for the case of the Mediterranean Region. *Tourism Management*, *42*, 207-212.

Union, E. (2009). Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. *Official Journal of the European Union*, *5*, 2009.

World Economic Forum. (2017). https://www.weforum.org/agenda/2017/04/who-s-the-best-in-europe-when-it-comes-to-renewable-energy/.

World Energy Resource. (2016). World Energy council. https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources-Full-report-2016.10.03.pdf

Wolde-Rufael, Y. (2005). Energy demand and economic growth: the African experience. Journal of Policy Modeling, 27(8), 891-903.

Xing, J. (2012). Tax structure and growth: How robust is the empirical evidence? *Economics Letters*, *117*(1), 379-382.

Yang, H. Y. (2000). A note on the causal relationship between energy and GDP in Taiwan. Energy economics, 22(3), 309-317.

Yu, E. S., & Choi, J. Y. (1985). The causal relationship between energy and GNP: an international comparison. The Journal of Energy and Development, 10(2), 249-272.

Yuan, J. H., Kang, J. G., Zhao, C. H., & Hu, Z. G. (2007). Energy consumption and economic growth: evidence from China at both aggregated and disaggregated levels. Energy Economics, 30(6), 3077-3094.

Zamani, M. (2007). Energy consumption and economic activities in Iran. Energy Economics, 29(6), 1135-1140.

Zivot, E., & Andrews, D. W. K. (2002). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of business & economic statistics*, *20*(1), 25-44.

Ziramba, E. (2009). Disaggregate energy consumption and industrial production in South Africa. Energy Policy, 37(6), 2214-2220.

Ziramba, E. (2015). Causal dynamics between oil consumption and economic growth in South Africa. *Energy Sources, Part B: Economics, Planning, and Policy*, *10*(3), 250-256.