ENERGY CONSUMPTION–TRADE OPENNESS – ECONOMIC GROWTH NEXUS IN G-8 COUNTRIES

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Abstract

This study aims to examine the relationship between energy consumption-economic growth and energy consumption-international trade (exports and imports) on aggregate level inG-8countries. We use the FMOLS and DOLS and the empirical results show that 1 % increase in economic growth is negatively linked with energy consumption by 0.46-1.22. A 1 % increase in exports and imports increase energy consumption by 0.24-0.32% and 0.13-0.344 % respectively. The unidirectional causality is found running from economic growth, exports and imports to energy consumption.

Keywords*:* *International trade, Energy consumption, Economic growth.*

1. INTRODUCTION

Energy is an important topic to study for economists on account of several reasons and also energy consumption increases with goods production increase, technological developments and alsowith population growth. Around the world energy consumption, economic production and international trade'strend move together so it is significant to learn more about the relationship among energy consumption, economic growth and trade openness.

The existing energy economics literature seems to provide numerous studies which have investigated the causal relationship between energy consumption and economic growth (for example see, Ozturk, 2010; Payne, 2010). Also, exports are considered as an engine of economic growthin theoretical growth model that in international economics literature exports and output relationshipis widely studied (Giles and Williams, 2000a, 2000b; Shahbaz, 2012). It is vital to understand the present environmental and energy policy, the relationship among energy consumption, trade openness and economic growth must be examined. Also, it is crucial to developed new energy and environmental policy. Energy consumption and economic growth relationship is vital because if there is a strong relationship between energy consumption and economic growth, it is very hard to change energy and environmental policies. Furthermore, if the

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relationship of energy consumption and economic growth is not significant, there is no relationship between these variables and the policies should not be effective on energy consumption and economic growth. In present economies, energy has been started to be a factor of production functions, cause of all production methods need energy source. Trade openness is an essential component of economic growth and provides an opportunity for countries; according to Sadorsky (2012) an increase in international trade increases economic activity and energy demand. Also, an energy demand decrease can negative effect on tradable goods production case; on the other hand, an energy demand increase should positive effect on tradable goods production case.

G8 countries are the 8 largest and wealthiest nations in the world and play an important role in global economic and financial governance in key areas. In year 2010 GDP share of world total (PPP) for G8 economies is more than 50%. Also in year 2005 these countries generated more than 50% of world's electricity. In year 2009,30 OECD member countries total exports and imports of goods and services reached to 9.7 trillion and 9.8 trillion USD respectively. In same period, for G8 countries, exports of goods and serviceswere 6.9 and imports 7.0 trillion USD (see in OECD database). For these reasons, in our study G8 countries will be a good sample to focus on the relationship of energy consumption, economic growth and trade openness.

This paper extends the literature on energy consumption, economic growth and trade openness in fiveways. First, this study uses aggregate variables for energy consumption, economic growth and trade openness so it is more comparable study than the previous studies which use electricity consumption and exports variables on the relationship between energy consumption and trade. Second, in literature most of researchers investigated only the relationship between energy consumption and economic growth or the relationship between economic growth and trade openness. But it is vital to understand the dynamic relationship of these variables; they must be taken in a combined model. Third, this paper investigates the energy consumption, economic growth and trade openness relationship for G-8countries, anarea of the world largest economies. Fourth, Pedroni (2004) panel cointegration approach is employed by while robustness of cointegration results in tested by applying the error correction based panel cointegration tests introduced by Westerlund (2007). The direction of causal relationship between the variables in investigated by using panel Granger causality approaches such as Homogenous Non-Causality (HNC) and Heterogeneous Non-Causality (HENC) developed by Dumitrescu and Hurlin (2012). Also, this is the first study investigating the link between energy consumption, economic growth andtrade openness in G-8 countries. These papers results are vital fordeveloping energy and environmental policy in G-8 countries.

The aim of this study is to examine the dynamic relationship between energy consumption, economic growth and international trade for a panel of G-8economies. The following section of the paper provides the literature for energy consumption, international trade and economic growth causality. Section-III shows data, the empirical model and results and section-IV provides conclusions and policy analysis.

2. LITERATURE REVIEW

The existence of relationship between energy consumption and economic growth has been investigated in a number of empirical studies. These studies indicate mixed existence of the relationship between energy consumptionand economic growth. Otherwise, the relationship between trade openness (imports and exports) and economic growth has not been thoroughly analysed. This study extends the literature on energy consumption, trade openness and economic growth by investigating the relations of these variables for G 8 countries.

This section provides the literature for energy consumption and economic growth, energy consumption and trade openness, and economic growth and international trade.

2.1 Energy Consumption and Economic Growth

The direction of causality between energy consumption and economic growth plays a key role in energy policies but no agreement on the direction of causality has been reached yet. About the disagreement of the direction of this causality Ozturk (2010) indicate that using different data and country sample, time periods and analysis techniques. It is seen that the relationship between energy consumption and economic growth is set up four testable hypotheses (Ozturk, 2010; Payne, 2010)1) The growth hypothesis; unidirectional causality running from energy consumption to economic growth, 2).The conservation hypothesis; unidirectional causality running from economic growth to energy consumption, 3).The feedback hypothesis; bidirectional causality for energy consumption and economic growth relationship and 4).The neutrality hypothesis; no causality between energy consumption and economic growth.If economic growth and energy consumption are positively correlated and the results support growth or feedback hypothesis, it is hard to change energy policies without negative effect on economic growth. But if results suggest growth or neutrality hypothesis, energy conservation policies can be made without harming economic growth.

A number of papers have investigated the relationship between energy consumption and economic growth in G-7 countries. For example, Soytas and Sari (2003) analyse the relationship of energy consumption and economic growth for G7 countries and for Italy results show unidirectional causality running from economic growth to energy consumption i.e. demand-side hypothesis and adversely in France, Germany andJapan. In a similar study Soytas and Sari (2006) aim to determine energy consumption changes impact on income in G-7 countries. And find bidirectional causality for Canada, Italy, Japan and UK, unidirectional causality runs from energy consumption to income for USA and France and adverse causality for Germany. Lee (2006) investigates the relationship between energy consumption and economic growth in 11 major industrialized countries. The empirical results suggest neutrality hypothesis for United Kingdom and Germany, unidirectional causality from energy consumption to economic growth for Canada and reverse causality for France, Italy and Japan. Narayan and Smyth (2008) apply Granger causality tests and find unidirectional causality running from energy consumption to economic growth and find that a 1% increase in energy consumption, increases economic growth by 0.12–0.39%. Chontanawat et al. (2008) use consistent data set and methodology for over 100 countries and support same causality for France, Germany, Italy and Japan. Also, Lee and Chien (2010) find same causality in Canada, Italy, and the UK while reverse causality for France and Japan and no causality for Germany and USA by employing the Toda and Yamamoto (1995) Granger causality test. Narayan and Popp (2012) empirical results support that energy consumption Granger causes economic growth for Japan while economic growth negatively Granger causes energy consumption in Canada and the US.

For the period of 1980–2005, Jinke et al. (2008) examine the causal relationships between coal consumption and economic growth, by using Granger causality tests and the results suggest conservation hypothesis in Japan and no cointegration in USA1. But Apergis and Payne (2010a) find the bidirectional causality in their study which investigates the coal consumption and economic growth relationship over the period 1980-2005 for 25 OECD countries by using multivariate panel framework. Apergis and Payne (2010b) investigate the natural gas consumption and economic growth relationship for a panel of 67 countries for the period 1992–2005, by using multivariate framework. The empirical results show bidirectional causality in both the short- and long-run. Also, Kum et al. (2012) find the bidirectional causality for France, Germany and USA, a unidirectional causality from energy consumption to economic growth for Italy and adverse for UK while no causality for Japan and Canada. In case of Pakistan, Shahbaz et al. (2013a) reported that natural gas consumption promotes economic growth.

For a panel of 79 countries, Akkemik and Goksal (2012) examine four different causal relationships between energy consumption and economic growth over the period of 1980–2007. The results exhibit the bidirectional Granger causality for Canada, Germany, Japan, UK and USA while unidirectional causality running from economic growth to energy consumption for France and Italy. Dedeoglu and Kaya (2013) investigate the relationship between energy consumption and economic growth over the period of 1980-2010 for 25 OECD countries and results suggest the feedback hypothesis. Over the past 4 decades, Coers and Sanders (2013) aim to determine the causality between energy consumption and economic growth in a panel of 30 OECD countries. The empirical results indicate that there is a unidirectional causality running from economic growth to energy

[1]Kumar and Shahbaz, (2012) reported the unidirectional causality running from coal consumption to economic growth in Pakistan but Shahbaz and Dube, (2012) noted the bidirectional causality between coal consumption and economic growth.

consumption in the long run. Kocaaslan, (2013) appliesmarkov switching Granger causality to test the relationship between energy consumption and real GDP and found that US economic activity is stimulated by energy consumption. Bozoklu and Yilanci, (2013) usethe frequency domain Granger causality to probe the energy-growth nexus in OECD countries. They note the temporary and permanent causality between energy demand and economic growth.

Recently, Yıldırım et al. (2014) investigate the causal relationship between energy consumption and economic growth by applying the bootstrapped causality approach using data of next 11 countries. They find that energy demand and economic growth have neutral effect. Mohammadi and Parvaresh, (2014) probe the relationship between energy consumption and economic growth using data of oil exporting countries. They note that energy causes economic growth and in resultantly, economic growth causes energy consumption in Granger sense. Jalil, (2014) appliesthe heterogeneous panel causality to test the link between energy consumption and economic growth in energy exporting and importing economies. The results show that energy consumption contributes in economic activity and enhances domestic production. Shahbaz et al. (2014a) investigate the relationship between industrial growth and energy demand and note that industrial growth adds in energy demand.

2.3 Energy Consumption and Trade Openness

More than the last 3 decades, many countries have practised huge increases in international trade and energy consumption for that the relationship between energy consumption and international trade is a vital area to study for economists. But studies on the energy consumption-international trade nexus are very scarce in literatureSadorsky (2011). According to Sadorsky (2012) in theory there are many ways that energy consumption and international trade mutually affect themselves. A rise exportsincrease means there is an increase in economic activity and this will increase the energy use. Also, a decrease in energy consumption will decrease the production of goods so it will have negative effect on international trade. In other worlds if there is a unidirectional causality running from energy consumption to international trade (exports or imports), then a decrease in energy consumption or means energy conservation policies will decrease trade and trades advantage. Adversely if international trade is found to Granger cause energy consumption or there is no causality between energy consumption and international trade, the conservation policies will not affect trade and trade liberalization policies which designed to promote economic growth.

The literature of energy consumption-economic growth and economic growth-international trade are very large while the energy consumption-international trade literature is very little known (Sadorsky, 2011; Dedeoğlu and Kaya, 2013). Narayan and Smyth (2009) investigate the causality amongenergy consumption, exports and economic growth for Iran, Israel, Kuwait, Oman, Saudi Arabia, and Syria. And empirical results support feedback hypothesis also if energy consumption increases 1%, economic growth increases 0.04% and if exports increase 1%, economic growth increase 0.17%. But Sadorsky (2011) finds Granger causality relationship running from exports to energy consumption and the feedback relationship between imports and energy consumption in which study that he examines the relationship between international trade and energy consumption for a panel of Middle Eastern economies (Bahrain, Iran, Jordan, Oman, Qatar, Saudi Arabia, Syria, and United Arab Emirates).

For Malaysia Lean and Smyth (2010a) examine the relationship among economic growth, energy consumption and international trade by using multivariate Granger causality tests over the period of 1971 to 2006 and find evidence of a Granger causality running from exports to energy consumption.While in a similar study Lean and Smyth (2010b) examine the relationship among economic growth, exports and electricity generation for Malaysia over the period of 1970 to 2008 and find unidirectional causality running from electricity generation to exports.Erkan et al. (2010)explores the relationship between energy consumption and exports in Turkey for the period 1970-2006 by using Granger causality tests and the empirical results show unidirectional causality running from energy consumption to exports. In the same case also Halicioglu (2011) examine this relationship over the period 1968 to 2008 but find unidirectional causality runs from exports to energy consumption.

Over the period 1980 to 2006 for Shandong, Li (2010) analyzed the relation between energy consumption and exports by using Granger causality test. And the empirical results show a unidirectional causality running from export to energy consumption. Also, Sami (2011) studiesthe relationship between energy consumption, exports and economic growth in Japan by using time series data from 1960 to 2007. The results suggest the unidirectional causality from exports to electricity consumption. In case of China, Shahbaz et al. (2013b) examine the relationship among energy consumption, economic growth and international trade for the period 1971-2011. They find the bidirectional causality between international trade and energy consumption.

Sadorsky (2012) analyses the causality between energy consumption and international trade in 7 South American countries (Argentina, Brazil, Chile, Ecuador, Paraguay, Peru and Uruguay) for the period of 1980-2007. For the short-run dynamics, results suggest the feedback relationship between energy consumption and exports, and the unidirectional causality running from energy consumption to imports. For the long run find evidence of relationship between international trade and energy consumption. Hossain (2012) attempts to determine the relationship between exports and energy consumption in Bangladesh, India and Pakistan by using the time series data for the period 1976-2009 and the results support the neutrality hypothesis. Shahbaz et al. (2013a) investigate the causality between natural gas consumption, exports and economic growth in the case of Pakistan. They report that natural gas consumption adds in economic growth and exports. Dedeoglu and Kaya (2013) examine the relationship among energy consumption, exports and imports for the period

1980-2010 in 25 OECD countries and the empirical results show the bidirectional causality. Also says if GDP increases 1%, export increase 0.32%, import increases 0.21% and energy use increases 0.16%. Katircioglu, (2013) probes the linkage between imports and energy consumption using data of Singapore economy. The results showed that imports growth is cause of energy consumption growth in Granger sense. Zhang et al. (2013) investigate the effect of domestic trade on regional energy demand using Chinese data. They find that trade has positive impact on regional energy use.

Recently, Nasreen and Anwer, (2014) investigate the trade-energy-growth nexus using data of 15 Asian countries. They apply panel cointegration and found the presence of cointegration among the series. Their analysis notes that energy consumption is positively impacted by economic growth and trade openness and the feedback hypothesis is confirmed between trade openness and energy demand. Shahbaz et al. (2014b) applythe heterogeneous panel cointegration and Granger causality to test the linkages between trade openness and energy consumption using data of 91 low, middle and high-income countries. They note that the relationship between trade-energy nexus is U-shaped low and middle-income countries but inverted U-shaped in high income countries. The bidirectional causal relation exists between both variables confirmed by non-homogenous causality approach. Aïssa et al. (2014) use African countries data to investigate the triangle among trade, energy (renewable) consumption and economic growth. They note that domestic output is stimulated by renewable energy consumption and trade but the neutral effect is found between trade openness and renewable energy consumption.

2.4 Economic Growth and Trade Openness

The researchers have increasingly shifted their attention to the relationship of international trade and economic growth that is significant and positively related is today widely accepted. Also there is a wide literature investigating the relationship and causality betweeneconomic growth and international trade (Giles and Williams,200a-b; Lewer and Van den Berg, 2003; Sadorsky, 2012). In literature three alternative relationships can be shown for economic growth and international trade relation (Awokuse,2007). First alternative is growth-led exports (GLE) and suggest a unidirectional causality running from economic growth to exports. Second hypothesis is exports-led growth (ELG) which argues that the causality is running from exports to economic growth. The last hypothesis is import-led growth (ILG) which support imports growth can be promote economic growth. Much of the economic growth and international trade literature investigates the directly link among exports and GDP or imports and GDP. For example, Ekanayake (1999) investigates the causality between exports growth andeconomic growth in India, Indonesia, Korea, Pakistan, Philippines, Sri Lanka, Thailand and Malaysia over the period 1960 to 1997. The results show the bidirectional causality in all cases except Malaysia for export growth and economic growth relation. For Malaysia there is a unidirectional causality from exports to economic growth.

Konya (2004), examines the relationship between export and economic growth by using Granger causality tests for 25 OECD countries over the period 1960-1998. The empirical results show that there is unidirectional causality running from economic growth to exports in Canada, USA and Japan, and there is bidirectional causality in the UK, and no causality in France. Hatemi (2002) found the bidirectional causality between exports and economic growth in Japan for the period of 1960-1999 by using Granger causality tests. Awokuse (2005a) investigates the relationship of export with economic growth in Korea and Awokuse (2005b) examines the causality between real exports and economic growth in Japan and find that there is bidirectional causality for this relationship. AlsoAwokuse (2007) aims to determine the impact of export and import expansion on growth in three transition economies. The results show that there is a unidirectional causality running from imports to economic growth for Czech Republic and Poland while the bidirectional causality for exports and economic growth relationship in Bulgaria.

For Malaysia Lean and Smyth (2010a) explores the relationship between economic growth and exports by using multivariate Granger causality tests over the period of 1971-2006 and results indicate that there is a unidirectional causality running from exports to economic growth. While in a similar study Lean and Smyth (2010b) investigate the relationship between economic growth and exportsover the period of 1970-2008 and results not support the export-led growth theories. For Japan, over the period of 1960 to 2007, Sami (2011) explores the relationship of exports and real income per capita by using bounds testing approach. And find cointegrating relationship between exports and economic growth. Samad (2011) examines the relationship among economic growth, exports and imports in Algeria and the results suggest that exports Granger causes economic growth and imports. In other worlds exports expansion Granger causes economic growth and economic growth promotes the imports growth. Ray (2011) analyses the causality between export and economic growth in India over the period 1972-73 to 2010-11 by using Granger causality. The empirical results suggest the bidirectional causality between export and economic growth.

Halıcıoglu (2011) aims to investigate the relationship between aggregate output and exports for Turkey for the period 1968-2008. Results suggest unidirectional causality runs from exports to aggregate output in the long run and bidirectional causality in the short run. For Pakistan, Shahbaz (2012) explores the impact of trade openness on economic growth and results support growth-led-trade hypothesis. Similarly, Rahman and Shahbaz (2013) also confirm that imports lead economic growth. Bojanic (2012) investigates the relationship between economic growth and trade openness for Bolivia over the period 1940-2010. The results confirm the unidirectional causality runs from trade openness to economic growth. Sadorsky (2012) aims to determine the causality between economic growth and international trade in 7 South American countries for the period 1980 to 2007. The panel cointegration tests suggest a long run relationship between economic growth and exports also economic growth and imports. In the short-run there is bidirectional relationship between economic growth and exports also economic growth and imports. Dedeoglu and Kaya (2013) examine the relationship between international trade and economic growth in OECD countries and find bidirectional causality for energy use-exports and energy use-imports relationship.

3. DATA AND EMPIRICAL STRATEGY

3.1 Data

We use annual data for the period of 1980-2012 in G-8 countries. For each country the data set consists of observations for real GDP (Y) in $ USD, for energy consumption energy use (E) in kg of oil equivalent, for real exports (X) in $ USD and real imports (M) in $ USD, for capital real gross capital formation (K) in $ USD and for labor total labor force (L). We have used population series to transform all the variables into per capita terms. The data set obtained from the World Development Indicator database. All variables are innatural logarithm. The review of relevant literature allows constructing an algebraic model given below for empirical investigation:

$$\ln E_{it} = \alpha_1 + \alpha_2 \ln Y_{it} + \alpha_3 \ln K_{it} + \alpha_4 \ln L_{it} + + \alpha_4 \ln I_{it} + + \alpha_4 \ln X_{it} + \mu_i \quad (1)$$

Where, $\ln$ is natural log, $\ln E_{it}$ is energy consumption per capita, $\ln Y_{it}$ is real GDP per capita proxy for economic growth, K_{it} is real capital use proxies by real gross fixed capital formation, I_{it} is real imports per capita, X_{it} is real exports per capita, L_{it} is lobar force per capita and μ_i is error term. We expect $\partial Y_{it} / \partial E_{it} < 0$ if economic growth is efficient otherwise $\partial Y_{it} / \partial E_{it} > 0$. If energy efficient capital is used during production process then $\partial K_{it} / \partial E_{it} < 0$ otherwise $\partial K_{it} / \partial E_{it} > 0$. A rise in labor affects energy demand via economic growth and industrialization channels. Economic growth creates employment opportunities via boosting industrial activities in an economy and increases energy consumption. We expect that $\partial L_{it} / \partial E_{it} > 0$.

Exports can effect energy consumption in several reasons. If there is an increase in the process of producing exports goods, there will be an increase in using machinery and equipment and so energy demand and also need energy to transport these goods to seaport, airport or other stations. We expect $\partial X_{it} / \partial E_{it} > 0$. Energy consumption can be effected by imports in two ways, first way with transportation and transportation network and second way if the imported goods are durable like automobiles, refrigerators, television etc., there will be an increase in energy demand to operate them. We expect $\partial I_{it} / \partial E_{it} > 0$.

3.2 Panel Unit Root Tests

We employ two panel unit root tests: Im, Pesaran and Shin (IPS, 2003) and Pesaran (2007) to check the stationary properties of the variables. The first test assumes cross-sectional independence. However, this assumption is likely to be violated for the trade and GDP variables[2]. Baltagi et al. (2007) show that there can be severe size distortions in the presence of cross-sectional dependence. Pesaran (2007) panel unit root test relaxes this assumption and is applicable in the presence of cross-sectional dependence. IPS (2003) test is estimated using the following model:

$$\Delta y_{i,t} = \alpha_i + \vartheta_i t + \theta_t + \rho_i y_{i,t-1} + \sum_{j=1}^{p} \varphi_{i,j} y_{i,t-j} + \upsilon_{i,t} \tag{2}$$

where ρ_i is the heterogeneous auto-regressive term and $v_{i,t}$ is the error term and assumed to be auto-correlated with different serial correlation and variance properties across the cross-sectional unit, but also independent across the unit of the sample. The IPS test is the adjusted average of ADF individual unit root test statistics[3]. The IPS statistics is asymptotically N(0, 1), as T and N goes to infinity. This tests the null hypothesis that each series in the panel has unit root for all cross-sectional units against the alternative that at least one of the series is stationary.

$$H_0 : \rho_i = 0 \quad for\ all\ i$$
$$H_A : \rho_i < 0 \quad i = 1, 2, ..., N$$
$$\rho_i = 0 \quad i = N_1 + 1, N_1 + 2, ..., N$$

The estimable equation of IPS unit root test is modelled as following:

$$\bar{t}_T = \frac{1}{N}\sum_{i=1}^{N} t_{i,t}(P_i) \tag{3}$$

where $t_{i,t}$ is the ADF t-statistics for the unit root tests of each country and P_i is the lag order in the ADF regression and test statistic can be calculated as following:

[2]Countries depends upon each other to enhance economic growth and to get benefit of FDI
[3]They tabulated the statistics for three specifications of the deterministic terms in (3).

$$A_T = \frac{\sqrt{N(T)[\bar{t}_T - E(t_T)}}{\sqrt{\operatorname{var}(t_T)}} \tag{4}$$

As $\bar{t}_T$ is explained above and values for $E[t_{iT}(P_i, 0)]$ can be obtained from the results of Monte Carlo simulation carried out by IPS. They have calculated and tabulated them for various time periods and lags. The IPS simulation indicated that in the presence of no serial correlation, the $\bar{t}_T$ statistics is more powerful even for small sample size. When the error term is serially correlated in heterogeneous panel and both N and T are sufficiently large, then, the power and size of $\bar{t}_T$ is just satisfactory. Another important characteristic of IPS test is that the power of this test is relatively more affected by rise in T then rise in N. Pesaran (2007) augmented the standard ADF regressions with the cross-section averages of the lagged level and first differences of the individual series. The panel unit root tests are based on the simple averages of the individual cross-sectional augmented ADF statistics. In the presence of N cross-sectional and t time series observation, Pesaran uses the following simple dynamic linear heterogeneous model:

$$\Delta x_{i,t} = \alpha_i + \rho_i x_{i,t-1} + c_i \bar{x}_{t-1} + d_i \Delta\bar{x} + \varepsilon_{i,t} \tag{5}$$

Where $\bar{x}_{t-1} = (1/N)\sum_{i=1}^{N} x_{i,t-1}$ *and* $\Delta\bar{x}_t = (1/N)\sum_{i=1}^{N} \Delta x_{i,t}$

The presence of cross-sectional averages of lagged levels $\bar{x}_{t-1}$ and first differences $\Delta\bar{x}_t$ of individual series capture the cross-sectional dependence through a factor structure. Pesaransuggests to modify equation-6 with appropriate lags in the presence of serially correlated error term. Pesaran (2007) obtains the modified IPS statistics based on the average of individual CADF, which is denoted as cross-sectional augmented IPS (CIPS). This is estimated from:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \tag{6}$$

Where $CADF_i$ is the cross-sectional augmented Dickey-Fuller statistic for the ith cross-sectional unit given by the t-ratio of ρ_i in the CADF regression-6. The distribution of the CIPS statistic is found to be non-standard even for large N.

3.3 Panel Cointegration Tests

The cointegration test was further developed by Philips and Ouliaris (1990) and Johansen (1988, 1991) and among others. Similar to panel unit root tests, extension of time-series cointegration to panel data is also recent. Panel cointegration tests that have been proposed so far can be divided into two groups: the first group of cointegration tests is based on the null hypothesis of cointegration (McCoskey and Kao, 1998; Westerlund, 2005) while the second group of cointegration tests take no cointegration as the null hypothesis (Pedroni, 1999; Kao, 1999; Larsson et al., 2001; Groen and Kleibergen, 2003). Four error correction based panel cointegration tests developed by Westerlund, (2007) are employed. These tests are based on structural dynamics rather than residuals dynamics. Theydo not impose any common factor restriction. Null hypothesis of no cointegration is tested by assuming whether the error correction term in a conditional error model is equal to zero. If the null of no error correction is rejected, then the null hypothesis of no cointegration is also rejected. The error correction model based on the assumption that all the variables are integrated of order 1 is as follows:

$$\Delta z_{it} = \delta' d_i + \theta_i (z_{i(t-1)} - \beta' y_{i(t-1)}) + \sum_{j=1}^{m} \theta_{ij} \Delta z_{i(t-j)} + \sum_{j=0}^{mi} \phi_{ij} \Delta y_{i(t-j)} + \omega_{it} \tag{7}$$

Where, $d_t = (1-t)'$ holds the deterministic components, $\delta_i' = (\delta_{1i}, \delta_{2i})'$ being the associated vector of parameters. In order to allow for the estimation of error correction parameter θ_i by least square, (7) can be rewritten as:

$$\Delta z_{it} = \delta' d_i + \theta_i z_{i(t-1)} + \pi' y_{i(t-1)} + \sum_{j=1}^{m} \theta_{ij} \Delta z_{i(t-j)} + \sum_{j=0}^{mi} \phi_{ij} \Delta y_{i(t-j)} + \omega_{it} \tag{8}$$

Here, θ_i is the adjustment term that determines the speed by which the system adjusts back to the equilibrium relationship. The reparameterization of the model makes the parameter θ_i remains unaffected by imposing an arbitrary β_i. Now, it is possible to construct a valid test of null hypothesis versus alternative hypothesis that is asymptotically similar and whose distribution is free of nuisance parameters. In a nutshell, Westerlund (2007) developed four tests that are based on least squares estimates of θ_i and its t-ratio for each cross-sectional i. Two of them called group mean statistics and can be presented as:

$$G_{\pi} = \frac{1}{N}\sum_{i=1}^{N}\frac{\hat{\theta}_i}{S.E(\hat{\theta}_i)} \quad (9)$$

and

$$G_{\alpha} = \frac{1}{N}\sum_{i=1}^{N}\frac{T\theta_i^{'}}{\theta_i^{'}(1)} \quad (10)$$

G_{τ} and G_{α} test the null hypothesis of $H_0:\theta_i = 0$ for all i versus the alternative hypothesis of $H_0:\theta_i < 0$ for at least one i. The rejection of the null hypothesis indicates the presence of cointegration for at least one cross-sectional unit in the panel. The other two tests are panel statistics and can be presented as:

$$P_{\pi} = \frac{\hat{\theta}_i}{S.E(\hat{\theta}_i)} \quad (11)$$

$$P_{\alpha} = T\hat{\theta} \quad (12)$$

P_{τ} and P_{α} test the null hypothesis of $H_0:\theta_i = 0$ for all i versus the alternative hypothesis of $H_0:\theta_i < 0$ for all i. The rejection of the null hypothesis means the rejection of no cointegration for the panel as a whole.

3.4. Estimation of Panel Cointegration Regression

The OLS estimators do not give efficient estimates in the presence of unique order of integration of the variables. To solve this problem, FMOLS developed by Pedroni (2000, 2001) is applied to calculate the values of long-run estimates. The FMOLS technique generates consistent estimates in small samples and does not suffer from large size distortions in the presence of endogeneity and heterogeneous dynamics. The panel FMOLS estimate equation (1) and $y_{it} = y_{i,t-1} + e_{it}$. The innovating vector $\omega_{it} = (\mu_{it}, e_{it})'$ is I(0) with asymptotic long-run covariance vector $\Omega_i = \begin{bmatrix} \Omega_{11i} & \Omega_{12i} \\ \Omega_{21i} & \Omega_{22i} \end{bmatrix}$ and auto covariances Γ_i, and $x_{it} = (y_{it}, z_{it})$ is I(1) and y_{it}, z_{it} are cointegrated. The panel FMOLS estimator for the coefficient β is defined as:

$$\hat{\beta} = N^{-1}\sum_{i=1}^{N}\left(\sum_{t=1}^{T} y_{it} - \bar{y}\right)^{-1}\left(\sum_{t=1}^{T} y_{it} - \bar{y}\right) z_{it}^{*} - T\hat{\eta}_i \qquad (13)$$

Where $z_{it}^{*} = (z_{it} - \bar{z}) - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} \Delta y_{it}$, $\hat{\eta}_i \equiv \hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^{0} - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} (\hat{\Gamma}_{22i} + \hat{\Omega}_{22i}^{0})$ and $\hat{L}_i$ is a lower triangular decomposition of $\hat{\Omega}_i$.[4]

3.5. Panel Causality Test

To test causality, we employ the panel causality test developed by Dumitrescu and Hurlin (2012). This test is a simplified version of Granger (1969) non-causality test for heterogeneous panel data models with fixed coefficients. Also, it takes into account the two dimensions of heterogeneity: the heterogeneity of regression model used to test the Granger causality and the heterogeneity of the causality relationships. We consider the following linear model and the associated t-statistics gives:

$$z_{it} = \alpha_i + \sum_{m=1}^{M} \gamma_i^{(m)} z_{i,t-m} + \sum_{m=1}^{M} \beta_i^{(m)} y_{i,t-k} + \varepsilon_{it} \qquad (14)$$

Where *i*=1,2,…….,N and *t* =1,2,…….,T. In above equation, y and z are two stationary variables observed for N individuals in T periods. $\beta_i = (\beta_i^{(1)}, ..., \beta_i^{(m)})'$ and the intercept term α_i are assumed to be fixed in the time dimension. We assume that lag order of M are identical for all cross-section units of the panel. We also allow the autoregressive parameter $\gamma_i^{(m)}$ and the regression coefficients $\beta_i^{(m)}$ to be varied across cross-sections. Under the null hypothesis, we assume that there is no causality relationship for any of the cross-section of the panel. This assumption is called the Homogenous Non-Causality (HNC) hypothesis, which is defined as:

$$H_0 : \beta_i = 0 \qquad \forall_i = 1, 2, ..., N$$

The alternative hypothesis is called as Heterogeneous Non-Causality (HENC) hypothesis. Two sub-group of cross-section units are specified under this hypothesis. There is causality relationship from *y* to *z* for the first one, but it is not necessarily based on the same regression model. For the second

[4]The associated t-statistics gives: $t_{\hat{\beta}^{*}} = N^{-1/2}\sum_{i=1}^{N} t_{\hat{\beta}^{*},i}$ Where $t_{\hat{\beta}^{*},i} = \left(\hat{\beta}_i^{*} - \beta_0\right)\left[\hat{\Omega}_{11i}^{-1}\sum_{t=1}^{T}(y_{it} - \bar{y})^2\right]^{1/2}$ ....(13)

sub-group, there is no causality relationship from *y* to *z*. We consider a heterogeneous panel data model with fixed coefficient in this group. The alternative hypothesis is as follows:

$$H_a : \beta_i = 0 \qquad \forall_i = 1, 2, ..., N_1$$

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

We assume that β_i may vary across cross sections and there are N_1 < N individuals processes with no causality from y to z. N_1 is unknown but it provides the condition $0 \leq N_1 / N < 1$. We propose the average statistics $W_{N,T}^{HNC}$, which is related with the Homogenous Non-Causality (HNC) hypothesis, as follows:

$$W_{N.T}^{HNC} = \frac{1}{N} \sum_{i=1}^{N} W_{i,T} \tag{15}$$

Where $W_{i,T}$ indicates the individual Wald statistics for the i^th cross-section unit corresponding to the individual test $H_0 : \beta_i = 0$. Let $X_i = [e : z_i : y_i]$ be the (T, 2K+1) matrix, where e indicates a (T, 1) unit vector and $Y_i = [y_i^{(1)} : y_i^{(2)} : .... : y_i^{(k)}]$, $Z_i = [z_i^{(1)} : z_i^{(2)} : .... : z_i^{(k)}]$. $\theta_i = (\alpha_i \ \gamma_i' \ \beta_i')$ is a vector of the parameter of the model. Also let $R = [0 : I_m]$ be a (M, 2M+1) matrix. For each i=1,2,…..,N, the Wald statistics $W_{i,T}$ corresponding to the individual test $H_0 : \beta_i = 0$ is defined as following:

$$W_{i,T} = \hat{\theta}_i' R' [\hat{\sigma}_i^2 R (Z_i' Z_i)^{-1} R']^{-1} R \hat{\theta}_i \tag{16}$$

Under the null hypothesis of non-causality, each individual Wald statistic converges to chi-squared distribution with M degree of freedom for $T \to \infty$.

$$W_{i,T} \Rightarrow \chi^2(M), \forall_i = 1, 2 ...... N \tag{17}$$

The standardized test statistics $Z_{N,T}^{HNC}$ for $T, N \to \infty$ is as follows:

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2M}} (W_{N,T}^{HNC} - M) \to N(0,1) \tag{18}$$

In (18) $W_{N,T}^{HNC} = (1/N)\sum_{1=1}^{N} W_{i,T}$. Further information about these statistics can be found in the study of Dumitrescu and Hurlin (2012).

4. RESULTS AND THEIR INTERPRETATIONS

Table-1 describes the descriptive statistics and pair-wise correlation. The correlation analysis reveals that economic growth is positively with energy consumption. The correlation of capital, labour, exports and imports with energy consumption is positive. The positive correlation is also found of capital, labour, exports and imports with economic growth. Labour, exports and imports are positively correlated with capital. The correlation of exports and imports with labour is positive. Exports and imports are positively correlated.

Table 1: Descriptive Statistics and Correlations

Variables	E_{it}	Y_{it}	K_{it}	L_{it}	M_{it}	X_{it}
Mean	12.6540	9.7730	8.2012	4.2029	8.1744	8.1130
Median	12.4404	10.2483	8.5960	4.1999	8.5802	8.4878
Maximum	14.8890	10.5973	9.1767	4.2973	9.8757	9.7221
Minimum	11.7333	5.3956	4.1784	4.0863	3.9555	3.5235
Std. Dev.	0.6470	1.2961	1.1055	0.0330	1.4088	1.4318
Skewness	1.3368	-2.2078	-2.1738	0.1362	-1.7889	-1.7755
Kurtosis	4.6119	6.3804	6.8266	3.9766	5.4931	5.4386
E_{it}	1.0000					
Y_{it}	-0.6171	1.0000				
K_{it}	0.4896	0.7490	1.0000			
L_{it}	0.3101	0.4672	0.2833	1.0000		
M_{it}	0.3790	0.4958	0.5075	0.2130	1.0000	
X_{it}	0.3152	0.4688	0.7072	0.2026	0.7231	1.0000

It is necessary to have understanding the unit root properties of the variables for the perusal of any standard econometric modelling. We have applied the IPS panel unit root test to examine integration properties of the variables. The results are reported in Table-2. All variables are tested in level and first difference form. This test is applied with constant and, constant and trend following lag order on the basis of AIC. We find that the all the series have unit root problem at their level form, but found to be stationary at first difference. This leads that all the variables are integrated at I(1) i.e. unique order of integration. The issue is that panel unit root tests assume that cross-sectional independence is having low power if the data have cross-sectional dependence. The problem is that our series such as exports, imports and GDP show the dependence of countries in the panel. This shows that there is cross-sectional dependence in the panel. In the presence of cross-sectional dependence, CADF panel unit root test provides efficient and reliable results.

Table 2: Panel Unit Root Analysis

Variables	**At level**				**At 1st Difference**			
	Drift & No Trend	P-value	Drift & Trend	P-value	Drift & No Trend	P-value	Drift & Trend	P-value
IPS Unit Root Test								
E_{it}	1.2952	0.9024	5.8242	1.0000	-4.1160	0.0000	-6.1310	0.0000
Y_{it}	-0.3764	0.3533	1.2234	0.8894	-5.8858	0.0000	-6.0198	0.0000
K_{it}	-0.3352	0.3801	0.4514	0.6742	-7.2862	0.000	-7.1954	0.0000
L_{it}	1.3023	0.9036	-0.1015	0.4596	-12.6341	0.0000	-2.8205	0.0024
M_{it}	1.1460	0.8714	-0.3267	0.3719	-9.2500	0.0000	-8.3723	0.0000
X_{it}	1.2230	0.8893	1.8427	0.9673	-7.0522	0.0000	-6.5667	0.0000
CIPS Unit Root Test								
E_{it}	-0.858	0.997	-2.076	0.802	-3.475	0.000	-3.836	0.000
Y_{it}	-1.361	0.896	-2.307	0.542	-3.330	0.000	-2.932	0.029
K_{it}	-1.083	0.982	-2.163	0.715	-3.590	0.000	-3.516	0.000
L_{it}	-0.082	1.000	-2.117	0.764	-5.219	0.000	-5.100	0.000
M_{it}	-2.214	0.096	-2.591	0.210	-4.076	0.000	-4.124	0.000
X_{it}	-1.952	0.302	-1.845	0.944	-2.992	0.000	-3.303	0.000

The results of CADF test are also reported in lower segment of Table-2. The results show that all the series are non-stationary with intercept, intercept and trend.

Table 3: Westerlund ECM panel cointegration tests Results

Test	G_τ	G_α	P_τ	P_α
Statistics	-2.898	-1.259	-7.325	-2.918
P-value	0.026	1.000	0.051	0.981

After first differencing, variables are found to be stationary. This indicates that all the series are integrated at I(1). We have applied panel cointegration test i.e. Westerlund ECM panel cointegrationtest and results are reported in Table-4. We find that the null hypothesis of no cointegration is rejected by the two tests i.e. G_τ and P_τ. It indicates the presence of cointegration between the variables such as energy consumption, income, capital, labour, exportsand imports in the panel of sample countries. We have applied the Johansen fisher panel cointegration to test the robustness of Westerlund ECM panel cointegration test. The results reported in Table-4 reveal the five cointegrating vectors which corroborate the robustness of cointegration results.

Table 4: Johansen Fisher Panel Cointegration Test Results

No. of CEs	Trace Statistics	P-Value	Max Eigen Statistics	P-Value
None	406.1	0.0000	179.7	0.0000
At most 1	213.6	0.0000	113.9	0.0000
At most 2	122.0	0.0000	70.57	0.0000
At most 3	64.36	0.0000	45.22	0.0000
At most 4	33.32	0.0026	28.59	0.0119
At most 5	23.09	0.0588	23.09	0.0588

Note: Intercept and trend is included in the cointegrating equations and VAR.

The results of panel DOLS and FMOLS are reported in Table-5. We find that economic growth has negative impact on energy consumption. This implies that growth in income induces the economies to adopt energy efficient technology for enhancing domestic production. This finding is consistent with Sadorsky (2013) who reported that economic growth is negatively linked with energy consumption in developing economies. The impact of capital formation is positive and statically significant at 5% (1%) level. The relationship between labour and energy consumption is positive at 5% (1%)level of significance. Payne (2009) also reported the positive impact of labour on energy consumption in case of USA and India. The impact of imports on energy consumption is positive at 1% level of significance. Exports are positively linked with energy consumption and it is statistically significant at 1% level. These findings are consistent with Sadorsky (2011) who noted that exports and imports lead energy consumption in Middle East countries and same view is reported by Sadorsky (2012) for South American countries.

Table 5: Panel DOLS and FMOLS Results

Dependent Variables = E_{it}				
Variables	**Panel FMOLS**		**Panel DOLS**	
	Coefficient	**P-value**	**Coefficient**	**P-value**
Y_{it}	-0.463	0.019	-1.218	0.000
K_{it}	0.177	0.035	0.295	0.000
L_{it}	0.750	0.048	3.677	0.000
M_{it}	0.133	0.050	0.344	0.000
X_{it}	0.241	0.000	0.320	0.000

Note: Robust S.E are used to estimate Panel OLS results.

The results of FMOLS and DOLS for single country analysis are reported in Table-6 and 7.

Table 6: Country Specific Results of FMOLS

Dependent Variables = E_{it}							
Country	**Variables**	Constant	Y_{it}	K_{it}	L_{it}	M_{it}	X_{it}
Canada	Coefficient	5.245	-0.118	0.182	-0.725	0.041	0.231
	P-value	0.011	0.738	0.071	0.633	0.648	0.000
Japan	Coefficient	-3.966	0.195	-0.448	4.673	0.437	0.115
	P-value	0.000	0.059	0.000	0.000	0.000	0.009
Italy	Coefficient	2.986	0.806	0.281	-1.127	-0.171	0.076
	P-value	0.000	0.015	0.001	0.002	0.010	0.217
United States	Coefficient	2.482	1.120	0.279	-0.665	-0.394	0.089
	P-value	0.037	0.000	0.000	0.169	0.000	0.011
United Kingdom	Coefficient	10.53	-0.127	0.272	-2.909	0.088	-0.179
	P-value	0.000	0.441	0.072	0.059	0.671	0.407
France	Coefficient	-2.877	1.671	0.054	0.928	-0.552	0.258
	P-value	0.020	0.000	0.534	0.233	0.000	0.029
China	Coefficient	3.008	-0.814	1.052	1.483	-0.515	0.542
	P-value	0.016	0.000	0.000	0.041	0.000	0.000
Germany	Coefficient	4.450	0.705	0.156	1.595	0.166	-0.003
	P-value	0.000	0.051	0.220	0.005	0.466	0.985

We find that economic growth has negative impact on energy demand in Canada, United Kingdom, China and Germany. In Japan, Italy, United States and France; energy consumption is positively lead by economic growth. Moreover Sami (2011) also reported that exports Granger causes energy (electricity) consumption in Japan.

Table 7: Country Specific Results of DOLS

Dependent Variables = E_{it}							
Country	**Variables**	Constant	Y_{it}	K_{it}	L_{it}	M_{it}	X_{it}
Canada	Coefficient	21.10	-1.858	1.166	-7.472	0.621	1.107
	P-value	0.032	0.087	0.032	0.131	0.211	0.062
Japan	Coefficient	-3.865	0.192	-0.454	4.633	0.446	0.109
	P-value	0.000	0.135	0.000	0.000	0.000	0.047
Italy	Coefficient	2.910	0.850	0.237	-1.111	-0.128	0.037
	P-value	0.000	0.020	0.008	0.005	0.076	0.583
United States	Coefficient	2.330	0.983	0.280	-0.330	-0.374	0.114
	P-value	0.102	0.000	0.000	0.555	0.000	0.005
United Kingdom	Coefficient	-10.89	-1.455	-0.099	11.31	0.245	0.421
	P-value	0.255	0.015	0.733	0.072	0.443	0.201
France	Coefficient	-2.246	1.505	0.005	0.922	-0.408	0.195
	P-value	0.078	0.012	0.960	0.299	0.016	0.188
China	Coefficient	0.954	-1.588	1.114	3.362	-0.294	0.689
	P-value	0.705	0.003	0.001	0.072	0.088	0.000
Germany	Coefficient	-2.790	-0.645	0.278	5.180	0.563	0.736
	P-value	0.421	0.074	0.193	0.017	0.069	0.012

After finding the marginal impacts of economic growth, capital, labour, exports and imports on energy consumption, we apply the Dumitrescu and Hurlin (2012) causality tests to examine the direction of causality between the variables5. Results of Dumitrescu and Hurlin DH causality test for global panel are reported in Table-9. The results of DH causality reveal thatenergy consumption is cause of economic growth. This implies that adoption of energy conservation policies would harm economic growth. The bidirectional causality is found between capital use and energy consumption and same is true for labour and energy consumption. The unidirectional causality exists running from exports to economic growth but no causality is found between imports and economic growth. Exports and imports cause energy consumption. This finding is contradictory with Sadorsky (2011) who noted the bidirectional causality between imports and energy consumption but exports cause energy consumption in Middle East countries. Similarly, Sadorsky

[5]All the variables are stationary at first difference i.e. I(1). The DH test of causality is applied on first differenced series.

(2012) also reported that the relationship between exports and energy consumption is bidirectional and energy consumption is cause of imports in case of South American countries.

Table 8: The Result of DH panel causality Test on 1st difference

Direction of Causality	W-Stat.	Zbar-Stat.	Prob.
Y_{it} does not homogeneously cause E_{it}	4.1354	2.2115	0.0270
E_{it} does not homogeneously cause Y_{it}	2.2747	0.1214	0.9034
K_{it} does not homogeneously cause E_{it}	4.1846	2.2666	0.0234
E_{it} does not homogeneously cause K_{it}	4.8820	3.0500	0.0023
L_{it} does not homogeneously cause E_{it}	7.4759	5.9637	2.E-09
E_{it} does not homogeneously cause L_{it}	43.9032	46.8811	0.0000
X_{it} does not homogeneously cause E_{it}	7.6857	6.1994	6.E-10
E_{it} does not homogeneously cause X_{it}	1.5808	-0.6580	0.5105
M_{it} does not homogeneously cause E_{it}	4.6946	2.8395	0.0045
E_{it} does not homogeneously cause M_{it}	2.66569	0.5605	0.5751
K_{it} does not homogeneously cause Y_{it}	5.3069	3.5273	0.0004
Y_{it} does not homogeneously cause K_{it}	10.7916	9.6881	0.0000
L_{it} does not homogeneously cause Y_{it}	2.43147	0.2974	0.7661
Y_{it} does not homogeneously cause L_{it}	42.9530	45.813	0.0000
X_{it} does not homogeneously cause Y_{it}	2.12950	-0.0417	0.9667
Y_{it} does not homogeneously cause X_{it}	3.63474	1.6490	0.0991
M_{it} does not homogeneously cause Y_{it}	2.2963	0.1456	0.8842
Y_{it} does not homogeneously cause M_{it}	5.1227	3.3204	0.0009
L_{it} does not homogeneously cause K_{it}	2.9801	0.9137	0.3609
K_{it} does not homogeneously cause L_{it}	44.1820	47.194	0.0000
X_{it} does not homogeneously cause K_{it}	3.9228	1.9726	0.0485
K_{it} does not homogeneously cause X_{it}	3.0743	1.0196	0.3079
M_{it} does not homogeneously cause K_{it}	4.1276	2.2026	0.0276
K_{it} does not homogeneously cause M_{it}	3.1345	1.0872	0.2769
X_{it} does not homogeneously cause L_{it}	31.848	33.3403	0.0000
L_{it} does not homogeneously cause X_{it}	3.1529	1.1078	0.2679
M_{it} does not homogeneously cause L_{it}	31.020	32.4100	0.0000
L_{it} does not homogeneously cause M_{it}	2.1825	0.0178	0.9858

M_{it} does not homogeneously cause X_{it}	2.0480	-0.1332	0.8940
X_{it} does not homogeneously cause M_{it}	2.4517	0.3202	0.7488

The feedback effect is found between capital and economic growth while economic growth causes labour, exports and imports. Capital use causes labour and exports cause capital. The unidirectional causality is running from imports to capital and exports (imports) to labour.

5. CONCLUSION AND POLICY IMPLICATIONS

The present study investigated the nexus energy consumption and economic growth by incorporating trade openness in energy demand function using the panel of G-8 countries over the period of 1980-2012. We have applied panel unit tests to examine the integrating properties of the variables. Long run cointegration relationship is investigated by applying panel cointegration approaches. The directional of causal relationship between the variables is tested by using DH panel causality.

Our empirical results indicate the presence of cointegration between the variables such as energy consumption, income, capital, labour, exports and imports in G-8 countries. To corroborate the robustness of cointegration results, the Johansen fisher panel cointegration to test the robustness of Westerlund ECM panel cointegration test is employed. As a result of panel FMOLS and DOLS that 1 % increase in economic growth is negatively linked with energy consumption by 0.46-1.22. A 1 % increase exports and imports increase energy consumption by 0.24-0.32% and 0.13-0.344 % respectively. These findings are consistent with Sadorsky (2011) who noted that exports and imports lead energy consumption in Middle East countries and same view is reported by Sadorsky (2012) for South American countries. In addition, exports boost energy consumption and imports also increase energy demand. This implies that overall trade openness has positive impact on energy consumption. The DH Granger causality analysis reveals that economic growth Granger causesenergy consumption. The feedback effect exists between capital use and energy consumption but labour Granger causes energy demand. The unidirectional causality is found running from exports and imports to energy consumption.

For future research, one should examine the dynamic interrelationships among income growth, economic growth, energy consumption, international trade and CO2 emissions for G-20 economies in a framework of cointegrated vector autoregression (CVAR) too. Johansen' s maximum likelihood procedure can be used to estimate the coefficients of the cointegrated VAR although the authors have used panel cointegration approaches. The Johansen approach can be used to identify the cointegrating, or long-run, relationships among the selected variables. Dinda and Coondoo (2006) pointed out that the environmental consequences of trade and other measures of economic activity are basically a long-run concept; hence, the use of cointegration method is indeed desirable to examine the true relationship among the environment, trade, income growth, economic growth, international trade and energy consumption.

The effect of trade liberalization on income, energy consumption, economic growth and the environment is essentially an empirical phenomenon and depends on various characteristics of the economy under consideration such as stages of economic development, openness levels and stringency of environmental regulations. As such, the claim that emission of greenhouse gases (i.e., anthropogenic carbon dioxide (CO2) emissions) through combustion of fossil fuels accelerated by (trade-induced) economic growth appears to be the major contributor of global warming, the environmental consequences of trade liberalization should be accounted for when estimating energy consumption-economic growth and energy consumption-international trade. In future research, Johansen and Juselius, (1992) and, Johansen et al. (2000) are suitable cointegration approaches which accommodate the information structural breaks in the series.

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