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DYNAMICS OF ENERGY CONSUMPTION AND ECONOMIC GROWTH: A PANEL ESTIMATION OF NET OIL IMPORTING COUNTRIES[2]

This study revisits the relationship between energy consumption and economic growth in twelve net oil importing countries that are divided between two panels, namely, low net oil importing countries and high net oil importing countries for the data from 1971 to 2014. The study estimates a panel vector error correction model (VECM) and panel variance decomposition analysis and it is found that: Firstly, the carbon emission is an important factor in the interlinkage between the growth and energy. The economic growth evidently appears to drive energy consumption. Further, the carbon emission increases with an increase in economic growth and energy consumption and this inference could be drawn in the case of both groups of countries. But its magnitude is more pronounced in low oil importing countries. Secondly, a uni-directional causal relationship running from economic growth to energy consumption is detected and hence supports conservation hypothesis regardless of the level of oil import dependency of the countries. It implies that energy conservation policies do not negatively impact the economic growth of the oil importing economies. Therefore, countries, irrespective of the level of net oil import, are suggested to pursue a low carbon economy through sustainability practices, preferably in high carbon density sectors such as constructions and infrastructure, industries and power. This paper contributes to the literature by initiating the discussion on the energy-economy nexus in net oil importing economies by incorporating environmental factor.
Keywords: energy use; economic growth; carbon emission; net oil importing countries; GDP, CO2; Panel VECM
JEL: C23; E01; Q56

1. Introduction

Energy is regarded to be an integral part of the human ecosystem, as it is an important component among the drivers of the society and the economy. In view of this, energy consumption per capita is deemed as a major indicator of the economic development of a country (Esen, Bayrak, 2017). In the present world, when the countries are aiming at

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achieving welfare state, energy is not considered only as an economic resource, but also regarded as a key strategic commodity at the international level. The history reveals that the demand for energy increased in countries with industrialisation and infrastructure development. This could be evidenced from the industrialisation of the European economies in the past centuries and the eventual rise in the demand for energy. Similar scenario could be observed from the Asian economies in the past three decades or so. This leads to the postulation that economic growth accelerates the demand for energy. Energy consumption and economic growth, thus, appear to be interdependent and this linkage is an inevitable phenomenon (Neto, et al., 2014; Vandaele, Porter, 2015). With an increasing thrust on the rapid economic development, the energy scarce countries meet the domestic energy gap by importing. The oil importing economies, by virtue of increasing use of energy, generate more growth and a higher standard of living. Energy consumption and economic growth are deemed to have severe environmental implications. Though it is well known that energy consumption and economic development cause environmental degradation, which is popularly measured using the metrics carbon emissions per capita, empirical studies provide little information about whether the level of pollution changes depending on the import dependence. A substantially large part of the studies failed in considering the environmental factor while analysing the energy – economy relationship. The oil importing economies, by virtue of increasing use of energy, generate more growth and higher standard of living. Substantial number of studies failed in considering the environmental factor while analysing the energy – economy relationship. While attempting to address this gap, the present paper has an objective to revisit the energy consumption-economic growth dynamics by bringing environmental quality into the framework. This framework has been tested for 12 net oil importing countries. To understand whether the level of environmental pollution varies based on the net oil import dependence, these net crude oil importing countries are grouped into high net oil importing countries and low net oil importing countries. This classification is based on the net import dependence is more or less than 50 percent of the domestic consumption. The paper, by classifying the select countries into high net oil importing countries and low net oil importing countries focuses on exploring whether growth-energy-emission nexus differ significantly between the two groups. This paper contributes to the research literature as it begins the discussion on the energy-economy nexus with due consideration to the environment in net oil importing economies.

2. Study Area and the Scenario Analysis

This paper categorises countries with net oil import dependence of more than 50% as high net oil importing countries, while countries with oil import dependence of less than 50% as low net oil importing countries. This study covers Korea Republic, Japan, Italy, Spain, Hong Kong and Greece under the high net oil importing countries as their and the UK, India, Brazil, the USA, Argentina and China in the group of low net oil importing countries. The selection of the countries is guided by the availability of data from World Development Indicators (WDI) of the World Bank. Annexure-1 and Annexure-2 report the trends in the energy consumption per capita, GDP per capita and CO_2 emissions per capita for both the groups of countries. The trends are mixed and not conclusive. In general, it appears that the decadal growth rate of the energy consumption and CO2 emissions have declined in developed countries, probably after reaching the stage of high mass consumption as posited in Rostow's stages of development. These countries, in the recent decades are also found with a reduced growth rate of CO2 emissions. This could be owed to the technological advancement in all economic processes and rising awareness. Whereas, the emerging economies are found to be consuming a higher rate of energy, accelerating economic development at an increasing rate and simultaneously contaminating the environment. Table 1 gives us the summary of the changes in these factors during 1971-2014. In specific, it could be denoted from the Annexure 1 & 2 and Table 1 that in some of the low net oil importing countries (UK, USA), despite the growth rate of energy consumption has been negative, the economy grows at a higher rate and the growth is cleaner and greener. Whereas, in Korea and Hong Kong, amongst others in high net oil importing countries, during the same period, there are visible trends of the rapid growth of energy consumption, boom in economy as well as growing damages to the environment. The dynamics in these trends in high and low net oil importing countries need an investigation.

Table 1

Growth Rate of EC/c, GDP/c and CO2/c between 1971-2014 (%)

Country	EC/c	GDP/c	CO2/c
Low Net Oil importing Countries			
UK	-25.6192	126.2905	-45.0442
India	138.1058	316.7854	376.5597
Brazil	108.921	133.952	148.1753
Argentina	46.35294	41.13171	30.4228
USA	-8.94552	115.5234	-21.3409
China	381.0863	2456.97	623.817
High Net Oil importing Countries			
Korea Republic	924.8335	1137.439	549.0681
Japan	37.12532	140.5015	26.4148
Italy	23.87377	87.98872	16.31703
Spain	97.97854	109.4991	33.8801
Hong Kong	165.577	486.8599	182.3533
Greece	115.8341	56.92515	96.22635

Note: EC/c is energy consumption per capita, GDP/c is per capita Gross Domestic Product measured at 2010 constant prices in US dollars and CO2/c is the emission of carbon dioxide per capita.

Source: Author's estimation from WDI raw data.

3. Theoretical Postulations

The economic growth theories (Solow, 1969; Arrow, 1962) postulate that achieving sustainability in economic growth is an essential condition of the welfare state that, in turn, is determined by, amongst others, the availability and effective utilisation of factors of production. In past decades, energy has emerged as an important driver of growth and the national growth policies of energy scarce economies focused on strategic collaborations with oil economies to meet former's domestic energy requirements through larger imports (Stern, 2000; Pokrovski, 2003). The oil importing economies, by virtue of increasing use of energy, generate more growth and higher standard of living. Further, theories also postulate that increasing economic activities and rising growth increase the energy consumption (Mahadevan, Asafu-Adjaye, 2007; Squally, 2007). This leads to the perception that energy and economy have interlinkage. Kraft & Kraft (1978) pioneered the investigation on the relation between energy and economy, and this was followed by an enormous number of studies.

The literature has debated the dynamics of the relation between energy and economic growth and resulted in the emergence of four different hypotheses viz. growth hypothesis, conservation hypothesis, feedback hypothesis and neutrality hypothesis. The growth hypothesis postulates that energy consumption leads to economic growth and hence indicates a uni-directional causality running from energy consumption to economic growth. It also demonstrates that energy conservation policies do not negatively affect the economic growth. In contrary, the conservation hypothesis theorises that energy conservation policies may not affect economic growth. Hence, the countries may implement sustainable development policies with less or no impact on the growth. It assumes a uni-directional causality running from economic growth to energy consumption. The feedback hypothesis predicts a bidirectional causality running between energy consumption and economic growth. It reflects the interdependence and complementarities among the variables. The neutrality hypothesis implies that neither the energy conservation policies affect economic growth nor economic growth affects energy consumption. It assumes the absence of a causal relationship between economic growth and energy consumption in any direction.

4. Analysis of Empirical Evidences

4.1. Bivariate models examining the nexus between energy consumption and economic growth

The first scientific study on the nexus between energy consumption and GNP was conducted by Kraft & Kraft (1978) for the US and obtained evidence to support the conservation hypothesis as a uni-directorial causality was found running from GNP to energy consumption. Energy conservation policies thus appeared to have no negative impact on the growth of the economy. Masih & Masih (1998) examined this issue in Thailand and Sri Lanka by applying econometric tools such as Johansen's multiple cointegration test, dynamic vector error-correction model (VECM), dynamic variance decomposition technique and impulse response function. The results confirm that shocks of energy consumption in both countries influence the economic growth and thereby supports the growth hypothesis.

Contrary to these, Oh & Lee (2004) had evidence to support the conservation hypothesis. They estimated VECM and found an absence of short-run causality between energy consumption and economic growth in Korea. While, in the long run, a uni-directional causality running from economic growth to energy use was detected. A similar result was observed by Chontanawat et al. (2008), who studied the relationship between energy consumption and economic growth in the context of over 100 OECD and non-OECD countries. Findings show that the causality running from energy use to economic growth is more pronounced in the developed OECD countries than the developing non-OECD countries. This leads to the inference that policy measures to control energy use for reducing CO2 emissions do significantly impact the economic growth of the developed OECD countries than the developing non-OECD countries.

An investigation by Aslan & Kum (2010) applying FMOLS and DOLS approaches using data from 1971 to 2005 explored the existence of a stronger causal relation running from economic growth to energy consumption. Hence, the result supports the conservation hypothesis. A VECM estimation by Ozturk et al. (2013) also found support for the conservation hypothesis. They observed that energy consumption and GDP had no causal relationship in the short run. While in the long run, a uni-directional causality running from GDP to energy consumption was detected and thus supports the conservation hypothesis. In contrast, Jalil & Feridun (2014) concluded that energy consumption accelerates economic growth. Using ARDL bounds testing methodology, their study reveals that in China, every 1% increase of energy consumption causes 0.17% growth in GDP.

Dudzeviciute & Tamosiuniene (2014) studied the relationship between energy consumption and economic growth in Lithuania, Latvia and Estonia from 1995 to 2012. The results are not uniform. A uni-directional causality running from GDP to energy consumption is found in Estonia, giving support to the conservation hypothesis. While, in Lithuania and Latvia, no causality was detected in any direction between energy consumption and GDP, which in turn supports the neutrality hypothesis.

Kim & Heo (2012) examined the relation between economic growth and energy consumption for the US using decomposed time series of energy consumption. The result observed a bidirectional causal relationship between the variables, thereby supporting the feedback hypothesis. A study by Shakouri & Yazdi (2017) also validated the feedback hypothesis. By applying ARDL bound-testing approach to South Africa, they explored a bidirectional causality between economic growth and energy consumption.

Cho et al. (2015) analysed the nexus between renewable energy consumption and economic growth in OECD and non-OECD countries. The multivariate panel VECM for the annual data from 1990 to 2010 found the long-run causality running unidirectionally from economic growth to renewable energy consumption in 31 developed OECD countries. This supports the conservation hypothesis. While the 49 non-OECD less developed countries had a bidirectional long-run causality validating feedback hypothesis. Hence, the results vary between the developed and the developing countries. Whereas, a multivariate time-varying model estimated by Arora and Shi (2016) for quarterly data of the USA from 1973 to 2014 found that the causal relationship between energy consumption and real GDP was varying over the time. A bidirectional causality was detected between the two variables in the decade of 1990's, but during 2000's the causality was found running from real GDP to energy consumption.

Pastén et al. (2015) found evidence to support the growth hypothesis. This inference was made from a panel data study of 16 Latin American countries by applying a random coefficient method using annual data from 1971 to 2001. A uni-directional causality running from energy to economic growth was detected. A contrasting result was found by Çetintaş (2016). The study focused on the economic growth – energy consumption relationship of 17 transition economies and had evidence to accept the conservation hypothesis. It explored a uni-directional causality running from economic growth to energy consumption in the long run, implying that in those transition economies, energy conservation policies do not impact economic growth negatively. In another bivariate study by Dlamini, et al. (2016) for South Africa using vector autoregression (VAR), however, found no strong evidence of causality in any direction between economic growth and energy consumption. In contrast, Rathnayaka et al. (2018) detected a bidirectional or feedback causality running between the said variables in China by estimating VECM.

Liu (2018) investigated the nexus between energy consumption and economic growth in China from 1982 to 2015 by estimating DOLS, FMOLS, ARDL and VECM models. The findings show that the economic growth of China is sensitive to energy consumption. Similar results are obtained by Azam (2019) in a panel of 10 developing Asian countries. It is found that energy has a significant impact on economic growth. The study used quarterly data from 1990 to 2014 and applied fully modified ordinary least squares and dynamic ordinary least squares methods and concludes that the Asian economies drive economic growth through sustained consumption of energy. A study on the Indian context by Habib (2019) also supported the conservation hypothesis. It observed that change in petroleum consumption has a significant impact on economic growth both in the short run and long run as a uni-directional causality was found running from petroleum consumption to economic growth.

4.2. Multivariate models examining the nexus between energy consumption and economic growth

Jafari, et al. (2015) estimated a multivariate model to examine the nexus between economic growth, energy consumption and emissions in Bahrain by employing Toda and Yamamoto's approach. The model was controlled for capital and urban population. The results indicate that Bahrain has a uni-directional causality running from economic growth to energy consumption, emissions and capital. Further, it is also found that carbon emission in Bahrain is Granger caused by urban population, economic growth, capital and energy consumption. In another study. Xiong, et al. (2015) estimated the relationship between energy consumption, economic growth, carbon emission and energy exports in Kazakhstan for the period ranging between 1993 and 2010. The study reveals that energy consumption was the major factor driving carbon emissions in Kazakhstan.

Mbarek, et al. (2016) investigated the causality relatios among energy consumption, greenhouse emissions and economic growth in Spain. It is observed from the study that: (1) energy consumption and greenhouse emissions have a feedback relationship; (2) energy consumption and economic growth have a significant and positive relationship; and (3) a uni-directional causality running from economic growth to greenhouse emissions.

In a multivariate causality analysis between economic growth and energy consumption in Turkey based on ARDL bounds testing approach, Pata & Terzi (2017) found a uni-directional causal relation flowing from energy consumption to economic growth and thereby supporting the validity of the growth hypothesis. In concurrence, Joo et al. (2015) also observed strong evidence to support the growth hypothesis. They investigated the relationship between economic growth, CO2 emissions and energy consumption for Chile and the causality was found running from energy consumption to economic growth, from CO2 emissions to economic growth, and from energy consumption to CO2 emissions. There was no evidence for causality running from economic growth to energy consumption, from CO2 emissions to energy consumption, and from economic growth to CO2 emissions. In contrast, Kais & Mbarek (2017) found evidence in three African countries to support the conservation hypothesis. Their study on the linkage between energy consumption, carbon dioxide emissions and economic growth applied a panel VECM model and results explored a short-run relationship running from economic growth to energy consumption; from economic growth to CO2 emissions; and also from energy consumption to CO2 emissions. Further, it also detected a long run bidirectional causality between energy consumption and economic growth and a uni-directional causality running from energy consumption to CO2 emissions.

Destek & Okumus (2017) disaggregated the energy into oil, natural gas, and coal and examined the relation between consumption of each of these energy sources and economic growth in G-7 countries for the period from 1970 to 2013 using panel bootstrap causality approach. The results are mixed. In Germany, Italy, Japan, and the United States, oil consumption is found granger cause economic growth, in Germany and UK economic growth causes oil consumption, in Italy, Japan, USA and UK, consumption of natural gas causes economic growth, in Germany economic growth causes natural gas, in Canada consumption of coal causes economic growth, in USA economic growth causes consumption of coal. Tamba (2017) examined the short-run and long-run causal relationship among energy consumption, economic growth, and CO2 emissions in Cameroon by applying an error correction model using annual data from 1971 to 2013. The long-run equilibrium between these three variables and their capability to return to equilibrium has been confirmed. This apart, a bidirectional long-run causality between all variables, viz, between economic growth, energy consumption and CO2, was also detected. While in the short-run causality was detected only between CO2 emissions and energy consumption. In this case, CO2 emissions granger cause energy consumption.

The relation between energy consumption, CO2 emissions and economic growth is also examined by Saidi & Hammami (2016) by estimating dynamic simultaneous-equation panel data models for 58 countries divided into six regional panels. Results are not uniform across the regions. For four panels, the result shows a directional causality between economic growth and energy consumption and similarly between economic growth and energy consumption. While for Latin American and Caribbean countries, a uni-directional causality running from CO2 emissions to economic growth was detected. Sulaiman & Rahim (2017) examined the relation between CO2 emission, energy consumption and economic growth in Malaysia for the period between 1975 and 2015 using ARDL approach and DOLS method. The study also estimated the vector error correction model, variance decomposition and impulse response function. The results show that energy consumption and economic growth drive CO2 in Malaysia. There are no evidences of economic growth being influenced by either energy consumption or CO2.

Salahuddin & Gow (2019) studied the relation between economic growth, energy consumption, foreign direct investment, and financial development on environmental quality. The environmental quality was measured by three different indicators: per capita CO2 emissions, energy intensity and Adjusted National Savings. This study was undertaken for the data of Qatar from 1980 to 2016 by applying ARDL model. It is observed from the results that energy consumption has an impact on all three indicators of environmental quality. FDI seems to have a negative long-run effect on environmental quality energy intensity. Results confirmed that all three variables (economic growth, energy consumption, and financial development) have a bidirectional causal relation with all three indicators of environmental quality (CO2 emissions, energy intensity and Adjusted National Savings).

Balcilar et al. (2019) examined the relation between CO2, energy consumption and economic growth in the G-7 countries using the historical decomposition method. Results found an interlink between the three variables such that fossil-based energy consumption causes substantial CO2 emissions, which in turn accelerates economic growth in Canada, Italy, Japan and to some extent the USA. It is also found that none of the countries has any evidence to support the EKC hypothesis.

A study by Bayar & Gavriletea (2109) focusing on emerging economies explores that in the long run, the energy efficiency positively influences the economic growth whereas, economic growth appears to have no significant impact from renewable energy. It also detected one-directional causality in the short run from both energy efficiency and renewable energy use to the economic growth. Li (2020) found an inter linkage between energy consumption, CO2 emissions and economic growth in China through a decoupling approach for the data from 1979 to 2018. The study reveals that though they are inter-linked, the speed of economic growth is higher than CO2 emissions and energy consumption.

4.3. Direction for this study

Though there is an abundance of literature on the relation between energy consumption and economic growth, the existing literature suffers from certain limitations. The findings from the literature on the relation between energy consumption and economic growth are not unanimous, rather conflicting as there is evidence to validate all four different but conflicting hypotheses. Some of the studies focussed on oil exporting countries, while some others focussed on a mixed group of oil exporting and importing countries. In cases of a mixed group, common policy suggestions are generalised across all countries based on the results, but practically such uniform policy suggestions are inappropriate as the inclination to and nature of energy consumption differs between oil exporting and oil importing countries. Further, it is also observed that hardly any study is available focussing on the oil importing countries. Again, the size of import of oil varies between the countries, and this will also impact the nature of relationship between energy consumption and economic growth. The present study takes these lapses and gaps in the available literature into account and contributes to the existing stock of literature.

5. Methodological Framework

5.1. Model Specification

Narayan & Smyth (2009) argued that most of the earlier studies on the energy-economic growth nexus employed a bivariate framework and such studies are subjected to the omitted variables bias and therefore, the findings and policy suggestions are potentially spurious. A study by Lutkepohl (1982) confirmed the notion that omitting relevant variable(s), in a bivariate model, may lead to a spurious finding of Granger causality. Subsequently, Triacca (1998) proved that omitted variables, in a bivariate framework, cause absence of causality between the variables. The inclusion of a third variable in the energy-growth analysis makes the model more robust as the sign and size of the coefficient reach closer to perfection and changes the direction of causality nearer to the reality (Odhiambo, 2009). In view of this, this study developed a tri-variate framework by including carbon emission to energy consumption and economic growth.

Some of the past studies, such as Jafari, et al. (2015), Xiong, et al (2015), Joo et al. (2015), Mbarek et al. (2016), Saidi & Hammami (2016), Sulaiman & Rahim (2017), Kais & Mbarek (2017), Salahuddin & Gow (2019), Balcilar et al. (2019) and Li (2020) among others studied the interlinkage between energy consumption, economic growth and carbon emission. It is revealed from their study that carbon emission is a significant having interlinkage with energy consumption and economic growth. The inclusion of carbon emission in the model, thus, will better explain the relation between energy and economy in the net oil importing economies. Thus, the proposed model of this study is broadly consistent with the literature, and is presented in equation (1):

$$GDP = f(EC, CO2) \tag{1}$$

The model states that economic growth (GDP) in net oil importing countries is the function of energy consumption (EC) and the level of carbon emissions (CO2). The economic growth is measured in terms GDP, the energy consumption is measured by energy use and carbon emission is measured in terms of CO2 emissions. The model has been presented in the form of a specific equation as given in equation (2).

$$GDP_{t} = \beta_0 + \beta_1 EC_{t} + \beta_2 CO2t + e_{t} \tag{2}$$

Wherein, βo is the constant term, β_1 and β_2 are coefficient terms of EC and CO2, respectively, and e is the error term. The study uses annual data for all the model variables, and the time series is represented by t.

To smoothen the data and thereby obtain a more robust results from the model estimation the actual values of the data series are converted to the natural logarithm. After the logarithmic transformation of the data the equation (2) is re-written as in equation (3):

$$lnGDP_{t} = \beta_0 + \beta_1\, lnEC_{t} + \beta_2\, lnCO2_{t} + e_{t} \tag{3}$$

The study focuses on several oil importing countries and hence, the data is a panel in nature. By incorporating the cross-country factor, equation (3) is modified further into:

$$lnGDP_{i,t} = \beta_0 + \beta_1\, lnEC_{i,t} + \beta_2\, lnCO2_{i,t} + e_{i,t} \tag{4}$$

In equation (4) i indicates the respective countries in the panel.

5.2. Data Description

As there is a lack of studies on the relation between energy and economy in oil importing countries, this study is based on the data accessed from 12 oil importing countries. For the purpose of the study, the countries are classified into two groups such as high net oil importing countries and low net oil importing countries in terms of their net oil import dependence is greater or lesser than 50% according to the data sourced from WDI, 2020. Similar approach to the classification of the oil importing countries was followed in other studies (for instance, Esen, Bayrak, 2017). High net oil importing countries are those with energy import dependency is more than 50%, while countries with oil import dependency of less than 50 percent are group as low net oil importing countries. In this study Korea Republic, Japan, Italy, Spain, Hong Kong and Greece represent the high net oil importing countries and the UK, India, Brazil, the USA, Argentina and China form low oil importing group. The selection of the countries is guided by the availability of data apart from oil import dependency ratio. The study is based on the annual data collected for the sample variables for the period ranging between 1971 and 2014. The selection of sample periods is also guided by the availability of data.

Table 2 reports the study variables, their definitions and symbols used for the study. The data are extracted from the World Development Indicators (WDI) of the World Bank.

Table 2

Description to the study variables

Variable	Description	Symbol
Response Variable		
GDP per capita	measured in constant 2010 US$	GDP
Regressors		
Energy consumption per capita	measured in kilogram of oil equivalent per capita	EC
Emission of carbon dioxide per capita	measured in metric tons per capita	CO2

Annexure 3 presents the descriptive statistics of variables used in the study. It could be summarised that for each of the variables, the deviation of maximum and minimum from the mean is short. The standard deviation is very low and thereby, the aggregate behaviour of the data sets is almost close to their respective average behaviour.

The coefficients of Skewness and Kurtosis indicate that all the variables used in the study are characterised by non-normal distribution. The coefficient of most of the variables are negative and they indicate that such variables are skewed to the left. Only EC in high net oil importing countries is skewed to the right. Further, the coefficients of kurtosis show that the leptokurtic for all variables applied in this study in low net oil importing countries have the presence of a high peak or a fat-tailed in their volatilities. While, the data sets variables of high importing countries have a low peak.

In addition, the estimated coefficients of Jarque–Bera statistics are positive, thereby indicating the rejection of the null hypothesis of normal distribution of the variables used in the study. Further, the coefficient values of Jarque–Bera are high and they reflect that the data series are not normally distributed at 1 percent level of significance.

Thus, the results of skewness, kurtosis, and Jarque–Bera infer that all variables used in the study are not normally distributed.

5.3. Econometric approaches

Guttormse (2004) and Mehrara (2007) observed that the literature on the applied econometric methodology to the energy-growth nexus has evolved over four generations. The methodology of the fourth generation is primarily the estimation of panel cointegration and panel error correction models. Literature on the methodological issues highlights the advantages of panel estimation over other estimation methodologies of earlier generations. For instance, Osbat (2004, quoted from Hasanov, et al., 2017) brings forth four such advantages: (1) a better and clear information could be accessed from panel data when time series are combined with cross-sectional dimensions; (2) the results from panel estimation are more efficient as it has potential to mitigate collinearity among the explanatory variables and to increase degrees of freedom; (3) this estimation technique provides for controlling the individual heterogeneity; (4) the effects that are not identified in the time series or cross-section data, are detected by the panel estimation. Since the panel framework appears to be more efficient, the present study has employed the panel estimation techniques.

The econometric methodology to the panel estimation, in this study, begins with testing for time series properties of the variables through panel unit root test (PURT) followed by testing for order of integration. Further, using the cointegration approach, the paper estimates the impact of economic growth and energy consumption on carbon emission and detects whether there exists any long-run relationship among these variables. If the variables are found co-integrated in the long run, a panel vector error correction model (VECM) is estimated to examine the short-run dynamics of the relationship between the variables. In the event of absence of cointegration, a panel vector autoregressive model (VAR) will be estimated. Literature advocates that the variance decompositions are a better framework to summarise the dynamic relations between variables in a VAR. The selection of econometric methodology is guided by the literature of the past.

The objectives of this paper are to estimate how are the variables related in the long run and short run and examine the dynamic causality between carbon emission, energy consumption and economic growth in oil importing countries. To investigate on these, this paper follows four steps in the methodological approach.

1) The non-stationarity of the study variables, i.e. GDP, EC and CO2 are examined using first-generation panel unit root test (PURT) methodology. Three different methods of PURT, such as Levin, Lin & Chu test, (Augmented Dickey-Fuller) ADF – Fisher Chi-square test and (Phillips-Perron) PP – Fisher Chi-square test are estimated. Among the three methods Levin, Lin & Chu test assumes a common unit root process across cross-sections. While ADF – Fisher Chi-square and PP – Fisher Chi-square tests assume

individual unit root process. In all these three tests, null hypothesis is that the panel data have a unit root or non-stationarity. The general form of equation estimated for PURT is as given in equation (5):

$$\Delta y_{i,t} = \alpha y_{i,t-1} + \sum_{k=1}^{Pi} \mu_{ik} \Delta y_{i,t-k} + \beta_i X_{i,t} + e_{i,t} \quad (5)$$

Where y is the variable to be tested, X is the exogenous variable/s, i and t are cross-section (country) and time elements respectively, e stands for error term and Δ is the first difference operator. Here the null hypothesis of unit root is $H_0 : \alpha = 0$. The alternative hypothesis of no unit root is $H_1 : \alpha = 0$ for all i = 1,2,3…N_1 and $\alpha < 0$ for all i = N1+1, N1+2, N1+3……N.

2) If all the time series variables are found integrated at the same order, preferably I(1), a panel cointegration test (PCT) is applied. The presence of the cointegration among the model variables is tested through three different methods of PCT such as Pedroni Residual Cointegration Test, Kao Residual Cointegration Test and Johansen Fisher Panel Cointegration Test.

Pedroni method considers the heterogeneity at two different levels. In the first level, it considers the heterogeneity across sections (countries). It is estimated by Equation (6).

$$y_{i,t} = \alpha_i + \delta_{i,t} + \beta_{1t} X1_{i,t} + \beta_{2t} X2_{i,t} + \cdots + \beta z_t XZ_{i,t} + e_{i,t} \quad (6)$$

Variables y and X are assumed as I(1). $\alpha_i + \delta_i$ stand for individual and trend effects. The second level tests the stationarity of the estimated residual, i.e. $\hat{e}_{i,t}$ by Equation (7):

$$\hat{e}_{i,t} = Q_i \hat{e}_{i,t-1} + e_{i,t} \quad (7)$$

Unlike Pedroni, Kao considers homogeneity in cointegration with only intercept and no trend. The PCT under Kao methodology is tested by estimating equation (8):

$$y_{i,t} = \alpha_i + \beta_{1t} X1_{i,t} + \beta_{2t} X2_{i,t} + \cdots + \beta z_t XZ_{i,t} + e_{i,t} \quad (8)$$

If the variables are found co-integrated, a panel vector error correction model (VECM) is estimated to examine the short-run dynamics of the relationship between the variables. In the event of an absence of cointegration, a panel vector autoregressive model (VAR) will be estimated. If a cointegration relationship is detected, then Equation (4) for GDP is represented as in equation (9).

$$InGDP_{i,t} = \alpha_i + \delta_{i,t} + \beta 1\, InEC_{i,t} + \beta 2\, InCO2_{i,t} + e_{i,t} \quad (9)$$

Later, the study measures the error correction term or the long run residuals by estimating equation (10).

$$e_{i,t} = ECT_{i,t} = \text{In}GDP_{i,t} - (\alpha_i + \delta_{i,t} + \beta 1 InEC_{i,t} + \beta 2\, InCO2_{i,t}) \quad (10)$$

The study estimates the panel VECM by applying the set of vectors that are presented in equation (11).

$$\begin{pmatrix} \Delta InGDP_{i,t} \\ \Delta InEC_{i,t} \\ \Delta InCO2_{i,t} \end{pmatrix} = \begin{pmatrix} b^1 \\ b^2 \\ b^3 \end{pmatrix} + \sum_{k=1}^{n} \begin{pmatrix} B_{11,k} & B_{12,k} & B_{13,k} \\ B_{21,k} & B_{22,k} & B_{23,k} \\ B_{31,k} & B_{32,k} & B_{33,k} \end{pmatrix} \begin{pmatrix} \Delta InGDP_{i,t-k} \\ \Delta InEC_{i,t-k} \\ \Delta InCO2_{i,t-k} \end{pmatrix} + \begin{pmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \end{pmatrix} ECT_{i,t-}{}^{1} + \begin{pmatrix} e^1{}_{i,t} \\ e^2{}_{i,t} \\ e^3{}_{i,t} \end{pmatrix} \quad (11)$$

Where b is the vector of intercept, τ is the vector of speed of adjustment coefficients. This reflects the speed with which the deviations from the long-run equilibrium are corrected. B is the metrics of short-run coefficients, e is vector of serially independent residuals. Δ is the difference operator and $ECT_{i,t-1}$ is the lagged error term that is generated from long-run association. If the coefficient of the lagged ECT is negative and significant based on t-statistic, then it could be interpreted that there exists a long-run causality running from deterministic variables to the response variable. The presence of significant coefficients in the first difference/second difference indicates the existence of short-run causality.

After VECM estimation, the study uses a panel variance decomposition technique applying VAR system. Though the VECM model measures the short-run and long-run causality between the variables, it does not capture the relative strength of causal relation between the variables beyond the selected time period (Abosedra et al., 2015). In contrast, the variance decomposition method is capable of measuring the magnitude of the predicted error variance for a series accounted for by innovations from each of the independent variables over different time-horizons beyond the selected time period (Abosedra et al., 2015). Engle & Granger (1987) and Ibrahim (2005) also echoed the same. They believe that with VAR framework, the variance decomposition method delivers more reliable results than conventional approaches.

6. Results and Discussion

6.1. Panel Unit Root Tests (PURTs)

The PURTs based on Levin, Lin & Chu, ADF – Fisher Chi-square and PP – Fisher Chi-square methods are estimated on the natural logarithms of GDP, EC and CO2 at a level and first difference and the results are presented in Table 3. In both the groups of countries (high net oil importing countries and low net oil importing countries), all three tests provide consistent results. Data series of GDP, EC and CO2 are non-stationary and have unit root at level I(0) across both groups of countries. Non-stationarity of GDP data series indicates that the shocks to the economy by economic policies such as monetary policy or fiscal policy have permanent effect on the level of economic growth. EC being non-stationary, innovations in energy utilisation will have a permanent effect on the energy consumption. Further, any measures to control carbon emissions seem to have a longstanding effect on the level of CO2 emissions.

While after the first difference I(1), all data series, i.e., ΔGDP, ΔEC and ΔCO2 are found stationary. Hence, the null hypothesis that the data series have a unit root cannot be accepted. Thus the results reveal that GDP, EC and CO2 are integrated of order one I(1). The stationarity level of the data series implies that any innovations or policy reforms pertaining to the variable concerned have transitory effects and the series returns to its trend path (Abosedra et al., 2015). At first difference, economic policy reforms, innovations in energy use and policies and innovations to control carbon emissions leave an only temporary effect on GDP, EC and CO2 as the shocks are transitory in the time trend path.

After concluding that all data series are integrated of order one I(1) regardless of groups of countries, the study proceeds to test whether the model variables are co-integrated before estimating the regression model.

Table 3

Results of Panel Unit Root Tests

Variable	Method	Order	Low Net Oil importing Countries		High Net Oil importing Countries	
			Statistic	*Prob*	*Statistic*	*Prob*
ln $CO2_{it}$	Levin, Lin & Chu	Level	-0.10674	0.4575	0.81212	0.7916
		1st diff	-4.10566	0.0000*	-6.40674	0.0000*
	ADF - Fisher	Level	14.3120	0.2812	4.48174	0.9731
		1st diff	55.2581	0.0000*	65.2300	0.0000*
	PP - Fisher	Level	13.3746	0.3424	2.54958	0.9980
		1st diff	148.076	0.0000*	165.542	0.0000*
ln GDP_{it}	Levin, Lin & Chu	Level	5.37236	1.0000	3.64824	0.9999
		1st diff	0.38117	0.6485	-3.96973	0.0000*
	ADF - Fisher	Level	0.30001	1.0000	0.89363	1.0000
		1st diff	35.1245	0.0004*	28.9187	0.0041*
	PP - Fisher	Level	0.19311	1.0000	0.43662	1.0000
		1st diff	71.5252	0.0000*	75.4133	0.0000*
ln EC_{it}	Levin, Lin & Chu	Level	1.63884	0.9494	1.14438	0.8738
		1st diff	-3.58792	0.0002*	-5.30731	0.0000*
	ADF - Fisher	Level	6.93667	0.8618	2.78181	0.9969
		1st diff	48.5796	0.0000*	52.4683	0.0000*
	PP - Fisher	Level	5.11775	0.9539	1.36763	0.9999
		1st diff	138.603	0.0000*	167.061	0.0000*

***** $p < 0.01$

6.2. Panel Cointegration Tests (PCTs)

Pedroni residual cointegration test, Kao residual cointegration test and Johansen Fisher panel cointegration test are applied in this study to verify long-run relationship between economic growth, energy consumption and carbon emissions. Pedroni test assumes intercept and trend and presents two sets of cointegration, firstly, within the dimension and secondly, between dimensions. Kao test assumes individual intercept, no trend and the cointegration is based on the ADF t statistic. Johansen Fisher test assumes intercept, no trend in CE & VAR and the cointegration, in this case, is based on the two sets of tests, namely, trace test and max-eigen test. The results of PCTs are presented in Table 4.

Pedroni test denotes a weak cointegration relation between the variables regardless of groups of countries. For a stronger cointegration, statistic values of most of the tests should have been significant, but not the case here. Whereas, results of Kao test present that GDP, EC and CO2 have a strong long-run relationship among themselves in both the groups of countries as the ADF statistic is significant. Also, the findings of Johansen Fisher test corroborate the existence of long-run relationship between the variables. The Fisher statistic values extracted from both trace test and max-eigen test are statistically significant and this leads to the rejection of the null hypothesis that there is 'none' number of co-integrating vectors between the three variables of the study. The Johansen Fisher test concludes that there exists at most one co-integrating equation between GDP, EC and CO2.

Table 4

Results of Panel Cointegration Test

Method	Test	Low Net Oil importing Countries		High Net Oil importing Countries	
		Statistic	*Prob*	*Statistic*	*Prob*
Pedroni	*Within-dimension*				
	Panel v-Statistic	2.482990	0.0065*	0.493719	0.3108
	Panel rho-Statistic	-1.710309	0.0436**	-0.440144	0.3299
	Panel PP-Statistic	-3.150557	0.0008*	-1.376593	0.0843***
	Panel ADF-Statistic	-1.312117	0.0947***	-0.991949	0.1606
	Between-dimension				
	Group rho-Statistic	-1.489683	0.0682***	0.159835	0.5635
	Group PP-Statistic	-3.119217	0.0009*	-1.517628	0.0646***
	Group ADF-Statistic	-0.374	0.3542	-1.251277	0.1054
Kao	ADF	-2.779904	0.0027*	-1.895081	0.0290**
Johansen Fisher	*Trace Test*				
	None	36.60	0.0003*	33.62	0.0008*
	At most 1	13.05	0.3654	14.78	0.2539
	At most 2	13.72	0.3187	16.80	0.1575
	Max-eigen test				
	None	36.79	0.0002*	28.46	0.0047*
	At most 1	11.95	0.4500	11.14	0.5169
	At most 2	13.72	0.3187	16.80	0.1575

* $p < 0.01$, ** $p < 0.05$ & *** $p < 0.10$

Based on the results of PCTs, the null hypothesis of no cointegration between the variables cannot be accepted and this provides stronger evidence for long run co-integrating association between GDP, EC and CO2.

The cointegration result is sensitive to the lag length used and hence it is critical to select an appropriate and reliable lag length. In this paper, the selection of lag length is guided by VAR Lag Order Selection Criteria and the result is presented in Annexure-4. Since the literature considers Schwarz information criterion (SC) as one of the highly accepted, the optimal lag length in this study is selected based on SC. Based on this criterion, lag 2 is found to be the optimal lag for both the groups of countries.

As all the variables are integrated of order one I(1) and the long run co-integrating relationship between them is established in both the groups of countries, the study proceeds to examine the causal relationship among the series by estimating an error correction model. The clear understanding of the direction of flow of the causal relationship would guide in framing appropriate policies for sustainable development.

6.3. Panel VECM

The VECM estimates long run and short-run causality between the GDP, EC and CO2. Table 5 presents the results of long-run causality. The error correction term (ECT) measures the speed of adjustment of the dependant variable towards long-run equilibrium for the shocks of determinants. The results are uniform across all three groups. The energy consumption and carbon emissions do not have a significant impact on the economic growth. While GDP and EC are found to be significant factors in determining the changes in CO2 irrespective of the size of oil imported by the countries. Similarly, EC is determined by GDP and CO2. Again, regardless of the group of countries, the speed of adjustment in CO2 towards its long-run equilibrium is faster than EC, as this is evident from the size of the ECT. The imbalances caused to CO2 by the fluctuations in EC and GDP, will return to their earlier state by 52%, and 11% during a year in high oil importing countries and low oil importing countries, respectively.

Irrespective of the size of oil imports, in both groups of countries, a bidirectional long-run causality is evident between EC and CO2. A uni-directional long-run causality running from GDP to EC and also from GDP to CO2 is detected. While no causality is found running from EC to GDP and also from CO2 to GDP.

Table 5

Panel Vector Error Correction Model

	Low Net Oil importing Countries			High Net Oil importing Countries		
	$\Delta lnGDP_{it}$	$\Delta lnEC_{it}$	$\Delta lnCO2_{it}$	$\Delta lnGDP_{it}$	$\Delta lnEC_{it}$	$\Delta lnCO2_{it}$
ECT(-1)	0.006664	-0.001501	-5.28E-06	-0.007416	-0.005311	-1.18E-05
Std. Error	0.00214	0.00047	1.40E-06	0.005853	0.000988	2.97E-06
t-Statistic	3.11733	-3.18552	-3.68159	-1.267123	-5.373097	-3.989363
Prob.	0.0019*	0.0015*	0.0002*	0.2055	0.0000*	0.0001*
R-squared	0.293614	0.112895	0.140031	0.183170	0.149624	0.103703
Adj.R-squared	0.272838	0.086804	0.114737	0.159146	0.124613	0.077341
S.E. of regression	424.9227	93.68118	0.285248	647.0502	109.2716	0.327998
F-statistic	14.13230	4.326920	5.536290	7.624333	5.982314	3.933845
Log likelihood	-1833.762	-1461.807	-36.41085	-1937.209	-1499.676	-70.76416
D-W stat	1.926086	1.91863	1.858199	1.943806	1.997797	1.986894

* $p < 0.01$

Diagnostic tests are performed to check the reliability of the results. The D-W statistic, as per the statistical norm, should be around 2 and in our case, for all models across groups of countries, it is almost 2. This implies that the result is not inflated by the autocorrelation in the residuals. Furthermore, high F-statistic also shows that variables as a group are jointly significant in all the models.

The short-run causality between the variables is also estimated and the results are presented in Table 6 and Table 7. The joint impact of the lagged terms of the deterministic factors on the dependent variable is measured through the Wald test. Table 6 and Table 7 also cover the results of Wald test.

Table 6

Short Run Causality and Joint Wald Test of Lagged Terms – Low Net Oil importing Countries

Regressor & Lagged Terms	Coefficient	t-statistic	Chi-square	df	Prob	Decision
Dependent Variable: $\Delta lnGDP_{it}$						
ΔlnEC-1	0.306379	0.37729	2.449575	2	0.2938	Accept Ho
ΔlnEC-2	1.184941	1.46637				
Δ*lnCO2-1*	-113.0239	-0.42915	3.658276	2	0.1606	Accept Ho
Δ*lnCO2-2*	-476.567	-1.81643				
Dependent Variable: $\Delta lnEC_{it}$						
ΔlnGDP-1	0.015221	0.80676	0.652774	2	0.7215	Accept Ho
ΔlnGDP-2	-0.005017	-0.27068				
ΔlnCO2-1	-113.9427	-1.96238	5.355688	2	0.0687	Reject Ho
ΔlnCO2-2	-60.19532	-1.04068				
Dependent Variable: $\Delta lnCO2_{it}$						
ΔlnGDP-1	3.67E-05	0.63873	0.443408	2	0.8012	Accept Ho
ΔlnGDP-2	-3.59E-08	-0.00064				
ΔlnEC-1	0.001212	2.22335	5.177912	2	0.0751	Reject Ho
ΔlnEC-2	0.000124	0.22908				

Table 7

Short Run Causality and Joint Wald Test of Lagged Terms – High Net Oil importing Countries

Regressor & Lagged Terms	Coefficient	t-statistic	Chi-square	df	Prob	Decision
Dependent Variable: $\Delta lnGDP_{it}$						
ΔlnEC-1	0.534875	0.82441	2.864065	2	0.2388	Accept Ho
ΔlnEC-2	-0.851234	-1.30231				
Δ*lnCO2-1*	-238.847	-1.0821	4.634272	2	0.0986	Reject Ho
Δ*lnCO2-2*	396.7019	1.77405				
Dependent Variable: $\Delta lnEC_{it}$						
ΔlnGDP-1	0.018295	1.5127	8.348459	2	0.0154	Reject Ho
ΔlnGDP-2	0.022002	1.82418				
ΔlnCO2-1	54.02000	1.44922	3.281622	2	0.1938	Accept Ho
ΔlnCO2-2	36.7989	-0.97446				
Dependent Variable: $\Delta lnCO2_{it}$						
ΔlnGDP-1	9.46E-05	2.6052	7.280340	2	0.0262	Reject Ho
ΔlnGDP-2	-7.14E-06	-0.19728				
ΔlnEC-1	-0.000113	-0.34338	1.591418	2	0.4513	Accept Ho
ΔlnEC-2	-0.000416	-1.2562				

A feedback causal relationship between CO2 and EC in the short run is found in low net oil importing countries. This implies that carbon emission is caused by energy use in low oil importing countries, and in turn, energy use is also caused by carbon emission. No short-run causality is found running between EC & GDP and GDP & CO2 in any direction. This has policy implications that if any sustainable development policy measures are implemented to reduce energy use and cut carbon emissions to protect the environment will not affect the national economic growth and the average income of the individuals.

In the case of high oil importing countries, changes in the economic growth appear to cause energy use in the short run, but not vice-versa. Further, a bidirectional short-run causality is detected between GDP and CO2. This implies that: firstly, more economic activities will cause more emissions; secondly, implementation of policy measures that are aimed at reducing emissions and improving the quality of the environment will affect the growth of the economy negatively.

Since the results of the study are based on the time series, it is important to test whether the results are affected by serial correlation in the data sets. To investigate whether error terms of the past in each variable data set transfer to future period, two accepted tests of serial correlation such as Portmanteau serial correlation tests and LM serial correlation tests are applied and results are reported in Table 8. Since the current study selected 2 optimal lag order, the focus is to check for any possible serial correlation beyond lag 2. The Q statistic of the Portmanteau test and LM statistic of LM test are not statistically significant in both low oil importing countries and high oil importing countries beyond lag 2. This leads to the rejection of the null hypothesis that there is serial correction at higher lag order than the optimal lag order of the study. Hence the model is not affected by serial correlation and the VECM results are reliable.

Table 8

VEC Residual Serial Correlation Tests

Test	Lags	Low Net Oil importing Countries		High Net Oil importing Countries	
		Q-Stat/LM Stat	Prob.	Q-Stat/LM Stat	Prob.
Portmanteau Tests	1	0.660899	NA*	0.357720	NA*
	2	3.426295	NA*	0.987591	NA*
	3	15.92378	0.3871	12.31249	0.6552
	4	32.70383	0.1105	25.14332	0.3980
LM Tests	1	19.82069	0.0191	9.029181	0.4346
	2	23.50618	0.0052	5.645103	0.7748
	3	13.77608	0.1305	13.27698	0.1505
	4	18.40263	0.0308	14.74965	0.0980

*The test is valid only for lags larger than the VAR lag order.

6.4. Variance Decomposition

Subsequent to analysing the short run and long-run dynamics, the paper proceeded to apply the variance decomposition technique to the VAR system to measure the predicted changes in the given variable for the innovations or shocks in each of the regressors over a time path beyond the selected time period. The results of the variance decomposition are presented in Table 9 and Table 10 for low oil importing countries and high oil importing countries, respectively. The results appear to be uniform across both the groups of countries. The innovative shocks of energy consumption and carbon emissions do not appear to contribute to economic well-being. The changes in economic growth are defined by its own shocks in the given time path that are linked to various exogenous factors. The theoretical argument of increasing energy consumption due to industrialisation, mechanisation, improved transportation and increased economic activities shall contribute to economic growth has not found supporting evidences. Innovative shocks of GDP explain 36% and 21% changes in the energy consumption of low net oil importing countries and high net oil importing countries, respectively. The explanatory power of GDP on EC remains stronger throughout from the time path of period 1 to period 10. The increased income of the people seems to induce more usage of automobiles, electric and electronic equipment at the household level and increased economic activities at the macro level, causing more consumption of energy. Interestingly, changes in energy consumption do not appear to be influenced by the shocks of carbon emissions. This contradicts with the outcome of some of the past studies, which argue that there is a significant flow of relationship from carbon emissions to energy consumption. The argument that increasing environmental pollution forces countries to reduce energy consumption is not validated in the case of either high net oil importing countries or low net oil importing countries.

Regardless of the level of net oil imports, innovative shocks of GDP and EC contribute to carbon emissions. The contribution of GDP to CO2 seems to be increasing as we move on in the time path from period 1 (short term) to period 10 (long term). In the long run, a shock in GDP is predicted to define 24% and 37% of changes in carbon emissions in low net oil importing countries and high net oil importing countries, respectively. Further, CO2 also depends heavily on the shocks of energy consumption. Innovative shocks stemming in energy consumption is predicted to contribute to carbon emissions by 53% and 44% in low net oil importing countries and high oil importing countries, respectively.

Table 9

Results of Variance Decompositions: Low Oil importing Countries

Period	SE.	$lnGDP_{it}$	$lnEC_{it}$	$lnCO2_{it}$
Variance Decomposition of $lnGDP_{it}$:				
1	424.9227	100.0000	0.000000	0.000000
4	1110.278	99.14993	0.019637	0.830437
7	1521.347	98.69163	0.038938	1.269429
10	1867.055	98.65588	0.031536	1.312586
Variance Decomposition of $lnEC_{it}$:				
1	93.68118	39.42447	60.57553	0.000000
4	199.8169	39.69283	57.56847	2.738698
7	257.5964	37.92656	58.15114	3.922305
10	302.7693	36.62524	58.85609	4.518667
Variance Decomposition of $lnCO2_{it}$:				
1	0.285248	38.59929	48.30788	13.09284
4	0.605804	43.02212	51.11776	5.860118
7	0.779357	42.68004	52.67464	4.645323
10	0.912115	41.86120	53.98635	4.152445

Table 10

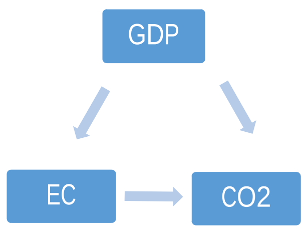
Results of Variance Decompositions: High Oil importing Countries

Period	SE.	$lnGDP_{it}$	$lnEC_{it}$	$lnCO2_{it}$
Variance Decomposition of $lnGDP_{it}$:				
1	647.0502	100.0000	0.000000	0.000000
4	1823.814	99.89028	0.022443	0.087280
7	2575.563	99.82472	0.062708	0.112572
10	3124.695	99.75724	0.124813	0.117943
Variance Decomposition of $lnEC_{it}$:				
1	109.2716	14.31004	85.68996	0.000000
4	220.7022	24.08636	75.73566	0.177978
7	296.7818	24.08560	75.81189	0.102508
10	358.4794	21.19152	78.73327	0.075206
Variance Decomposition of $lnCO2_{it}$:				
1	0.327998	18.45833	49.76449	31.77718
4	0.688084	28.26668	41.51276	30.22056
7	0.909971	26.95764	42.36541	30.67694
10	1.082698	24.41986	44.99684	30.58330

From the analysis of variance decompositions, it is found that there is no feedback effect between EC and GDP. However, GDP, EC and CO2 are found strongly interlinked. The flow of relationship between the variables as found from variance decompositions in both the groups of countries could be presented as in Figure 1. This indicates that the relationship flows from GDP to energy consumption and GDP and EC to CO2. The results of variance decompositions are consistent with findings of VECM with minor discrepancies.

Figure 1

Flow of relationship between GDP, EC and CO2



Though the direction of flow of relationship between GDP, EC and CO2 is the same in low net oil importing countries and high net oil importing countries, the magnitude of the relationship differs between the two groups of countries. In low net oil importing countries, shocks of energy consumption contribute 53 percent to the carbon emissions, whereas it is 44 percent in high net oil importing countries. The countries having a high dependency on the net imported oil are spending Forex heavily on import payments and hence are likely to be more responsible and judicious in using the energy. This might cause lower emissions unlike the countries having a lower dependency on imported oil. Abundant availability of energy domestically at highly affordable price might cause irrational and substantial usage of the energy leading to high carbon emissions. Shocks in GDP though impact EC in both the groups of countries, it is more pronounced in low oil importing countries. In low net oil importing countries, 36 percent of changes in EC is due to the shocks of GDP, while it is only 21 percent in high net oil importing countries. Hence energy consumption in low net oil importing countries is more vulnerable to shocks of GDP. This is because many of these countries such as China, India, Brazil and Argentina are emerging economies, and increased GDP is seen deployed for further economic projects that in turn push demand for more energy. On the other hand, since the economies are not highly developed, the capabilities of the people and industry to absorb recession and slowdown is week, energy consumption gets affected. Whereas, high net oil importing countries such as Korea Republic, Japan, Italy, Spain are basically developed economies that have reached optimal growth and any rise in GDP does not incentivise them to venture with new economic engagements and hence energy consumption remains stagnant despite economic growth.

7. Conclusion and Policy Implications

Unlike many of the past studies, carbon emission has been included to the model that examines the dynamics of the relationship between economic growth and energy consumption. The results reveal that carbon emission is an important factor in the interlinkage between economic growth and energy consumption. The economic well-being of the net oil importing countries is found inducing their energy consumption. Further, it is also noticed from the results that higher economic well-being and increased energy consumption cause damages to the environment. This implies that carbon emission increases with an increase in economic growth and energy consumption. Further, though this trend is visible in both the groups of countries, the magnitude of linkage between economic growth, energy consumption and carbon emissions is more pronounced in the panel of low oil importing countries such as UK, India, Brazil, the USA, Argentina and China. In other words, in these countries the sensitivity of: i) energy consumption to the fluctuations in GDP and ii) carbon emissions to changes in energy consumption and economic growth – is higher than high oil importing countries of Korea Republic, Japan, Italy, Spain, Hong Kong and Greece.

The study explores a uni-directional causal relationship running from economic growth to energy consumption. As no causality is found running from energy consumption to economic growth in oil importing countries, the highly debated feedback hypothesis cannot be accepted in this case. Rather, the results of the study support the case of the conservation hypothesis regardless of the level of oil import dependency of the countries.

In summary, energy consumption and economic growth are detected to be the main drivers of carbon emissions in net oil importing countries in general, and high oil importing countries in particular. Further, it is also evident that the economic growth of the net oil importing countries neither depends on energy consumption nor on carbon emissions. Hence, energy conservation policies, measures of environmental protection and regulations on emissions do not negatively impact the growth of the oil importing economies. High net oil importing countries amongst all net oil importing countries, are suggested to pursue a low carbon economy through adopting sustainable development strategies, with no compromise on the economic well-being. Thus, the study proposes to improve and rationalise energy consumption structure, develop renewable energy, design and use energy-efficient technologies and machines, improve industrial efficiency and increase forest cover up to 33 percent of the total geographical area of the nation. Appropriate policies governing these areas will not only improve energy efficiency and energy saving but also curb carbon emission. Overall, it is suggested that all growth related polices in the sectors of construction and infrastructure, industries and energy need to target at emission reduction.

References

Abosedra, S., Shahbaz, M., Sbia, R. (2014). The links between energy consumption, financial development, and economic growth in Lebanon: evidence from cointegration with unknown structural breaks. – Journal of Energy, Article ID 965825.

Arora, V., Shi, S. (2016). Energy consumption and economic growth in the United States. – Applied Economics, Vol. 48(39), p. 3763-3773.

Arrow, K. J. (1962). The economic implications of learning by doing. Hahn ED (editor), Readings.

Aslan, A., Kum, H. (2010). An investigation of cointegration between energy consumption and economic growth: dynamic evidence from East Asian countries. – Global Economic Review, Vol. 39(4), p. 431-439, DOI: 10.1080/1226508X.2010.533852.

Azam, M. (2019). Energy and economic growth in developing Asian economies. – Journal of the Asia Pacific Economy, DOI: 10.1080/13547860.2019.1665328.

Balcilar, M., Ozdemir, Z. A., Tunçsiper, B. et al. (2019). On the nexus among carbon dioxide emissions, energy consumption and economic growth in G-7 countries: new insights from the historical decomposition approach. – Environment, Development and Sustainability, https://doi.org/10.1007/s10668-019-00563-6.

Bayar, Y., Gavriletea, M.D. (2019). Energy efficiency, renewable energy, economic growth: evidence from emerging market economies. – Quality & Quantity, Vol. 53, p. 2221–2234. https://doi.org/10.1007/s11135-019-00867-9.

Çetintaş. H. (2016). Energy consumption and economic growth: the case of transition economies. – Energy Sources, Part B: Economics, Planning, and Policy, Vol. 11(3), p. 267-273, DOI: 10.1080/15567249.2011.633595.

Cho, S., Heo, E., Kim, J. (2015). Causal relationship between renewable energy consumption and economic growth: comparison between developed and less-developed countries. - Geosystem Engineering, Vol. 18(6), p. 284-291.

Chontanawat, J., Hunt, C. L, Pierse, R. (2008). Does energy consumption cause economic growth?: evidence from a systematic study of over 100 countries. – Journal of Policy Modeling, Vol. 30(2), p. 209-220, https://doi.org/10.1016/j.jpolmod.2006.10.003.

Destek, M. A., Okumus, I. (2017). Disaggregated energy consumption and economic growth in G-7 countries. – Energy Sources, Part B: Economics, Planning, and Policy, Vol. 12(9), p. 808-814, DOI: 10.1080/15567249.2017.1286527.

Dlamini, K., Balcilar, M., Gupta, R., Inglesi-Lotz, R. (2016). Relationship between energy consumption and economic growth in South Africa: Evidence from the bootstrap rolling-window approach. – Energy Sources, Part B: Economics, Planning, and Policy, Vol. 11(7), p. 617-625, DOI: 10.1080/15567249.2013.843618.

Dudzeviciute, G., Tamosiuniene, R. (2014). Energy consumption and economic growth nexus in the Baltic countries: causality approach. – Journal KSI transactions on knowledge society, Vol. 7(4), p. 12-17, http://www.tksi.org/JOURNAL-KSI/PAPER-PDF-2014/2014-4-03.pdf.

Engle, R. F., Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. – Econometrica, Vol. 55(2), p. 251-276.

Esen, O., Bayrak, M. (2017). Does more energy consumption support economic growth in net energy-importing countries?. – Journal of Economics, Finance and Administrative Science, Vol. 22(4), p. 75-98.

Guttormsen, A. G. (2004). Causality between energy consumption and economic growth: department of economics and resource management [Working paper], D-24. Agriculture University of Norway.

Habib, Ul. M. (2019). An econometric analysis of relationship between economic growth and petroleum consumption in India. – Jindal Journal of Business Research, Vol. 8(2), p. 118-127, https://doi.org/10.1177/2278682119833195.
Hasanov, F., Bulut, C., Suleymanov, E. (2017). Review of energy-growth nexus: a panel analysis for ten Eurasian oil exporting countries. – Renewable and Sustainable Energy Reviews, Vol. 73, p. 369-386.
Ibrahim, M. (2005). Sectoral effects of monetary policy: evidence from Malaysia. – Asian Economic Journal, Vol. 19(1), p. 83-102.
Jafari, Y., Ismail, M. A., Othman, J., Mawar, M. Y. (2015). Energy consumption, emissions and economic growth in Bahrain. – Chinese Journal of Population Resources and Environment, Vol. 13(4), p. 297-308, DOI: 10.1080/10042857.2015.1078493.
Jalil, A., Feridun, M. (2014). Energy-driven economic growth: energy consumption – economic growth nexus revisited for China. – Emerging Markets Finance and Trade, Vol. 50(5), p. 159-168, DOI: 10.2753/REE1540-496X500511.
Joo, Y., Kim, C.S., Yoo, S. (2015). Energy consumption, CO2 emission, and economic growth: evidence from Chile. – International Journal of Green Energy, Vol. 12(5), p. 543-550, DOI: 10.1080/15435075.2013.834822.
Kais, S., Mbarek, M.B. (2017). Dynamic relationship between CO2 emissions, energy consumption and economic growth in three North African countries. – International Journal of Sustainable Energy, Vol. 36(9), p. 840-854.
Kim, J., Heo, E. (2012). Energy and economic growth: causality analysis using decomposed energy consumption. – Geosystem Engineering, Vol. 15(3), p. 171-178.
Kraft, J., Kraft, A. (1978). On the relationship between energy and GNP. – Journal of Energy Development, 3, p. 401-403.
Li, S. (2020). Economic Growth Decouples Energy Consumption and Carbon Dioxide Emission – An Evidence from China. – In: Wang, T. S., Ip, A., Tavana, M., Jain, V. (eds.). Recent Trends in Decision Science and Management. Advances in Intelligent Systems and Computing, Vol. 11(42).
Liu, X. (2018). Aggregate and disaggregate analysis on energy consumption and economic growth nexus in China. – Environmental Science and Pollution Research, Vol.25, p. 26512-26526, https://doi.org/10.1007/s11356-018-2699-2.
Lutkepohl, H. (1982). Non-causality due to omitted variables. – Journal of Economics, Vol. 19, p. 367-378.
Mahadevan, R., Asafu-Adjaye, J. (2007). Energy consumption, economic growth and prices: a reassessment using panel VECM for developed and developing countries. – Energy Policy, Vol. 35(4), p. 2481-2490.
Masih, A.M.M., Masih, R. (1998). A multivariate co-integrated modelling approach in testing temporal causality between energy consumption, real income and prices with an application to two Asian LDCs. – Applied Economics, Vol. 30(10), p.1287-1298.
Mbarek, M. B., Boukarraa, B., Saidi, K. (2016). Role of energy consumption and economic growth in the spread of greenhouse emissions: empirical evidence from Spain. – Environmental Earth Sciences, Vol. 75, p. 1161.
Mehrara, M. (2007). Energy consumption and economic growth: the case of oil exporting countries. – Energy Policy, Vol. 35(5), p. 2939-2945.
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, Vol. 37(1), p. 229-236.
Neto, A. B. F., Perobelli, F. S., Bastos, S. Q. (2014). Comparing energy use structures: An input-output decomposition analysis of large economies. – Energy Economics, Vol. 43, p. 102-113.
Odhiambo, N. M. (2009). Electricity consumption and economic growth in South Africa: a trivariate causality test. – Energy Economics, Vol. 31, p. 635-640.
Oh, W., Lee, K. (2004). Energy consumption and economic growth in Korea: testing the causality relation. – Journal of Policy Modeling, Vol. 26 (8&9), p. 973-981.
Osbat, Ch. (2004). Panel unit root and panel cointegration methods. European Central Bank.
Ozturk, I., Kaplan, M., Kalyoncu, H. (2013). The causal relationship between energy consumption and GDP in Turkey. – Energy & Environment, Vol. 24(5), p. 727-734.
Pastén, R., Saens, R., Marín, R, C. (2015). Does energy use cause economic growth in Latin America?. – Applied Economics Letters, Vol. 22(17), p. 1399-1403.
Pata, U. K., Terzi, H. (2017). A multivariate causality analysis between energy consumption and growth: the case of Turkey. – Energy Sources, Part B: Economics, Planning, and Policy, Vol. 12(9), p. 765-771, DOI: 10.1080/15567249.2016.1278484.
Pokrovski, V. N. (2003). Energy in the theory of production. – Energy, Vol. 28, p. 769-788.

Rathnayaka, R.M.K.T., Seneviratna, D.M.K.N., Long, W. (2018). The dynamic relationship between energy consumption and economic growth in China. – Energy Sources, Part B: Economics, Planning, and Policy, Vol. 13(5), p. 264-268.

Saidi, K., Hammami, S. (2016). Economic growth, energy consumption and carbon dioxide emissions: recent evidence from panel data analysis for 58 countries. – Quality & Quantity, Vol. 50, p. 361-383. https://doi.org/10.1007/s11135-014-0153-1.

Salahuddin, M., Gow, J. (2019). Effects of energy consumption and economic growth on environmental quality: evidence from Qatar. – Environmental Science and Pollution Research, Vol. 26, p. 18124-18142.

Shakouri, B., Yazdi, S.K. (2017). Causality between renewable energy, energy consumption, and economic growth. – Energy Sources, Part B: Economics, Planning, and Policy, 12(9), p. 838-845.

Solow, R. M. (1969). Growth theory: an exposition. Oxford: Clarendon Press.

Squally, J. (2007). Electricity consumption and economic growth: bounds and causality analyses of OPEC members. – Energy Economics, Vol. 29(6), p. 1192-1205.

Stern, D. A. (2000). Multivariate cointegration analysis of the role of energy in the US economy. – Energy Economics, Vol. 22, p. 267-283.

Sulaiman, C., Rahim, A. S. (2017). The relationship between CO2 emission, energy consumption and economic growth in Malaysia: a three-way linkage approach. – Environmental Science and Pollution Research, Vol. 24, p. 25204-25220.

Tamba, J. G. (2017). Energy consumption, economic growth, and CO2 emissions: evidence from Cameroon. – Energy Sources, Part B: Economics, Planning, and Policy, Vol. 12(9), p. 779-785, DOI: 10.1080/15567249.2016.1278486.

Triacca, U. (1998). Non-causality: the role of the omitted variables. – Economic Letters, Vol. 60(3), p. 317-320.

Vandaele, N., Porter, W. (2015). Renewable energy in developing and developed nations: outlooks to 2040. University of Florida, Summer.

World Development Indicators (WDI). Retrieved on 9 April, 2020: https://databank.worldbank.org/source/world-development-indicators.

Xiong, C., Yang, D., Huo, J., Zhao, Y. (2015). The relationship between energy consumption and economic growth and the development strategy of a low-carbon economy in Kazakhstan. – Journal of Arid Land, Vol. 7, p. 706-715.

ANNEXURES

Annexure 1

Trends in EC, GDP and CO2 in Low Net Oil importing Countries

Country	Year	EC	Decadal Growth (%)	GDP	Decadal Growth (%)	CO2	Decadal Growth (%)
UK	1971	3733.28		18281.72		11.82	
	1981	3415.38	-8.52	21453.85	17.35	9.96	-15.80
	1991	3707.95	8.57	27992.39	30.48	9.87	-0.85
	2001	3784.93	2.08	36592.81	30.72	9.23	-6.46
	2011	2972.15	-21.47	39731.42	8.58	7.08	-23.33
	2014	2776.84	-6.57	41369.80	4.12	6.50	-8.22
India	1971	267.35	-90.37	393.53	-99.05	0.36	-94.42
	1981	293.74	9.87	438.01	11.30	0.47	30.65
	1991	357.37	21.66	575.50	31.39	0.74	55.91
	2001	416.01	16.41	851.62	47.98	0.97	31.15
	2011	577.99	38.94	1410.43	65.62	1.47	52.10
	2014	636.57	10.13	1640.18	16.29	1.73	17.28
Brazil	1971	715.84	12.45	5108.40	211.45	1.05	-39.06
	1981	883.88	23.47	7796.85	52.63	1.39	32.06
	1991	942.04	6.58	7963.11	2.13	1.45	4.02
	2001	1076.28	14.25	8804.33	10.56	1.90	31.67
	2011	1367.19	27.03	11627.81	32.07	2.22	16.83
	2014	1495.54	9.39	11951.21	2.78	2.61	17.45
Argentina	1971	1387.01	-7.26	7368.08	-38.35	3.67	40.31
	1981	1440.78	3.88	7380.67	0.17	3.60	-1.78
	1991	1435.48	-0.37	6721.28	-8.93	3.54	-1.69
	2001	1570.90	9.43	7776.14	15.69	3.59	1.34
	2011	1952.05	24.26	10883.32	39.96	4.64	29.47
	2014	2029.92	3.99	10398.69	-4.45	4.78	2.95
USA	1971	7644.52	276.59	23670.35	127.63	20.98	338.78
	1981	7647.54	0.04	29028.90	22.64	19.77	-5.78
	1991	7631.47	-0.21	35542.14	22.44	19.06	-3.59
	2001	7827.89	2.57	44728.60	25.85	19.64	3.05
	2011	7030.03	-10.19	48862.42	9.24	16.98	-13.54
	2014	6960.68	-0.99	51015.14	4.41	16.50	-2.79
China	1971	464.93	-93.32	238.43	-99.53	1.04	-93.68
	1981	597.15	28.44	360.43	51.17	1.46	40.12
	1991	736.85	23.40	786.13	118.11	2.23	52.66
	2001	928.81	26.05	1901.41	141.87	2.74	23.00
	2011	2086.49	124.64	4961.23	160.92	7.24	164.08
	2014	2236.73	7.20	6096.49	22.88	7.54	4.18

Annexure 2

Trends in EC, GDP and CO2 in High Net Oil importing Countries

Country	Year	EC	Decadal Growth (%)	GDP	Decadal Growth (%)	CO2	Decadal Growth (%)
Korea Republic	1971	516.11		1965.64		1.78	
	1981	1046.41	102.75	3904.13	98.62	3.61	102.44
	1991	2306.64	120.43	9249.39	136.91	6.04	67.36
	2001	4033.32	74.86	15667.38	69.39	9.50	57.36
	2011	5216.59	29.34	22724.71	45.04	11.80	24.19
	2014	5289.28	1.39	24323.57	7.04	11.57	-1.97
Japan	1971	2531.09	-52.15	19328.01	-20.54	7.55	-34.79
	1981	2864.37	13.17	26744.56	38.37	7.90	4.72
	1991	3575.25	24.82	39253.64	46.77	8.87	12.28
	2001	4008.27	12.11	42239.18	7.61	9.46	6.68
	2011	3610.81	-9.92	44538.73	5.44	9.32	-1.55
	2014	3470.76	-3.88	46484.16	4.37	9.54	2.37
Italy	1971	1949.15	-43.84	17908.89	-61.47	5.76	-39.59
	1981	2265.93	16.25	24652.54	37.66	6.69	16.11
	1991	2645.67	16.76	31324.53	27.06	7.47	11.63
	2001	3020.62	14.17	37017.37	18.17	7.90	5.84
	2011	2828.40	-6.36	36192.87	-2.23	6.70	-15.21
	2014	2414.48	-14.63	33666.69	-6.98	5.27	-21.36
Spain	1971	1244.90	-48.44	14032.81	-58.32	3.76	-28.67
	1981	1820.10	46.20	17331.07	23.50	5.49	46.01
	1991	2397.71	31.74	23027.25	32.87	5.79	5.48
	2001	3060.88	27.66	29321.89	27.34	7.29	25.91
	2011	2689.68	-12.13	30147.00	2.81	5.79	-20.61
	2014	2464.64	-8.37	29398.61	-2.48	5.03	-13.03
Hong Kong	1971	741.96	-69.90	6086.24	-79.30	2.26	-55.02
	1981	995.04	34.11	11448.78	88.11	3.61	59.24
	1991	1554.12	56.19	19132.40	67.11	4.98	38.08
	2001	2109.68	35.75	22975.10	20.08	5.65	13.54
	2011	2087.21	-1.07	33888.50	47.50	6.19	9.55
	2014	1970.48	-5.59	35717.69	5.40	6.39	3.24
Greece	1971	984.04	-50.06	14379.90	-59.74	3.15	-50.74
	1981	1505.28	52.97	18677.48	29.89	5.21	65.52
	1991	2094.62	39.15	19746.38	5.72	7.18	37.66
	2001	2578.11	23.08	24111.42	22.11	8.64	20.34
	2011	2407.76	-6.61	24495.71	1.59	7.19	-16.75
	2014	2123.90	-11.79	22565.68	-7.88	6.18	-14.04

Annexure 3

Descriptive Statistics

Particulars	Low Net Oil importing Countries			High Net Oil importing Countries		
	ln $CO2_{it}$	*ln* EC_{it}	*ln* GDP_{it}	*ln* $CO2_{it}$	*ln* EC_{it}	*ln* GDP_{it}
Mean	1.279602	7.352188	8.706647	1.839872	7.709000	9.921251
Median	1.279177	7.265925	8.983869	1.880500	7.780677	10.02302
Maximum	3.113986	9.040548	10.83988	2.468351	8.573437	10.74687
Minimum	-1.014649	5.588404	5.474060	0.578078	6.246321	7.583573
Std. Dev.	1.131120	1.010450	1.601965	0.364241	0.456876	0.619564
Skewness	-0.008484	0.135269	-0.512246	-1.087464	-0.71235	-1.565471
Kurtosis	2.003800	2.005371	1.999889	4.262991	3.371814	5.702785
Jarque-Bera	10.91973	11.68725	22.54787	69.58003	23.84835	188.1862
Probability	0.004254*	0.002898*	0.000013*	0.000000*	0.000007*	0.000000*
Sum	337.8148	1940.978	2298.555	485.7263	2035.176	2619.210
Sum Sq. Dev.	336.4909	268.5252	674.9345	34.89263	54.89755	100.9552
Observations	264	264	264	264	264	264

*$p < 0.01$

Annexure 4

VAR Lag Order Selection Criteria

Group	Lag	LogL	*Criteria*				
			LR	FPE	AIC	SC	HQ
Low Net Oil importing Countries	0	-4920.72	NA	1.32e+14	41.03098	41.07449	41.04851
	1	-2968.09	3840.164	12243143	24.83410	25.00813	24.90422
	2	-2941.27	52.08802*	10553449*	24.68554*	24.99010*	24.80826*
	3	-2934.11	13.70752	10718272	24.70095	25.13603	24.87625
	4	-2929.6	8.539178	11128463	24.73833	25.30393	24.96623
High Net Oil importing Countries	0	-4727.72	NA	2.65e+13	39.42267	39.46618	39.44020
	1	-3299.81	2808.227	1.94e+08	27.59841	27.77244	27.66853
	2	-3271	55.93088	1.65e+08	27.43336	27.73791*	27.55607*
	3	-3260.41	20.30672*	1.63e+08*	27.42007*	27.85515	27.59537
	4	-3253.02	13.98568	1.65e+08	27.43346	27.99906	27.66135

* indicates lag order selected by the criterion