Energy Markets and Environmental Sustainability: The Case of Three Emerging Economies

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ABSTRACT

The quest of ensuring that the standard of living for individuals in the society through improvement in the production process, consumption of goods and services, determination of market prices to allow easy and equitable access to finished goods come with consequences (or tradeoff with) on a sustainable environment. This has led to an extensive discourse on energy-growth-environment nexus. This thesis will take three dimensions as its structure. The first dimension of this thesis reaffirms that the critical role of energy in the industrial life of an economy. Theoretical and empirical evidence reveals that energy prices play an important role in affecting the economy’s productivity. Hence, we investigate the short-run and long-run effect of energy prices and total taxes of the variables of interest on energy consumption in Turkey. The ARDL technique was employed to analyze the short-run and long-run relationship between the variables of interest for the period 2000-2018 using quarterly data. The empirical results reveal that an increase in the tax of heavy fuel oil for electricity generation by one percent will lead to 0.0221% and 0.2540% increase in energy consumption in kg oil equivalent per capita in the short-run and long-run at 5% and 1% significance level respectively. A one percent increase in the PHFt will lead to a 0.0202% and 0.2104% increase in the long-run energy consumed at 5% and 1% level of significance in the short-run. Our findings suggest critical policy direction for the government, and stakeholders to have market-determined energy prices rather than government subsidizing consumption, and appropriate tax policy to ensure fiscal discipline and stability. The second focus primarily is to empirically investigate the natural gas consumption-economic growth nexus in Iran, while incorporating real gross fixed capital formation (GFCF) and the role of oil revenue (OR) as additional

variables to make it a multivariate framework to avoid possible omission variable bias in the estimations. The quarterly frequency data from 1990Q1 to 2017Q4 is used. The empirical results suggest that natural gas consumption exerts a significant positive impact on economic output in Iran, and also that there is a one-way causality from natural gas consumption to economic output. This study corroborates the natural gas-led growth hypothesis; being natural gas consumption a suitable alternative, as a complementary green energy source (IGU, 2015). There is a need for energy portfolio diversification in Iran to attain full gains from the energy sector, reducing other energies' emissions. The findings provide policymakers useful insight into the state of the energy sector in Iran.

Finally, modeling the dynamic nexus among coal consumption, pollutant emissions and real income with empirical evidence from South Africa were considered in this dissertation. This study explores the interaction among coal consumption, pollutant emissions and real income for South Africa in a multivariate setting. The annual frequency data spanning from 1965 to 2017 is used for analysis. Empirical evidence supports the validity of the inverted U-shaped pattern between energy consumption and environmental degradation in South Africa. The Toda-Yamamoto Granger causality test shows a feedback causality between economic growth and carbon dioxide emissions, as well as between GDP and coal consumption. Based on these outcomes, policy directions such as diversification of the South Africa energy mix to renewables and cleaner energy sources and also the adoption of carbon capturing and storage techniques were suggested to engender a cleaner and friendlier environment.

Keywords: Energy prices, Energy consumption, Coal consumption, CO_2 emissions, Economic growth, Sustainable environment, EKC, Turkey, Iran, and South Africa.

ÖZ

Üretim sürecinde iyileştirme, mal ve hizmetlerin tüketimi, mamul malların dünyanın geri kalanıyla birbirine bağlı ve iyi koordine edilmiş bir şekilde birbirine kolay ve adil bir şekilde erişebilmesi için piyasa fiyatlarının belirlenmesi yoluyla toplumdaki bireyler için yaşam standardının sağlanması arayışı genellikle sürdürülebilir bir çevre üzerinde sonuçlar doğurur (veya dengede kalır). Bu, enerji-büyüme-çevre bağlantısı üzerinde kapsamlı bir konu yaratmıştır. Bu tez üç kısıma ayrılmıştır. Bu tezin ilk kısmı, bir ekonominin endüstriyel yaşamında enerjinin kritik rolünün vardır. Ayrıca teorik ve ampirik bulgular, enerji fiyatlarının ekonominin verimliliğini etkilemede önemli bir rol oynadığını göstermektedir. Bu nedenle, Türkiye'de enerji fiyatlarının kısa vadeli ve uzun vadeli etkisinin ve ilgili değişkenlerin toplam vergilerinin enerji tüketimi üzerindeki etkisinin araştırılmasına ihtiyaç duyulmaktadır. İlgili değişkenler arasındaki kısa dönemli ve uzun dönemli ilişkinin 2000-2018 dönemleri için çeyreklik veriler kullanılarak analiz edilmesi için gecikmesi dağıtılmış otoregresif sınır testi, (ARDL) tekniği kullanılmıştır. Ampirik sonuçlar, elektrik üretimi için ağır akaryakıt vergisinde yüzde bir artışın, kısa vadede ve uzun vadede kişi başına kg yağ cinsinden% 5 ve %1 anlamlılık düzeyinde enerji tüketiminde% 0,0221 ve% 0,2540 artışa yol açacağını göstermektedir. Bulgularımız, hükümetin, politika yapıcıların ve diğer paydaşların, hükümeti tüketime sübvanse etmek yerine piyasa tarafından belirlenmiş enerji fiyatlarına sahip olmaları için kritik politika yönelimi ve mali disiplini ve istikrarı sağlamak için uygun vergi politikasını önermektedir. İkinci odak noktası, İran'daki doğal gaz tüketimi-ekonomik büyüme ilişkisini ampirik olarak araştırırken, tahmin sonuçlarında olası ihmal değişken sapmasını önlemek için modeli çok değişkenli bir çerçevede inceleyebilmek için ek değişkenler olarak gerçek brüt sabit

sermaye oluşumunu (GFCF) ve petrol geliri (OR) modele dahil edilmiştir. Bu amaçla, 1990 ve 2017 dönemleri için çeyreklik veriler kullanılmıştır. Analiz sonuçları, yapısal kırılmayı açıklarken değişkenler arasında bir eşbütünleşme ilişkisini göstermektedir. Ampirik bulgular, doğal gaz tüketiminin İran'daki ekonomik çıktı üzerinde önemli bir pozitif etki yaptığını ve doğal gaz tüketiminden ekonomik çıktıya tek yönlü bir Granger nedensellik ilişkisi olduğunu göstermektedir. Bu nedenle, bu çalışma doğal gaz kaynaklı büyüme hipotezini desteklemektedir; ayrıca tamamlayıcı yeşil enerji kaynağı olarak doğal gaz tüketimine uygun bir alternatif olmaktır (IGU, 2015). Bu çalışmada varılan önemli sonuçlardan biri, İran'da enerji sektöründen tam kazanılan ve diğer enerjilerin emisyonlarını azaltan enerji portföyü çeşitlendirmesine ihtiyaç olduğu yönündedir. Ana metinde daha detaylı açıklanmalar bulunmaktadır. Araştırma bulguları, politika yapıcılara İran'daki enerji sektörünün durumu hakkında yararlı bilgiler vermektedir. Son olarak, bu çalışmada kömür tüketimi, kirletici emisyonları ve gerçek gelir arasındaki dinamik bağın Güney Afrika'dan ampirik kanıtlarla modellenmesi düşünülmüştür. Bu çalışma, çok değişkenli bir ortamda kömür tüketimi, kirletici emisyonları ve Güney Afrika için gerçek gelir arasındaki etkileşimi araştırmaktadır. Bu amaca ulaşmak için, 1965'ten 2017'ye kadar olan yıllık veriler kullanılmaktadır. Ampirik bulgular, Güney Afrika'daki enerji tüketimi ve çevresel bozulma arasındaki U şeklindeki modelin geçerliliğini desteklemektedir. Toda-Yamamoto Granger nedensellik testi, ekonomik büyüme ve karbondioksit emisyonları ile GSYİH ve kömür tüketimi arasında çift yönlü nedenselliğini göstermektedir. Bu sonuçlara dayanarak, Güney Afrika enerji karışımının yenilenebilir enerji kaynaklarına ve daha temiz enerji kaynaklarına çeşitlendirilmesi ve aynı zamanda daha temiz ve daha dostça bir ortam oluşturmak için karbon yakalama ve depolama tekniklerinin benimsenmesi gibi politika yönleri önerilmektedir.

Anahtar Kelimeler: Enerji fiyatları, Enerji tüketimi, Kömür tüketimi, Karbon emisyonları, Ekonomik büyüme, Sürdürülebilir çevre, Çevresel Kuznets Eğrisi, Türkiye, İran ve Güney Afrika.

DEDICATION

To my creator and maker, God Almighty, the sustainer, provider

and the one who holds my life.

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey Fuller
AIC	Akaike Information Criteria
ARDL	Autoregressive Distributed Lag
BH	Bayer and Hanck
CCR	Canonical Cointegration Regression
CGE	Computable General Equilibrium
CO_2	Carbon Dioxide Emissions
DF-GLS	Dickey and Fuller Generalized Least Squares
DOLS	Dynamic Ordinary Least Squares
EC	Energy Consumption
ECM	Error Correction Model
EIA	Energy Information Administration
EKC	Environmental Kuznets Curve
ERS	Kapetanios et al
FMOLS	Fully Modified Ordinary Least Square
FPE	Final Prediction Error
GDP	Gross Domestic Product
GFCF	Gross Fixed Capital Formation
GHG	Green House Gas
HELE	High Efficiency Low Emission
HQ	Hannan Quinn
IEA	International Energy Agency
IMF	International Monetary Funds

KPSS	Kwiatkowski, Phillips, Schmidt and Shin
MWALD	Modified Wald Methodology
NG	Natural Gas
NGC	Natural Gas Consumption
OECD	Organization for Economic Co-operation and Development
OPEC	Organizations of Petroleum Exporting Countries
OR	Oil Revenue
PE	Price of Electricity
PHF	Price of Heavy Fuel
PNG	Price of Natural Gas
PP	Phillips Perron
PSC	Price of Steam Coal
RGDP	Real Gross Domestic Product
SDG	Sustainable Development Goals
SIC	Schwarz Information Criteria
STIRPAT	Stochastic Impacts by Regression on Population, Affluence and Technology
TE	Total Tax of Electricity
THF	Total Tax of Heavy Fuel
TNG	Total Tax of Natural Gas
TSC	Total Tax of Steam Coal
TY	Toda-Yamamoto
UN	United Nations
VAR	Vector Auto Regressive
VECM	Vector Error Correction Model

WDI	World Development Indicator
ZA	Zivot-Andrews

Chapter 1

INTRODUCTION

The benefits of energy consumption are not maximized without the consequences of such consumption on the sustainability of the environment. The need to meet human numerous demands by way of ensuring the standard of living in society puts pressure on the production and consumption of goods and services. The importance of energy consumption to the growth of the economy in the last two or three decades has been strongly acknowledged not only by economists but also by policymakers, engineers, businessmen, government and energy agencies. As outlined by EIA, 2018, that there is a connection between the country's economy and its energy consumption. The demand for energy consumption has to increase swiftly, mostly for natural gas and oil, this is a result of the rapid increase in economic growth across the globe. Furthermore, the contributory link between NGC and economic growth has been an interesting point for many researchers (Lee and Chang, 2005; Zamani 2007; Isik, 2010 or Solarin and Shahbaz, 2015, among others); the link between globalization and pollutant emissions vis-à-vis carbon emissions, greenhouse gas and other environmental or anthropogenic gases (Destek & Ozsoy, 2015; You & Lv, 2018; Saint Akadiri, Alola & Akadiri, 2019; Khan, Teng & Khan, 2019; Pata, 2019; Shahbaz *et al.*, 2019).

This PhD thesis is premised on the theoretical framework of Simon Kuznets (1955) which has gained so much popularity over the years and has become one of the foundational blocks in the energy literature especially as it is used to represent the concept of Environmental Kuznets Curve Hypothesis (EKC). A systematic way of determining the exploitation of the environment at the expense of growing the economy is the core concept of EKC. This concept considers the relationship between economic growth and inequality. The idea of measuring carbon dioxide emissions in the environment as a direct consequence of energy-related economic activities is captured by the concept of EKC. Several studies as documented in the literature have validated the EKC hypothesis after Grossman and Krueger (1995) made the idea popular (Katircioğlu & Katircioğlu, 2018; Katircioğlu & Taşpinar,2017; Katircioğlu,2014). This thesis generally contributes to the frontier of knowledge by interrogating the energy consumption pattern as basically influenced by the prices and taxes of identified variables used in the study, the nexus of intense energy consumption and the determinant of carbon dioxide emissions in maintaining the path of economic growth and environmental sustainability.

The first strand of this dissertation considers the causality effects of energy prices on energy consumption, the perspective is derived from the insights of the Turkish economy.

Energy is one of the major inputs in the production process of an economic activity that ensures that goods and services either as complements or substitute are produced. The production of these goods and services faces price fluctuations which affect the supply amount and consequently affect the capacities and functionalities of the various sector of the economy. Industries are key players in the development strides of any nation, energy inputs are fundamental to industries operations across the globe as the share of domestic production among the global energy products has grown over the years.

Given the regular conditions of demand and supply, price is the major determinant of the quantity of energy to consume, however, the total tax of heavy fuel oil (THF hereafter), total tax of natural gas (TNG), total tax of steam coal (TSC) and total tax of electricity (TE) also affect energy consumption pattern as these taxes are transferred totally to the final consumer; this means that changes in taxes will result in changes in prices (Marion and Muehlegger, 2011). We can deduce that the association between tax and consumption can be converted into the relationship between price and consumption. Therefore, prices and taxes of the variables under consideration do influence the energy consumption pattern in a significant way.

The second strand of this dissertation explores the interaction between natural gas consumption and economic growth, but this time by extending the bi-variate framework to a multi-variate through the incorporation of an additional important variable. This is significant to the addition of extant literature and expansion of the knowledge frontiers in the following ways: (i) the natural gas (NG) economic growth nexus is augmented with real gross fixed capital formation (GFCF) to ascertain the role of capital in economic output as well as oil rent-seeking which plays a vital role in Iranian economy which has not been properly documented in the literature. Also, it explores the role of non-oil GDP on NG consumption in Iran's economic output given its peculiarity. A good understanding of the interaction among the variables of interest will be helpful to the government and other relevant stakeholders to engage in meaningful, constructive and robust energy-growth-environmental policy construct. The second section of this study beams its searchlight on Iran being the neighboring country of Turkey who supplies oil and gas. In conclusion, we will then be able to compare Iran and Turkey, as well as Turkey and South Africa, as emerging economies with similar considerable economic sizes.

The last strand of this dissertation considers modeling the dynamic nexus among coal consumption, pollutant emissions and real income: empirical evidence from South Africa. A major challenge facing any country of the world endowed with non-renewable energy resources is the ability to formulate energy and environmental strategic policies such that safe and secured energy is produced to meet energy needs while reducing significantly carbon dioxide (CO_2) emissions (WCA, 2019). This challenge requires growing attention as demand for energy is rising (EIA, 2018). The primary priority of players in this sector is to diversify energy sources and discover a secure and stable energy supply (Gnansounou, 2008; Ferguson, 2007; Toth and Rogner, 2006). The majority of the endowment reserves (that is, crude oil and natural gas) sources are found around a certain geographical region of the world and specifically, about 68% and 67% respectively are located in the Middle East and Russia. This suggests high risk to countries that depend significantly on the importation of energy as there may be instability and the supply of these resources would not be guaranteed (WCA, 2018). Ensuring the sustainability of crude-oil supply has been of top priority to countries bringing in oil especially after the crisis of 1973. Safeguarding the supply of oil in the oil-importing countries of the world has necessitated the search for an alternative source of domestic energy. This motivated the quest for another source of low-priced energy supply from many energy-importing countries, as it is captured in their policy and strategy documents (Toth and Rogner, 2006).

Coal is globally abundant and most cheap in respect of fossil fuel. With the need for cheap alternative energy supply sources, coal has the capability of providing adequate demand for secured energy (WCA, 2018). Although coal enjoys acceptance as a creditable source of energy due to the earlier factors mentioned, there is also a group of persons that believe that global warming can be traced to the high consumption of coal which usually results in the carbon dioxide (CO_2) emission increase from burning coal. This study, therefore, explores the interaction among coal consumption, pollutant emission and real income for the South African economy using the multivariate framework and seeks to investigate Environmental Kuznets Curve (EKC) by incorporating coal consumption.

Given the above premise, the following research questions are germane to making meaningful contributions to the frontier of knowledge: (1) what are the disaggregated impact of energy prices on energy consumption and consequently Turkey's economic growth path? (2) what impact does the disaggregated energy taxes have on energy consumption? (3) what is the impact of augmented NG economic growth nexus with real gross fixed capital formation on Iran's economic outlook? (4) what is the relationship between non-oil GDP and NG consumption in Iran's economic output? (5) what effect does the interaction of coal consumption, pollutant emissions and real income have on the South African economy? (6) does the coal consumption extended EKC hypothesis hold for South Africa?

Finally, the concluding section of this dissertation will highlight the major findings, provide answers to the research questions and contribute to the existing knowledge as well as put forward policy implications, comparing Turkey with the other two emerging economies with similar sizes to make policy suggestions that will be needed by various stakeholders in making sound and reliable decisions.

Chapter 2

THE IMPACT OF ENERGY PRICES AND TAXES ON ENERGY CONSUMPTION: INSIGHTS FROM TURKEY

2.1 Introduction

The price of energy does have a significant effect on energy consumption, just as a total tax on energy also affects the consumption and even improvement in the usage of energy by extension. There is a connection between energy prices and their consumption which is fundamental and intuitive. Over the years there has been a discussion on the fluctuation of energy prices. From the theoretical perspective, on the assumption of ceteris paribus, the classical economics opine that there is an inverse relationship between price and quantity demanded of a normal good. From the basic knowledge of economics, we can suggest strongly that negative and positive signs define the relationship that exists between energy prices, total taxes, and energy consumption. Extant empirical studies reveal the predisposition of the negative energy price relationship to forecast (Tang and Tan 2012, 2013, 2014; Fatai et al. 2003; Conrad 2000) as well as positive energy price association (Conrad 2000). Also, Tang and Tan (2014) suggest how weak the negative price-quantity relation is in their study. Determining the effect of energy prices and total taxes on energy consumption are supposed to be heteroscedastic when considering the time frame i.e the short and long-run, direction and to what extent is the impact of these variables on energy consumption. Economic behaviors have been observed in the short-run to lack elasticity. So, the changes in the energy prices and total taxes have little or no effect on the energy consumed efficiently whereas it has an inverse effect on energy consumed in a careless manner (inefficiently). On the other hand, changes in energy prices and total taxes do have an inverse effect on energy consumed both in the short and long-run, irrespective of the efficiencies and inefficiencies that occur during the period of energy consumed. The elasticity of energy consumption in the long-run would cause price elasticity of energy not consumed in an optimal way to be higher in the short-run than in the long-run. Therefore, it is important to carefully evaluate the energy prices and total taxes relationship with energy consumption, such that the results arrived at will not be misleading when used to develop a blueprint of policies. Energy is one of the major inputs in the production process of an economic activity that ensures that goods and services either as complements or substitute are produced. The production of these goods and services faces price fluctuations which affect the supply amount and consequently affect the capacities and functionalities of the various sector of the economy. Industries are key players in the development strides of any nation, energy inputs are fundamental to industries operations across the globe as the share of domestic production among the global energy products has grown over the years.

Given the regular conditions of demand and supply, price is the major determinant of the quantity of energy to consume, however, the total tax of heavy fuel oil (THF hereafter), total tax of natural gas (TNG hereafter), total tax of steam coal (TSC hereafter) and total tax of electricity (TE hereafter) also affect energy consumption pattern as these taxes are transferred totally to the final consumer; this means that changes in these taxes will result in changes in prices (Marion and Muehlegger, 2011). We can deduce that the association between tax and consumption can be converted into the relationship between price and consumption. Therefore, prices and taxes of the variables under consideration do influence the energy consumption pattern in a significant way. This thesis investigates the consequences of the price of heavy fuel oil for electricity generation (hereafter referred to as PHF), price of natural gas for electricity generation (PNG hereafter), price of steam coal for electricity generation (PSC hereafter) and price of electricity for Industry (PE hereafter) alongside with the total taxes associated with each of the earlier mentioned, on energy consumption pattern of Turkey. The remaining part of this study will follow this sequence: section 2.2 presents the literature review of the study, section 2.3 will discuss the methodological framework for the study, section 2.4 presents empirical results and discussion. Section 2.5 provides the conclusion and policy implications.

2.2 Literature Review

The relationship between energy consumption, energy price and tax policy in recent time have received considerable attention from researchers and scholars in the literature. Most of the studies with these nexuses were inclined with the negative price form of responsiveness and their basis for this position can either be traced to theoretical underpinning or economic insight or reasoning. This position as held by researchers can be attributed to the following reasons: (1) from the perspective of the researcher and (2) the kind of estimating techniques employed in the study. However, according to the knowledge of the authors, no study has examined energy consumption and considering energy prices and total taxes to ascertain the level of energy consumed.

Studies over the years have concentrated on energy consumption determinants and consider energy price as a critical factor. According to Adom et al. (2012), efforts were directed to identify the factors responsible for total electricity demand, also measure the short and long-run effect over the sample period of 1975 to 2005 in Ghana employing the ARDL bounds technique. The study considered electricity price with per capita GDP, industrial electricity efficiency and the degree of urbanization as critical factors in determining the electricity demand function.

Fatai et al. (2003) constructed a model to forecast the electricity demand for New Zealand with data span covering from 1960 to 1999 using the ARDL, error correction model (ECM), and FMOLS technique. From the empirical results, the following factors: electricity's relative price in the industrial sector, temperature and total production impacts demand for electricity; the negative elasticities of electricity price with the three techniques earlier mentioned were revealed as 0.18, 0.24 and 0.19 in the short-run and 0.59, 0.55 and 0.44 in the long-run accordingly. Tang and Tan (2012) revisited the relationship between electricity consumption and economic growth in Portugal from 1974 to 2008 employing the error correction model. The result of the empirical analysis showed the critical role of income and employment to determine the consumption of electricity, whereas energy price elasticity was shown to be 0.157 in the long-run and 0.482 in the short-run both in the negative.

Holtedahl and Joutz (2004) in their study evaluated demand in Taiwan with regards to residential electricity given the price of electricity, household disposable income, degree of urbanization and population growth covering the period of 1955 to 1995 employing the ECM technique. The results revealed that the energy price elasticity to be -0.15 in the long-run and -0.154 in the short-run. Also, Atakhanova and Howie (2007) examined the electricity demand in Kazakhstan between the period of 1994 to 2003 using panel data techniques. The explanatory variables in the model include electricity price, industrial efficiency, income growth and population. The results from the empirical analysis revealed that electricity had a low-price elasticity for which was not statistically significant to enable the rejection of the null hypothesis.

Furthermore, previous studies have investigated the effect of energy prices on energy consumption directly and the outcome of these studies show an observable nexus between energy prices and energy consumption. Several studies are in agreement that an increase in energy prices resulting to decline in energy consumption such as Li and Lin (2015); Fei and Rasiah (2014); IMF (2013), and Martinsen et al. (2007). Some studies were aimed at considering the channels by which energy prices influence energy consumption. According to Zhang et al. (2014a, b), the study revealed that impact of increasing energy prices on energy consumption is evident in the transportation sector, whereas Zafeiriou et al. (2014) holds that increases in energy prices led to a reduction in energy consumption of the traditional sources through the stimulation of consumers’ preferences for new energy sources as opposed to the old ones with high prices. Nevertheless, Steinbuks and Neuhoff (2014) in their study hold the opinion that improvements in energy efficiency, as well as reductions in energy inputs due to an increase in energy prices, are the major causes of the decline in the consumption of energy.

Tang and Tan (2013) studied the impact of energy prices, economic growth and technological innovation on electricity consumption in Malaysia. This study employed the error correction model technique with the covering from 1970 to 2009. The results from the analysis suggest a -1.685-electricity price elasticity in the long term. Also, Tang and Tan (2014) considered the contributory relationships between energy consumption, financial development, economic growth, relative price and FDI in

Malaysia employing the error correction model technique over 1972 to 2009. The results revealed no significant evidence in the short-run but on the long-run energy price elasticity showed a significant elasticity coefficient as -1.0352.

From the empirical study of Martinez and Ines (2011) the outcome reveals that energy prices are not the key factor to improving energy efficiency whereas most studies align with the positive nexus between energy prices and energy efficiency, by extension to the confirmation of the positive impacts of increasing energy prices for industrial energy savings Apeaning and Thollander (2013); Chen and Wu (2011); Wing (2008); Fisher-Vanden and Jefferson (2004) and Birol and Keppler (2000). Other studies evaluated the unpredictability that characterizes the relationship between energy prices and energy intensity which is not limited to the non-linear effects (Kaufman 2004), regional differences (Yang 2011); asymmetric impacts (Hang and Tu 2007) and even dynamic effects (Adofo et al.2013). From the studies mentioned above, it is obvious that higher energy prices have an impact on energy saving, but a look from a macro viewpoint, suggests that energy prices are interrelated with other aspects of the economy.

Semboja (1994) affirm that the effective policy tool to control energy consumption and at the same time increase the government revenue is the use of energy tariffs and sales taxes which was carried out in studying the economic impact of energy taxes on Kenya’s economy. Ghalwash (2007) in a study used an econometrics model to examine the impact of environmental taxes on consumer demand in Sweden. The result of this analysis revealed that there is a negative price elasticity in all the energy prices and positive elasticity with income, whereas the environmental tax had an indeterminate effect on energy consumption. The outcome of this analysis corroborates with the underlying behavior of demand, supply, and income relationship. The price elasticity of heating energy products is usually seen to be lower than the tax elasticity which is seen to be higher than the original commodity. Bento et al. (2009) in their study about the refined oil vehicles where the vehicles were grouped into different categories and considerations was based on the heterogeneity of households and motor vehicles. The study advocates that with an increase in gasoline prices by one cent per gallon, gasoline consumption declines by 0.20%. In the case of a tax rebate, an increase in gasoline prices by 25% will result in an average of $30 annual expenditure for each household. This shows that the impact of increasing gasoline taxes on the expenditure of households to a large extent depends on the proportion of tax rebates. Cao (2007) in his study used the recursive dynamic CGE model and the result showed that the flow of population migration from urban to a rural area can be hindered by the implementation of fuel tax policy, also this can slow down economic development through worsening the distortions of the relevant labor market.

In recent studies, scholarly literature abounds in the area of energy price elasticity and energy tax in many developing and developed economies of the world. For instance, the investigation on China's refined oil price elasticity, tax and demand relations, as well as tax policies and carbon dioxide emissions reduction. It is important to note that fiscal policy is necessary to guide and influence energy consumption.

Soytas and Sari (2003) in their scholarly article holds the argument that energy consumption affects economic growth in Korea and Italy, whereas a one-way causality was seen from energy consumption to economic growth in countries like Turkey, Germany, and Japan. Masih and Masih (1996) with studies on some developed economies found a one-way causality from energy consumption to economic growth in India but in the case of Pakistan and Indonesia, the unidirectional causality was from economic growth to energy consumption. Huang et al. (2008) in their studies found evidence for the neutrality hypothesis for the low-income economies, however, regardless of the results found by Shahbaz and Lean (2012), Aqeel and Butt (2001), Shahbaz and Feridun (2012), for Pakistan, Lee (2006) for the case of Italy, France and Japan, Lee and Chian (2010) for the case of France and Japan was different. Lee (2006) for the cases of the United Kingdom, Canada, Sweden, Germany, and Switzerland discovered a one-way causality running from economic growth towards energy consumption, and Narayan and Smyth (2009) for the G-7 countries also found a one-way causal relationship running from the economic growth to energy consumption.

Mykata and Mulder (2003) in their study of the energy consumption efficiency using fifty-six (56) countries with ten industrial activities from both developing and developed countries found that the role of energy prices is limited in the development of energy consumption efficiency whereas technology change was considered an important factor in energy consumption efficiency growth. This implies that the transfer of technology and technical knowledge is very important among the various economies of the world. Adenikinju and Olumuyiwa (1999) evaluated the relationship between energy consumption and improving productivity in the manufacturing industries in Nigeria. The empirical results of this study revealed that with technological improvement in the manufacturing sector (including Nigeria and other countries in the world) properly achieved, then significant outcomes will be experienced from reforming energy prices. The results from this study revealed an energy-efficient know-how in the industrial sector of the economy. Furthermore, energy prices can help in determining the real cost of production inputs and this will result in energy consumption efficiency for the producers as well as offer a combination of inputs that have the least cost of production. According to (2017), India witnessed a scenario where the doubling of energy prices resulted in a decline of productivity by 7% in the industrial sector of the economy whereas in the case of Canada productivity in the long-run was hardly affected in the industrial sector unlike India, increase in the energy prices has a negative impact on productivity and consequently reduces the welfare. From a general perspective, results from studies have it that energy prices lack the capacity to ensure an effective role in the development of energy consumption efficiency. However, technological improvement is known to increase energy consumption efficiency as well as plays a critical and greater role relative to advancing towards less-energy consuming industries.

Having known how central the place of energy is the industrial life of any economy, and how other sectors of the economy depend on it for smooth operations to take place, we can suggest that one important factor out of the many that theoretically and empirically affect economy's productivity is energy prices. Hence, this research study seeks to examine or investigate the effect of energy prices and total taxes as well as its relationship on energy consumption in Turkey.

In the real sense of it, for any economy to attain technical progress and optimal utilization of the industrial and energy structures, then there must be an effective driving force. This force would require some form of external guide and coordination. One of these means is the price which plays a major role. The role of energy prices and its impact on technology, industries, and energy structures are documented in the literature in the studies by Valadkhani and Babacan (2014); Wing (2008); Birol and Keppler (2000), and Finn (2000). In situations where the government gets too involved in determining the allocation of resources without allowing the market forces through price mechanism to determine it, what will happen in such a case is that energy prices cannot play its critical role in allocating scarce resources efficiently.

On the other hand, there is an agreement that rising energy prices are an effective tool in energy consumption reduction. However, with the knowledge of the role of energy prices through the interaction between the forces of demand and supply, the government can interface minimally by regulating energy prices through finance and tax policies in the long-run whose benefit will not just be limited to energy saving but will be helpful to curb inflation in the economy.

2.3 Methodological Framework of the Effect of Prices and Taxes on Energy Consumption

The consumer is always known to bear the burden of taxes usually passed to the demand side in the form of high prices as shown in Marion and Muehlegger (2011). So, we take the analysis of the effect of consumption tax on demand and substitute with investigating the effect of price on demand. This section of the study will focus basically on the introduction of the data used and the estimation techniques employed given the variables chosen.

2.3.1 Data

This study uses quarterly data gathered from World Development Indicator as published by the World Bank (2019). The quarterly data were interpolated from the annual series. Energy prices data was sourced from the International Energy Agency (OECD/IEA) quarterly series. It is important to note that the energy prices refer to the weighted average index representing the industry and the household using Turkey as the case study. To achieve homogeneity in the empirical analysis, the series will be converted to logarithmic form. Table 1 offers a description of the data while Tables 2 and 3 report basic summary statistics and correlation matrix analysis.

Table 2.1: Variable Description

Variables	Symbols	Unit of Measurement	Data Sources
Energy Consumption	EC	Kg of oil equivalent per capita	World Bank
Prices of Heavy Fuel Oil	PHF	Per tonne	IEA
Total Tax of Heavy Fuel Oil	THF	Per tonne	IEA
Prices of Natural Gas	PNG		IEA
Total Tax of Natural gas	TNG	Per MBtu	IEA
Prices of Steam coal	PSC	Per tonne	IEA
Total Tax of Steam Coal	TSC	Per tonne	IEA
Prices of Electricity	PE	Per megawatt	IEA
Total Tax for Electricity	TE		IEA

Source: Author's compilation
OECD/IEA International Energy Agency, Quarterly Statistics, Energy Prices and Taxes, Quarterly Volumes 1999-2018, Paris. (Data gathered from the sources of Ministry of Energy and Natural Resources of Turkey, Eurostat (Retail Energy Prices), Energy Market Regulatory Authority of Turkey (for Oil prices), Turkish Hard Coal Enterprises Institution (for Coal Prices) and Directorate General of Petroleum Pipeline Corporation-BOTAŞ (for Natural Gas Prices), Turkey. For details see page 294.

2.3.2 Model Structure

This study will use the logarithm model of energy consumption demand, prices of heavy fuel oil, natural gas, electricity, steam coal, and taxes of heavy fuel oil, natural gas, electricity and steam coal. This model will be expressed as:

$Q = f(P_i, T_i)$

where Q is defined as energy consumption, P_i represents the average prices of heavy fuel oil, natural gas, electricity and steam coal, and T_i denotes total taxes of heavy fuel oil, natural gas, electricity and steam coal. These variables will be used in constructing eight models in other to establish the relationship and impact of prices and taxes on energy consumption. In an attempt to avoid multicollinearity problems between average prices and total tax variables in our estimates the parameters will be assessed individually and it is important to note that the prices and taxes are for electricity generation (power sector or in another words transformation sector) except for electricity which is generated for the industry.

The logarithmic model predicting energy consumption demand is more suitable compared to the linear model. It is expressed as:

$$lnEC_t = \beta_0 + \beta_1 lnPHF_t + \varepsilon_t \tag{2.1}$$

$$lnEC_t = \beta_0 + \beta_1 lnTHF_t + \varepsilon_t \tag{2.2}$$

$$lnEC_t = \beta_0 + \beta_1 lnPNG_t + \varepsilon_t \tag{2.3}$$

$$lnEC_t = \beta_0 + \beta_1 lnTNG_t + \varepsilon_t \tag{2.4}$$

$$lnEC_t = \beta_0 + \beta_1 lnPSC_t + \varepsilon_t \tag{2.5}$$

$$lnEC_t = \beta_0 + \beta_1 lnTSC_t + \varepsilon_t \tag{2.6}$$

$$lnEC_t = \beta_0 + \beta_1 lnPEt + \varepsilon_t \tag{2.7}$$

$$lnEC_t = \beta_0 + \beta_1 lnTE_t + \varepsilon_t \tag{2.8}$$

where EC_t represents energy consumption at time t; PHF_t denotes the price of heavy fuel oil for electricity generation at time t, and THF_t represents a total tax of heavy fuel oil for electricity generation in time t. From Equation 2.3 and 2.4, PNG_t represents the price of natural gas for electricity generation at time t and TNG_t denotes total tax of natural gas for electricity generation at time t. Equations 2.5 and 2.6 have the following variables where PSC_t denotes the price of steam coal for electricity generation at time t while TSC_t represents a total tax of steam coal for electricity generation at time t. Equations 2.7 and 2.8 have the following notations where PE_t refers the price of electricity for the industry and TE_t denotes total tax of electricity for the industry. The error term with zero mean is denoted with ε_t at time t whereas β_1 represents the slope coefficient of the variables and β_0 is the intercept or constant term.

The study will follow the procedure of testing for stationarity among the series, then the ARDL bounds test, Long-run, and Short-run ARDL will be conducted, FMOLS, DOLS, and CCR will be carried out and finally the Granger causality test.

2.3.3 Stationarity Test

Time series data usually require some form of stability as a basis for conducting an econometric analysis. This study employs the Augmented Dickey-Fuller (1981) with Phillips and Perron (1988) unit root tests for the variables under consideration. Although these tests have a shortfall of providing inconsistent and spurious results when confronted with structural breaks, the Zivot-Andrews (ZA) as an alternative technique provides the capacity to capture structural breaks in uniquely and further allows for robustness in estimation. The null hypothesis (H_0: p = 0) holds the assumption of the presence of unit root in the series whereas the alternative hypothesis (H_1: p = 1) refutes the position that there is a unit root. Stationarity is said to be in existence when the null hypothesis is rejected, implying that there is no unit root (no random walk) in the series, meaning the series are stationary. The Zivot-Andrews test is modeled empirically to capture a single structural break in the following manner such as:

$$\Delta Y_t = \vartheta_1 + \vartheta_2 t + \varphi Y_{t-1} + \gamma DU_t + \sum_{i=0}^{k} \xi_i \, \Delta Y_{t-i} + \varepsilon_t \tag{2.9}$$

$$\Delta Y_t = \vartheta_1 + \vartheta_2 t + \varphi Y_{t-1} + \phi DT_t + \sum_{i=0}^{k} \xi_i \, \Delta Y_{t-i} + \varepsilon_t \tag{2.10}$$

$$\Delta Y_t = \vartheta_1 + \vartheta_2 t + \varphi Y_{t-1} + \gamma DU_t + \phi DT_t + \sum_{i=0}^{k} \xi_i \, \Delta Y_{t-i} + \varepsilon_t \tag{2.11}$$

Here, DU_t represents the dummy variable which shows the shift that occurs at each point of possible breaks at either intercept, trend or a combination of intercept and trend. The ZA unit root test has a null hypothesis of (unit root), meaning, H_0: $\varphi > 0$ against an alternative (stationarity), H_1: $\varphi < 0$. That is, failure to reject H_0 means the presence of unit roots while and rejection implies stationarity.

2.3.4 Autoregressive Distributed Lag Technique

With the decision of stationarity from the unit root test in the series, a further step is taken to establish and explore long term equilibrium relationships within the variables under consideration. The ARDL bounds test is a good measure of cointegration especially when using a not too large sample, it is efficient and robust in establishing cointegration. It comes with a unique feature of fitted regression dynamics as well as error correction dynamics for both the short-run and the long-run. It can also be used in determining the unknown order of integration of variables. The model is estimated in the bounds test framework via the unrestricted error correction model where all variables are taken as endogenous. The UECM is estimated as:

$$\Delta Y = \mu_0 + \mu_1 t + \lambda_1 y_{t-1} + \sum_{i=1}^{N} \theta_1 v_{it-1} + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \sum_{i=1}^{N} \sum_{j=1}^{P} \omega_{ij} \Delta V_{it-j} + \Psi D_t + \varepsilon_t \tag{2.12}$$

where *Vt* denotes vector; *Dt* accommodates for a structural break in the framework as an exogenous variable. The test has a null of no cointegration with the bounds test, which is computed using F-statistics. The following are the possible decisions from cointegration: (a) when the null hypothesis is validated with the F statistics computed from the bounds test, then this is a case of no cointegration. (b) when the F value computed is higher than the upper bounds of the critical values reported, then reject the null hypothesis of no cointegration, meaning there is cointegration in the series. (c) when the F value lies between the upper and lower bounds, this case is referred to as being inconclusive. The ARDL bounds test is expressed as follow:

$$\Delta LnY_t = \beta_0 + \sum_{i=1}^{m} \alpha_i \Delta lnY_{t-i} + \sum_{i=0}^{m} \delta_i \Delta lnX_{t-i} + \lambda_1 \Delta lnY_{t-1} + \lambda_2 lnX_{t-1} + \varepsilon_t \tag{2.13}$$

Where β_0 indicates the intercept and ε_t denotes the error term. The first part of equation 2.13 represents the error correction dynamics of the model and the second part of the equation 2.13 represents the long-run relationship of the model. The bounds test suggests a long-run equilibrium relationship among the variables as shown between the null and alternative hypothesis expressed:

H_0: $\lambda_1 = 0$ (2.14)

H_1: $\lambda_1 \neq 0$ (2.15)

2.3.5 Granger Causality Test

There is a consensus in the econometrics literature that traditional regression does not necessarily mean causal relationships. Thus, the reason and motivation of establishing the direction of causality between the variables of interest. This is needful to provide government, policymakers, and stakeholders with sufficient predictability power given the variables of interest. Granger causality test validates whether any lag value of a series affects the current value of the other variables. Suppose that X granger cause Y, this will imply that in the total realizations taking into account both the past and the present, X is suggested as a good predictor of variable Y. The bivariate form can be expressed as:

$X_t = \beta_0 + \beta_1 X_{t-1} + \beta_2 Y_{t-1} + \varepsilon_t$ (2.16)

$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 X_{t-1} + \varepsilon_t$ (2.17)

The equation above can be tested by using the null hypothesis against the alternative hypothesis and vice versa. The following are the different forms that granger causality can take (a) unidirectional meaning an interaction from either X to Y or from Y to X (b) bidirectional denoting two-way relationship (feedback) and (c) neutrality implying no interaction between the X and Y variables.

2.3.6 Cointegration Estimation

The cointegration regression usually follows after determining the long-run relationship among the variables of interest. They include the following fully modified ordinary least squares (FMOLS) as brought forward by Phillips and Hansen (1990), dynamic ordinary least squares (DOLS) as advanced by Stock and Watson and finally Park's (1992) Canonical Cointegration Regression (CCR). They cointegration regression model is unique in that it offers reliable estimates especially for small samples and also provides a robust check to the regression estimation.

2.3.6.1 FMOLS

This is a scenario whereby cointegration is observed among the variables integrated at order one. It further offers optimal cointegration regression estimates (Phillips and Hansen, 1990; Hansen, 1995; Phillips, 1995; Pedroni, 2001a, b). The FMOLS model is unique in addressing and dealing with issues bothering around endogeneity and autocorrelation and still deliver a robust estimate. Given the equation below:

$$Y_{i,t} = \alpha_i + \beta_i X_{i,t} + \varepsilon_{i,t} \quad \forall_t = 1, \dots, T, \; i = 1, \dots\dots N \qquad (2.18)$$

Allowing for $Y_{i,t}$ and $X_{i,t}$ are cointegrated with slopes β_i, where β_i may or may not be homogeneous across i. Hence, the equation becomes:

$$Y_{i,t} = \alpha_i + \beta_i X_{i,t} + \sum_{k=-K_i}^{K_i} \gamma_{i,k} \Delta X_{i,t-k} + \varepsilon_{i,t} \quad \forall t = 1,2, \dots, T, \; i = 1, \dots N \qquad (2.19)$$

We reflect $\xi_{i,t} = (\hat{\varepsilon}_{i,t}, \Delta X_{i,t})$ and $\Omega_{i,t} = \lim_{T \to \infty} E\left[\frac{1}{T}\left(\sum_{i=1}^{T} \xi_{i,t}\right)\left(\sum_{i=1}^{T} \xi_{i,t}\right)\right]$ as the long covariance. here $\Omega_i = \Omega_i^0 + \Gamma_i + \Gamma_i'$; The the simultaneous covariance is depicted by Ω_i^0 also the weighted sum of autocovariance is Γ_i . Thus, the equation of the FMOLS is rendered as:

$$\hat{\beta}_{FMOLS}^{*} = \frac{1}{N} \sum_{i=1}^{N} \left[\left(\sum_{i=1}^{T} \left(X_{i,t} - \bar{X}_i \right)^2 \right)^{-1} \left(\sum_{i=1}^{T} \left(X_{i,t} - \bar{X}_i \right) Y_{i,t}^{*} - T_{\hat{\gamma}_i} \right) \right] \qquad (2.20)$$

where

$$Y_{i,t}^{*} = Y_{i,t}^{*} - \bar{Y}_i - \frac{\hat{\Omega}_{2,1,i}}{\hat{\Omega}_{2,2,i}} \Delta X_{i,t} \; and \; \hat{\gamma}_i = \hat{\Gamma}_{2,1,i} + \hat{\Omega}_{2,1,i}^{0} - \frac{\hat{\Omega}_{2,1,i}}{\hat{\Omega}_{2,2,i}} \left(\hat{\Gamma}_{2,2,i} + \hat{\Omega}_{2,2,i}^{0} \right). \qquad (2.21)$$

2.3.6.2 DOLS

The DOLS is known to have merit over the FMOLS and such can be substituted (Saikkonen, 1991; Stock and Watson, 1993). The DOLS technique by design is such that it can function efficiently asymptotically while at the same time able to eliminate feedback in the cointegrating system. Econometrically, the estimation process contains the cointegrating regression which possesses both lags and leads and a such its results are dynamic and powerful over the FMOLS as supported by Arellano, (1989) considering the orthogonality in the cointegrating equation error term:

$$Y_t = \alpha_i + \beta X'_t + D'_{1t} D' \gamma_1 \sum_{j=-q}^{r} \Delta X'_{t+j} \rho + v_{1,t} \tag{2.22}$$

The differenced regressors with lag and lead of q and r respectively absorb all the long-run correlation between (υ1t and υ2t) while the least-square estimates of $\theta = (\beta', \gamma')'$ houses asymptotic distribution similar to canonical cointegration regression and fully modified ordinary least squares.

2.3.6.3 CCR

This form of cointegrating regression is an improvement from the ordinary least square estimator's shortfall. The CCR circumvent the bias of second order by the transformation of the variables. The covariance matrix form of the long-run estimator is rendered as:

$$\Omega = lim_{n\to\infty} \ \mathrm{E} \sum_{t=1}^{n} (u_t) \sum_{t=1}^{n} (u_t)' = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{bmatrix} \tag{2.23}$$

where Ω can be represented as follows:

$$\Omega = \sum + \Gamma + \Gamma' \tag{2.24}$$

and

$$\sum = lim_{n\to\infty} \ \mathrm{E} \sum_{t=1}^{n} (u_t u'_t) \tag{2.25}$$

$$\Gamma = lim_{n\to\frac{1}{n}} \ \mathrm{E} \sum_{k=1}^{n-1} \sum_{t=k+1}^{n} \mathrm{E}(u_t u'_{t-k}) \tag{2.26}$$

$$\cap = \sum + \Gamma = (\cap_{1,} \cap_2) = \begin{bmatrix} \cap_{11} & \cap_{12} \\ \cap_{21} & \cap_{22} \end{bmatrix} \tag{2.27}$$

The transformed series is obtained as:

$$Y_{1t}^{*} = Y_{2t} - \sum^{-1}(\cap_2)' \ u_t \tag{2.28}$$

$$Y_{2t}^{*} = Y_{2t} - \sum^{-1}(\cap_2)' \ u_t \tag{2.29}$$

$$Y_{1t}^{*} = Y_{1t} - (\sum^{-1}(\cap \quad _2 \ \beta + (0, \Omega_{12}, \Omega_{22}^{-1})')' u_t \tag{2.30}$$

Where CCR acquires the following form:

$$Y_{1t}^{*} = \beta' + Y_{2t}^{*} + u_{1t}^{*} \tag{2.31}$$

$$Y_{1t}^{*} = u_{1t} - \Omega_{12}, \Omega_{22}^{-1} u_{2t} \tag{2.32}$$

Equation-2.29 the OLS estimators share the same fashion as the ML estimation. The long-run correlation of y1t and y2t caused asymptotically endogeneity were circumvented for by variables transformation. The asymptotic bias issue because of cross-correlation between (u_{1t} and u_{2t}), were addressed in Equation-2.30 with the transformation of the variables.

2.4 Empirical Result and Discussion

From the norm and convention in econometrics literature regarding empirical analysis, the graphical plot is necessary to determine the pattern and behavior of the variables of interest, especially when dealing with time-series estimations. Figure 1(a, c and d) show a positive relationship between the dependent variables and the independent variables. To be more specific, an upward trend is observed in the energy consumption for all the models and a corresponding upward trend can be observed from of PHF, PSC and PE for the industry and taxes for heavy fuel oil for electricity generation, steam coal for electricity generation and electricity for the industry. Figure 1b shows an upward trend in energy consumption while the PNG and TNG initially was trending upward but after a point, experienced a sharp decline significantly and barely was on the increase. It is interesting to note that while the period of a sharp decline in the price and tax of natural gas for electricity generation, the energy consumption was still on the upward trend. Insights from the policy perspective suggest that energy consumption is very sensitive to prices and taxes for the case of heavy fuel oil, steam coal, and electricity. On the other hand, energy consumption is observed to comply with the first law of demand stating that the higher the price, the lower the quantity demanded and vice versa, this implies that natural gas has become a normal good for this assumption to take effect, unlike the other resources. This further allows an inverse relationship between the PNG, TNG and energy consumption.

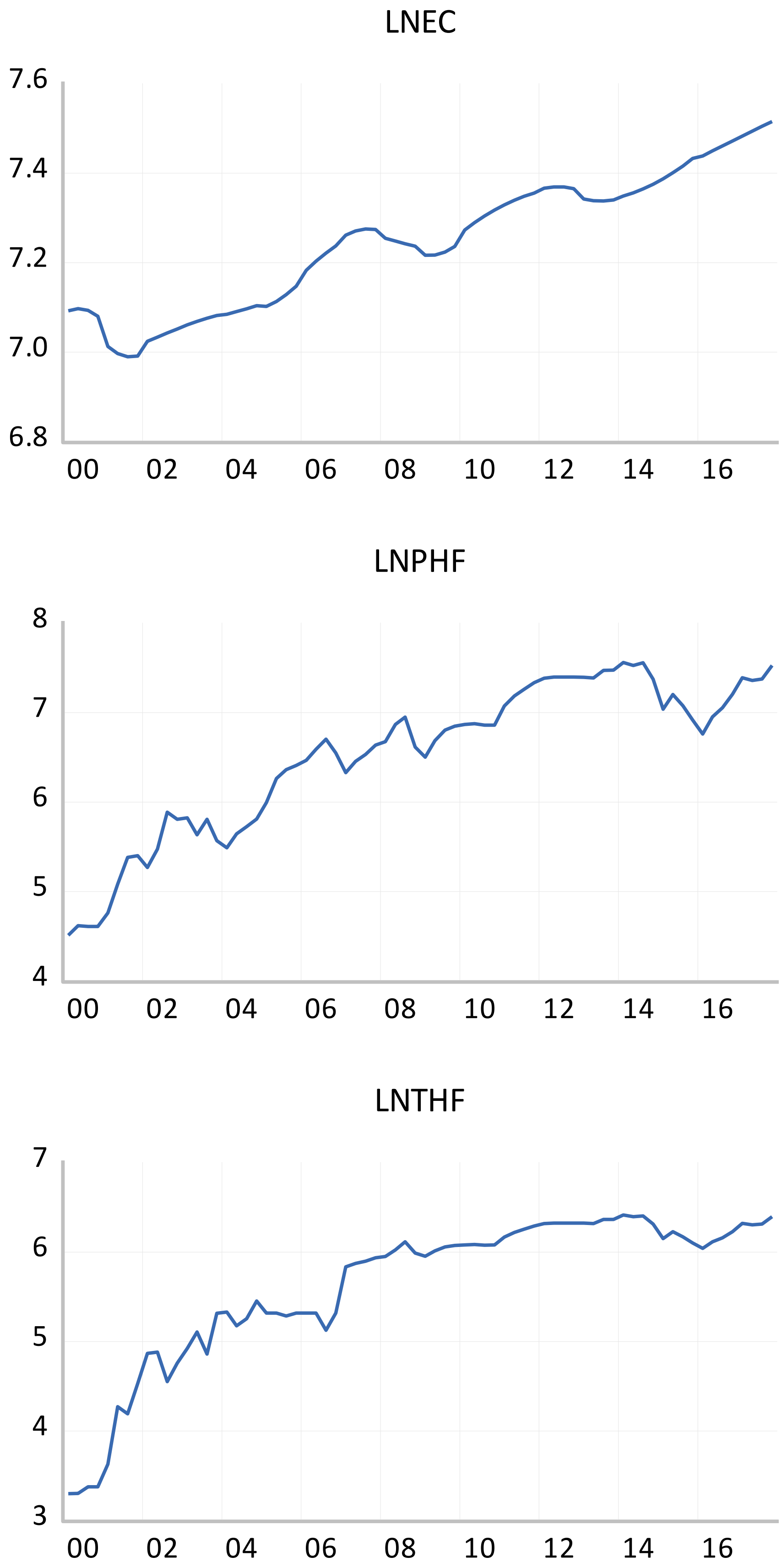


Figure 2.1a: Graphical Plot of LNEC, LNPHF and LNTHF

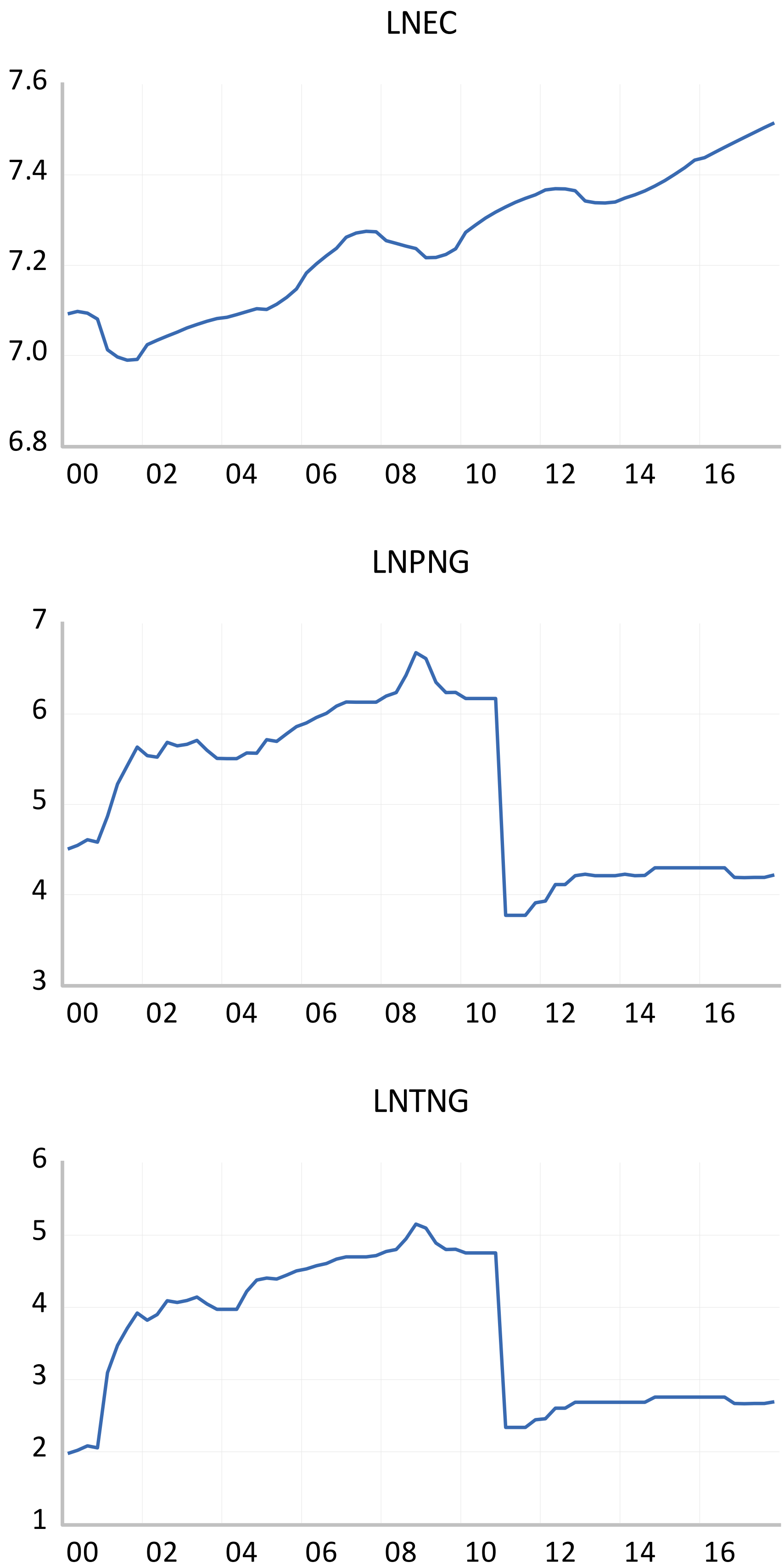


Figure 2.1b: Graphical Plot of LNEC, LNPNG and LNTNG

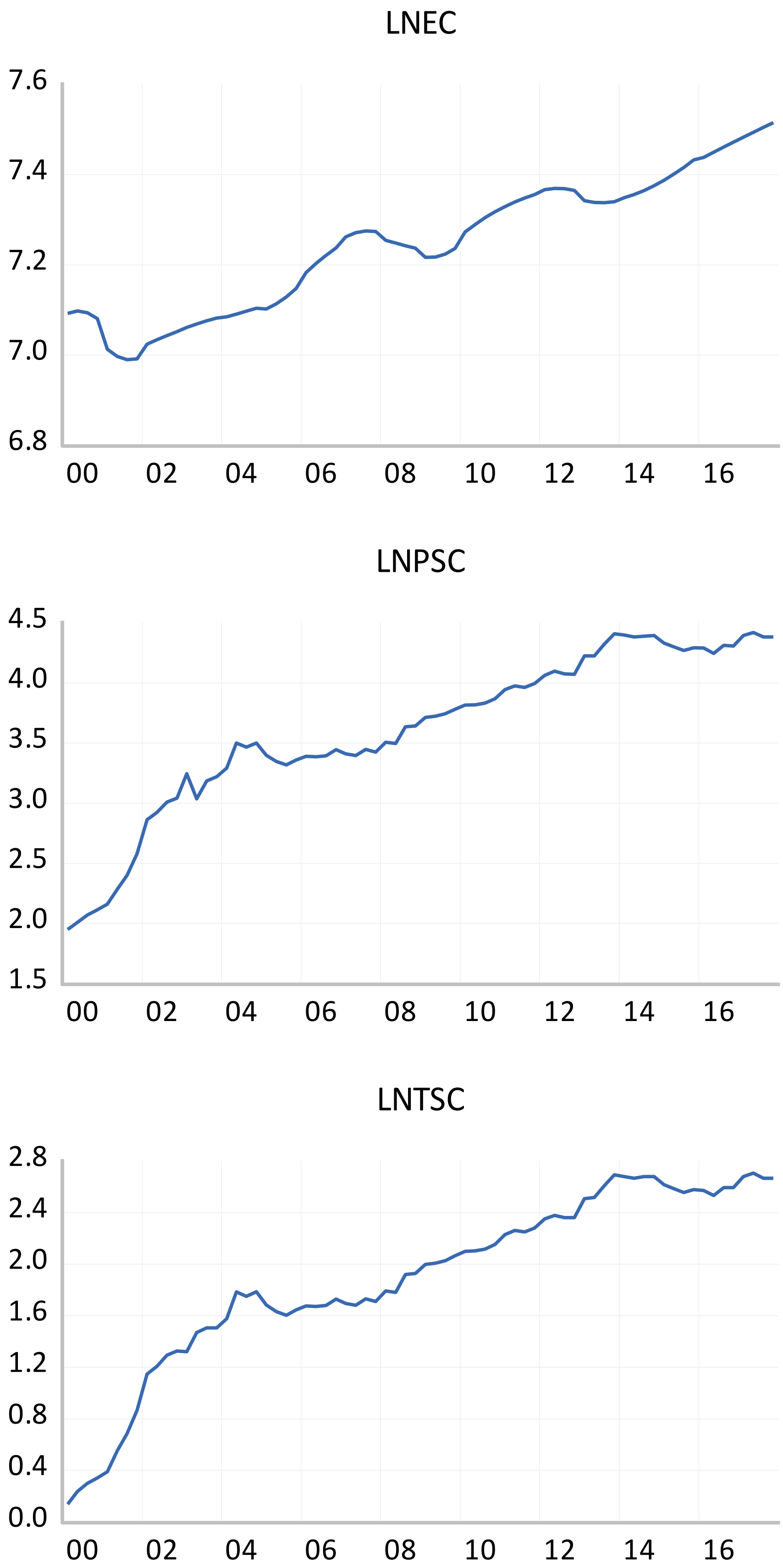


Figure 2.1c: Graphical Plot of LNEC, LNPSC and LNTSC

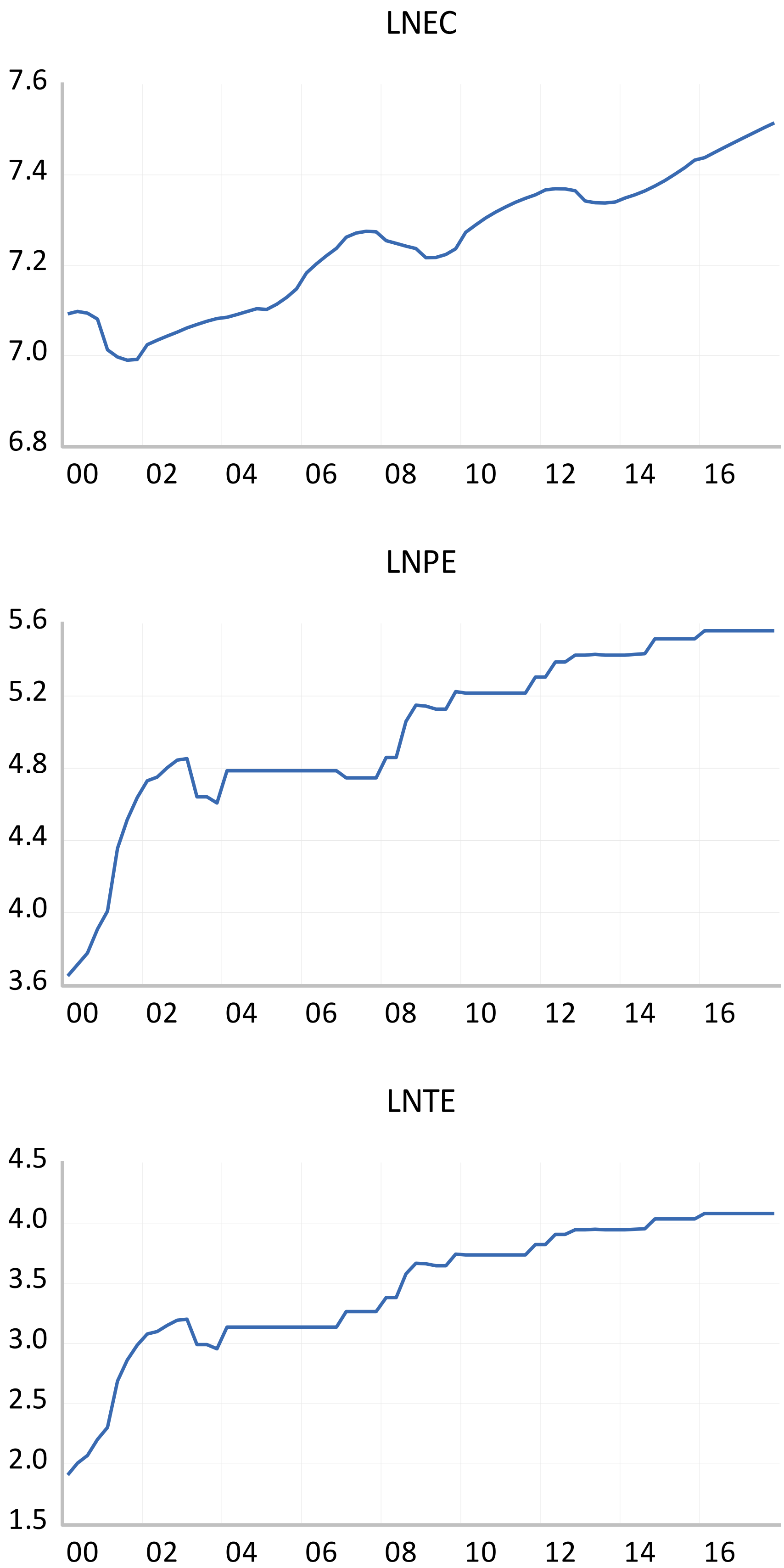


Figure 2.1d: Graphical Plot of LNEC, LNPE and LNTE

Table 2.2a: Summary of Statistics

	$LNEC_t$	$LNPHF_t$	$LNTHF_t$
Mean	7.2465	6.5232	5.6175
Median	7.2580	6.7322	6.0188
Maximum	7.5152	7.5600	6.4134
Minimum	6.9898	4.5120	3.2996
Std. Dev.	0.1473	0.8474	0.8408
Skewness	-0.0757	-0.7890	-1.3455
Kurtosis	1.8807	2.6393	4.0500
Jarque-Bera	3.8268	7.8615	25.034
Probability	0.1475	0.0196	0.0000
Sum	521.74	469.67	404.46
Sum Sq. Dev.	1.5409	50.985	50.196
Observations	72	72	72

Source: Author's compilation

Table 2.2b: Summary of Statistics

	$LNEC_t$	$LNPNG_t$	$LNTNG_t$
Mean	7.2464	5.1399	3.5874
Median	7.2580	5.5073	3.8622
Maximum	7.5152	6.6788	5.1521
Minimum	6.9898	3.7706	1.9783
Std. Dev.	0.1473	0.8961	0.9913
Skewness	-0.0757	-0.0128	-0.0123
Kurtosis	1.8807	1.4241	1.4097
Jarque-Bera	3.8268	7.4518	7.5888
Probability	0.1475	0.0240	0.0224
Sum	521.74	370.07	258.29
Sum Sq. Dev.	1.5409	57.015	69.775
Observations	72	72	72

Source: Author's compilation

Table 2.2c: Summary of Statistics

	$LNEC_t$	$LNPSC_t$	$LNTSC_t$
Mean	7.2464	3.6110	1.8916
Median	7.2580	3.6778	1.9629
Maximum	7.5152	4.4200	2.7080
Minimum	6.9898	1.9490	0.1371
Std. Dev.	0.1473	0.6691	0.6812
Skewness	-0.0757	-0.8201	-0.8721
Kurtosis	1.8807	3.0384	3.1762
Jarque-Bera	3.8268	8.0760	9.2216
Probability	0.1475	0.0176	0.0099
Sum	521.74	259.99	136.19

Sum Sq. Dev.	1.5409	31.794	32.950
Observations	72	72	72

Source: Author's compilation

Table 2.2d: Summary of Statistics

	$LNEC_t$	$LNPE_t$	$LNTE_t$
Mean	7.2464	5.0110	3.4591
Median	7.2580	5.1269	3.6454
Maximum	7.5152	5.5614	4.0792
Minimum	6.9898	3.6495	1.9073
Std. Dev.	0.1473	0.4696	0.5466
Skewness	-0.0757	-0.9648	-0.9074
Kurtosis	1.8807	3.7730	3.4325
Jarque-Bera	3.8268	12.963	10.443
Probability	0.1475	0.0015	0.0054
Sum	521.74	360.79	249.05
Sum Sq. Dev.	1.5409	15.662	21.217
Observations	72	72	72

Source: Author's compilation

Table 2.2(a-d) gives summary statistics of the variables of interest ranging from mean to Jarque-Bera (JB) test statistics. The tax component of each of the models in Table 2.2 (a-d) has the lowest mean, while energy consumption for each of the models served as the variable with the highest mean.

Table 2.3 (a-d) report the Pearson correlation for the four models earlier specified. This test aims to ascertain the linear relationship between two or more variables in the models. This information will help validate the strength of the association existing among the variables of interest. The potential signs can be obtained from the correlation estimates which further substantiate the relationship in existence among the variables. From the results displayed in Table 2.3 (a-d), there are both positive and negative relationships between the variables of interest. Table 2.3a shows a positive, significant and strong estimated coefficients of correlation between energy consumption and PHF (0.8718), between energy consumption and THF (0.8128), between the price of heavy fuel oil for electricity generation and total tax of heavy fuel oil for electricity generation (0.9478). Table 2.3b, on the contrary, shows negative, significant and strong estimated coefficients of correlation between energy consumption and price of natural gas for electricity generation (-0.0534), between energy consumption and total tax of natural gas for electricity generation (-0.4055), but a positive, significant and strong estimated correlation between the price of natural gas for electricity generation and total tax of natural gas for electricity generation (0.9676). Table 2.3c & 2.3d show significant, positive and strong estimated correlations between energy consumption and price of steam coal for electricity generation (0.8765), between energy consumption and TSC (0.8710), between the PSC and total tax of steam coal for electricity generation (0.9987). Also, significant, positive and strong estimated coefficients were seen between energy consumed and price of electricity for the industry (0.8268), between energy consumption and total tax of electricity for the industry (0.8502), between the price of electricity for the industry and total tax of electricity for the industry (0.9957). From the results reported, there is a strong suggestion of linear correlation among the variables of interest as well as the existence of a functional relationship. Therefore, based on ceteris paribus assumption (all things being equal) an increase/decrease in any of the variables will lead to a significant increase/decrease in the other variables.

Table 2.3a: Correlation Matrix Analysis

	LNECt	LNPHFt	LNTHFt
$LNEC_t$	1.0000		
t-Statistic	-------		
Probability	-------		
$LNPHF_t$	0.8718	1.0000	
t-Statistic	14.894	-----------	
Probability	0.0000	-----------	

$LNTHF_t$	0.8128	0.9478	1.0000
t-Statistic	11.674	24.872	----------
Probability	0.0000	0.0000	----------

Source: Author's compilation

Table 2.3b: Correlation Matrix Analysis

	LNECt	LNPNGt	LNTNGt
$LNEC_t$	1.0000		
t-Statistic	----------		
Probability	----------		
$LNPNG_t$	-.05345	1.0000	
t-Statistic	-5.2918	------------	
Probability	0.0000	------------	
$LNTNG_t$	-0.4055	0.9676	1.0000
t-Statistic	-3.7114	32.103	------------
Probability	0.0000	0.0000	----------

Source: Author's compilation

Table 2.3c: Correlation Matrix Analysis

	LNECt	LNPSCt	LNTSCt
$LNEC_t$	1.0000		
t-Statistic	-------		
Probability	-------		
$LNPSC_t$	0.8765	1.0000	
t-Statistic	15.238	-----------	
Probability	0.0000	-----------	
$LNTSC_t$	0.8710	0.9987	1.0000
t-Statistic	14.836	169.45	----------
Probability	0.0000	0.0000	----------

Source: Author's compilation

Table 2.3d: Correlation Matrix Analysis

	LNECt	$LNPE_t$	$LNTE_t$
$LNEC_t$	1.0000		
t-Statistic	------		
Probability	-------		
$LNPE_t$	0.8268	1.0000	
t-Statistic	12.298	---------	
Probability	0.0000	---------	
$LNTE_t$	0.8502	0.9957	1.0000
t-Statistic	13.512	90.212	--------
Probability	0.0000	0.0000	--------

Source: Author's compilation

Table 2.4 (a-d) report the results of Augmented Dickey-Fuller (1979) and Phillips Perron (1988) unit root test. The series under investigation are all stationary at first difference. Similarly, Table 2.5 (a-d) presents the Zivot and Andrews (2002) unit root results. The ZA results capture the endogenous structural breaks in the series. It further shows that the series is stationary at 1% and 5% significance level. On this ground, the null hypothesis could not be rejected at the level form. Hence, the series are integrated at order one. The structural break dates fall within the period when there was global increase in energy prices which influenced the Turkish energy market. Corresponding periods, economic, political and pandemic crisis such as Euro crisis in 2011, bird flu in 2006, and terrorism between 2004 – 2006 etc validate the structural break dates.

Table 2.4a: Results of Unit Root Test

Models	Variables	At Level		At 1st Difference		Decision
		t-Statistic	Prob	t-Statistic	Prob	
ADF Test						
	$LNEC_t$	-0.0081	0.9542	-4.2743	0.0010^{***}	I(1)
	$LNPHF_t$	-2.2985	0.1753	-6.8088	0.0000^{***}	I(1)
	$LNTHF_t$	-2.5382	0.3095	-8.2908	0.0000^{***}	I(1)
PP Test						
	$LNEC_t$	0.2557	0.9743	-4.3952	0.0007^{***}	I(1)
	$LNPHF_t$	-2.3073	0.1725	-6.6982	0.0000^{***}	I(1)
	$LNTHF_t$	-2.5314	0.3126	-8.2961	0.0000^{***}	I(1)

Note: ***,**,* represent 1%, 5% and 10% significance level.

Table 2.4b: Results of Unit Root

Models	Variables	At Level		At 1st Difference		Decision
		t-Statistic	Prob	t-Statistic	Prob	
ADF Test						
	$LNEC_t$	-0.0081	0.9542	-4.2743	0.0010^{***}	I(1)
	$LNPNG_t$	-1.3268	0.6128	-7.8777	0.0000^{***}	I(1)
	$LNTNG_t$	-1.7379	0.4081	-7.6170	0.0000^{***}	I(1)
PP Test						
	$LNEC_t$	0.2557	0.9743	-4.3952	0.0007^{***}	I(1)

	$LNPNG_t$	-1.3799	0.5874	-7.8774	0.0000***	I(1)
	$LNTNG_t$	-1.8251	0.3656	-7.6157	0.0000***	I(1)

Note: ***,**,* represent 1%, 5% and 10% significance level.

Table 2.4c: Results of Unit Root Test

Models	Variables	At Level		At 1st Difference		Decision
		t-Statistic	Prob	t-Statistic	Prob	
ADF Test						
	$LNEC_t$	-0.0081	0.9542	-4.2743	0.0010***	I(1)
	$LNPSC_t$	-2.4555	0.3488	-8.1069	0.0000***	I(1)
	$LNTSC_t$	-2.7737	0.2118	-6.2654	0.0000***	I(1)
PP Test						
	$LNEC_t$	0.2557	0.9743	-4.3952	0.0007***	I(1)
	$LNPSC_t$	-2.4642	0.3446	-8.3005	0.0000***	I(1)
	$LNTSC_t$	-2.7032	0.2387	-6.4777	0.0000***	I(1)

Table 2.4d: Results of Unit Root Test

Models	Variables	At Level		At 1st Difference		Decision
		t-Statistic	Prob	t-Statistic	Prob	
ADF Test						
	$LNEC_t$	-0.0081	0.9542	-4.2743	0.0010***	I(1)
	$LNPE_t$	2.9075	0.9990	-5.8406	0.0000***	I(1)
	$LNTE_t$	2.8501	0.9988	-5.9936	0.0000***	I(1)
PP Test						
	$LNEC_t$	0.2557	0.9743	-4.3952	0.0007***	I(1)
	$LNPE_t$	1.9526	0.9873	-5.7423	0.0000***	I(1)
	$LNTE_t$	1.8864	0.9852	-5.9126	0.0000***	I(1)

Note: ***,**,* represent 1%, 5% and 10% significance level.

Table 2.5a: Unit Root Test (Breaks)

		Statistics (Level)			Statistics (Difference)			
		ZA_I	ZA_T	ZA_B	ZA_I	ZA_T	ZA_B	Decision
LNECt								
	t-Statistic	-3.3421	-3.3647	-3.7299	-7.3519	-6.5936	-6.7059*	I(1)
	Break Point	2005Q2	2006Q4	2005Q2	2007Q2	2014Q1	-6.705975	
	Lag Length	4	5	4	3	3	3	
LNPHFt								
	t-Statistic	-4.4088	-3.4937	-3.6771	-6.7269	-6.7230	-7.4687	I(1)
	Break Point	2014Q4	2011Q4	2014Q4	2003Q2	2014Q4	2014Q4	
	Lag Length	4	4	4	4	4	4	
LNTHFt								
	t-Statistic	-4.4376	-3.3854	-3.4703	-7.9610	-8.1046	-8.5821	I(1)
	Break Point	2006Q4	2011Q3	2007Q1	2004Q1	2004Q3	2006Q4	
	Lag Length	4	4	4	3	3	3	

Note: ZA_I denotes model with a break in the intercept; ZA_T represents a model with breaks in the trend and ZA_B signifies model with a break in both intercept and trend. The asterisks ***,**.* represent 0.01%, 0.05% and 0.10% significance level.

Table 2.5b: Unit Root Test (Breaks)

		Statistics (Level)			Statistics (Difference)			
		ZA_I	ZA_T	ZA_B	ZA_I	ZA_T	ZA_B	Decision
LNECt								
	t-Statistic	-3.3421	-3.3647	-3.7299	-7.3519	-6.5936	-6.7059	I(1)
	Break Point	2005Q2	2006Q4	2005Q2	2007Q2	2014Q1	2011Q2	
	Lag Length	4	5	4	3	3	3	
LNPNGt								
	t-Statistic	-11.053	-2.3950	-10.730	-8.6639	-8.2872	-8.6819	I(0)
	Break Point	2011Q1	2006Q3	2011Q1	2011Q3	2011Q2	2011Q3	
	Lag Length	3	4	3	4	4	4	
LNTNGt								
	t-Statistic	-8.6545	-2.4212	-7.0528	-8.6545	-8.3571	-8.7639	I(1)
	Break Point	2011Q1	2006Q1	2011Q1	2011Q3	2011Q2	2011Q3	
	Lag Length	2	4	3	4	4	4	

Note: ZA_I denotes model with a break in the intercept; ZA_T represents a model with breaks in the trend and ZA_B signifies model with a break in both intercept and trend.

Table 2.5c: Unit Root Test (Breaks)

		Statistics (Level)			Statistics (Difference)			
		ZA_I	ZA_T	ZA_B	ZA_I	ZA_T	ZA_B	Decision
LNECt								
	t-Statistic	-3.3421	-3.3647	-3.7299	-7.3519	-6.5936	-6.705	I(1)
	Break	2005Q	2006Q	2005Q	2007Q	2014Q		
	Point	2	4	2	2	1	-6.705	
	Lag							
	Length	4	5	4	3	3	3	
LNPSCt								
	t-Statistic	-3.4590	-3.3454	-3.4272	-5.6897	-5.1887	-8.6819	I(1)
	Break	2015Q	2013Q	2013Q	2003Q	2005Q	2011Q	
	Point	1	4	1	2	2	3	
	Lag							
	Length	4	4	4	4	4	4	
LNTSCt								
	t-Statistic	-3.2508	-2.4212	-3.0369	-8.0446	-7.6440	-8.7639	I(1)
	Break	2015Q	2006Q	2015Q	2004Q	2005Q	2011Q	
	Point	1	1	1	3	2	3	
	Lag							
	Length	4	4	4	4	4	4	

Note: ZA_I denotes model with a break in the intercept; ZA_T represents a model with breaks in the trend and ZA_B signifies model with a break in both intercept and trend.

Table 2.5d: Unit Root Test (Breaks)

		Level			Difference			
		ZA_I	ZA_T	ZA_B	ZA_I	ZA_T	ZA_B	Decision
lnEC								
	t-Statistic	-3.3422	-3.3647	-3.7300	-7.3520	-6.5936	-6.7060	I(1)
	Break	2005Q	2006Q	2005Q	2007Q	2014Q		
	Point	2	4	2	2	1	-6.775	
	Lag							
	Length	4	5	4	3	3	3	
lnPE								
	t-Statistic	-3.7934	-2.6371	-5.4242	-4.8395	-6.3773	-6.5979	I(1)
	Break	2008Q	2015Q	2008Q	2008Q	2003Q	2004Q	
	Point	3	1	3	1	3	1	
	Lag							
	Length	13	13	13	12	15	15	
lnTE								
	t-Statistic	-4.2523	-3.7586	-3.8347	-4.2849	-7.8270	-8.2309	I(1)
	Break	2008Q	2015Q	2008Q	2007Q	2003Q	2004Q	
	Point	1	1	3	1	3	1	
	Lag							
	Length	9	9	9	4	19	18	

Note: ZA_I denotes model with a break in the intercept; ZA_T represents a model with breaks in the trend and ZA_B signifies model with a break in both intercept and trend.

Table 2.6a: Lag Length

Lag	LogL	LR	FPE	AIC	SC	HQ
0	34.76466	NA	7.67e-05	-0.96257	-0.86303	-0.92323
1	298.3311	495.1854	3.42e-08	-8.6767	-8.27858	-8.51938
2	318.8192	36.63028	2.42e-08*	-9.02483	-8.32811*	-8.74952*

Note: HQ stands for Hannan Quinn, AIC represents Akaike information criterion, SC denotes Schwarz information criteria, FPE means Final prediction error and lastly LR signifying sequential modified LR statistic.

Table 2.6b: Lag Length (LNEC LNPNG LNTNG)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	34.24829	NA	7.79e-05	-0.94692	-0.847388	-0.90759
1	319.9772	536.8240	1.78e-08	-9.33264	-8.934523*	-9.17533

Note: HQ stands for Hannan Quinn, AIC represents Akaike information criterion, SC denotes Schwarz information criteria, FPE means Final prediction error and lastly LR signifying sequential modified LR statistic.

From Table 2.6 (a-d), the results of the parsimonious lag order from Schwartz Bayesian Information criteria (SC) was chosen as the optimum selection of the lag for the study, and this was consistent among all the models though while model 2.1, 2.2, 2.5 & 2.6 used two lag length, models 2.3, 2.4, 2.7 & 2.8 used one length.

Table 2.6c: Lag Length (LNEC LNPSC LNTSC)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	185.5464	NA	7.95e-07	-5.53171	-5.432179	-5.49238
1	442.2273	482.2490	4.37e-10	-13.0372	-12.63907	-12.87988
2	464.0351	38.98971	2.97e-10	-13.4253	-12.72860*	-13.15

Note: HQ stands for Hannan Quinn, AIC represents Akaike information criterion, SC denotes Schwarz information criteria, FPE means Final prediction error and lastly LR signifying sequential modified LR statistic.

Table 2.6d: Lag Length(LNEC LNPE LNTE)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	182.3913	NA	8.74e-07	-5.4361	-5.3365	-5.39677
1	481.7491	562.4299	1.32e-10	-14.2348	-13.8367*	-14.0775

Note: HQ stands for Hannan Quinn, AIC represents Akaike information criterion, SC denotes Schwarz information criteria, FPE means Final prediction error and lastly LR signifying sequential modified LR statistic.

Table 2.7 (a-d) reports the ARDL bounds test for the four models and further confirms the presence of a long-run relationship among the variables under consideration. The results of the empirical analysis show that at 1% and 5% significance level accordingly, where the F statistics of the bounds test is higher than the upper bounds of the critical value bounds, there is cointegration among the variables of interest. These can be deduced also as there is in existence among the series a stable and long-run equilibrium relationship among the four models.

Table 2.7a: ARDL Bounds Test Output

Test Statistic	Value	k
F-statistic	6.04	2
Critical Value Bounds		
Significance	I (0)	I (1)
10%	3.38	4.02
5%	3.88	4.61
2.50%	4.37	5.16
1%	4.99	5.85

Table 2.7b: ARDL Bounds Test Output

Test Statistic	Value	k
F-statistic	7.73	2
Critical Value Bounds		
Significance	I (0)	I (1)
10%	4.19	5.06
5%	4.87	5.85
2.50%	5.79	6.59
1%	6.34	7.52

Table 2.7c: ARDL Bounds Test Output

Test Statistic	Value	k
F-statistic	7.42	2
Critical Value Bounds		
Significance	I (0)	I (1)
10%	4.19	5.06
5%	4.87	5.85

2.50%	5.79	6.59
1%	6.34	7.52

Table 2.7d: ARDL Bounds Test Output

Test Statistic	Value	k
F-statistic	9.20	2
Critical Value Bounds		
Significance	I (0)	I (1)
10%	4.19	5.06
5%	4.87	5.85
2.50%	5.79	6.59
1%	6.34	7.52

Table 2.8a: Short and Long-run ARDL Outcome

LNEC = f (LNPHF)

Variables	Coefficient	Std Error	t-Statistics	Prob
Short-run outcome				
ECT (-1)	-0.0497	0.0141	-3.5147	0.0008
ΔLNPHF	0.0202	0.0089	2.2680	0.0269
Constant	0.3000	0.1207	2.4843	0.0155
R^2	0.4556			
R^2 Adjusted	0.4131			
Long-run outcome				
LNPHF	0.2104	0.0374	5.6233	0.0000
Constant	5.9135	0.1798	32.8792	0.0000

Table 2.8b: Short and Long-run ARDL Outcome

lnEC = f (lnTHF)

Variables	Coefficient	Std Error	t-Statistics	Prob
Short-run outcome				
ECT (-1)	-0.0387	0.0116	-3.3197	0.0015
ΔlnTHF	0.0221	0.0087	2.5264	0.0140
Constant	0.2268	0.1085	2.0900	0.0406
R^2	0.4313			
R^2 Adjusted	0.4054			
Long-run outcome				
lnTHF	0.2540	0.0669	3.7940	0.0003
Constant	5.8462	0.3542	16.5060	0.0000

Table 2.8 (a-h) presents the results of the short and long-run relationship estimated with the use of the ARDL model. The result reveals a significant positive and negative effects on the variables of interest both in the short and long run of the models. Specifically, Tables 2.8a & 2.8b show that an increase in the price of heavy fuel oil for electricity generation by one percent will lead to a 0.0202% and 0.2104% increment in energy consumed at 5% and 1% level of significance in the short-run and long-run respectively. An increase in the tax of heavy fuel oil for electricity generation by one percent will lead to 0.0221% and 0.2540% increase in energy consumption in the short term at 5% and long term at 1% significance level.

Tables 2.8c and 2.8d demonstrates that a one percent increase in $lnPNG_t$ will lead to 0.0052% and 0.1531% decreases in energy consumption in the short-run and long-run respectively. However, these values are not statistically significant given the various levels of significance, whereas a one percent increase in lnTNG results to 0.0107% decrease in energy consumption in kg oil equivalent per capita in the short-run given 5% level of significance but in the case of long-run is not significant even with negative sign implying an inverse relationship with the energy consumption.

Table 2.8c: Short and Long-run ARDL Outcome

lnEC = f (lnPNG)				
Variables	Coefficient	Std Error	t-Statistics	Prob
Short-run outcome				
ECT (-1)	0.0208	0.0052	3.9701	0.0002
ΔlnPNG	-0.0052	0.0055	-0.9477	0.3467
Constant	-0.1614	0.1088	-1.4828	0.1428
R^2	0.0662			
R^2 Adjusted	0.0526			
Long-run outcome				
lnPNG	-0.1531	0.1311	-1.1680	0.2469
Constant	7.7469	0.7151	10.8325	0.0000

Table 2.8d: Short and Long-run ARDL Outcome

lnEC = f (lnTNG)				
Variables	Coefficient	Std Error	t-Statistics	Prob
Short-run outcome				
ECT (-1)	0.0165	0.0038	4.3578	0.0000
ΔlnTNG	-0.0107	0.0048	-2.2141	0.0302
Constant	-0.1262	0.0942	-1.3396	0.1849
R^2	0.1532			
R^2 Adjusted	0.1409			
Long-run outcome				
lnTNG	-0.2040	0.1694	-1.2039	0.2328
Constant	7.6113	0.5248	14.5028	0.0000

Table 2.8e and 2.8f display that a percent increase in $lnPSC_t$ and $lnTSC_t$ will result in an impact on the energy consumed, however, these positive impacts are not statistically significant at 10% level in the short-run, however, in the long-run, an increase by one percent in lnPSCt and lnTSCt will lead to a 0.2753% and 0.2781% increase in energy consumed in kg oil equivalent per capita at 1% significance level respectively.

Table 2.8e: Short and Long-run ARDL Outcome

lnEC = f (lnPSC)				
Variables	Coefficient	Std Error	t-Statistics	Prob
Short-run outcome				
ECT (-1)	-0.0589	0.0158	-3.7166	0.0004
ΔlnPSC	0.0189	0.0166	1.1407	0.2582
Constant	0.3701	0.1340	2.7621	0.0075
R^2	0.4365			
R^2 Adjusted	0.4109			
Long-run outcome				
lnPSC	0.2753	0.0502	5.4856	0.0000
Constant	6.2839	0.1792	35.0584	0.0000

Table 2.8f: Short and Long-run ARDL Outcome

lnEC = f (lnTSC)				
Variables	Coefficient	Std Error	t-Statistics	Prob
Short-run outcome				
ECT (-1)	-0.0579	0.0153	-3.7857	0.0003
ΔlnTSC	0.0251	0.0198	1.2669	0.2098
Constant	0.3909	0.1375	2.8428	0.0060
R^2	0.4418			
R^2 Adjusted	0.4165			
Long-run outcome				
lnTSC	0.2781	0.0545	5.1070	0.0000
Constant	6.7476	0.1099	61.4115	0.0000

Table 2.8g and 2.8h show that an increase in $lnPE_t$ by one percent will have a negative and positive impact on the energy consumed in Turkey both in the short-run and long-run by 0.0501% decrease and 0.4260% increase accordingly at 1% significance level. In the case of $lnTE_t$, an increase by one percent will lead to a 0.0499% decrease and 0.3645% increase in kg oil equivalent per capita of energy consumption at 1% significance level in the short-run and long-run respectively.

Table 2.8g: Short and Long-run ARDL Outcome

lnEC = f (lnPE)				
Variables	Coefficient	Std Error	t-Statistics	Prob
Short-run outcome				
ECT (-1)	-0.0399	0.0144	-2.7725	0.0072
ΔlnPE	-0.0501	0.0239	-2.0907	0.0404
Constant	0.2112	0.0733	2.8810	0.0053
R^2	0.2231			
R^2 Adjusted	0.2002			
Long-run outcome				
lnPE	0.4260	0.1053	4.0437	0.0001

Table 2.8h: Short and Long-run ARDL Outcome

lnEC = f (lnTE)				
Variables	Coefficient	Std Error	t-Statistics	Prob
Short-run outcome				
ECT (-1)	-0.0875	0.0332	-2.6301	0.0106
ΔlnTE	-0.0449	0.0224	-2.0080	0.0487
Constant	0.6037	0.2265	2.6647	0.0097
R^2	0.1852			
R^2 Adjusted	0.1612			
Long-run outcome				
lnTE	0.3645	0.0854	4.2680	0.0001
Constant	6.1679	0.2886	21.3706	0.0000

From the ceteris paribus assumption (all things being equal), the constant of the models estimated have been observed to be positive, negative and significant in the short and long run at 1% and 5% significance level. The speed of adjustment coefficient [ECT (-1)*] of energy consumption in the short-run to the long-run path of steady-state after a shock is reported in Table 2.8 (a-h). The ECT (-1)* is negative (-0.0497) and (-0.0387) and significant at 1% level of significance for model 2.1 and 2.2 shown in Table 2.8a and 2.8b; The ECT (-1)* for the next series of the model in Table 2.8c and 2.8d are positive with (0.0208) and (0.0165) and the level of significance is at 1%. From Table 2.8e and 2.8f, the ECT (-1)* are negative (-0.0589) and (-0.0579) and the level of significance at 1%. Finally, the ECT (-1)* for the last set of the model in Table 8g and 8h are negative (-0.0399) and (-0.0875) and significant at 1% and 5% level of significance respectively. These negative and positive values denote the quarterly adjustment of kg oil equivalent per capita of energy consumption deviation from the long-run path.

Table 2.9 (a-h) reports the results of FMOLS, DOLS, and CCR for the models under consideration. The first set of models reported in Table 2.9a and 2.9b reveals that a one percent increase in the price of heavy fuel oil for electricity generation will lead to 0.1723%, 0.1639% and 0.1657% increase in kg oil equivalent per capita of energy consumption for FMOLS, DOLS, and CCR respectively at 1% level of significance. On the other hand, one percent increase in a total tax of heavy fuel oil for electricity generation will lead to 0.0934%, 0.0892% and 0.0895% decrease in kg oil equivalent per capita of energy consumption for FMOLS, DOLS, and CCR at 1%, 5% and 5% level of significance respectively. This suggests that energy consumption is highly inelastic and by intuition explains the rationale in the increase in price leading to an increase in energy consumed. Also, we observe that an increase in taxes leads to a decline in the energy consumption too. There seems to be serious involvement of the government in the determination of the price of this essential source by way of subsidy to finance the government budget as a fiscal transfer and it is evident in an increase in tax of heavy fuel oil leading to a decline in energy consumption.

Table 2.9a: FMOLS, DOLS and CCR Estimation Result

Dependent Variable: lnECt			
Variables	FMOLS	DOLS	CCR
lnPHF	0.17230*	0.1639*	0.1657*
	{5.1688}	{8.8259}	{7.1209}
C	6.1248*	6.1748*	6.1691*
	{27.8311}	{49.4783}	{40.4613}
R^2	0.7653	0.8157	0.7693
R^2- Adjusted	0.7619	0.8042	0.7659
S.E of regression	0.0718	0.0639	0.0712
Long-run variance	0.0521	0.0131	0.0294
Mean dependent var.	7.2486	7.2469	7.2486
S.D. dependent var.	0.1472	0.1446	0.1472
Sum squared resid	0.3558	0.2620	0.3499

Note: The asterisk's * denotes 0.01% significance level. {} signifies t-statistic-value.

Table 2.9b: FMOLS, DOLS and CCR Estimation Result

Dependent Variable: lnECt

Variables	FMOLS	DOLS	CCR
lnTHF	-0.0934*	-0.0892**	-0.0895**
	{-2.8435}	{-2.2318}	{-2.6367}
C	7.3211*	7.2928*	7.3155*
	{60.2911}	{49.2729}	{58.9543}
R2	0.9492	0.9587	0.9508
R2- Adjusted	0.9468	0.9547	0.9486
S.E of regression	0.0339	0.0308	0.0334
Long-run variance	0.0030	0.0027	0.0031
Mean dependent var.	7.2486	7.2469	7.2486
S.D. dependent var.	0.1472	0.1446	0.1472
Sum squared resid	0.0770	0.0586	0.0745

Note: The asterisk's *,** denotes 0.01% and 0.05% significance level accordingly. {} signifies t-statistic-value.

Table 2.9c and 2.9d present the results of models 2.3 and 2.4 of FMOLS, DOLS, and CCR. This result shows that an increase in the price of natural gas for electricity generation by one percent will lead to 0.1014%, 0.0927% and 0.0945% decrease in kg oil equivalent per capita of energy consumption for FMOLS, DOLS, and CCR at 5%, 1% and 1% level of significance accordingly. Alternatively, a one percent increase in a total tax of natural gas for electricity generation will lead to 0.0698%, 0.0725% and 0.0694% decrease in kg oil equivalent per capita of energy consumption at 5% level of significance for FMOLS, DOLS, and CCR respectively. These empirical results corroborate with the basic principle of the law of demand where an increase in price results in a decline in quantity demanded. Prices of natural gas are inversely related to energy consumption.

Table 2.9c: FMOLS, DOLS and CCR Estimation Result

Dependent Variable: lnECt			
Variables	FMOLS	DOLS	CCR
lnPNG	-0.1014^{**}	-0.0927^{*}	-0.0945^{*}
	{-2.4490}	{-2.8928}	{-3.0924}
C	7.7690^{*}	7.7256^{*}	7.7344^{*}
	{35.8995}	{45.9845}	{48.4056}
R^2	0.2993	0.3591	0.3034
R^2- Adjusted	0.2892	0.3190	0.2933
S.E of regression	0.1241	0.1193	0.1237
Long-run variance	0.0971	0.0512	0.0526
Mean dependent var.	7.2487	7.2469	7.2486
S.D. dependent var.	0.1472	0.1446	0.1472
Sum squared resid	1.0627	0.9118	1.0565

Note: The asterisk's *,** denotes 1% and 5% significance level. {} signifies t-statistic-value.

Table 2.9d: FMOLS, DOLS and CCR Estimation Result

Dependent Variable: lnECt			
Variables	FMOLS	DOLS	CCR
lnTNG	-0.0698^{**}	-0.0725^{**}	-0.0694^{**}
	{-2.4567}	{-2.4515}	{-2.4930}
C	7.5039^{*}	7.5136^{*}	7.5023^{*}
	{70.559}	{67.5743}	{72.1010}
R^2	0.1940	0.3323	0.1942
R^2- Adjusted	0.1823	0.2906	0.1825
S.E of regression	0.1331	0.1218	0.1330
Long-run variance	0.0543	0.0507	0.0543
Mean dependent var.	7.2486	7.2469	7.2486
S.D. dependent var.	0.1472	0.1446	0.1472
Sum squared resid	1.2225	0.9499	1.2222

Note: The asterisk's *,** denotes 1% and 5% significance level. {} signifies t-statistic-value.

Table 2.9e and 2.9f report the results of FMOLS, DOLS, and CCR of model 2.5 & 2.6. The result shows that a one percent increase in the price of steam coal for electricity generation will lead to 0.1388%, 0.1295%, and 0.1383% decrease in kg oil equivalent per capita of energy consumption for FMOLS, DOLS, and CCR at 1% level of significance. On the other hand, a one percent increase in the total tax of steam coal for electricity generation will result to 0.1369%, 0.1289% and 0.1355% decrease in kg oil equivalent per capita of energy consumption at 1% level of significance for the FMOLS, DOLS, and CCR respectively.

Table 2.9g and 2.9h report that an increase in the price of electricity for the industry at one percent will lead to 0.1773%, 0.1898% and 0.1736% decrease in kg oil equivalent per capita of energy consumption for the FMOLS, DOLS, and CCR at 1% level of significance. On the other hand, an increase in the total tax of electricity for the industry by one percent will lead to 0.1675%, 0.1728% and 0.1660% decrease in kg oil equivalent per capita of energy consumption at 1% level of significance for FMOLS, DOLS, and CCR respectively.

Table 2.9e: FMOLS, DOLS and CCR Estimation Result

Dependent Variable: lnECt

Variables	FMOLS	DOLS	CCR
lnPSC	-0.1388*	-0.1295*	-0.1383*
	{-3.9484}	{-3.3588}	{-4.0731}
C	7.3155*	7.2926*	7.3141*
	{90.0953}	{79.7627}	{94.8038}
R^2	0.9615	0.9670	0.9615
R^2- Adjusted	0.9598	0.9638	0.9598
S.E of regression	0.0295	0.0275	0.0295
Long-run variance	0.0022	0.0022	0.0022

Mean dependent var.	7.2487	7.2469	7.2487
S.D. dependent var.	0.1472	0.1446	0.1472
Sum squared resid	0.0584	0.0468	0.0583

Note: The asterisk's * denotes 1% significance level. {} signifies t-statistic-value.

Table 2.9f: FMOLS, DOLS and CCR Estimation Result

Dependent Variable: lnECt

Variables	FMOLS	DOLS	CCR
lnTSC	-0.1369*	-0.1289*	-0.1355*
	{-4.0695}	{-3.4794}	{-4.2744}
C	7.0743*	7.0700*	7.0732*
	{292.0499}	{222.7499}	{317.0040}
R^2	0.9622	0.9681	0.9623
R^2- Adjusted	0.9605	0.9650	0.9606
S.E of regression	0.0292	0.0270	0.0292
Long-run variance	0.0022	0.0021	0.0022
Mean dependent var.	7.2486	7.2469	7.2487
S.D. dependent var.	0.1472	0.1446	0.1472
Sum squared resid	0.0573	0.0454	0.0572

Note: The asterisk's * denotes 1% significance level. {} signifies t-statistic-value.

Table 2.9g: FMOLS, DOLS and CCR Estimation Result

Dependent Variable: lnECt

Variables	FMOLS	DOLS	CCR
lnPE	-0.1773*	-0.1898*	-0.1736*
	{-5.5374}	{-4.5192}	{-6.1606}
C	7.7391*	7.7956*	7.7230*
	{57.6841}	{43.1312}	{66.6206}
R^2	0.9727	0.9753	0.9728
R^2- Adjusted	0.9715	0.9729	0.9716
S.E of regression	0.0249	0.0238	0.0248
Long-run variance	0.0017	0.0017	0.0017
Mean dependent var.	7.2487	7.2470	7.2487

S.D. dependent var.	0.1472	0.1446	0.1472
Sum squared resid	0.0414	0.0351	0.0412

Note: The asterisk's * denotes 1% significance level. {} signifies t-statistic-value.

Table 2.9h: FMOLS, DOLS and CCR Estimation Result

Dependent Variable: lnECt			
Variables	FMOLS	DOLS	CCR
lnTE	-0.1675*	-0.1728*	-0.1660*
	{-4.7728}	{-3.8107}	{-5.3450}
C	7.4007*	7.4111*	7.3966*
	{85.6085}	{63.8332}	{99.3134}
R^2	0.9696	0.9710	0.9697
R^2- Adjusted	0.9683	0.9682	0.9683
S.E of regression	0.0262	0.0258	0.0262
Long-run variance	0.0020	0.0021	0.0020
Mean dependent var.	7.2487	7.2470	7.2487
S.D. dependent var.	0.1472	0.1446	0.1472
Sum squared resid	0.0461	0.0413	0.0460

Note: The asterisk's * denotes 1% significance level. {} signifies t-statistic-value.

Table 2.10 (a-d) reports the Granger causality results among the variables of interest from the four models. The results help to ascertain the predictability power of one variable over the other to help in formulating policy direction. Table 2.10a reporting the causality for the first model shows a one-way causality from PHF to EC, whereas feedback causality is seen between THF and EC as well as between THF and PHF. The one-way causality between PHF to EC implies that the price of heavy fuel oil for electricity generation drives kg oil equivalent per capita energy consumption. This corroborates with the law of demand that goods consumed depend on the price of that product itself. Furthermore, the feedback causality implies that both tax and energy consumption depend on each other, so appropriate tax policy will drive and influence energy consumption and vice versa. In the same vein, bidirectional causality between PHF and THF show the both fiscal and price mechanism can drive each other. Caution be exercise while determining the price and tax for the optimal energy consumption.

Table 2.10b reports bidirectional causality between PNG to EC and between TNG to EC and vice versa. Also, it shows that there is no causal relationship between PNG with TNG. The feedback relationship between PNG and EC implies that the price of natural gas for electricity generation drives and influences energy consumption and vice versa. Similarly, the total tax of natural gas for electricity generation granger causes kg oil equivalent per capita of energy consumption and vice versa. Finally, the no causality between PNG and TNG implies neither the price of natural gas nor the total tax of natural gas for electricity generation can granger cause each other.

Table 2.10c reports a unidirectional causality for all the variables in the third model. This one-way causality runs from PSC to EC, from TSC to EC and from TSC to PSC. This implies that the price of steam coal for electricity generation drives the kg oil equivalent per capita of energy consumption and energy consumption does not granger cause the price of steam coal for electricity generation. This situation is also applicable to the total tax of steam coal for electricity generation to energy consumption as well as from the total tax of steam coal for electricity generation.

Table 2.10d reports that there is feedback causality among all the variables under investigation in the last model. Bidirectional causality is seen from PE to EC, from TE to EC and from TE to PE. The feedback relationship among the variables strongly suggests that either of the above-mentioned variables is capable of influencing each other. To drive energy consumption, the appropriate price and tax measures should be taken to boost energy consumption as desired and where energy consumption needs to minimize, price and tax can be manipulated to yield intended outcomes.

The knowledge of the direction and flow of causality will help arm policymakers and stakeholders to know the right kind of mix to achieve the desired outcome.

Table 2.10a: Granger Causality Test

Null Hypothesis	Causality	F-Stat	Prob.
LNPHF → LNEC	PHF → EC	4.64428	0.0130**
LNEC → LNPHF		1.76333	0.1796
LNTHF → LNEC	THF ↔ EC	3.06209	0.0536***
LNEC → LNTHF		3.35370	0.0411**
LNTHF → LNPHF	THF ↔ PHF	4.94003	0.0101**
LNPHF → LNTHF		2.55054	0.0858***

Note that → denotes unidirectional causality whereas ↔ it represents bidirectional causality and ≠ stands for neutrality. Asterisks (*, **, ***) denotes 1%, 5% and 10% significance level of rejection accordingly.

Table 2.10b: Granger Causality Test

Null Hypothesis	Causality	F-Stat	Prob.
LNPNG → LNEC	PNG ↔ EC	2.89375	0.0935***
LNEC → LNPNG		4.56384	0.0363**
LNTNG → LNEC	TNG ↔ EC	6.41735	0.0136**
LNEC → LNTNG		6.37960	0.0139**
LNTNG → LNPNG	TNG ≠ PNG	0.39775	0.5304
LNPNG → LNTNG		1.88282	0.1745

Note that → denotes unidirectional causality whereas ↔ it represents bidirectional causality and ≠ stands for neutrality. Asterisks (*, **, ***) denotes 1%, 5% and 10% significance level of rejection accordingly.

Table 2.10c: Granger Causality Test

Null Hypothesis	Causality	F-Stat	Prob.
LNPSC → LNEC	PSC → EC	12.6896	0.0007*
LNEC → LNPSC		0.02466	0.8757
LNTSC → LNEC	TSC → EC	13.0130	0.0006*
LNEC → LNTSC		0.00955	0.9224
LNTSC → LNPSC	TSC → PSC	21.8386	1.00E-05*

LNPSC → LNTSC		0.85207	0.3592

Note that → denotes unidirectional causality whereas ↔ it represents bidirectional causality and ≠ stands for neutrality. Asterisks (*, **, ***) denotes 1%, 5% and 10% significance level of rejection accordingly.

Table 2.10d: Granger Causality Test

Null Hypothesis	Causality	F-Stat	Prob.
LNPE → LNEC	PE ↔ EC	3.64681	0.0101**
LNEC → LNPE		5.31295	0.0010*
LNTE → LNEC	TE ↔ EC	2.99798	0.0255**
LNEC → LNTE		6.15758	0.0003*
LNTE → LNPE	TE ↔ PE	3.05224	0.0236**
LNPE → LNTE		3.15342	0.0204**

Note that → denotes unidirectional causality whereas ↔ it represents bidirectional causality and ≠ stands for neutrality. Asterisks (*, **, ***) denotes 1%, 5% and 10% significance level of rejection accordingly.

2.5 Conclusion and Policy Implications

In this chapter we examined the impact or effect of energy prices of heavy fuel oil for electricity generation, natural gas for electricity generation, steam coal for electricity generation and electricity for the industry and their corresponding total taxes on energy consumption using Turkey as a benchmark. The purpose of this research is to ascertain to what extent the prices and taxes of the above-mentioned variables affect energy consumption in an emerging economy like Turkey. In the bid to achieve our research objective, the role of energy prices and total taxes on energy consumption over the period 2000 – 2018 using quarterly data and autoregressive distributed lag technique was employed for empirical estimators and then the Granger causality for predictive relationship analysis.

Our graphical and empirical results revealed that there is a positive relationship between energy prices, total taxes for the variables under investigation and energy consumption, except for the price and total tax of natural gas which had a sharp and significant structural breakdown and during this period energy consumption was still trending. This graph suggests that the Turkish economy is energy-dependent on heavy fuel oil, steam coal and electricity fully but for the case of natural gas, it was initially until the structural breakdown. This position is confirmed by the positive relationship that is obtained between the prices and total taxes of heavy fuel oil, steam coal, natural gas (initially) and electricity with energy consumption. By implication, Turkish energy policies need to be diversified to allow for less dependence on these sources and enable market-based prices such that negative relationships can induce an increase in energy consumption. Government regulation using the fiscal policy should be deliberate to reduce the burden of tax on consumers. The increase in consumption of energy despite the continuous rise in the prices and taxes suggests that electricity (energy consumption) is an essential commodity that is needed for all areas of economic productivity and activities. Since it is a necessity goods, irrespective of the price, consumers will be willing to pay for its consumption and that accounts for the rise in energy consumption as prices of energy and taxes rise. Economy of Turkey is constantly growing and demand for electricity in manufacturing sector as well as by households keep rising. Apparently, the renewables are insufficient and Turkey eventually need to consume electricity from the transformation industry. Regardless the increase in price, insufficient renewables makes it inevitable to be dependent on fossil induced electricity for at least another decade. This study supports the positive relationship between energy prices, total taxes, and energy consumption.

The Turkish economy needs to deliberately synchronize the macroeconomic objectives, energy policies and the new medium-term fiscal plan to ensure and preserve macroeconomic stability, increase production and welfare level, focus actualizing price stability and strengthen fiscal discipline.

The empirical findings from our study are insightful and suggestive to the government, policymakers, researchers, and stakeholders in the relevant field, especially considering that Turkey is an emerging world economy with high demand for energy resources for productive activities. Our findings suggest critical policy direction for the government, policymakers and other stakeholders to have market-determined energy prices rather than government subsidizing consumption, and appropriate tax policy to ensure fiscal discipline and stability. Evidence from this study revealed that the PHF, THF had an increasing effect on energy consumption both in the short and long-run; the price of natural gas was decreasing both in the long-run and in the short-run with energy consumption, whereas total taxes were decreasing in the long-run and short-run with significance in the short-run. The price of steam coal had an increasing effect in the long-run and short-run, with the long-run alone being significant. The total tax for steam coal had an increasing effect in the long-run and short-run on energy consumption with the short-run being insignificant. Both the price and tax of steam coal had no significant effect in the short-run, even though it was a positive effect on energy consumed accordingly. The price of electricity for the industry had a decreasing effect on energy consumed in the short-run and positive effects in the long-run, whereas the total tax of electricity for the industry had a decreasing effect on energy consumed in the short-run and increasing effect in the long-run. Both in the short-run and long-run, the estimates were statistically significant at 0.05% and 0.01% level respectively. Further empirical results from the long-run relationship among the results apart from the price of heavy fuel oil for electricity generation and total taxes of heavy fuel oil for electricity generation show consistency with the principle of the higher the price, the lower the quantity demanded of good that are normal all things being equal. This also suggests that the market forces of the Turkish economy can interact to determine the market price for these goods. For the exception in the price and total tax of heavy fuel oil for electricity generation being positively related to energy consumption can be deduced as a heavy fuel oil for this purpose is an essential commodity that makes it difficult for the increase in price to discourage consumers in getting more quantities.

These results show that there is a need to seek creative ways to further harness and blend macroeconomic policies with energy policies to maximize the full potential with the use of natural resources endowed the economy of Turkey. This synergy will further help to enhance the reduction in prices and taxes which will boost economic growth at an optimal level. Continuous rise in the prices of goods and taxes reduces welfare and standard of living and this is against Turkey's new medium fiscal plan for 2019 to 2021. Deliberate and creative means be sought to achieve this plan. Hence this study further proposes rigorous research on the energy price nexus, tariff regulations and improved income in other developing economies of the world.

This implies that while there is no proper synergy between energy and macroeconomic policies, the maximum benefits of these resources will not be harnessed and as a result economic growth will not be optimally achieved. Recall that continuous rise in the price levels and taxes reduces welfare and standard of living. This is also not in tune with Turkey's new medium fiscal plan for 2019 to 2021. Creative means should be sought to achieve this plan. Hence, this study further proposes rigorous research on the energy price nexus, tariff regulations and economic growth in other emerging economies of the world.

Chapter 3

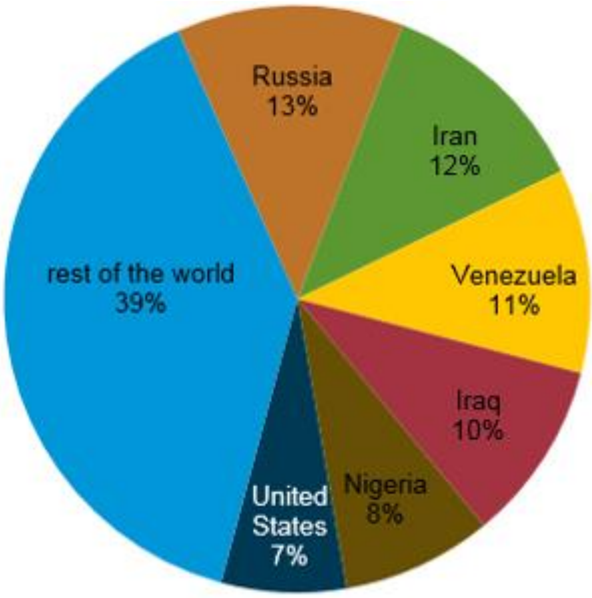
THE MULTIVARIATE MODELLING OF NATURAL GAS USE IN A NEIGHBORING COUNTRY: THE CASE OF IRAN

3.1 Introduction

The importance of energy consumption to the growth of the economy in the last two or three decades has been strongly recognized not only by economists but also by policymakers, academics, practitioners, engineers, businessmen, government, civil societies and energy agencies. As outlined by EIA, 2018, that there is a connection between the country's economy and its energy consumption. The demand for energy consumption has increased swiftly, mostly for natural gas and oil, this is a result of the rapid increase in economic growth across the globe. Furthermore, the contributory connection between NGC and economic growth has been an interesting point for many researchers (Lee and Chang, 2005; Zamani, 2007; Isik, 2010 or Solarin and Shahbaz, 2015, among others).

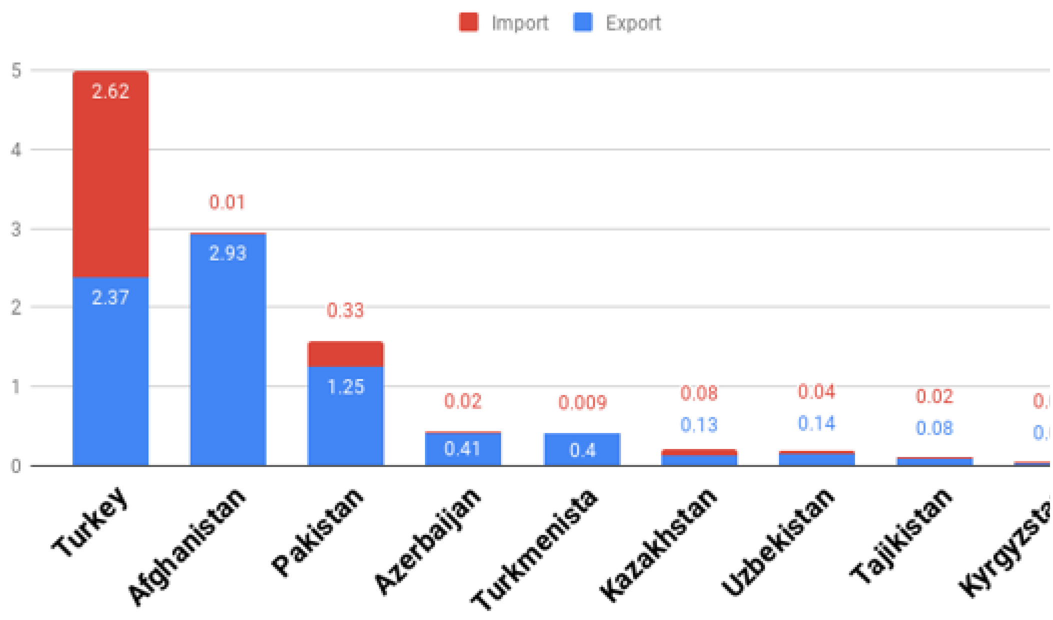
Natural gas (NG hereafter) is an alternative non-renewable energy source that boost economic activities in nations endowed with huge deposits either developed, developing and emerging economics (Apergis and Payne, 2010). NG a form of hydrocarbon gas element occurs naturally, consisting primarily of methane, generally, NG most frequently constitutes varying amounts of other higher alkanes sometimes a small fraction of carbon dioxide, nitrogen, hydrogen sulfide, or helium. In the face of a continuous decline in oil reserves in most oil-producing economies, NG has been identified as a suitable alternative as it produces 30% less carbon dioxide than crude oil and 45% less than burning coal. According to the studies conducted by Shahbaz et al. (2013a, b) and Apergis and Payne (2010) posited that NG can take over the important role of crude oil in the economic growth process if due attention is given. Empirical studies on the theme describe NG as an essential non-renewable energy source that can be harnessed to boost economic activities irrespective of the level of development of such economies. On this premise, a need to revisit the energy-growth nexus with NG as the central focus arises. Chapter 3 therefore focuses on industrial natural gas consumption (NGC) rather than household sector consumption for the case of Iran, as being the neighboring country of Turkey. Certainly, with one difference; Turkey is an importer of gas, yet Iran is one of the main suppliers to Turkey. This research study adopts the use of recent econometric techniques. This will be of great use to stakeholders and policymakers that design and formulate energy strategies.

The choice of Iran as a case study is due to her large NG output and consumption. Iran is the second largest net-reserve holder after Russia. The country not only hosts the world's second-largest NG reserves after Russia but also is the fourth-largest producer of NG in the world. Qatar recently became the second biggest reserve holder following a massive discovery of natural gas in the Gulf Sea, namely at the South Pars and the North Field. Recent statistics from the Iranian Petroleum Ministry reveals that 16% of the world's reserves of NG is deposited in Iran. 33% of these reserves are associated NG while the remaining 67% are non-associated (Iran Oil Ministry Annual Bulletin, 5th edition). In 2010, Iran's NG net export was about 1.57 billion cubic meters, with its NG production valued at 138.5 billion cubic meters. In the same period, the total imports cost 6.85 billion whereas exports stood at 8.42 billion cubic meters, the key trade partners being Turkey, Azerbaijan, Turkmenistan, and Armenia. Figs. 3.1 to 3.3 provides a picture of the dynamic of natural gas trade. For instance, Fig. 3.1 shows the persistent trend in the last 2-3 decades of production and consumption of natural gas. Subsequently Figs. 3.1 and 3.2 also renders a pictorial display of top natural gas flaring nations in the world and net trading partners with Iran.



Source: U.S. Energy Information Administration, based on OPEC Annual Statistical Bulletin (2015)

Figure 3.1: Top natural gas flaring countries



Source: IEA (2018)

Figure 3.2: Top trading natural gas importing and exporting countries with Iran.

The adoption of NG as a feasible alternative to other fossil fuels has increased Iran's domestic consumption of NG. This increment is also noticeable in exports as the country's NG exports increased by five-fold to 60 billion cubic meters by 2014 as outlined by Iran Oil Ministry Annual Bulletin. This increase in NG consumption is a result of the combination of the following factors: reduction in the domestic supply price of NG, wasting energy technologies, inappropriate and abundant use of NG. This consumption situation raises certain issues; on one hand, one may assume that increased NG consumption will produce a cleaner environment and birth economic prosperity, while on the other hand, however, numerous researchers have suggested that in general, resource extraction often crowds out other economic activities, especially manufacturing, and reduces the growth impact of other sectors of the economy (Mankiw et al., 1992; Sachs and Warner, 2001). The above assertion is known as the Dutch disease hypothesis. Thus, it pertinent to examine how NG affects the economic growth of Iran. Also, while NG demand may be able to affect economic growth, economic growth may affect NG demand, as the strength of an economy can influence the energy market. For example, during periods of boom, increases in demand for goods and services may cause increases in NG consumption. Thus, the need to underpin the directional causality flow between NG consumption- economic outputs is pertinent and timely.

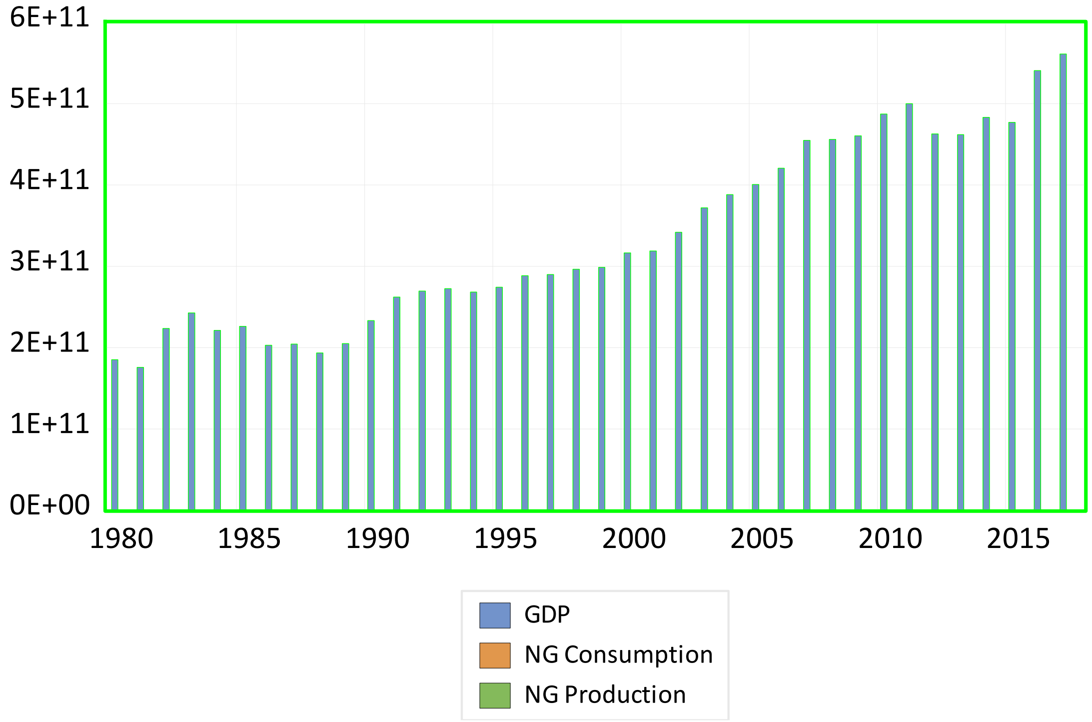


Fig. 3.3: Iran Economic growth and Dry natural gas production and consumption

Recently, there has been growing interest in examining the linkage between economic growth and NG consumption. Studies on this issue have however produced contradictory empirical outcomes. These contradictions in extant literature may be as a result of the bivariate econometric frameworks mostly adopted in past studies. A major flaw of bivariate models is that they suffer from omitted variable bias (model misspecification) and for this reason, their estimation outcomes are spurious. The implication is that the policy implications from such studies are unreliable (Dolado and Lutkepohl, 1996). There is thus a need to incorporate additional important variables with relatively high explanatory powers. Hence, scholars such as (interalia Apergis and Payne, 2010; Kum et al., 2012), among others have studied the theme under consideration in a multivariate framework using diverse econometric approaches.

Against the above-highlighted premise that this study explores the interaction between consumption of natural gas-economic growth nexus by extending the bi-variate framework by incorporation of the important variable to make multivariate. The addition of our study to the frontiers of knowledge is in four-fold; (i) In terms of scope, we augment the NG-economic growth nexus with real gross fixed capital formation (GFCF) to ascertain the role of capital in economic output and also with oil rent-seeking for Iran given the pivotal role oil plays in Iranian economy an area which has not been properly documented in the literature. Also, the present chapter also explore the role of non-oil GDP on NG consumption in Iran economic output given the peculiarity of our case study. The Iranian economy has suffered from war and western sanction before the 1990s so it pertinent to see if such episodes plays out on the current empirical discourse (Amadeh et al., 2009; Hafeznia et al., 2017; Akadiri and Akadiri, 2018). (ii) In terms of methodological advancement, because most economic and financial datasets are plagued with possible break dates we account for a structural break in our econometric analysis. The need to set up measures of accounting for possible structural break(s) dates are pertinent, otherwise, obtain coefficient estimates will be inconsistent and unreliable for policy analysis. (iii) This study applies estimation techniques such as Zivot and Andrews (1992) unit root to detect the unit root/stationarity traits of variables under consideration. (iv) For cointegration relationship, we utilize Pesaran's ARDL methodology and the newly advanced Bayer and Hanck (2013) combined cointegration test as complementary to Pesaran's test while we apply Toda-Yamamoto-Granger causality test (1995) a modified Wald methodology (MWALD) which is known to render more robust results than the conventional Granger causality test is adopted to detect the direction of causality to explore the causality flows between the variables under review.

The rest of the current chapter proceeds as follows; section-3.2 provides a brief review of related studies on NG-economic growth. Section-3.3 of this chapter dwells on the methodological construction and data while section-3.4 concentrates on empirical findings and discussion. Finally, this chapter’s study summary (conclusions) and possible policy direction are rendered in section-3.5.

3.2 Theoretical Background

A few theoretical studies have been documented formally that model a direct connection between energy and economic growth, energy and environment. The extant empirical literature on the theme cut across single country, cross country and panel analysis. We set off by briefly discussing the theoretical foundation. Subsequently, empirical studies that outline the transmission mechanism that explains the energy- income nexus. For this particular chapter, the incorporation of oil rent and capital to economic growth is explained.

The quest for economic growth seems the most pertinent issue for most if not all economies across the globe. Thus, the need to identify growth indicators is key for government administrators and policymakers. There is a large body of theoretical studies on economic growth, the majority relies on the well-known Solow growth model. The Solow growth model outlines that a substantial level of labor and capital accumulation with the right level of technology known as the "Solow residual" explains economic growth. Over the years the conventional Solow growth model has been augmented with other variables like energy use, tourism, population and other demographic indicators (Soytas and Sari, 2009).

The study of Kraft and Kraft (1978) empirically serves as the bedrock in energy literature when considering the relationship between income and energy consumption. The study serves as an invitation to several other studies in the energy economics literature. It is from Kraft and Kraft (1978) that this study establishes an interaction between economic growth and energy consumption for the United States. Further motivation for this present study is hinged on the theoretical context developed by (Dietz and Rosa, 1994; York et al., 2004) popularly referred to as Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT).

Iran as being one of the biggest reserve holder of the world's natural gas resources and major consumer domestically, with a lot of revenues derived from NG can lead to an increase in the accumulation of foreign exchange reserves. Where there is a considerable improvement in the terms of trade, this will have a ripple effect on the appreciation of the real exchange rate. This will also translate in the short run to economic growth. However, with the sanctions imposed by the US, the trade volume and revenues declined tremendously over the last few years.

The transmitting mechanism by which energy consumption translates into economic growth is seen from the accrual of the revenues generated from the proceeds of NG consumption. The increase from this revenue is used both for investment in the public infrastructure architecture as well as consumption. In the work of Basher and Fachin (2013), long-run interaction is established to exist between savings and investment. In recent times, there has been a drift from household consumption to the industrial sector given the adoption of new technologies for exploration and exploitation of NG. These new technologies in the form of a high-efficiency low emission (HELE) approach will increase the industrial consumption of NG in Iran in the coming years. More so, government intervention in terms of pipeline installation and subsidies has also encouraged private sector investment in no more measure. This finding helps to relax the constrain of low domestic savings which are usually encountered by private investment, so higher income from the NG revenues induces higher savings thereby increase in investment and accumulation of capital which is key in expanding the economic activities in the domestic economy (Ramey, 2011; Esfahani and Yousefi, 2017).

Numerous studies in recent years investigating the relationship between energy consumption (including both renewable and nonrenewable sources) and economic growth abound in the energy literature. Payne (2010) and Ozturk (2010) in their comprehensive review of various pieces of literatures on NG and economic growth nexus summarized four hypotheses that are testable.[1]

There are limited papers in the literature about the causal relationship between NG consumption and economic growth. This review will explore it categorically to ascertain the extent to which the gap exists. The first category explores studies that have to deduce causality between these variables using the cointegration technique. The second category considers bivariate studies that have employed causality tests. The third category explores the trivariate approach while still employing the causality tests. The last category while building on the shortfalls of previous categories, uses multivariate series to implement the causality tests. Beginning with the first category, Lee and Chang (2005) studies have applied the cointegration techniques to examine the relationship between NG and economic growth. These studies used Johansen (1988), Hansen (1992), and Gregory and Hansen (1996) test of cointegration to examine for the period 1954–2003 the relationship between NG consumption and economic growth. The test results revealed causality flow from NG consumption to real GDP using the weak exogeneity as a notion of long-run causality in a cointegration system.

Zamani (2007) has investigated the relationship between the Iranian economy and NG consumption covering the period from 1967 to 2003. Evidence from the studies showed a bidirectional relationship between NG consumption and GDP. Similar studies in Taiwan was conducted by Hu and Lin (2008) using Hansen and Seo (2002) cointegration test to investigate the relationship between real GDP and NG consumption. The result supported and confirmed the feedback hypothesis for Taiwan. In Pakistan for the period 1972–2007, Khan and Ahmad (2008) used Johansen (1988) along with Johansen and Juselius (1990) tests to examine the relationship between NG consumption per capita, gas price and real GDP per capita. The conservative hypothesis was ascertained and confirmed from the analysis. Isik (2010) investigated the relationship between NG consumption and economic growth for the period span of 1977–2008 in Turkey. The result showed a positive influence of NG consumption by economic growth in the short run whereas in the long-run negative relationship was observed. Considering various reviews made by scholars as a contribution to the body of knowledge on this subject, there seems to be a major weakness of applying cointegration tests to determine causality direction without including Granger causality formally. Nevertheless, cointegration existence does not necessarily specify causality direction.

Certain bivariate studies have applied a series of causality tests to deduce that there exists a causal relationship between NG consumption and economic growth. Yu and Choi (1985) in attempt to determine the direction of causality in the UK, US and Poland deployed Sims (1972) and the result showed causality flowing economic output (GDP) towards NG consumption, whereas in the case of US and Poland there was no causality established among the variables. Investigating the relationship between NG consumption and economic growth in Pakistan drove Siddiqui (2004) to use Hsiao (1981) for the period span 1970–2003. No causality was found among the variables as revealed by the results. A case of single causality was observed to be flowing from NG consumption to economic output as investigated by Yang (2000) in his studies seeking to establish causality between utilization of gas and economic growth in Taiwan from the period of 1954 through 1997.

Adeniran (2009) deployed Sims (1972) tests of causality to investigate the causal relationship in Nigeria from 1980 to 2006. Causality was observed from the results to flow from the real GDP to NG consumption.

Furthermore, Payne (2010) for the period 1949–2006 in the US. The study investigated the causal relationship between economic growth and NG consumption. Positive causality that is a directional causality flowing from economic growth towards NG consumption was the outcome of the study. Also, in a different bivariate study by Zahid (2008), where three countries (India, Bangladesh, and Pakistan) were investigated with regards to causality relationship from 1971 to 2003. One direction causality flowing from NG consumption was observed from the results to the economy in Bangladesh, whereas no causality was demonstrated for India and Pakistan. Lim and Yoo (2012) using quarterly data from 1991 to 2008 examined the causal relationship between NG consumption and economic growth in Korea for both the short and long run. Evidence of double-sided Granger causality was reported from the result of NG consumption and economic growth. Das et al. (2013) examined the interaction or association existing between NG consumption and economic growth from 1980 to 2010 in Bangladesh. Results from this study established that NG consumption flows to real GDP in the long run and it is one way with Granger causality test. A similar study by Bildirici and Bakirtas (2014) explored the relationship between economic growth and NG consumption among the various types of energy available for countries including Russia, Turkey, and Brazil. Evidence from the result tests showed feedback causality relationships between economic growth and NG consumption for the countries under study.

Pirlogea and Cicea (2012) also considered the causal relationship between NG consumption and economic growth per capita for the period 1990–2010 in Romania and Spain. Evidence from test results using Granger (1969) revealed a causal relationship flowing from NG consumption towards economic growth in Spain, whereas in Romania there was no causal relationship established.

More recently, Solarin and Ozturk (2016) assessed the causal relationship between NG consumption and economic growth in a panel of OPEC members, and their findings revealed a feedback relationship. However, evidence obtained when member countries were examined individually was different. There was evidence of growth hypothesis in countries like Iraq, Kuwait, Nigeria, and Saudi Arabia, whereas the conservative hypothesis held in other member countries like Algeria, Iran, the United Arab Emirates, and Venezuela. Furthermore, the neutrality hypothesis was evident in the case of Angola and Qatar, while Ecuador was the only country with a feedback hypothesis.

In the study on Malaysia by Solarin and Shahbaz (2015), the feedback hypothesis was confirmed. Studies on the theme of Iran are limited. However, Zamani (2007), using the vector error correction model (VECM), examined disaggregated energy consumption estimates from 1967 to 2003 and found a long-term bidirectional causality relationship stemming from economic growth to NG consumption. More recently, Esen and Oral (2016) and Hafeznia et al. (2017) affirmed the substantial contribution of NG to economic growth in the various investigated countries.

Kum et al. (2012) examined the relationship between NG consumption and economic growth in the G-7 countries (US, UK, Japan, Italy, Germany, France, and Canada) for the period 1970–2008. With control for capital in the model, test results showed causality flowing from NG consumption towards economic growth for Italy, whereas in the case of the UK no causality is established from NG consumption to economic growth. From the results, it also revealed the US, Germany, and France were observed to have bidirectional causality whereas for Canada and Japan no causal relationship was established. Lotfalipour et al. (2010) investigated causal relationships between economic growth, carbon emissions and fossil fuel consumption for Iran during the 1967–2007 period. Proxying with NG consumption, results revealed unidirectional Granger causality flowing from NG consumption to GDP. Saboori and Sulaiman (2013) investigated the relationship between NG consumption and economic growth in Malaysia from 1980 to 2009. In the short run, the evidence is observed from the result showing unidirectional causality flowing from NG consumption to economic growth. In the case of the long-run from the same result, bidirectional causality is evident between NG consumption and carbon emissions, economic growth, and NG consumption.

The problem of omission of an important variable is minimized using the trivariate approach, through the addition of extra variable is of little effect to resolve this problem. This has necessitated recent studies to adopt the use of a multivariate framework to resolve this issue. Shahbaz et al. (2013c) examined the relationship in Pakistan covering the period from 1972 to 2010. Export, capital, and labor were added in the multivariate model. Variance decomposition analysis was carried to establish causal relationship flowing from the NG consumption to economic growth. Apergis and Payne (2010) investigated the relationship between NG consumption and economic growth for the period of 1992–2005 using a panel of 67 countries. This study included the capital formation and labor force to the model. With the use of heterogeneous panel cointegration, there was evidence of bidirectional causality and long-run relationships between economic growth and NG consumption.

According to the studies of Farhani et al. (2014) who explored the role of NG consumption with fixed capital formation and trade over the specified period 1980–2012 on Tunisia economic growth. Result revealed a bidirectional causal relationship between NG consumption and economic growth. Ighodaro (2010) examined the link between NG utilization and economic growth in Nigeria for the period 1970–2005. With the inclusion of broad money and health expenditure variables into the model, evidence from the result revealed unilateral causal relationships as well as long-run links flowing from NG utilization to economic growth.

While research on energy-economic growth is quite large, there is only a limited number, which tested the income-energy nexus through the channel of oil rent and natural gas consumption with each providing an inconclusive result. The studies of Emami and Adibpour (2012) clearly outlined the pivotal role of oil rent on economic growth in Iranian economic growth. A positive shock on oil rent translates into increased economic output. On the contrary, a negative shock from oil rent birth decline in output level. The above position of oil rent driving economic growth is also consistent with the study of Mehrara (2007) for top oil-exporting countries. Also, the inclusion of low-cost capital as a substitute for labor in connection with expansionary and redistributive policies results in a fast wage rate (Esfahanin and Yousefi, 2017). At the same time as the country's oil boom revenue rises it causes the real exchange rate to rise, this induces the demand for domestic production of tradable to shift. This will cause total factor productivity and labor productivity to increase. Thus, on the above premise, the present study seeks to fill these identified gaps. Where little or less attention has been documented. The current chapter revisits the natural gas led growth nexus with a new perspective by the inclusion of oil rent and non-oil GDP, capital to make a more robust theoretical and empirical contribution.

Table-3.1 below renders a summary of studies on the theme under consideration with diverse estimation techniques for bloc or country-specific cases.

Table 3.1: Summary of literature on Natural gas-economic growth nexus

Authors and Year	Time	Region	Methodology	Empirical Finding
Akadiri and Akadiri (2018)	1980-2013	Iran	ARDL, TY	Y x NG
Hafeznia et al. (2017)	N/A	Iran	Descriptive statistics, Graphs	NG ↔ Y
Esen and Oral (2016)	N/A	Iran, Russia, Qatar, Turkmenistan	Descriptive statistics, Graphs	NG ↔ Y
Furuoka (2016)	1980 – 2012	China	ARDL,GC,TY	NG → Y
Solarin and Ozturk (2016)	1980 – 2012	OPEC member countries	Panel GC	NG ↔ Y
Balitskiy et al. (2016)	1997-2011	EU-26	Panel cointegration	NG↔ Y
Destek (2016)	1991-2013	OECD countries	FMOLS, DOLS Panel VECM	NG↔ Y
Shahiduzzaman and Alam (2014)	1970 – 2009	Australia	ARDL	NG ↔ Y
Bildirici and Bakirtas (2014)	1980 – 2011	Brazil, Russia and Turkey	ARDL, JML,GC	NG ↔ Y
Solarin and Shahbaz (2014)	1971-2012	Malaysia	BH, ARDL, VECM,	NG ↔ Y
Rafindadi and Ozturk (2015)	1971- 2012	Malaysia	ARDL,BH,GC	NG ↔ Y
Ozturk and Al-Mulali (2015)	1980- 2012	Gulf Cooperation Council (GCC) Countries	Pedroni cointegration test	NG ↔ Y
Dogan (2015)	1995-2012	Turkey	VECM, GC	NG ↔ Y
Farhani et al. (2014)	1980-2010	Tunisia	ARDL, TY	NG↔ Y
Saboori and Sulaiman (2013)	1980 - 2013	Malaysia	ARDL, JML, GC	NG ↔ Y
Shahbaz et al. (2013)	1972 - 2010	Pakistan	ARDL,JML,GC	NG → Y
Das et al. (2013)	1980 - 2010	Bangladesh	JML,GC	Y → NG
Kum et al. (2012)	1991-2008	Korea	GC	NG ↔ Y
Lotfalipour et al. (2010)	1967 - 2007	Iran	TY	NG → Y
Apergis and Payne (2010)	1992-2005	67 Countries	Pedroni cointegration	NG ↔ Y

Ighodaro (2010)	1970-2005	Nigeria	VECM, JJ	NG → Y
Isik (2010)	1977-2008	Turkey	ARDL	NG ↔ Y
Amadeh et al. (2009)	1973-2003	Iran	ARDL, VECM	NG ← Y
Reynolds and Kolodziej (2008)	1928-1987,1988-1991,1992-2003	Soviet Union	GC	NG → Y
Hu and Liu (2008)	1973-2003	Taiwan	VECM	NG ← Y
Sari at al. (2008)	2001 -2005	US	ARDL, VECM	NG ← Y
Zamani (2007)	1967-2003	Iran	JML, VECM	NG ↔ Y
Lee and Chang (2005)	1954-2003	Taiwan	JML, WE	NG → Y
Siddiqui (2004)	1970 - 2003	Pakistan	ARDL, HGC(Hsiao's Granger Causality Test)	NG x Y
Fatai et al. (2004)	1960-1999	New Zealand and Australia	ARDL, JML, TY	Y x NG
Aqeel and Butt (2001)	1955-1996	Pakistan	GC	Y x NG
Yang (2000)	1954-1997	Taiwan	GC	NG → Y
Yu and Choi (1985)	1947-1974	US, UK	GC	NG ← Y

Note: NG- Natural gas consumption, Y- economic growth. Where NG → Y means one-way causality from NG consumption to economic growth and Y → NG is from economic growth to NG consumption. Y ↔ NG depicts a feedback Granger causality and Y x NG denotes neutrality hypothesis where there is no causal interaction between NG and Y. Also, in Table 3.1 above N. A- not applied. The following abbreviation tests are rendered as Autoregressive Distributed Lag Model to Cointegration (ARDL), Granger Causality (GC). Also, the (JML) mean Johansen's Maximum Likelihood technique, Johansen Juselius cointegration (JJ), Vector Error Correction Model (VECM) Bayer and Hanck cointegration test (BH) and Toda and Yamamoto causality tests (TY) respectively.

3.3 Methodological Construction

3.3.1 Data

To investigate the interaction between NG consumption and economic output in Iran, a multivariate framework that also includes real gross capital fixed formation (RGFCF) (constant 2010) as a proxy for physical capital is adopted. The data for the real gross domestic product (RGDP) (constant 2010), as well as Non-oil GDP that disentangle the impact of oil on economic growth also is accounted for in the model construction. Real gross capital formation and carbon dioxide emissions in Kt. Oil rent was also incorporated into the study to account for the significant role of oil revenue in the Iranian economy. The data were gathered from WDI (https://data.worldbank.org/indicator), while data for NG was retrieved from the U.S Energy Information Administration database (EIA, 2018). Oil rent and Non-oil GDP were sourced from the Thomson Reuters Data Stream quarterly from 1990Q1 to 2017Q4 for the econometric analysis.

The study's empirical path is as follows; (i) Unit root analysis through traditional non-stationarity tests of Augmented Dickey and Fuller, (1981) and Phillips and Perron (1988) tests and added to capture for a breakpoint in stationarity analysis is the Zivot and Andrews, (1992). The aforementioned test will be employed to explore the maximum integration order of the interest variables as well as aid in avoiding I(2) variables. (ii) The estimation of cointegration among the series was achieved via the Pesaran et al. (2001) Bounds testing complemented with the newly advanced combined cointegration test of Bayer and Hanck (2013). Finally, Granger causality procedure is estimated to observe the causal relationships between the variables.

3.3.2 Model framework

The functional relationship for our study draws empirical strength from Solarin and Shahbaz (2015) and Solarin and Ozturk (2016), given as:

$$GDP = f\,(NGC, GFCF, OR) \tag{3.1}$$

$$LnGDPt = \alpha + \beta 1 LnNGCt + \beta 2 LnGFCF + \beta 3 LnOR + \varepsilon t \tag{3.2}$$

$$Nonoil\_GDP = f\,(NGC, GFCF, OR) \tag{3.3}$$

$$LnNonoil\_GDPt = \alpha + \beta 1 LnNGCt + \beta 2 LnGFCF + \beta 3 LnOR + \varepsilon t \tag{3.4}$$

Logarithm transformation is carried out on equation (3.1) to also achieve homoscedasticity.

Here, α represents constant while β_1, β_2, β_3 are partial slope parameters. The apriori expectation of the above-fitted models aligns with theory and empirical support. The expectation for $\beta_1 > 0$. That is in confirmation of the natural gas led-growth hypothesis. Like natural gas, consumption contributes to economic growth. $\beta_2 > 0$. This implies that capital accumulation plays a positive role in the Iran economy as supported by an earlier study of Akadiri and Akadiri (2018). Finally, the expected sign for β_3 is ambiguous as it could be either positive or negative depending on the time and economic structure. Empirical studies have reported a mixed outcome. As a negative sign is supported by the wartime, sanctions, political instability and corruption witnessed in the energy sector with the rest of the world in Iran also contributed. As oil revenue decline and a lot of trading partners found substitute energy, that is, alternative and other trading hubs also had its toll on the country's economy see (Mehrara, (2007); Emami and Adibpour, (2012). On the contrary, a positive sign is also visible if all earlier mentioned menace is controlled for, especially corruption in the energy sector that has crippled economic progress over the years in Iran (World Bank, 2017).

3.3.3 Stationarity Test

The need for unit root and stationarity tests in time series analysis is pertinent among variables. This is essential to appraise the order of the variable integration. This is in the quest to avoid spurious regression. The econometrics literature has well documented numerous tests, among which are the Augmented Dickey and Fuller, (1981), Phillips and Perron (1988) and Elliott et al., (1992) test. A shortcoming of the conventional unit root tests highlighted above is that they fail to account for the structural break(s). These tests offer invalid and inconsistent estimates in the presence of structural break(s) dates. It is, however, a well-known fact that most macro-finance and economic datasets are plagued with structural breaks reflecting economic episodes and events. Thus, our study complements the conventional unit root tests with the Zivot-Andrews (1992) unit root test. The Zivot-Andrews unit root test is reputed to account for structural break in a singular manner.

The ZA unit root test has a null hypothesis of (unit root), meaning, H_0: $\theta > 0$ against an alternative (stationarity), H_1: $\theta < 0$. That is, failure to reject H_0 means the presence of unit roots while and rejection implies stationarity.

3.3.4 Cointegration Test

The econometrics literature has well documented several procedures for the cointegration relationship among interest series. Two series are said to have a long-run relationship (cointegrated), if there is a somewhat linear combination among such series. Examples of the available cointegration tests are Engle and Granger, (1987), Johansen and Juselius (1990), Philips and Ouliaris (1990), Johansen (1991). Others include Gregory and Hansen (1996) and Carrion-i-Silvestre and Sansó (2006). However, all aforementioned tests have varying conclusions ranging from cointegration to non-cointegration null hypothesis. Bayer and Hanck (2013) recently advanced the cointegration test providing more robust results by the amalgamation of different individual test statistics premised on the test of Engle and Granger (1987), Johansen (1991), Boswijk (1995) and Banerjee et al. (1998). The Fishers' formulae of the combined Bayer and Hanck (2013) test are provided below as outlined in a study by Shahbaz et al. (2016).

$$EG - JOH = -2[\ln(P_{EG}) + (P_{JOH})] \tag{3.5}$$

$$EG - JOH - BO - BDM = -2[\ln((P_{EG}) + (P_{JOH}) + (P_{BO}) + (P_{BDM}) \tag{3.6}$$

Here, $P_{EG}, P_{JOH}, P_{BO} and P_{BDM}$ are the corresponding probability values of the various individual cointegration tests.

3.3.5 Autoregressive Distributive Lag (ARDL) Approach

Furthermore, to reinstate the robustness of cointegration between NG consumption and economic output, gross fixed capital formation, and carbon dioxide emissions, we leverage the ARDL bounds testing technique that offers more robust and efficient estimates on the case of small sample size when compared to other conventional cointegration tests. Furthermore, the ARDL bounds test reports both short and long-run dynamics of the fitted regression alongside the error correction model term (ECT) simultaneously. In addition to the above-mentioned merits, the technique is also useful in case of an unknown order of integration of series. That is, the technique can be employed irrespective of whether the series is I(0) or I(I), but not I(2). The model is estimated in the bounds test framework via the unrestricted error correction model where all variables are taken as endogenous.

The test has a null of no cointegration with the bounds test, which is computed using F-statistics. The decision rule houses three scenarios. First, if the computed F-statistics is greater than the upper bounds of the critical values reported, the null is rejected. Second, if F-statistic lies with both lower and upper bounds, the decision is inconclusive and third, scenario state that if F statistic lies below the upper bounds, it is a case of no cointegration. The hypotheses for the bounds test are specified below as:

H_0: $\varphi_1 = \varphi_2 = \ldots. = \varphi_{k+2} = 0$ (3.7)

H_1: $\varphi_1 \neq \varphi_2 \neq \ldots. \neq \varphi_{k+2} \neq 0$ (3.8)

3.3.6 Cointegration Estimation Equation

Cointegration regression is necessary after establishing long-run association among series. Several of such tests abound in the literature, among such are fully modified ordinary least squares (FMOLS) advanced by Phillips and Hansen (1990), dynamic ordinary least squares (DOLS) by Stock and Watson (1993). Others include Park's (1992) Canonical Cointegration Regression (CCR). This cointegration estimation methodology offers robustness check of estimated regression as well as they offer reliable results in cases of small sample sizes, they are efficient.

3.3.6.1 Fully Modified Least Squares (FMOLS)

When cointegration exists among series integrated at first-order I(1), (FMOLS) estimation offers optimal cointegrating regression estimates (Phillips and Hansen (1990); Hansen, (1995); Phillips, (1995); Pedroni, (2001a, b). The method can address issues of endogeneity and autocorrelation and still render robust estimates.

3.3.6.2 Dynamic Ordinary Least Squares (DOLS)

The long-run regression estimator of fully modified dynamic least-square can be substituted with the dynamic ordinary least squares, given her merit over the FMOLS (Saikkonen, (1991); Stock and Watson, (1993). The DOLS technique is built to be an asymptotically efficient estimator as well as eliminate reaction in the cointegrating system. Econometrically, the estimation process contains the cointegrating regression which possesses both lags and leads, considering the orthogonality in the cointegrating equation error term.

3.3.6.3 Canonical Cointegration Regression (CCR)

The Canonical Cointegration Regression (CCR) is unique by circumventing bias of second-order a shortcoming of the ordinary least squares (OLS) estimator by a transformation of the variables

3.3.7 Granger Causality Approach

The traditional regression does not imply causal interaction. Thus, there is a need for the causality test to probe directional causality between variables. This is necessary, given the inherent insight that can be gleaned from such estimations by policymakers and stakeholders in general. Our study employs the Granger causality approach as the primary means of detecting the predictability power that exists among the variables. When we say variable X Granger causes Y, it implies that variable X and its past realizations are good predictors of variable Y. A general model specification for the bivariate (X, Y) Granger causality test is expressed thus:

$$X_t = \gamma_0 + \gamma_1 X_{t-1} + \gamma_2 Y_{t-1} + \varepsilon_t \tag{3.9}$$

$$Y_t = \gamma_0 + \gamma_1 Y_{t-1} + \gamma_2 X_{t-1} + \varepsilon_t \tag{3.10}$$

In equation-3.9, the null hypothesis that X doesn't Granger causes Y is tested against the alternate hypothesis that X Granger causes Y. The hypotheses are similarly stated for equation-3.10. It is also worthy of note that the causal relationships can take one of the following forms; unidirectional (meaning from X to Y or vice versa), bidirectional (implying feedback relationship from both ends) and neutrality (implying no casual interaction between the variables).

3.3.7.1 Toda-Yamamoto Granger Causality Methodology

The fact that conventional regression does not connotes causality interpretation. This necessitates the need to estimate the causality test. The current chapter relies on the modified Wald stat (MWALD) Toda- Yamamoto (1995) causality test to detect the flow of causality for the selected variables under consideration. The Toda-Yamamoto (TY, hereafter) is preferred to the traditional Granger causality because the TY possesses some distinct traits relative to the conventional Granger causality test. The TY can be conducted regardless of the cointegration relationship among variables.

Also, there is no precondition of stationarity properties of variables to be either integrated of order 1 or stationary at levels. However, the variable(s) should not be integrated of order 2. The TY methodology is conducted on a VAR setting, with a known VAR (k + dmax). Where dmax denotes the maximum order of integration of the variables and K represents the optimum lag order as suggested by the appropriate lag selection criterion. The present study employs a multivariate VAR (k + dmax) model which encompasses economic growth (GDP), oil rent, Non-oil GDP and Natural gas consumption. The model specification is rendered below as:

$$\ln GDP = \varphi_0 + \sum_{k=1}^{n} \varphi_{1k} \ln GDP_{t-k} + \sum_{r=m+1}^{d_{\max}} \varphi_{2r} \ln GDP_{t-r} + \sum_{k=1}^{n} \beta_{1k} \ln GFCF_{t-k} + \sum_{r=m+1}^{d_{\max}} \beta_{2r} \ln GFCF_{t-r} +$$
$$\sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln NGC_{t-r} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln NGC_{t-r} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln OR_{t-r} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln OR_{t-r} + \varepsilon_{1t} \tag{3.11}$$

$$\ln NGC = \beta_0 + \sum_{k=1}^{n} \beta_{1k} \ln NGC_{t-k} + \sum_{r=m+1}^{d_{\max}} \beta_{2r} \ln NGC_{2,t-r} +$$
$$\sum_{k=1}^{n} \varphi_{1k} \ln GDP_{t-k} + \sum_{r=m+1}^{d_{\max}} \varphi_{2r} \ln GDP_{t-r} + \sum_{k=1}^{n} \xi_{1k} \ln GFCF_{t-k} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln GFCF_{t-r} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln OR_{t-r} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln OR_{t-r} + \varepsilon_{2t} \tag{3.12}$$

$$\ln GFCF = \xi_0 + \sum_{k=1}^{n} \xi_{1k} \ln GFCF_{t-k} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln GFCF_{t-r} +$$
$$\sum_{k=1}^{n} \delta_{1k} \ln GDP_{t-k} + \sum_{r=m+1}^{d_{\max}} \delta_{2r} \ln GDP_{t-r} + \sum_{k=1}^{n} \beta_{1k} \ln NGC_{t-k} + \sum_{r=m+1}^{d_{\max}} \beta_{2r} \ln NGC_{t-r} + \sum_{r=m+1}^{d_{\max}} \beta_{2r} \ln OR_{t-r} + \sum_{r=m+1}^{d_{\max}} \beta_{2r} \ln OR_{t-r} + \varepsilon_{3t} \tag{3.13}$$

$$\ln OR = \varphi_0 + \sum_{k=1}^{n} \varphi_{1k} \ln OR_{t-k} + \sum_{r=m+1}^{d_{\max}} \varphi_{2r} \ln OR_{t-r} + \sum_{k=1}^{n} \beta_{1k} \ln GFCF_{t-k} + \sum_{r=m+1}^{d_{\max}} \beta_{2r} \ln GFCF_{t-r} +$$
$$\sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln GDP_{t-r} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln GDP_{t-r} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln NGC_{t-r} + \sum_{r=m+1}^{d_{\max}} \xi_{2r} \ln NGC_{t-r} + \varepsilon_{4t} \tag{3.14}$$

where GDP, NGC, OR and GFCF are all expressed in section 3.1. Also, ε_{1t} , ε_{2t} and ε_{3t} represent stochastic terms for fitted models. Where k denotes the optimal lag order.

By using the standard Chi-square statistics, Wald tests are employed to the first n coefficient matrices.

3.4 Empirical Findings and Discussions

In time series estimations, it is essential to have a visual plot of the variables to have a glimpse of how the dataset fares. Figure-3.1 below shows the variables under review. From Figure-3.1, it is conspicuous that there exists a noticeable structural break(s). Thus, our study modeled for such structural break(s) in the estimation section. Table-3.2 reports the basic summary (descriptive) statistics and correlation matrix analysis in the panel. Table-3.2 shows that all series investigated are normally distributed as reported by the Jarque-Bera probability which is desirable. Also observed is an obvious significant disparity between the minimum and maximum over the period investigated, which is worth further investigation. The correlation matrix is also reported at the bottom of Table 3.2. The correlation results show a positive association between NG intake and economic output (GDP) for the study area, which is desirable and expected for Iran, being a net exporter of NG. Also revealed is a significant positive synergy between RGFCF and economic growth, thus suggesting the key role of real gross capital formation in the Iranian economy. A similar positive association is seen between oil revenue and economic growth which give credence to Iran as an oil-exporting country. This is instructive and informative to policy economists.

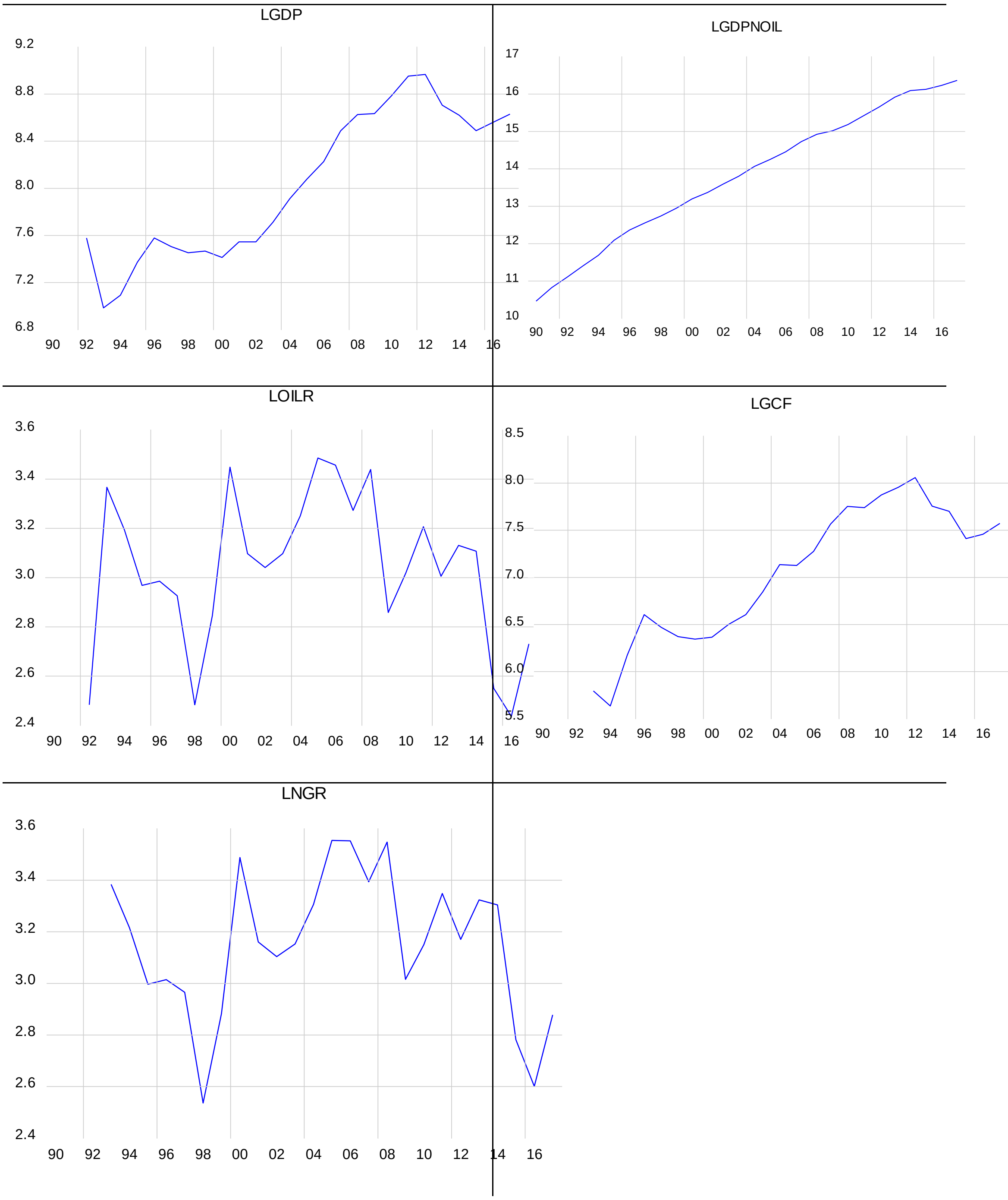


Figure 3.4: Visual plot of variables under consideration

Table 3.2: Descriptive and Correlation Coefficients Matrix Estimate

	LGCF	LGDP	LNNGC	LOILR	LGDPNOIL
Mean	7.0438	8.0535	3.1531	3.0562	14.1660
Median	7.1354	8.0758	3.1606	3.0973	14.2500
Maximum	8.0583	8.9661	3.5541	3.4856	16.3652
Minimum	5.6355	6.9852	2.5360	2.4372	11.4015

Std. Dev.	0.7116	0.6261	0.2806	0.2936	1.5240
Skewness	-0.3243	-0.0815	-0.4585	-0.4963	-0.1775
Kurtosis	1.9009	1.5427	2.5794	2.6479	1.8396
Jarque-Bera	1.6966	2.2398	1.0601	1.1553	1.5339
Probability	0.4281	0.3263	0.5886	0.5612	0.4644
LGCF	1.0000				
LGDP	0.9864	1.0000			
LNGC	0.1413	0.0944	1.0000		
LOILR	0.0473	0.1006	0.9766	1.0000	
LGDPNOIL	0.9192	0.9331	0.0170	0.2173	1.0000

Source: Authors' computation

Tables-3.3 and 3.4 render the unit root test analysis. The need for the tests enhances the accuracy of estimates and by extension avoid the pitfall of misleading policy implication(s). This research study adopts the traditional unit root tests of ADF and PP. However, given the established criticism on the tests with size and power problem, we complement with ZA unit root test that circumvents for these pitfalls mentioned. All unit root tests are in harmony. That is, all the variables (that is, real GDP, NGC, GFCF, OILR, and GDPNOIL) are integrated of order one I(1). Table-3.4 reports the ZA unit root test that presents structural breaks. The estimated structural break dates resonate with significant economic and political episodes of western sanctions and war periods in Iran. For example, the pre crises of global financial crises of 2006Q2 were captured. Also, the impact of sanctions imposed on Iran by most western nations, especially the US in the late 1980s is visible in natural gas variable and economic growth variable.

Table 3.3: Unit root test results (without break)

Panel A: Level		
Variables	ADF	PP
Ln GDP	-2.2805(1)	-1.4473(1)
LnNGC	-2.2636(1)	-2.6048(1)
LnGFCF	-2.2804(1)	-1.4473(1)
LnOILR	-2.0877(1)	-1.3349(1)
LnGDPNOIL	-1.5112(1)	-1.9817(1)
Panel B: First Difference		
Variables	ADF	PP
Ln GDP	-4.8588(1)*	-5.0679(1)*
LnNGC	-3.2091(1)*	-2.6048(1)*
LnGFCF	-4.8587(1)*	-4.8723(1)*
LnOILR	-5.2129(1)*	-4.7304(1)*
LnGDPNOIL	-4.5248(1)*	-4.3972(1)*

Source: Authors' computation
Note:*. **, denotes 1% and 5% significance rejection level respectively. Mackinnon (1996) one sided P-value is reported. Models with intercept and trend were reported for all test statistics. ( ) denotes optimal lag length

Table 3.4: Zivot and Andrews unit root test results (with single structural break date)

Variables	level		Δ	
	ZA test-stat.	Break Period	ZA test-stat.	Break Period
LnGDP	-4.7194(1)	2006Q2	-5.7194(1)**	2006Q2
LnNGC	-3.5610(1)	2004Q2	-5.1224(1)*	2004Q2
LnGFCF	-4.1319(1)	2000Q2	-5.1319(1)*	2006Q2
LnOILR	-4.9720(1)	2004Q3	-5.7726(1)**	1999Q3
LnGDPNOIL	-2.8101(1)	2012Q3	-5.8215(1) **	2012Q3

Source: Authors' computation
Note:*. **, denotes 1% and 5% significance level of rejection respectively. Δ Denotes the first difference and numbers in ( ) represent the lag length.

Table 3.5: Lag criteria selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	107.12	NA	1.62E-06	-1.9832	-1.8815	-1.9419
1	760.71	1244.3	7.65E-12	-14.244	-13.736	-14.038
2	841.24	147.11	2.22E-12	-15.485	-14.570*	-15.114
3	849.74	14.880	2.57E-12	-15.341	-14.019	-14.805
4	855.01	8.8017	3.18E-12	-15.134	-13.405	-14.434
5	911.57	90.278	1.47E-12	-15.914	-13.779	-15.049
6	961.59	75.992*	7.78e-13*	-16.569*	-14.026	-15.538*
7	968.02	9.2750	9.56E-13	-16.385	-13.435	-15.190
8	972.85	6.5964	1.22E-12	-16.170	-12.814	-14.810

Note: where LR represent sequential modified LR statistic, FPE means Final prediction error. Also Akaike information criterion (AIC), Schwarz information criterion (SIC) and finally Hannan Quinn information (HQ).

Table 3.6: Bayer and Hanck combined cointegration test results

Models	EG-JOH	EG-JOH-BO-BDM	Structural break	cointegration remark
GDP=f(NGC,GCF,OR)	55.340*	165.86*	2006Q2	Yes
GDPNONOIL=f(NGC, GCF,OR)	56.878*	115.80*	2004Q2	Yes

Source: Authors' computation.
Note:* ,**represents 1%, 5% significance rejection levels respectively Critical values for EG-JOH at 1% and 5% are 16.259 and 10.637 respectively, while for EG-JOH-BO-BDM are 31.169 and 20.486 respectively

Table-3.5 above reports the lag selection criterion. This is done to choose the most parsimonious and appropriate model. Our study adopts the Schwarz information criterion (SIC) for all subsequent analyses. The SIC is chosen over other available information criteria because of the large sample size and structure of our study. Table-3.6 demonstrates the cointegration relationship for all estimated models and affirms the cointegration (long-run equilibrium) relationship. That is, there is a convergence between the real GDP, real fixed gross capita formation, oil revenue, and non-oil GDP.

This is established by the rejection of the null hypothesis of no cointegration. Table-3.6 used the real GDP and Non-oil GDP variables as the dependent variable for the period under consideration. As a form of robustness check, we further carry out cointegration by ARDL bounds testing. The bounds test results presented in Table-3.7 corroborates the Bayer and Hanck results to confirm the equilibrium relationship among investigated series while controlling for structural break dates in the estimation.

Table 3.7: The ARDL Test Results

Cointegration by bounds testing		Diagnostic test				
Models	Optimal length	Break year	F-statistics	χ^2 white	χ^2 ARCH	χ^2 RESET
GDP=f(NGC,GCF,OR)	1,1,1,1	2006Q2	10.459*	0.0876	0.3917	0.401
GDPNONoil=f(NGC, GCF,OR)	1,1,1,1	2004Q2	4.4768**	0.2805	0.1024	0.916
Critical values						
	lower bounds 1(0)	Upper bounds 1(1)				
1%	3.65	4.66				
5%	2.79	3.67				
10%	2.37	3.20				

Source: Authors' computation
Note:* ,**represents 1%, 5% significance rejection levels respectively

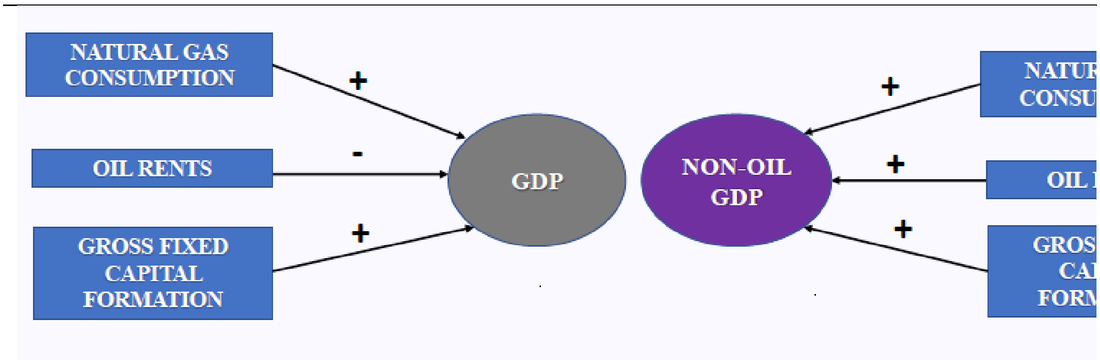
Having confirmed the cointegration relationship among investigated variables, it becomes pertinent to investigate the long-run equilibrium relationships with estimated coefficients. To achieve this, DOLS, FMOLS and CCR regressions are estimated to illustrate the magnitude of cointegration. The DOLS possesses some unique traits that allow for estimation notwithstanding the order of integration of the variables. However, the explained variable is required to be integrated of order one. Also, the technique helps to ameliorate the issue of serial correlation and other internalities as also emphasized by Esteve and Requena, (2006).

Table 3.8: FMOLS, DOLS and CCR Estimation Results

Depend variable:	LGDP			LNON-OILGDP		
Variable	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
LNGC	1.3276***	2.0391*	1.1890***	15.228*	11.807*	11.532*
	[1.6823]	[4.8340]	[1.5779]	[7.9990]	[6.8553]	[6.6900]
LOILR	-0.1533	-0.0346	-0.1667	0.3754	0.0882	0.0935
	[-0.9082]	[-0.3452]	[-1.0460]	[0.9214]	[0.2150]	[0.2531]
LGCF	1.7170*	1.8442*	1.6767*	6.3025*	5.6017*	5.5027*
	[11.340]	[24.504]	[12.387]	[17.255]	[18.228]	[17.608]
C	-46.728*	-56.748*	-44.415*	-283.71*	-234.17*	-229.19*
	[-4.6903]	[-10.609]	[-4.8139]	[-11.804]	[-10.722]	[-10.912]
R-squared	0.8175	0.8893	0.8170	0.8705	0.9338	0.8988
Adjusted R-squared	0.8124	0.8755	0.8119	0.8668	0.9255	0.8959
S.E. of regression	0.2731	0.2233	0.2735	0.6353	0.4659	0.5616
Long-run variance	0.2250	0.0439	0.2250	1.3097	0.7324	1.2256

Mean dependent var	7.9834	7.9786	7.9834	13.8364	13.8440	13.8364
S.D. dependent var	0.6307	0.6330	0.6307	1.7414	1.7082	1.7414
Sum squared resid	7.9830	4.7885	8.0040	43.192	20.846	33.753

Source: Authors’ computation.
Note: *, **,*** represents 1%, 5% and 10% rejection significant levels respectively. [ ] are t-statistics.



Note: Oil rents are not significant in both models.

Figure 3.5: Estimation Scheme

The empirical results reflect a negative connection between income and oil rents; while natural gas rents and gross fixed formation present a positive connection with income in Iran between 1992-2017. The negative connection between oil rents and economic growth would be motivated by the existence of irregular behaviors (Arezki and Brückner (2009) in Iranian economic system, as a consequence of corruption, development of political rights or civil liberties, which would reduce income levels in Iran, Ross (1999), Arezki and Brückner (2009). Thus, we consider that policymakers should be aware of the impact of oil rents over redistribution and corruption, to adopt measures to attract the promotion of renewable technologies.

On the other hand, natural gas rents have contributed positively to enhance ascending economic growth in Iran (Mastorakis, and Khoshnevis (2014), BP, (2018). Pirlogea and Cicea (2012) reported that natural gas consumption causes economic growth in Spain. The position of natural gas-induced economic growth is also consistent with the study of Shahbaz et al. (2013) found that natural gas consumption contributes to economic growth in the case of Pakistan. For the Iranian case, the country has been reflected as the second most massive natural gas field and the third producer of natural gas in the world as outlined by (EIA 2010, BP 2018). Iran was ranked the third-largest natural gas producer in the world with more than 223 billion cubic meters of natural gas, enjoying a 6.1-percent share in the global gas market (BP 2018). The replacement of oil products with natural gas consumption was an essential policy of government in the energy sector during the fourth development plan (2005–2009). Nowadays, more than 40% of total energy consumption in Iran is provided by natural gas, reflecting the relevance of this energy factor in the process of economic growth and development plans (MOE 2008, BP 2018). We can suggest that the main reasons for the increasing rate of natural gas consumption are due to the low price of domestic supply of natural gas that leads to economic justification of the use of wasting energy technologies, non-optimal allocation, in the appropriate and abundant use of natural gas. So, unlike the pattern of natural gas consumption in industrialized countries, the highest share of its consumption in Iran is allocated to the household and commercial sectors Mastorakis and Khoshnevis, (2014).

During the last years, sanctions have reduced gross capital formation in Iran, especially in construction investment and public investment (World Bank 2017). From the empirical results, this variable presents a positive connection with income level, suggesting the necessity of an advance in non-oil sectors, related to more sustainable growth. Hence, in medium-term the growth rates are expected to revert to an average of 4% in Iran (World Bank 2017), reflecting the positive effect that measures connected with sustainable growth would exert over this situation. So, this research study suggests that the non-oil sector and private investments play a significant role, even the oil sector lessens the enlargement of the Iranian economy.

This research study further reveals that a 1% increase in NG consumption translates into a corresponding increase in economic growth by a magnitude of 1.3276%, 2.0391% and 1.1890% for FMOLS, DOLS, and CCR respectively. Likely a 1% increase in NG consumption will amount into a corresponding increase in non-oil GDP by the following magnitude 15.2284%, 11.8075% and 11.5328% for FMOLS, DOLS, and CCR respectively.

Interestingly, the study observes positive synergy between real gross capital formation, economic growth, and non-oil GDP. This is a call for Iran to strengthen her institutions to enhance capital accumulation both in the short and long-run and consequently grow her economy.

The fitted model residual diagnostic test results indicate that the model is adequate for policy construction given it free from autocorrelation, model misspecification, and heteroscedasticity.

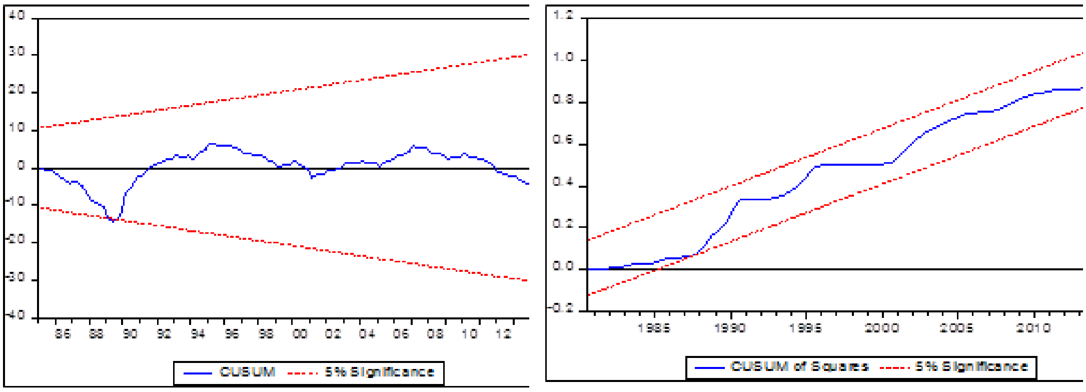


Figure 3.6: CUSUM and CUSUM Sq

Figure-3.2 further buttresses the argument that the fitted model with real GDP as the dependent variable in Table 3.8 is stable, given the CUSUM and CUSUMSQ stability lines lie within the 5% threshold interval, an indication that the model is stable.

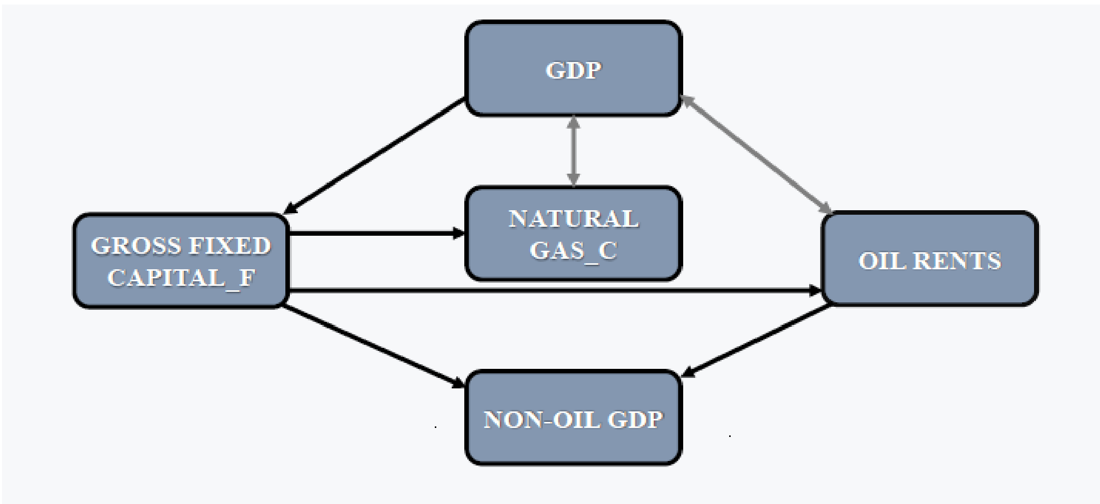


Figure 3.7: Granger Causality Scheme

Table 3.9: Pairwise Granger Causality Tests

Null Hypothesis:	Causality	F-Statistic	Prob.
LNNGC ≠> LNGDP	GDP↔NGC	2.64256	(0.0379)
LNGDP ≠> LNNGC		3.41028	(0.0137)
LNOR ≠> LNGDP	GDP↔OIL RENTS	139.299	(2.E-11)
LNGDP ≠> LNOR		2.30640	(0.0622)
LNGFCF ≠> LNGDP	GDP →GFCF	1.13801	(0.4245)
LNGDP ≠> LNGFCF		3.32265	(0.0153)

LNGDP_NON_OIL ≠> LNGDP	NON-OIL GDP→GDP	8.93305	(0.0001)
LNGDP_CURRENT ≠> LNGDP_NON_OIL		1.74898	(0.1514)
LNOR ≠> LNNGC	OIL RENTS →NGC	3.25689	(0.0166)
LNNGC ≠> LNOR		1.84008	(0.1302)
LNGFCF ≠> LNNGC	GFCF→NGC	15.7445	(6.E-06)
LNNGC ≠> LNGFCF		0.87441	(0.6389)
LNGDP_NON_OIL ≠> LNNGC	NON-OIL GDP ≠NGC	1.00636	(0.5245)
LNNGC ≠> LNGDP_NON_OIL		0.57483	(0.8973)
LNGFCF ≠> LNOR	GFCF→OIL RENTS	2.34405	(0.0587)
LNOR ≠> LNGFCF		1.06388	(0.4789)
LNGDP_NON_OIL ≠> LNOR	OIL RENTS→NON-OIL GDP	1.24691	(0.3540)
LNOR ≠> LNGDP_NON_OIL		2.57140	(0.0420)
LNGDP_NON_OIL ≠> LNGFCF	GFCF→NON OIL-GDP	0.73563	(0.7658)
LNGFCF ≠> LNGDP_NON_OIL		4.67394	(0.0034)

Note ≠> means does not Granger cause

Table- 3.9 (Fig 3.7) presents the direction of causalities and Fig 3.7 demonstrates the flow chart of the variables under review. As shown, there exists a unidirectional causality running from gross capital formation to NG consumption. This implies that capital formation is essential to increase NG consumption. A similar trend of unidirectional causality flow is seen running from real GDP to gross capital formation. This study gives support to the NG consumption induced economic growth hypothesis in Iran as causality is observed from NG consumption to economic growth, also accentuated by Bildirici and Bakirtas, (2014); Solarin and Shahbaz, (2015); Ozturk and Al-Mulali, (2015); Dogan, (2015); Farhani et al., (2014); Saboori and Sulaiman, (2013); Balitskiy et al., (2016); Destek, (2016); Solarin and Ozturk, (2016); Esen and Oral, (2016); Hafeznia et al., (2017), among others (see Table 3. 1). This study joins the group of studies that support the NG-economic growth hypothesis Lee and Chang, (2005); Reynolds and Kolodziej, (2008); Shahbaz et al., (2013). However, NG driven economic growth is not a panacea for Iran’s sustainable economic growth, given the dwindling price and energy market dynamics globally. This implies that there is a need for diversification of the energy portfolio in Iran to more environmentally friendly sources like renewable energy sources is encouraged by this study (see Fig. 3.8) (see Table 3.10).

The empirical results also support bidirectional causality between oil rents and economic growth in Iran, in line with Najjarzadeh and Mohsen (2004) and Shahbazi (2013), who showed similar results for Iran. The causality results validate the feedback hypothesis between energy and economic growth in Iran. Finally, Toda-Yamamoto causality test was implemented to reinforce the empirical results.

Table 3.10: VAR Granger Causality/Block Exogeneity Wald Tests

	LNOR	LNGDP	LNGDP_NON_OIL	LNGFCF	LNNGC
LNOR	-	3.3336	4.2099	2.8355	7.7083
	-	(0.8525)	(0.7553)	(0.8998)	(0.3590)
LNGDP_CURRENT	22.967*	-	1.2238	10.634	5.4164
	(0.0017)	-	(0.9904)	(0.1554)	(0.6093)
LNGDP_NON_OIL	13.966**	17.071*	-	20.053*	5.9620
	(0.0518)	(0.0169)	-	(0.0055)	(0.5442)
LNGFCF	5.2706	13.568**	12.280***	-	11.168
	(0.6270)	(0.0594)	(0.0917)	-	(0.1314)
LNNGC	15.365*	14.303**	7.0574***	7.7434	-
	(0.0316)	(0.0460)	(0.0917)	(0.3558)	-
All	53.967	37.034	37.337	59.213	32.828
	(0.0023)	(0.1181)	0.1116	(0.0005)	(0.2421)

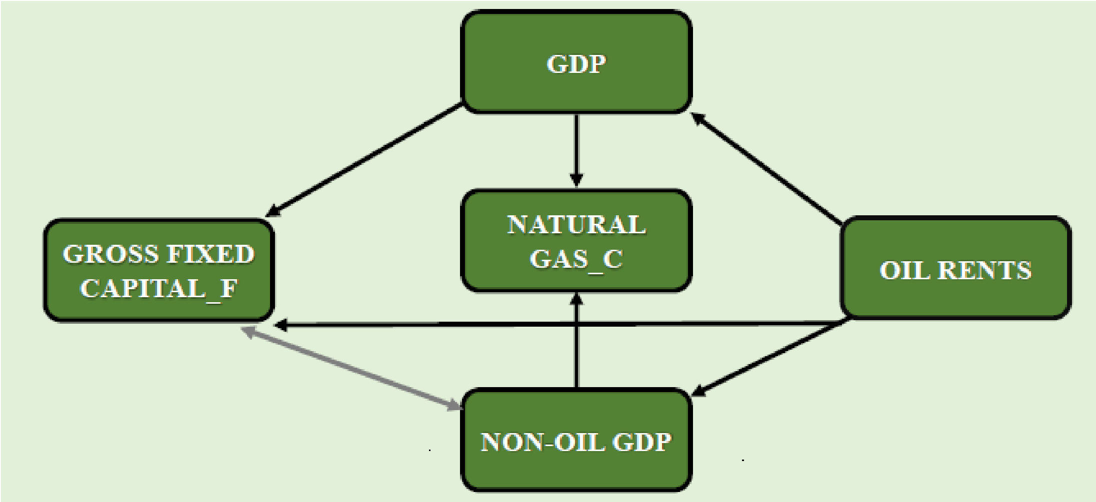


Figure 3.8: VAR Granger Causality Scheme

3.5 Concluding Remark/Policy Implications

This country-specific chapter seeks to investigate the interaction between natural gas consumption-economic growth nexus for the case of Iran by the inclusion of real GFCF and CO_2 emissions as additional variables in a multivariate framework to avoid omitted variable bias which previous studies failed to address. To do this, quarterly data from 1990Q1 to 2017Q4 gathered from WDI (https://data.worldbank.org/indicator) and the U.S Energy Information Administration database (EIA) was used for the econometric analyses. This chapter accounts for a structural break in all estimations. For the stationarity test, beyond the conventional ADF and PP tests, the Zivot Andrews unit root test which accounts for the single structural break was also employed. For the cointegration analysis, with the noted break year properly accounted for in the estimation combined cointegration advanced by Bayer and Hanck (2013) is employed. The Bayer and Hanck (2013) test result were further confirmed via the Pesaran ARDL bounds testing to cointegration approach as a form of robustness test. For causal interaction, the Granger pairwise causality and the Toda-Yamamoto Granger block exogeneity Wald test is used to reinforce causality results. Empirical findings reveal bidirectional causality seen between natural gas consumption and economic growth, confirming the feedback hypothesis for the study area. Thus, government officials in Iranian are encouraged to promote more efficient use of natural gas, to enhance the process of economic growth. The promotion of natural gas sources will improve the use of safe energy utilization, with a lower cost of production (Shahbaz et al., 2013a).

Further empirical investigation reveals cointegration among the variables under several structural breaks. Thus, it implies that there exists a long-run bond between interest variables (cointegration) over the period considered. This finding is a pointer that in the long-run capital formation, NG consumption and oil rents are drivers of long-run economic growth in Iran.

Empirical finding from the study gives credence to the NG consumption-induced economic growth hypothesis as causality interaction is observed from the consumption of natural gas to economic output. Thus, it implies that embarking on aggressive NG exploitation and exploration will spur economic growth. Cleaner energy sources like photo voltaic, solar, wind, thermal bioethanol and biomass among others are crucial and encouraged in Iran. This is in agreement with the claim put forth in the recent study of Balsalobre-Lorente et al., (2018) for 5-EU countries that confirm the positive role of renewable energy rather than fossil fuel energy sources which are not as clean as natural gas and already mentioned cleaner energy sources (Saidi and Hammami, 2015; Emir and Bekun, 2018).

A further piece of empirical results shows a unidirectional contribution from gross fixed capital formation to NG consumption both in the long and short run. It is instructive that in Iran, capital plays a positive and significant role in economic output. Our empirical results validate the necessity of sustainable growth connected through the attraction of foreign capital investments via financial liberalization and promotion of clean energy sources. As a way for further research direction and contribution to literature, other scholars can query the theme under review by accounting for asymmetry in the econometric modeling. There is also room to investigate a panel of net exporters of NG to ascertain if NG consumption drives economic growth in this set of countries

Investigating energy consumption and CO_2 emissions in Iran in this chapter has given an idea to the readers to compare Iran with another neighboring country, Turkey, which is discussed in the previous chapter. It is our query to check another emerging economy with similar considerable size, such as South Africa, in the next chapter to have better idea and make a final comparison among three nations in the Conclusion part of this thesis.

Chapter 4

MODELING THE DYNAMIC NEXUS AMONG COAL CONSUMPTION, POLLUTANT EMISSIONS AND REAL INCOME FROM AN EMERGING ECONOMY: EMPIRICAL EVIDENCE FROM SOUTH AFRICA

4.1 Introduction

A major challenge facing any country of the world endowed with non-renewable energy resources is the ability to formulate energy and environmental strategic policies such that safe and secured energy is produced to meet energy needs while reducing significantly carbon dioxide (CO_2) emissions (WCA, 2019). This challenge requires growing attention as demand for energy is rising (EIA, 2018). The primary priority of players in this sector is to diversify energy sources and discover secure and stable energy supply Gnansounou, (2008); Ferguson, (2007); Toth and Rogner, (2006). The majority of the endowment reserves (that is, crude oil and natural gas) sources are found around a certain geographical region of the world and specifically, about 68% and 67% respectively are located in the Middle East and Russia. This suggests high risk to countries that depend significantly on the importation of energy as there may be instability and the supply of these resources would not be guaranteed (WCA, 2018). Ensuring the sustainability of crude-oil supply has been of top priority to countries bringing in oil especially after the crisis of 1973. Safeguarding the supply of oil in the oil-importing countries of the world has necessitated the search for an alternative source of domestic energy. This motivated the quest for another source of low-priced energy supply from many energy-importing countries, as it is captured in their policy and strategy documents (Toth and Rogner, 2006).

Coal is globally abundant and most cheap in respect of fossil fuel. With the need for cheap alternative energy supply sources coal has the capability of providing adequate demand for secured energy (WCA, 2018). The current world deposit of coal is projected to be available for about 136 years ahead, whereas the projection for natural gas and crude oil are for about 30 and 52 years, respectively (IEA, 2017). By the year 2030, it is expected that coal becomes the second-largest main fuel or energy source as noted by Shafiee and Topal, (2008). Shafiee and Topal, (2008) in 2005, accentuated that coal accounted for the share of world energy as follows: 72% in South Africa, 63.4% in China, 38.7% in India, 23.8% in the USA, 23.1% in South Korea, and 21.1% in Japan. Also, the total electricity generation from coal sources are accounted in the following ways: 95% in South Africa, 79% in China, 69% in India, 51% in the USA, 38% in South Korea, and 29% in Japan as stated by (WDI, 2007 and 2008).

Although coal enjoys acceptance as a creditable source of energy due to the earlier factors mentioned, there is also a group of persons who believe that global warming can be traced to the high consumption of coal which usually results in the carbon dioxide (CO_2) emission increase from burning coal. This study, therefore, explores the interaction among coal consumption, pollutant emission and real income for the South African economy using the multivariate framework.

Even with the overwhelming evidence supporting coal consumption as an important energy source for many countries, there are scanty studies that have engaged recent and advance econometric techniques in testing the nexus between coal consumption and economic growth (Jinke *et al.*, 2008). Hence, in this chapter, it is aimed to explore the importance of coal in energy supply as well as validate the source of global warming by using adequate and recent econometric methodologies. The dynamic relationship between coal consumption, pollutant emissions, and real income will be investigated with an empirical methodology.

One of the goals of the United Nations (UN) in terms of its sustainable development growth (SDGs) is access to energy, which is resonated in the goal 7 of the SDG. Across the globe, economies are also confronted with climate change issues that are aggravated by Greenhouse Gas as a result of CO_2 emissions, which is SDGs 13. All the above highlights inform the choice of this study's variables as well as to investigate the relationship between energy (coal) consumption and economic growth in South Africa.

The theme under consideration has received great attention in the energy economics literature for developed and emerging economies. However, very few studies exist for Sub Saharan African countries that explore the nexus among energy, income and environment which are noted by Mapapu and Phiri, (2018); Amuakwa-Mensah and Adom, (2017); Khobai and Le Roux, (2017); Ben Jebli *et al.*, (2015); Bildirici and Bakirtas, (2014); Kohler, (2013); Shahbaz *et al.*, (2013); Menyah and Wolde-Rufael, (2010). Thus, this research study seeks to bridge this gap for the case of South Africa, where only a few studies exist, such as by Balcilar *et al.,* (2010); Odhiambo, (2009); Ziramba, (2009). The South African economy has a very rich and dynamic energy mix which is worthy of investigation. In this chapter, Environmental Kuznets Curve (EKC) will be investigated by incorporating coal consumption for South Africa.

The rest of this chapter takes the following sequence: section 4.2 provides some stylized facts. Section 4.3 briefly reviews the related literature. Section 4.4 examines the data methodology used for the study, whilst section 4.5 focuses on empirical results and discussion. Finally, section 4.6 gives concluding remarks together with plausible indications of policy.

4.2 A Synopsis on Energy Mix in South Africa

South African economy is largely dependent on coal resources. The major leading sectors are related to the electricity: liquid fuels manufacturing, basic iron, and steel, which collectively account for more than 80% of domestic coal demand in terms of value and 70% in terms of volume. Recent statistics reveal that about 90% of the country's power is generated by using coal, followed by nuclear with about 5.2%, and 3.2% from natural gas (EIA, 2017). South Africa remains one of the biggest players in the production of coal with a 6th position in terms of ranking in the world (Ratshomo and Nembahe, 2018). Coal is the primary driver of energy production in South Africa and it is known that its energy production and supply chain is well organized. Although South Africa is naturally and abundantly endowed with coal energy production and consequently importation, there is a lack of such abundance in natural gas and crude oil. South Africa is also endowed with a reasonable amount of renewable energy sources. DEM (2016) reported the contribution of renewable energy exploited for electricity power generation for industrial and residential consumption. According to Beg *et al.* (2002), approximately 250,000 job opportunities have been created by the South African energy sector to its citizenry, and this accounts for about 15% of the total output of the economic activities in the country.

4.3 Literature Review

In recent times, energy consumption and real income nexus have dominated literature and this discussion is on-going such as the one with Balcilar *et al.*., (2019); Bekun *et al.*, (2019); Gong, B*et al.*., (2019); Nathaniel *et al.*., (2019); Zhang and Zhou, (2018); Kurniawan and Managi, (2018); Hao *et al.*, (2016); Mohiuddin *et al.*,(2016); Kim and Yoo, (2016); Caraiani and Dascălu, (2015). Despite the extensive and robust discussion on the subject matter, a consensus has not been reached with regards to causality direction between these two variables. There are three distinct yet competing hypotheses postulated with sufficient evidence to support the relationship between energy consumption and economic growth. Bi-directional causality (with a feedback mechanism) is observed in some countries; whereas in other countries there is no causality observed in any direction (neutrality hypothesis). In other evidence, there is one-way causality interaction from economic growth towards energy consumption, while in several papers emerge an opposite causality flow, from energy to economic growth (Magazzino, 2016b).

Parallel to the nexus between aggregate energy consumption and real income, there is a contradiction when examining the empirical relationship between coal consumption and economic growth. Raza and Shah (2019) examined the causal relationship between coal consumption and economic growth by including the fiscal deficit, rural-urban population, and unemployment for Pakistan over the period 1981-2017. Their results posit that there are a short-run and long-run bi-directional causal relationship between coal consumption and economic growth. Abuoliem *et al.* (2019) evaluated the relationship between domestic, international macroeconomic indicators and financial sector index in a frontier market (Amman Stock Exchange, ASE). Their findings indicate that the deposit interest rate positively influences the financial sector in the short- and long-run, while the producer price index and the global oil price have significant negative impacts on the financial sector. However, Al-mulali and Che Sab (2018) showed that there is no short-run and long-run Granger causality between coal consumption and economic growth for panel countries. Bekhet *et al.* (2017) examined the energy-financial development-growth nexus for GCC countries. The empirical results show that economic growth is associated with increased CO_2 emissions in Saudi Arabia, Oman, Qatar, and Bahrain; furthermore, financial development is identified as a driver of energy emissions reduction. Shahbaz *et al.* (2016) employed a time-varying Granger causality technique to ascertain the flow of causality among economic growth, energy consumption and CO_2 emissions for the next 11 countries. They found that economic growth causes energy consumption in the Vietnam, Turkey, and the Philippines while a bi-directional time-varying causal relationship between economic growth and energy consumption in South Korea. Matar and Bekhet (2015) assessed the empirical dynamic relationship among the electrical consumption, economic growth, export, and financial development in Jordan over the 1976-2011 period, providing evidence of a long-run equilibrium relationship between electricity consumption and the economic growth, and a unidirectional relationship from real GDP to electrical consumption. Bildirici and Bakirtas (2014) disaggregated energy consumption into coal, natural gas, and oil consumption to detect causal relationships among coal, natural gas, oil consumption and economic growth for BRICTS countries. Their results also confirmed that bi-directional causality between coal consumption and economic growth for China and India. These findings are in line with the results of Lin and Lotz (2018). Nasiru (2012) for Nigeria found one-way directional causality flowing from economic growth to coal consumption. Li and Leung (2012) investigated the relationship between coal consumption and economic growth using provincial-level panel data for the case of China. Their findings were conflicting as Coastal region revealed a bi-directional causal interaction between, whereas for Central region the causal relationship was unidirectional, from economic growth towards coal consumption. The bi-directional causality implies both coal consumption and economic growth can have a lasting impact on each other. Take for instance, should policies of energy conservation be adopted as the policy direction, this may retard coal consumption and this will impact economic growth. Likewise, an expansionary energy policy will accelerate economic growth and induce more coal consumption. Wolde-Rufael (2010) and Li *et al.* (2008) examined the causal relationship between coal consumption and GDP in China. They found unidirectional causal relationship running from economic growth to coal consumption. Reynolds and Kolodziej (2008) investigated the energy-economic growth nexus in the case of the former Soviet Union, discovering a unidirectional causal relationship from economic growth to coal consumption. A similar study was conducted by Jinke *et al.* (2008) and their finding revealed a one-way directional causality flow from economic output towards coal consumption in Japan and China, whereas in South Africa, South Korea and India there was no evidence of causality at all. Yuan *et al.* (2008) examined the relationship between economic growth and coal consumption in China and found no causality. Yoo (2006) in his investigation for South Korea discovered a bi-directional causality from coal consumption to economic growth. Soytas and Sari (2006) investigated the relationship between energy consumption and economic growth in China using aggregated and disaggregated levels of energy consumption. They found no causal relationship between total energy consumption and economic growth. Zhou and Chau (2006) found unidirectional causal relationships from oil consumption to economic growth in the short-run, whereas in the long-run a bidirectional causal relationship was found. Wolde-Rufael (2004) discovered for Shanghai a unidirectional link from coal consumption to real GDP. Lee and Chang (2005) found evidence of a bi-directional causal relationship between coal consumption and economic growth in Taiwan. Fatai *et al.* (2004) did not find any causality link between coal consumption and economic growth in the case of New Zealand. Fatai *et al.* (2004) for Pacific Rim countries of Australia and New Zealand found a unidirectional causal relationship from economic growth to coal consumption for Australia, using Johansen-Juselius and TY tests; however, there was not any causality nexus emerges when the ARDL model is used.

From the previous studies, we can observe contradictory outcomes with regards to the interactions and causal relationship between coal consumption and real income and this has serious implications on policy directions. Suppose there is one-way directional causality flowing from real income to coal consumption, this would suggest that policies that are targeted at reducing coal consumption, if executed, will have little or no negative impact on economic growth. But, if the unidirectional causal effect is the opposite of the aforementioned, then policies that are targeted at reducing coal consumption could be detrimental and may result in less economic growth. Alternatively, where there is an absence of causality between the variables under investigation, neutrality hypothesis is taken into account, and measures taken by policymakers and stakeholders to reduce coal consumption may have no significant impact on economic output or income. On the other hand, where there is a bi-directional causal relationship flowing from coal consumption towards economic growth and vice versa, coal consumption is capable of stimulating economic growth, and the increase in real income further induce more demand for coal. This situation, therefore, allows both coal consumption and economic growth to serve as a perfect complement for each other. This further implies that coal conservative policies are very likely to be injurious to economic growth. Hence, this research chapter aims to contribute to the existing literature in three different fronts: (a) investigating the EKC for South Africa; (b) the exploration of the role of coal consumption on its economic output over the investigated period; (c) the adoption of recent and more robust econometric procedures (Maki; 2012; Toda and Yamamoto 1995).

4.4 Data and Empirical Strategy

This study uses annual time series over the period 1965-2017[1] to address the nexus between carbon dioxide emission (CO_2) (k_t), real per capita gross domestic product (GDP) (with 2010 constant dollar prices), the square of real per capita gross domestic product (GDP^2) and coal consumption (COAL) (k_t) in South Africa. We derived data on GDP and CO_2 from the World Development Indicators (WDI, 2019) database, while the COAL series was retrieved from the US Energy Information Administration (EIA database). CO_2 emissions variable is used as a proxy for environmental degradation, while GDP is used as a proxy for economic growth. We follow the empirical works of Magazzino (2016a) and Balcilar *et al.* (2019):

$$CO_2 = f(GDP, GDP^2, COAL) \qquad (4.1)$$

$$lnCO_{2t} = \alpha + \delta_1 LnGDP_t + \delta_2 LnGDP^2{}_t + \delta_3 LnCOAL_t + \varepsilon_t \qquad (4.2)$$

where α denotes the constant term, δ's is the slope parameters and ε_t is the error term with zero mean and constant variance, i.e. $\varepsilon_t \sim IN(0, \sigma^2)$. Also, all variables are taken in their natural logarithm form.

[1] The data span is selected based on data availability.

The first investigation of the selected series pertains to stationarity properties. Among the battery of tests proposed in the econometric literature, we applied the Augmented Dickey and Fuller (ADF, 1979), the Leybourne (1995), the Dickey and Fuller Generalized Least Squares (DF-GLS), the Elliott *et al.* (ERS, 1996), the Phillips and Perron (PP, 1988), the Kapetanios *et al.* (KSSUR, 2003), the Kapetanios and Shin (KSUR, 2008), the Ng-Perron (NP, 2001), and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS, 1992) tests. These tests are also used to identify the maximum order of integration of the variables. However, the aforementioned unit root and stationarity tests are not reliable to decide the order of integration of the variables in the presence of structural break(s). Thus, to consider a possible structural break in the series, we also employ the Zivot and Andrews (ZA, 1992) unit root test, which suggests three different specifications of the model.

To examine the existence of a long-run equilibrium relationship among the non-stationary series, we applied the Maki (2012) cointegration test under consideration of multiple structural breaks. Unlike other traditional cointegration tests – as Johansen (1991), Johansen and Juselius (1990), and Engle and Granger (1987) – this technique accounts for the existence of structural break(s) in the series. Subsequently, most of the finance and economic series have jumped and break due to the economic or financial crisis in the country. That is a major argument canvassed by Maki (2012), Gregory and Hansen (1996), and Gregory *et al.* (1996). In this regard, Maki's (2012) cointegration test is superior to the other conventional test to avoid spurious or biased results. The only condition for employing this technique is that all the examined series are integrated of order 1, i.e. *I(1)*. Four different models exist to apply the Maki (2012) cointegration techniques. These models are given as:

Model 1: With break-in intercept and without trend

$$y_t = \mu + \sum_{i=1}^{p} \mu_i D_{i,t} + \theta' z_t + \mu_t \quad (4.3)$$

Model 2: With break-in intercept and coefficients and without trend

$$y_t = \mu + \sum_{i=1}^{p} \mu_i D_{i,t} + \theta' z_t + \sum_{i=1}^{p} \theta_i' z_t D_{i,t} + \mu_t \quad (4.4)$$

Model 3: With break-in intercept and coefficients and with the trend

$$y_t = \mu + \sum_{i=1}^{p} \mu_i D_{i,t} + \alpha t + \theta' z_t + \sum_{i=1}^{p} \theta_i' z_t D_{i,t} + \mu_t \quad (4.5)$$

Model 4: With break-in intercept, coefficients and the trend

$$y_t = \mu + \sum_{i=1}^{p} \mu_i D_{i,t} + \alpha t + \sum_{i=1}^{p} \alpha_i t D_{i,t} + \theta' z_t + \sum_{i=1}^{p} \theta_i' z_t D_{i,t} + \mu_t \quad (4.6)$$

The causality term refers to the existence of the predictability power of one series on the other one. The Toda-Yamamoto (TY, 1995) causality test is carried out to investigate the presence and direction of the causal relationship between the variables in this study. The TY causality is a modified version of the Wald test that has superior traits than the conventional Granger causality test. This superiority ranges from its resilient and robust nature. Also, this test can be performed irrespective of the integration order of the analyzed series (Amiri and Ventelou, 2012). The TY technique is conducted on Vector AutoRegressive (VAR) with (k+d_{max}) lags, where *k* denotes the optimum lag order. The equations can be formulated as follow:

$$CO_2 = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} CO_{2,t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{2j} CO_{2,t-j} + \sum_{i=1}^{k} \delta_{1i} COAL_{t-i} + \sum_{j=k+1}^{d_{max}} \delta_{2j} COAL_{t-j} + \sum_{i=1}^{k} \beta_{1i} GDP_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} GDP_{t-j} + \varepsilon_{1t} \quad (4.7)$$

$$COAL = \delta_0 + \sum_{i=1}^{k} \delta_{1i} COAL_{t-i} + \sum_{j=k+1}^{d_{max}} \delta_{2j} COAL_{t-j} + \sum_{i=1}^{k} \alpha_{1i} CO_{2,t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{2j} CO_{2,t-j} + \sum_{i=1}^{k} \beta_{1i} GDP_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} GDP_{t-j} + \varepsilon_{2t} \quad (4.8)$$

$$GDP = \beta_0 + \sum_{i=1}^{k} \beta_{1i} GDP_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} GDP_{t-j} + \sum_{i=1}^{k} \delta_{1i} COAL_{t-i} + \sum_{j=k+1}^{d_{max}} \delta_{2j} COAL_{t-j} + \sum_{i=1}^{k} \alpha_{1i} CO_{2,t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{2j} CO_{2,t-j} + \varepsilon_{3t} \tag{4.9}$$

4.5 Empirical Results and Discussions

This section focuses on the empirical results and their discussion. Preliminary analysis such as graphical plot, summary statistics, and correlation matrices is the first point in data analysis. This enables us to have a glimpse of the variables under consideration (Magazzino, 2017). Figure 4.1 depicts the evolution of the series. All variables show a positive trend over the investigated period. Thus, this study investigates dynamic interactions within the variables. Table 4.1 presents the summary statistics and correlation matrices for the variables. Economic growth has the highest mean while coal consumption exhibits the lowest mean. All variables show a significant departure from their mean as reported by the standard deviation. In terms of symmetry, all series are negatively skewed. The relationship between the variables is reviewed with the correlation analysis in the last column of Table 4.1. We observed strong and significant positive correlation coefficients. Thus, the need to further validate or refute the above assertion is needed given that correlation analysis is not sufficient.

The next step is to check the order of integration of the series to avoid spurious and biased results (Magazzino, 2017). Hence, the study conducts stationarity and unit root tests. We applied time-series techniques on stationarity and unit root processes. Table 4.2 gives the results, to determine the order of integration.

All tests lean towards the conclusion that the original series (*CO_2*, *COAL,* and *GDP*) are non-stationary. However, their first-differences can be considered as stationary processes. Thus, the carbon dioxide emissions, coal consumption, and real GDP are integrated of order one, or *I(1)*. This leads to the question of whether these series are cointegrated. Starting from multiple series that alone are non-stationary, we can discover a linear combination of them that is stationary. This is the case when the original series share a common trend in the long-run.

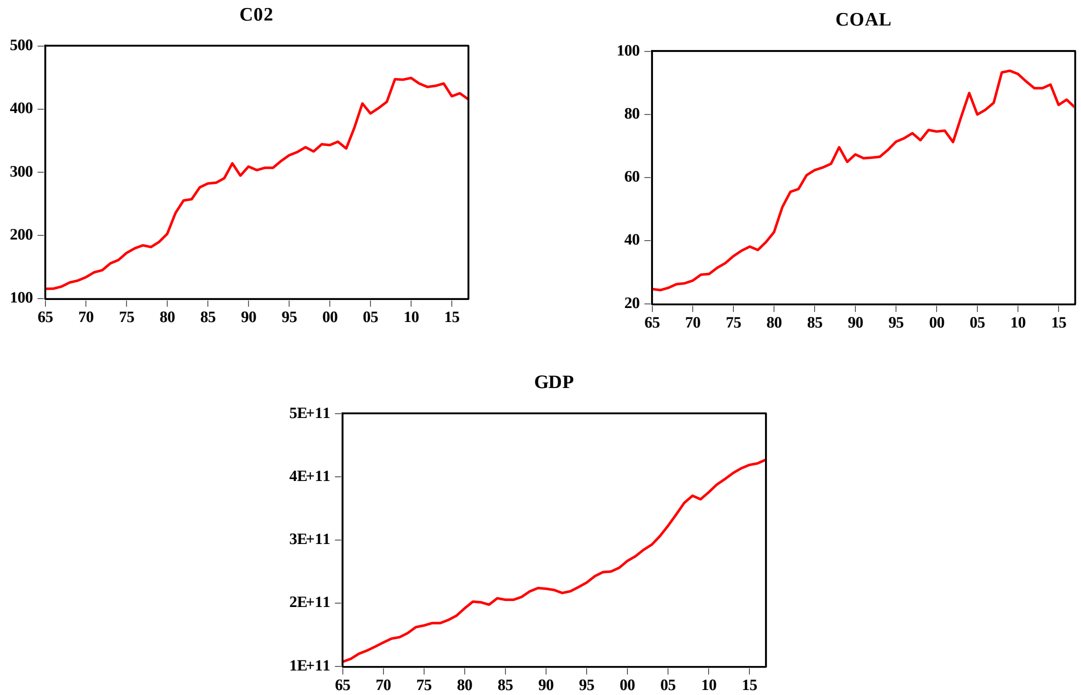


Figure 4.1: Evolution of the selected variables (level form)

Table 4.1: Descriptive Statistics and Correlation Analysis

Vari able	Mean	Median	Std. Dev.	Skew ness	Kurto sis	JB test	Range	IQR
CO_2	5.599	5.727	0.430	-0.648	2.118	5.430* (0.062)	1.361	0.757
CO AL	4.042	4.199	0.433	-0.747	2.107	6.685** (0.035)	1.351	0.739

GDP	26.15	26.120	0.381	-0.023	2.154	1.585 (0.453)	1.381	0.568

Notes: ***p<0.01, **p<0.05, *p<0.10.
Source: Authors elaborations.

Table 4.2: Results for Unit Roots and Stationarity Tests

Variable	Unit root and stationarity tests						
	ADF	Leybourne	DF-GLS	ERS	PP	KSUR	KSSUR
CO_2	-2.912*	1.032	0.125	0.125	-2.731*	-0.386	-1.837
	(-2.929)	(-2.300)	(-2.250)	(-2.343)	(-2.928)	(-2.558)	(-2.934)
COAL	-2.666*	0.873	0.164	-0.038	-2.401	-0.546	-2.230
	(-2.929)	(-2.300)	(-2.250)	(-2.343)	(-2.928)	(-2.558)	(-2.934)
GDP	-2.616	-1.407	-1.666	-1.666	-2.373	-2.760	-2.987
	(-3.499)	(-3.113)	(-3.171)	(-3.228)	(-3.498)	(-3.243)	(-3.406)
ΔCO_2	-3.986***	-5.766***	-3.566***	-5.688***	-6.297***	-2.892***	-2.930*
	(-2.930)	(-2.296)	(-2.256)	(-2.288)	(-2.929)	(-2.563)	(-2.935)
ΔCOAL	-4.152***	-5.620***	-3.379***	-5.236***	-6.248***	-2.661**	-2.940**
	(-2.930)	(-2.296)	(-2.256)	(-2.288)	(-2.929)	(-2.563)	(-2.935)
ΔGDP	-4.545***	-4.058***	-3.879***	-4.238***	-4.673***	-3.985***	-4.499***
	(-2.930)	(-2.296)	(-2.256)	(-2.288)	(-2.929)	(-2.563)	(-2.935)

Notes: Deterministic component: constant. When it is required, the lag length is chosen according to the SBIC. 5% Critical Values are given in parentheses. ***p<0.01, **p<0.05, *p<0.10.

Moreover, also the NP and KPSS tests indicate that the series are integrated of order 1, at the 1% statistical significance level. This implies that all the variables are the first-difference stationary.

Table 4.3: Unit Root Test Results without considering Structural Break(s)

	KPSS		Ng-Perron	
Variable	KPSS[a]	KPSS[b]	MZa[c]	MZa[d]
Level				
CO_2	0.925*	0.229*	0.841	-0.697
COAL	0.784*	0.232*	0.617	-0.767

GDP	0.973*	0.112*	1.262	-6.984
First Differences				
ΔCO_2	0.576	0.066	-24.570*	-25.215
ΔCOAL	0.569	0.079	-23.987*	-25.026
ΔGDP	0.240	0.157	20.352*	-21.913

Notes: * denotes 0.01 significance level. All variables are in their natural logarithm form.
[a] KPSS test with constant term; the null hypothesis of stationary for one-sided test; 0.01,0.05 and 0.10 critical values are 0.216, 0.146, 0.119, respectively.
[b] KPSS test with the constant term and linear trend; the null hypothesis of stationary for a one-sided test; 0.01,0.05 and 0.10 critical values are 0.739, 0.463, 0.347, respectively.
[c] Ng-Perron Unit root test with a constant term.
[d] Ng-Perron Unit root test with a constant term and linear trend.

Table 4.4: Unit Root Test under Structural Break

	Level			Δ		
Variable	ZA_T	ZA_I	ZA_B	ZA_T	ZA_I	ZA_B
CO_2	-3.218	-2.318	-4.262	-7.399*	-7.606*	-8.098*
Time Break	1985	1980	1981	2008	1989	2003
Lag Length	0	0	0	0	0	0
COAL	-3.548	-2.598	-4.741	-7.351*	-7.495*	-7.973*
Time Break	1985	1979	1981	1982	1989	1983
Lag Length	0	0	0	0	0	0
GDP	-3.223	-3.998	-3.807	-5.224*	-5.779*	-5.950*
Time Break	1986	1985	1990	1984	1994	1994
Lag Length	1	1	1	0	0	0

Notes: (1) The symbol Δ means the first difference. (2) The * denotes 0.01 significance level. (3) ZA_T, ZA_I, and ZA_B refer to the model with a structural break in trend; with a structural break in the intercept and with a structural break in trend and intercept, respectively

Subsequently, given the integration property of the series, the need to conduct a cointegration test is vital to examine the long-run relationship among the variables. This study applies the novel and recent Maki cointegration tests under multiple structural breaks (SBs). Table 4 reports the Maki cointegration test results for five SBs. The test statistics were rejected for several SBs models. This means that these series converge to a long-run equilibrium path over the sample period[2].

[2] This study is also conducted the ARDL Bounds testing for robustness check. The result is consistent with Maki cointegration results.

Table 4.5: Maki (2012) Cointegration Test Results

Break Years	Models	Test Statistics	Break Years
TB≤4			
	Model 0	-5.854 (-5.871)	1977,1989,1996,2004
	Model 1	-5.272 (-6.086)	1979,1989,1998,2004
	Model 2	-8.954** (-7.625)	1974,1989,2001,2009
	Model 3	-9.710** (-8.269)	1978,1990,1997,2003
TB≤5			
	Model 0	-5.854 (-6.038)	1977,1989,1996,2004,2010
	Model 1	5.272 (-6.250)	1974,1979,1989,1998,2004
	Model 2	-8.954** (-8.110)	1974,1982,1989,2001,2009
	Model 3	-9.710** (-8.800)	1978,1990,1997,2003,2009

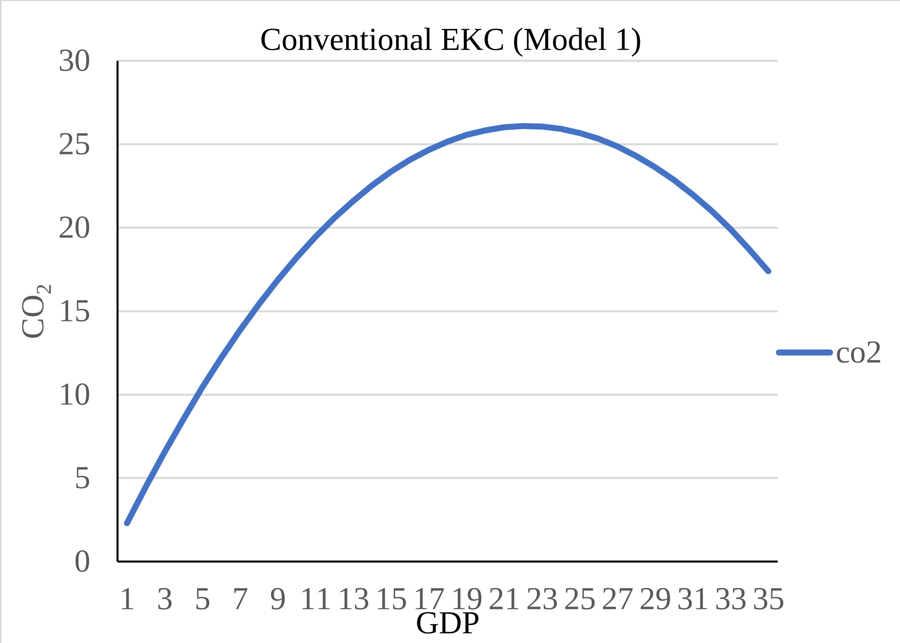
Notes: (1) Critical values are given in the brackets at 0.05 significance level which is provided from Table 1 of Maki (2012). (2) ** indicates the rejection of the null hypothesis of no long-run relationship under multiple structural breaks at 0.05 significance level.

Table 4.6 renders the long-run coefficients and magnitudes of the variables. The first model in the Table 4.6 tests the conventional EKC hypothesis. Carbon dioxide emissions (CO_2) is the dependent variable whereas GDP and GDP^2 are independent variables. This study found a statistically significant positive relationship for GDP and negative for its squared term (GDP^2) on CO_2. Thereafter, model 1 is extended by adding coal consumption to further validate the presence of EKC hypothesis. Model 2 also confirms the presence of EKC for South Africa given GDP is positively significant, while GDP squared is negatively significant (See Katircioglu 2017). This outcome is in line with the Environmental Kuznets Curve (EKC) hypothesis in the energy literature. The EKC hypothesis postulates a trade-off relationship between environmental degradation and economic growth. This means that an economy at the early stage of its growth trajectory focuses more on economic growth rather than on the quality of its environment. This is the current position for South Africa as it is still at the scaled stage of its growth path (Bekun *et al.*, 2019a; Bekun *et al.*, 2019b; Akadiri *et al.*, 2019). The scaling stage of the Southern economy is insightful to government officials and energy administrators. Thus, policies to stimulate the economy are welcome with caution on the quality of the environment (Shahbaz and Sinha, 2019). There exists a positive relationship between energy consumption ($COAL$) and CO_2 emissions. A 1% increase in coal consumption increases environmental degradation by 0.76%. This reflects the current energy position of South Africa as it ranks seventh-largest Greenhouse Gas (GHG) top in coal consumption, which is in non-renewable energy sources (Winkler, 2007). The coal-driven economy is laudable in South Africa. However, there is a need for policy mix by government administrators to match the breaks on the excessive pollutant emission (CO_2) from emanating from the exploration of coal. As such, South African energy administrators need to diversify the energy portfolio to renewable energy like biomass, hydro, and solar energy sources (Emir and Bekun, 2019).

Table 4.6: FMOLS Results for $CO2 = (GDP, GDP2, COAL)$

Variables	Model 1	Model 2
Constant	-47.585*	-49.626**
	(7.978)	(20.253)
	[0.000]	[0.018]
GDP	2.352*	3.709**
	(0.317)	(1.532)
	[0.0000]	[0.019]
GDP^2	-0.053*	-0.066**
	(0.0013)	(0.029)
	[0.0002]	[0.028]
COAL		0.755*
		(0.026)
		[0.000]
Turning point	22	28
Adj. R^2	0.953988	0.999
S.E. Regression	0.087063	0.011

Notes: ***p<0.10, **p<0.05, *p<0.01 while [ ] and ( ) denote P-values and standard errors respectively



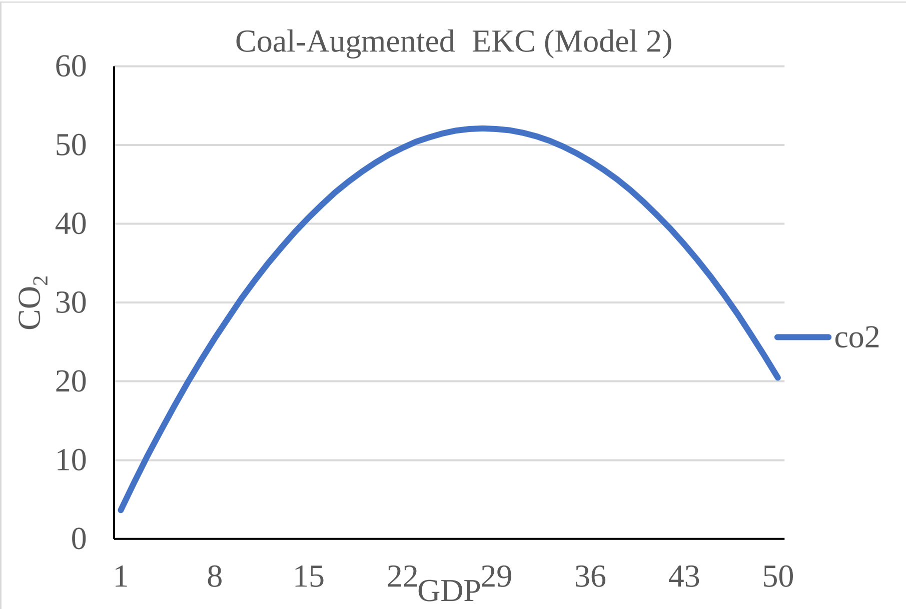


Figure 4.2: Plot of Conventional and Coal-Augmented EKCs

The fitted model passes conveniently the 0.05 threshold of stability test as reported in the CUSUM and CUSUMsq plots in Figure 4.2.

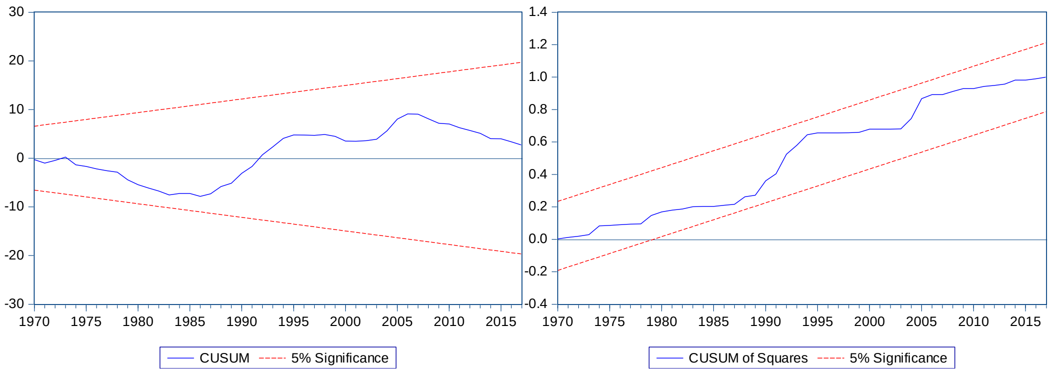


Figure 4.3: Plot of CUSUM and CUSUMsq

To detect the causality relationship between variables, we employed the TY causality method as reported in Table 4.7. We observe a two-way causality relationship between GDP and CO_2 emissions. This implies that there is a trade-off between economic growth and environmental degradation for South Africa.

Table 4.7: Test Results of Toda-Yamamoto Causality Tests

	Causality Direction		
Dependent Variable	CO_2	COAL	GDP
CO_2		1.689 (0.194)	3.761^{*} (0.053)
COAL	1.873 (0.171)		2.998^{*} (0.083)
GDP	3.175^{*} (0.075)	3.970^{**} (0.046)	

Notes: $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

This result supports the study of Tang and Tan (2013), Zhou and Chau (2006), and Wolde-Rufael (2004). Also, feedback causality emerges between GDP and COAL. This is also consistent with the study of Bekun *et al.* (2019a), Li and Leung (2012), Yoo (2006), and Yang (2000). These results are insightful for government administration in South Africa since the economy strives for its energy sector. Hence, these outcomes are indicative of the decision-makers in the energy market. Attempt to implement energy conservative policies will hurt economic growth.

4.6 Conclusions and Policy Implications

This chapter applies a recent and up to date econometrics procedure to explore the relationship between coal consumption, economic growth and carbon dioxide emissions in the case of South Africa. This is in a bid to arm decision-makers for better decision-making.

Empirical results show a statistical relationship between coal consumption, economic growth and CO_2 emissions. This means that all variables are critical for economic growth as an equilibrium relationship is observed among them. However, there is a trade-off with the quality of the environment. Our empirical results highlight that as the South African economy grows, there is an increase in the environment pollutant to a certain threshold (turning point), after which a decline is experienced. This pattern is known as the EKC phenomenon, validated here in the long-run. Besides, the coefficient of GDP is statistically significant and positive, with its square term negative. This is indicative and put caution for South Africa to strengthen its environmental treaty agreement implementation. As a matter of urgency and deliberately on the South Africa government official's other local environmental regulation are needed, like the Action Plan for Energy, Climate for the City of Cape Town as well as the adoption of renewable technologies in its energy mix. Thus, the need for synergy between sustainable and efficient energy consumption and environmental consciousness with key macroeconomic objectives is pivotal for robust and sound policy formulation. Departure from the already itemize trajectory will not only jeopardize economic progress but also increase environmental degradation in the country.

Based on the highlighted findings, the focus is on environmental sustainability for nations across the globe and South Africa is no exception. Thus, pragmatic joint efforts on the part of the government and private sector are needed to attain the SDG. The following policy direction will aid to attain the SDG:

(a) The need for adoption of more efficient, cleaner and cheaper energy technologies. This entails the transition from fossil fuel-based energy sources to renewables in the energy portfolio. This is a foundational pre-requisite for sustainable economic growth without a threat to environmental quality.

(b) Government administrators should reinforce the commitment to both national and international energy and environmental treaties. For instance, the South Africa government has made stride with the Action Plan for Energy, the Climate for the City of Cape Town and the adoption of renewable technologies in its energy mix. Nevertheless, more is required to attain the SDG on climate change and access to energy. It is also worthy to mention that South Africa is a signatory of the Kyoto Protocol agreement.

Conclusively, findings from this study serve as a blueprint for other economies on the continent to curb environmental issues. As a line of further studies, more investigation might be needed to ascertain if asymmetry exists on the nexus amongst energy consumption, economic growth, and environmental degradation.

Chapter 5

CONCLUSION

This PhD thesis attempts to empirically investigate the causal effects of energy prices on energy consumption and its impact on economic growth and the environmental sustainability of selected emerging economies with similar considerable sizes endowed with these resources, which may give the reader a potential chance to compare them. The thesis comprises three strands as stated in the body of the work.

It is important to give specific answers to the research questions posed in chapter one of this thesis after careful insights into the studies as further meaningful contributions to the frontier of knowledge: (1) what are the disaggregated impact of energy prices on energy consumption and consequently Turkey's economic growth path? Having disaggregated energy prices into four components (PHF, PNG, PSC and PE), the empirical results of this study revealed that the price of heavy fuel oil had a direct and significant impact on energy consumption. Simply put that an increase in price of heavy fuel oil will translate into an increase in energy consumption in Turkey. This suggest the importance of heavy fuel oil in the industrial life of the economy and by extension knowing the connection between energy consumption and economic growth, would imply that increase in heavy fuel oil results in an increase in energy consumption, and higher energy consumption would positively stimulate the industrial sector which will result in economic growth in Turkey. The other price components empirically revealed negative and significant relationships with energy consumption.

This negative relationship between PNG, PSC and PE and energy consumption is desirable approaching it from the demand point of view. We observed both negative and positive impact of disaggregated energy prices on energy consumption and by extension on the economy of Turkey. (2) what impact does the disaggregated energy taxes have on energy consumption? The empirical results of the disaggregated energy taxes on energy consumption revealed negative relationship across the variables of interest (THF, TNG, TSC and TE). These implies that an increase in the taxes o any of this component will result to a reduction in the quantity of energy consumption. These results validate the principles of determinant of demand. (3) what is the impact of augmented NG economic growth nexus with real gross fixed capital formation on Iran's economic outlook? The empirical result of our study revealed that there is a positive impact of augmented NG economic growth nexus especially with the incorporation of real gross fixed capital formation in the model on the economic growth of Iran with appreciable and significant values. Our result further revealed that real gross fixed capital formation plays an important role in increasing the economic output and outlook of Iran. (4) what is the relationship between non-oil GDP and NG consumption in Iran's economic output? This study through empirical result revealed a positive relationship between NG consumption and non-oil GDP. This contribution is significant to the economic output of Iran as it accounts for about 15% of the non-oil GDP. (5) what effect does the interaction of coal consumption, pollutant emissions and real income have on the South African economy? The empirical results from our analysis revealed that coal consumption has a positive effect on the economic growth path of South Africa as well as positive and negative effect on carbon emissions in the environment. In clear terms, the interaction between coal consumption and real income is observed to enhance economic growth significantly. Also, the effect of these interaction is observed by validating the position that it enhances environmental degradation as a result of the positive effect between GDP and carbon dioxide emissions. This position improves with negative effect as observed between GDP squared and carbon dioxide emissions. The effects of these interactions are beneficial to the South African economy. (6) does the coal consumption extended EKC hypothesis hold for South Africa? Our empirical result confirms that the coal consumption extended EKC hypothesis holds for the South African economy. This is revealed by the positive and negative signs of the GDP and carbon dioxide emissions and between GDP squared and carbon dioxide respectively. The positive and negative signs support the inverted U-shaped pattern between energy consumption and environmental degradation in South Africa. This position is in properly aligns with the energy literature.

In chapter two, the empirical findings give insights to all stakeholders on policy direction to have a market-determined energy price rather than government-regulated prices which do not enhance the efficiency of the resources both in terms of price determination (price mechanism) mix and optimal consumption. This further makes it difficult to ascertain the actual impact of this consumption on environmental sustainability. Evidence from this study revealed that the price of heavy fuel oil, total tax of heavy fuel oil had an increasing effect on energy consumption both in the short and long-run; the price of natural gas was decreasing both in the long-run and in the short-run with energy consumption, whereas total taxes were decreasing in the long-run and short-run with significance in the short-run. The price of steam coal had an increasing effect in the long-run and short-run, with the long-run alone being significant. The total tax for steam coal had an increasing effect on the long-run. Both the price and tax of steam coal had no significant effect in the short-run, even though it was a positive effect on energy consumed accordingly. The price of electricity for the industry had a decreasing effect on energy consumed in the short-run and positive effects in the long-run, whereas the total tax of electricity for the industry had a decreasing effect on energy consumed in the short-run and increasing effect in the long-run.

In chapter three, the empirical findings reveal bidirectional causality seen between natural gas consumption and economic growth, confirming the feedback hypothesis for the study area. Thus, government officials in Iran are encouraged to promote more efficient use of natural gas, to enhance the process of economic growth. The promotion of natural gas sources will improve the use of safe energy utilization, with a lower cost of production (Shahbaz et al., 2013a).

Empirical finding from the study gives credence to the NG consumption-induced economic growth hypothesis as causality interaction is observed from the consumption of natural gas to economic output. Thus, it implies that embarking on aggressive NG exploitation and exploration will spur economic growth.

Interestingly, a further piece of empirical results shows a unidirectional contribution from gross fixed capital formation to NG consumption both in the long and short run. It is instructive that in Iran, capital plays a positive and significant role in economic output. Our empirical results validate the necessity of sustainable growth connected through the attraction of foreign capital investments via financial liberalization and promotion of clean energy sources.

Lastly, chapter four interest was in modeling the dynamic nexus among coal consumption, pollutant emissions, and real income. The study further investigated the Environmental Kuznets Curve (EKC) by incorporating coal consumption for South Africa.

Empirical results show a statistical relationship between coal consumption, economic growth and CO_2 emissions. This means that all variables are critical for economic growth as an equilibrium relationship is observed among them. However, there is a trade-off with the quality of the environment. Our empirical results highlight that as the South African economy grows, there is an increase in the environment pollutant to a certain threshold (turning point), after which a decline is experienced. This pattern is known as the EKC phenomenon, validated here in the long-run. Besides, the coefficient of GDP is statistically significant and positive, with its square term negative. This is indicative and put caution for South Africa to strengthen its environmental treaty agreement implementation.

Thus, the need for synergy between sustainable and efficient energy consumption and environmental consciousness with key macroeconomic objectives is pivotal for robust and sound policy formulation. Departure from the already itemize trajectory will not only jeopardize economic progress but also increase environmental degradation in the country.

From the research of the above three emerging economies, we can find similarities and differences among Turkey, Iran and South Africa that will aid in the understanding of the nexus and its impact between energy consumption and the environment.

Firstly, the three countries are emerging economies with close proximity. They have in abundance one form of energy resource that drives their individual economy. None of these economies were part of the first Kyoto Protocol agreement of 1992, an international treaty under the United Nations Framework Convention on Climate Change (UNFCCC) committed to ensure reduction of the greenhouse gas which was believed to be caused predominantly by the human activities. They are all dependent on their energy resources as major sources of income for their individual countries. These energy sources are major contribution to their environmental degradation. The methodology used in the analysis are common among the different countries, though there were specific techniques employed in each country too. The results in the three countries affirm that the exploration and exploitation of the energy resources does have harmful effect on the environment of this countries as well as benefits, further evidence was seen with increase in output concurrently with increase in the environmental degradation. The energy resources available to these countries are non-renewable energy sources and it is responsible to the increase of the carbon emissions in the environment. Each of these countries in their history has had to deal with crisis in their country that had a great toll on economic growth and development. These three economies are committed to meet up the SDGs as stipulated.

On the other hand, some differences were observed among the three countries and are not limited to the following; (1) though the countries have similarities in term of size, they solutions arrived at to deal with the challenges identified were designed to address specific problems based on the uniqueness of the resources each country has comparative advantage. Due to the different challenges facing these countries couple with the peculiarities resulting from their location and the likes, efforts deployed only yields results in various degrees. It is interesting to note that these countries are not relenting in providing the adequate resolutions to the various energy-environment based issues.

Conclusively, findings from this study serve as a blueprint for other economies on the continent to curb environmental issues while at the same time enhancing economic growth and development using the natural resources endowed by nature.

REFERENCES

Abuoliem, N., Nor, S.M., Matar, A., Hallahan, T., (2019). Crude oil prices, macroeconomic indicators and the financial sector in Jordan: Dynamic causes and responses. *Journal of International Studies*, 12, 3, 131-146.

Adofo YO, Evans J, Hunt LC (2013). How sensitive to time period sampling is the asymmetric price response specification in energy demand modeling? *Energy Econ* 40:90–109

Akadiri S. S., Akadiri AC. (2018). The Role of NG Consumption in Economic Growth. *Strategic Planning for Energy and the Environment* (in press).

Akadiri, S. S., Alola, A. A., & Akadiri, A. C. (2019). The role of globalization, real income, tourism in environmental sustainability target. Evidence from Turkey. *Science of the Total Environment*.

Akadiri, S. S., Alola, A. A., Akadiri, A. C., & Alola, U. V. (2019b). Renewable energy consumption in EU-28 countries: policy toward pollution mitigation and economic sustainability. *Energy Policy*, *132*, 803-810.

Al-mulali, U., Che Sab, C.N.B., (2018). The impact of coal consumption and CO_2 emission on economic growth. *Energy Sources, Part B: Economics, Planning, and Policy*, 13, 4, 218-223.

Amadeh H., Ghazi M., Abbasifar Z. (2009). Causality relation between energy consumption and economic growth and employment in Iranian economy. *Tahghighat-e-eghtesadi Journal* 44(86), 1-38.

Amiri, A., Ventelou, B., 2012. Granger causality between total expenditure on health and GDP in OECD: Evidence from the Toda-Yamamoto approach. *Economics Letters*, 116, 3, 541-544.

Amuakwa-Mensah, F., Adom, P.K., (2017). Quality of institution and the FEG (forest, energy intensity, and globalization) – environment relationships in sub-Saharan Africa. *Environmental Science and Pollution Research International*, 24, 21, 17455-17473.

Apeaning RW, Thollander P. (2013). Barriers to and driving forces for industrial energy efficiency improvements in African industries: a case study of Ghana's largest industrial area. *J Clean Prod* 53:204–213.

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

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

Arellano M. (1989). On the efficient estimation of simultaneous equations with covariance restrictions. *Journal of Econometrics*, 42(2), 247-265.

Atakhanova, Z., & Howie, P. (2007). Electricity demand in Kazakhstan. *Energy Policy*, 35, 3729‑3743.

Balcilar, M., Bekun, F.V., Uzuner, G., (2019). Revisiting the economic growth and electricity consumption nexus in Pakistan. *Environmental Science and Pollution Research*, 26, 12, 12158-12170.

Balcilar, M., Ozdemir, Z.A., Arslanturk, Y., (2010). Economic growth and energy consumption causal nexus viewed through a bootstrap rolling window. *Energy Economics*, 32, 6, 1398-1410.

Balitskiy S., Bilan Y., Strielkowski W., Štreimikienė D. (2016). Energy efficiency and NG consumption in the context of economic development in the European Union. *Renewable and Sustainable Energy Reviews* 55, 156-168.

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., Farhani, S. (2018). How economic growth, renewable electricity and natural resources contribute to CO_2 emissions? *Energy Policy* 113, 356-367.

Banerjee A., Dolado J., Mestre, R. (1998). Error-correction mechanism tests for cointegration in a single-equation framework. *Journal of time series analysis* 19(3), 267-283.

Basher, S. A., & Fachin, S. (2013). The long-run relationship between savings and investment in oil-exporting developing countries: a case study of the Gulf Arab states. OPEC *Energy Review,* 37(4), 429-446.

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

Beg, N., Morlot, J.C., Davidson, O., Afrane-Okesse, Y., Tyani, L., Denton, F., Parikh, K., (2002). Linkages between climate change and sustainable development. *Climate Policy*, 2, 2-3, 129-144.

Bekhet, H.A., Matar, A., Yasmin, T., (2017). CO_2 emissions, energy consumption, economic growth, and financial development in GCC countries: Dynamic simultaneous equation models. *Renewable and Sustainable Energy Reviews*, 70, 117-132.

Bekun, F. V., Alola, A. A., & Sarkodie, S. A. (2019). Toward a sustainable environment: Nexus between CO_2 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.

Ben Jebli, M., Ben Youssef, S., Ozturk, I., (2015). The Role of Renewable Energy Consumption and Trade: Environmental Kuznets Curve Analysis for Sub-Saharan Africa Countries, *African Development Review*, 27, 3, 288-300.

Bento, A.M., Goulder, L.H., Jacobsen, M.R., von Haefen, R.H., (2009). Distributional and efficiency impacts of increased US gasoline taxes. *Am. Econ. Rev*. 99, 667-699.

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.

Birol F., Keppler JH (2000). Prices, technology development and the rebound effect. *Energy Policy* 28:457–469.

Boswijk HP. (1995). Efficient inference on cointegration parameters in structural error correction models. *Journal of Econometrics* 69(1), 133-158.

Cao, J., 2007. Essays on Environmental Tax Policy Analyses: Dynamic Computable General Equilibrium Approaches Applied to China. Kennedy School of Government, Harvard University.

Caraiani, C., Lungu, C. I., Dascălu, C., (2015). Energy consumption and GDP causality: A three-step analysis for emerging European countries. *Renewable and Sustainable Energy Reviews*, 44, 198-210.

Chen SY, Wu RC. (2011). Structural adjustment, energy intensity reduction and CO2 abatement in the course of economic transition: Shanghai and national comparative analysis. *Shanghai Econ Rev* 4:10–23.

Das A., McFarlane A., Chowdhury M. (2013). The dynamics of NG consumption and GDP in Bangladesh. *Renewable and Sustainable Energy Review* 22, 269–274.

Destek MA. (2016). NG consumption and economic growth: Panel evidence from OECD countries. *Energy* 114, 1007-1015.

Destek, M. A., & Ozsoy, F. N. (2015). Relationships between economic growth, energy consumption, globalization, urbanization and environmental degradation in Turkey. *International Journal of Energy and Statistics*, *3*(04), 1550017.

Dickey DA., Fuller WA. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica: *Journal of the Econometric Society* 49(4), 1057-1072.

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, 427-431.

Dietz, T., & Rosa, E. A. (1994). Rethinking the environmental impacts of population, affluence and technology. *Human ecology review,* 1(2), 277-300.

Dogan E. (2015). Revisiting the relationship between NG consumption and economic growth in Turkey. Energy Sources, Part B: *Economics, Planning, and Policy* 10(4), 361-370.

Dogan, E. (2015). The relationship between economic growth and electricity consumption from renewable and non-renewable sources: A study of Turkey. *Renewable and Sustainable Energy Reviews*, *52*, 534-546.

Dolado JJ., Lütkepohl, H. (1996). Making Wald test work for cointegrated VAR systems. *Econometrics. Theory* 15:369– 386.

Elliott G., Rothenberg TJ., Stock JH. (1992). Efficient tests for an autoregressive unit root. *Econometrica* 64, 813-836.

Elliott, G., Rothenberg, T.J., Stock, J.H., (1996). Efficient tests for an autoregressive unit root. *Econometrica*, 64, 813-836.

Emami, K., and Mehdi Adibpour M. (2012). Oil income shocks and economic growth in Iran. *Economic Modelling* 29 (5), 1774-1779.

Emir, F., & Bekun, F. V. (2018). Energy intensity, carbon emissions, renewable energy, and economic growth nexus: New insights from Romania. *Energy & Environment*, 1-17 doi.org/10.1177/0958305X18793108

Emir, F., Bekun, F.V., (2019). Energy intensity, carbon emissions, renewable energy, and economic growth nexus: new insights from Romania. *Energy & Environment*, 30, 3, 427-443.

Energy Information Administration (EIA), 2018. Annual Energy Outlook 2019 (access date 04.03.2019).

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica*, 251-276.

Esen V., Oral B. (2016). NG reserve/production ratio in Russia, Iran, Qatar and Turkmenistan: A political and economic perspective. *Energy Policy* 93, 101-109.

Esteve V., Requena F. (2006). A cointegration analysis of car advertising and sales data in the presence of structural change. *International Journal of the Economics of Business* 13(1), 111-128.

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

Farhani, S., Shahbaz, M., Ozturk, I., (2014). Coal consumption, industrial production and CO_2 emissions in China and India. *Department of Research – Ipag Business School Working Papers*, 2014-225.

Fei Q, Rasiah R. (2014). Electricity consumption, technological innovation, economic growth and energy prices: does energy export dependency and development levels matter? *Energy Procedia* 61:1142–1145.

Ferguson, C.D., (2007). Nuclear Energy: Balancing benefits and risks. *Council of Foreign Relations*, 28.

Finn M. (2000). Perfect competition and the effects of energy price increases on economic activity. *J Money Credit Bank* 32:400–416.

Fisher-Vanden K, Jefferson G.H. (2004). What is driving China's decline in energy intensity? *Resour Energy Econ* 26:77–97.

Furuoka F. (2016). NG consumption and economic development in China and Japan: an empirical examination of the Asian context. *Renewable and Sustain Energy Review* 56, 100 –115.

Ghalwash, T., (2007). Energy taxes as a signaling device: an empirical analysis of consumer preferences. *Energy Policy* 35, 29-38.

Gnansounou, E., (2008). Assessing the energy vulnerability: the case of industrial countries. *Energy Policy*, 36, 3734-3744.

Gong, B., Zheng, X., Guo, Q., Ordieres-Meré, J., (2019). Discovering the patterns of energy consumption, GDP, and CO_2 emissions in China using the cluster method. *Energy*, 166, 1149-1167.

Gregory AW., Hansen BE. (1996). Residual-based tests for cointegration in models with regime shifts. *Journal of Econometrics* 70(1), 99-126.

Gregory, A.W., Nason, J.M., Watt, D.G., (1996). Testing for structural breaks in cointegrated relationships. *Journal of Econometrics*, 71, 1-2, 321-341.

Hafeznia H., Pourfayaz F., Maleki, A. (2017). An assessment of Iran's NG potential for transition toward low-carbon economy. *Renewable and Sustainable Energy Reviews* 79, 71-81.

Hansen, H. (1995). Cointegrated Vector Autoregressive Models. Department of Economics, University of Copenhagen.

Hao, Y., Liu, Y., Weng, J.H., Gao, Y., (2016). Does the Environmental Kuznets Curve for coal consumption in China exist? New evidence from spatial econometric analysis. *Energy*, 114, 1214-1223. https://www.iea.org/countries/Turkey/. Retrieved 19 July 2019.

Holtedahl, P.,& Joutz, F. L. (2004). Residential electricity demand in Taiwan. *Energy Economics,* 26, 201‑224.

Huang, B., Hwang, M. J., Yang, C.W. (2008). Causal relationship between energy consumption and GDP growth revisited: a dynamic panel data approach, *Ecol. Econ.* 67, 41–54 (Scholar).

Ighodaro C. (2010). Cointegration and causality relationship between energy consumption and economic growth: further empirical evidence for Nigeria. *Journal of Business Economics and Management* 1, 97-111.

IGU (2015). Natural gas: A partner for renewable energy. International Gas Union, pp.1-15.

IMF (2013) Energy subsidy reform: lessons and implications. http://www.imf.org/external/np/pp/eng/2013/012813.pdf

International Energy Agency (IEA) Quarterly statistics, Energy Prices and Taxes, First Quarter 2000 – fourth quarter, 2018.

Iran Oil Ministry Annual Bulletin, 5th Edition, pages 190-193 (available in Persian)

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

Jinke, L., Hualing, S., Dianming, G., (2008). Causality relationship between coal consumption and GDP: difference of major OECD and non-OECD countries. *Applied Energy*, 85, 421-429.

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.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamic Control*, 12, 231‑254.

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica*, *59*(6): 1551-1580.

Kapetanios, G., Shin, Y., (2008). GLS detrending-based unit root tests in nonlinear STAR and SETAR models. *Economics Letters*, 100, 377-380.

Kapetanios, G., Shin, Y., Snell, A., (2003). Testing for a unit root in the nonlinear STAR framework. *Journal of Econometrics*, 112, 359-379.

Katircioglu S (2017) Investigating the role of oil prices in the conventional EKC model: evidence from Turkey. Asian Econ Financ Rev 7(5):498–508

Katircioglu ST, Katircioglu S (2018a) Testing the role of fiscal policy in the environmental degradation: the case of Turkey. Environ Sci Pollut Res 25(6):5616–5630. https://doi.org/10.1007/s11356-017- 0906-1

Katircioglu S, Katircioglu ST (2018b) Testing the role of urban development in the conventional environmental Kuznets curve: evidence from Turkey. Appl Econ Lett 25(11):741–746. https://doi.org/10.1080/13504851.2017.1361004

Katircioglu ST, Taspinar N (2017) Testing the moderating role of financial development in an environmental Kuznets curve: empirical evidence from Turkey. Renew Sust Energ Rev 68(September 2016): 572–586. https://doi.org/10.1016/j.rser.2016.09.127

Kaufman, R.K. (2004). The mechanisms for autonomous energy efficiency increases: a cointegration analysis of the US energy/GDP ratio. *Energy* 25:63–86.

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

Khan, M. K., Teng, J. Z., & Khan, M. I. (2019). Effect of energy consumption and economic growth on carbon dioxide emissions in Pakistan with dynamic ARDL simulations approach. *Environmental Science and Pollution Research*, 1-11.

Khobai, H., Le Roux, P., (2017). The relationship between energy consumption, economic growth and carbon dioxide emission: The case of South Africa. *International Journal of Energy Economics and Policy*, 7, 3, 102-109.

Kim, H.M., Yoo, S.H., (2016). Coal consumption and economic growth in Indonesia. *Energy Sources, Part B: Economics, Planning, and Policy*, 11, 6, 547-552.

Kohler, M., (2013). CO_2 emissions, energy consumption, income and foreign trade: A South African perspective. *Energy Policy*, 63, 1042-1050.

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

Kurniawan, R., Managi, S., (2018). Coal consumption, urbanization, and trade openness linkage in Indonesia. *Energy Policy*, 121, 576-583.

Kwiatkowski, D., Phillips, P.C., Schmidt, P., Shin, Y., (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root?. *Journal of Econometrics*, 54, 1-3, 159-178.

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

Lee, C. (2006). The causality relationship between energy consumption and GDP in G-11 countries revisited, Energy Policy 34, 1086–1093 (Scholar).

Leybourne, S.J., (1995). Testing for unit roots using forward and reverse Dickey-Fuller regressions. *Oxford Bulletin of Economics and Statistics*, 57, 559-571.

Li K, Lin B. (2015). How does administrative pricing affect energy consumption and CO_2 emissions in China? *Renew Sustain Energy Rev* 42:952–962.

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

Lotfalipour MR., Ali Falahi M., Ashena M. (2010). Economic growth, CO_2 emissions, and fossil fuels consumption in Iran. *Energy* 35, 5115– 5120.

Magazzino, C., (2016a). The relationship between CO_2 emissions, energy consumption and economic growth in Italy. *International Journal of Sustainable Energy*, 35, 9, 844-857.

Magazzino, C., (2016b). The relationship between real GDP, CO_2 emissions and energy use in the GCC countries: a time-series approach. *Cogent Economics & Finance*, 4, 1.

Magazzino, C., (2017). Stationarity of electricity series in MENA countries. *The Electricity Journal*, 30, 10, 16-22.

Magazzino, C., (2017). The relationship among economic growth, CO2 emissions, and energy use in the APEC countries: a panel VAR approach. *Environment Systems and Decisions*, 37, 3, 353-366.

Maki, D., (2012). Tests for cointegration allowing for an unknown number of breaks. *Economic Modelling*, 29, 5, 2011-2015.

Mankiw NG., Romer D., Weil DN. (1992). A contribution to the empirics of economic growth. *The quarterly journal of economics*, 107(2), 407-437.

Mapapu, B., Phiri, A., (2018). Carbon Emissions and Economic Growth in South Africa: A Quantile Regression Analysis. *International Journal of Energy Economics and Policy*, 8, 1, 195-202.

Marion, J., Muehlegger, E., (2011). Fuel tax incidence and supply conditions. *J. Public Econ.* 95, 1202-1212.

Martinez P, Ines C. (2011). Energy efficiency development in German and Colombian non-energy-intensive sectors: a nonparametric analysis. *Energy Effic* 4:115–131.

Martinsen D, Krey V, Markewitz P. (2007). Implications of high energy prices for energy system and emissions—the response from an energy model for Germany. *Energy Policy* 35:4504–4515.

Masih, A. M. M., Masih, R. (1996). Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error-correction modeling techniques, *Energy Econ*. 18, 165–183 (Scholar).

Matar, A., Bekhet, H.A., (2015). Causal interaction among electricity consumption, financial development, exports and economic growth in Jordan: Dynamic simultaneous equation models. *International Journal of Energy Economics and Policy*, 5, 4, 955-967.

Mehrara, M. (2007). Energy consumption and economic growth: the case of oil exporting countries. *Energy policy* 35(5), 2939-2945.

Menyah, K., Wolde-Rufael, Y., (2010). Energy consumption, pollutant emissions and economic growth in South Africa. *Energy Economics*, 32, 1374-1382.

Mohiuddin, O., Asumadu-Sarkodie, S., Obaidullah, M., (2016). The relationship between carbon dioxide emissions, energy consumption, and GDP: A recent evidence from Pakistan. *Cogent Engineering,* 3, 1, 1210491.

Najjarzadeh R., Mohsen, A. (2004), the relationship between energy consumption and economic growth in Iran Economic sectors, *Quarterly Energy Economics Review*, 1(2), 61-80.

Narayan, P. K., Smyth, R (2009). Multivariate Granger causality between electricity consumption, exports and GDP: evidence from a panel of Middle Eastern countries, *Energy Policy* 37, 229–236 (Scholar).

Nasiru, I., (2012). Coal consumption and economic growth in Nigeria: A two-step residual-based test approach to cointegration. *European Scientific Journal*, 8, 9, 140-155.

Nathaniel, S., Nwodo, O., Adediran, A., Sharma, G., Shah, M., Adeleye, N., (2019). Ecological footprint, urbanization, and energy consumption in South Africa: including the excluded. *Environmental Science and Pollution Research*, 26, 26, 27168-27179.

Odhiambo, N.M., (2009). Electricity consumption and economic growth in South Africa: A trivariate causality test. *Energy Economics*, 31, 5, 635-640.

Ozturk I., Al-Mulali U. (2015). NG consumption and economic growth nexus: panel data analysis for GCC countries. *Renewable and Sustainable Energy Review* 51, 998–1003.

Park JY. (1992). Canonical Cointegrating Regressions. *Econometrica* 60(1), 119–143.

Pata, U. K. (2019). Environmental Kuznets Curve and Trade Openness in Turkey: Bootstrap

Pedroni, P. (2001a), Fully Modified OLS for Heterogeneous Cointegrated Panels, in: B.H. Baltagi, T.B. Fomby, R. Carter Hill (Eds), Advances in Econometrics, Non-Stationary Panels, Panel Cointegration, and Dynamic Panels, Vol. 15, *JAI Press*: Amsterdam.

Pedroni, P. (2001b), Purchasing Power Parity Tests in Cointegrated Panels, *Review of Economics and Statistics*, 83(4), 727-731.

Pesaran, M. H., Shin, Y., & Smith, J. R. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3):289–326.

Phillips PC, Hansen BE. (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*, 75, 2, 335-346.

Phillips, PC (1995). Fully Modified Least Squares and Vector Autoregression. *Econometrica,* 63(5), 1023-1078

Rafindadi A, Ozturk I. (2015). NG consumption and economic growth nexus: is the 10th Malaysian plan attainable within the limits of its resource. *Renewable and Sustainable Energy Review* 49, 1221 – 1232.

Ramey, V A. (2011), Identifying government spending shocks: It's all in the timing." *The Quarterly Journal of Economics* 126(1), 1-50.

Ratshomo, K., and Nembahe, R., (2018). *South African Energy Sector Report*. Department of Energy – Republic of South Africa, November.

Raza, M.Y., Shah, M.T.S., (2019). Analysis of coal-related energy consumption in Pakistan: an alternative energy resource to fuel economic development. *Environment, Development and Sustainability*, 1-22.

Reynolds D., 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.

Saboori B., Sulaiman J. (2013). Environmental degradation, economic growth and energy consumption: Evidence of the environmental Kuznets curve in Malaysia. *Energy Policy* 60, 892–905.

Sachs JD, Warner AM. (2001). The curse of natural resources. *European economic review*, 45(4-6), 827-838.

Saidi K., Hammami S. (2015). The impact of CO_2 emissions and economic growth on energy consumption in 58 countries. *Energy Reports* 1, 62-70.

Saikkonen P. (1991). Asymptotically Efficient Estimation of Cointegration Regressions. *Econometric Theory* 7(1), 1–21.

Sari R., Ewing B., 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.

Semboja, H.H.H., 1994. The effects of energy taxes on the Kenyan economy: a CGE analysis. *Energy Econ*. 16, 205-215.

Shafiee, S, Topal, E., (2008). An econometric view of worldwide fossil fuel consumption and the role of US. *Energy Policy*, 36, 775-786.

Shahbaz M., Khan S., Tahir M. (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.

Shahbaz M., Lean H., Farooq A. (2013). NG consumption and economic growth in Pakistan. *Renewable and Sustainable Energy Review* 18, 87–94.

Shahbaz M., Lean HH. (2012). Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. *Energy policy* 40, 473-479.

Shahbaz M., Loganathan N., Muzaffar AT., Ahmed K., Jabran MA. (2016). How urbanization affects CO2 emissions in Malaysia? The application of STIRPAT model. *Renewable and Sustainable Energy Reviews* 57, 83-93.

Shahbaz, M., Balsalobre-Lorente, D., & Sinha, A. (2019). Foreign direct Investment–CO_2 emissions nexus in Middle East and North African countries: Importance of biomass energy consumption. *Journal of Cleaner Production*, *217*, 603-614.

Shahbaz, M., Feridun, M. (2012). Electricity consumption and economic growth empirical evidence from Pakistan, *Qual. Quan*. 46, 1583–1599 (Scholar).

Shahbaz, M., Hye, Q., Tiwari, A. Leitao, N. (2013a). Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. *Renewable and Sustainable Energy Reviews* 25, 109-121.

Shahbaz, M., Loganathan, N., Muzaffar, A. T., Ahmed, K., & Jabran, M. A. (2016). How urbanization affects CO_2 emissions in Malaysia? The application of STIRPAT model. *Renewable and Sustainable Energy Reviews, 57,* 83-93.

Shahbaz, M., Mahalik, M. K., Shahzad, S. J. H., & Hammoudeh, S. (2019). Testing the globalization-driven carbon emissions hypothesis: international evidence. *International Economics, 158,* 25-38.

Shahbaz, M., Mahalik, M.K., Shah, S.H., Sato, J.R., 2016. Time-varying analysis of CO_2 emissions, energy consumption, and economic growth nexus: Statistical experience in next 11 countries. *Energy Policy*, 98, 33-48.

Shahbaz, M., Sinha, A., (2019). Environmental Kuznets curve for CO_2 emissions: a literature survey. *Journal of Economic Studies,* 46, 1, 106-168.

Shahbaz, M., Tiwari, A., Nasir, M., (2013). The effects of financial development, economic growth, coal consumption and trade openness on CO_2 emissions in South Africa. *Energy Policy*, 61, 1452-1459.

Shahbazi K. (2013). Investigating the granger causality relationship between the consumption of different oil products and economic growth in Iran. *International Journal of Accounting and Economics Studies.* 1(3), 74-83.

Shahiduzzaman M., Alam K. (2014). A reassessment of energy and GDP relationship: the case of Australia. *Environ Dev Sustain* 16, 323 – 44

Siddiqui R. (2004). Energy and economic growth in Pakistan. *Pak Dev Rev* 43:175–200.

Solarin SA, Ozturk I. (2016). The relationship between NG consumption and economic growth in OPEC members. *Renewable and Sustainable Energy Reviews* 58, 1348–1356.

Solarin SA., Shahbaz M. (2015). NG 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.

Soytas, U., Sari, R. (2009). Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member. *Ecological Economics* 68, 1667-1675.

Soytas, U., Sari, R. (2003). Energy consumption and GDP: causality relationship in G-7 countries and emerging markets., *Energy Econ*. 25, 33–37 (Scholar).

Soytas, U., Sari, R., (2006). Energy consumption and income in G-7 countries. *Journal of Policy Modeling*, 28, 7, 739-750.

Steinbuks J, Neuhoff K. (2014). Assessing energy price induced improvements in efficiency of capital in OECD manufacturing industries. *J Environ Econ Manag* 68:340–356.

Stock JH, Watson MW. (1993). Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems. *Econometrica* 61 (4), 783–820.

Tang, C. F., & Tan, B. W. (2014). The linkages among energy consumption, economic growth, relative price, foreign direct investment, and financial development in Malaysia. *Quality and Quantity*, 48, 781‐797.

Tang, C. F., & Tan, E. C. (2012). Electricity consumption and economic growth in Portugal: evidence from a multivariate framework analysis. *Energy Journal*, 33, 23–48.

Tang, C.F., Tan, E.C., (2013). Exploring the nexus of electricity consumption, economic growth, energy prices and technology innovation in Malaysia. *Applied Energy*, 104, 297-305.

The Paris Agreement. (2015). https://unfccc.int/process/conferences/pastconferences/ parisclimate-change-conference-november-2015/ Paris-agreement. Retrieved 13 July 2019.

Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of econometrics*, *66*(1-2), 225-250.

Toth, F.L., Rogner, H.H., (2006). Oil and nuclear power: past, present, and future. *Energy Economy*, 28, 1-25.

United Nations Framework Convention on Climate Change (UNFCC). https://unfccc.int/. Retrieved 13 July 2019.

Valadkhani A, Babacan ADA (2014) The impacts of rising energy prices on non-energy sectors in Australia. Econ Anal Policy 44:386–395

WDI, (2019). World Bank Development Indicator. https://data.worldbank.org/ (access date March, 2019).

Wing IS (2008) Explaining the declining energy intensity of the US economy. *Resour Energy Econ* 30:21–49.

Winkler, H., (2007). Long Term Mitigation Scenarios Technical Report. Available at https://www.africaportal.org/documents/9813/07-Winkler-LTMS-Technical_Report.pdf (access date 15.02.2019).

Wolde-Rufael, Y., (2004). Disaggregated industrial energy consumption and GDP: the case of Shanghai, 1952–1999. *Energy Economics,* 26, 69-75.

Wolde-Rufael, Y., (2010). Coal consumption and economic growth revisited. *Applied Energy* 87, 160-167.

World Bank. (2017). Development Indicators. Accessed May, 2019 http://databank.worldbank.org.

World Bank. (2019). Development Indicators. Accessed October, 2019 http://databank.worldbank.org.

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

Yang SY (2011) An empirical study on the impact of administrative monopoly power price on local energy efficiency. *Energy Procedia* 5:916–920.

Yang, H.Y., (2000). Coal consumption and economic growth in Taiwan. *Energy Sources*, 22, 2, 109-115.

Yoo, S.H., (2006). Causal relationship between coal consumption and economic growth in Korea. *Applied Energy*, 83, 1181-1189.

York, R., E. A. Rosa, & T. Dietz. (2004). The ecological footprint intensity of national economies. *Journal of Industrial Ecology* 8:139–54. doi:10.1162/1088198043630487

You, W., & Lv, Z. (2018). Spillover effects of economic globalization on CO2 emissions: a spatial panel approach. *Energy Economics*, *73*, 248-257.

Yu E., Choi J. (1985). Causal relationship between energy and GNP: an international comparison. *Journal of Energy Development* 10(2), 249-272.

Yuan, J.H., Kang, J.G., Zhao, C.H., Hu, Z.G., (2008). Energy consumption and economic growth: evidence from China at both aggregated and disaggregated levels. *Energy Economics,* 30, 3077-3094.

Zafeiriou E, Arabatzis G, Tampakis S, Soutsas K. (2014). The impact of energy prices on the volatility of ethanol prices and the role of gasoline emissions. *Renew Sustain Energy Rev* 33:87–95.

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

Zhang D, David CB, Cao H. (2014a). International oil shocks and household consumption in China. *Energy Policy* 75:146–156.

Zhang Q, Ye XL, Zhou Y. (2014b). Rising mechanism of energy prices: a consideration of money. *China Finance* 11:77–78.

Zhang, M., Bai, C., Zhou, M., (2018). Decomposition analysis for assessing the progress in decoupling relationship between coal consumption and economic growth in China. *Resources, Conservation and Recycling*, 129, 454-462.

Zhou, G., Chau, K.W., (2006). Short and long-run effects between oil consumption and economic growth in China. *Energy Policy*, 34, 3644-3655.

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

Zivot, E., & Andrews, D. W. K. (1992). Further evidence on the Great Crash, the oil price shock, and the unit root hypothesis. *Journal of Business and Economic Statistics 10*(3): 251-270.