Causality between Trade Openness and Energy Consumption: What Causes What in High, Middle and Low Income countries

Muhammad Shahbaz
COMSATS Institute of Information Technology, Lahore, Pakistan
Email: shahbazmohd@live.com

Samia Nasreen
Government College University Faisalabad, Faisalabad, Pakistan
Email: sami_lcu@yahoo.com

Chong Hui Ling
University of Malaya Kuala Lumpur Malaysia
Contact No. +60 123495113,
Email: felicia.chonghl@gmail.com

Rashid Sbia*
*Department of Applied Economics
Free University of Brussels
Avenue F. Roosevelt, 50 C.P. 140
B- 1050 Brussels, Belgium
Rashid.Sbia@ulb.ac.be

Abstract:
This paper explores the relationship between trade openness and energy consumption using data of 91 high, middle and low income countries. The study covers the period of 1980-2010. We have applied panel cointegration and causality approaches for long run and causal relationship between the variables.

Our results confirm the presence of cointegration between the variables. The relationship between trade openness and energy consumption is inverted U-shaped in high income countries but U-shaped in middle and low income countries. The homogenous and non-homogenous causality analysis reveals the bidirectional causality between trade openness and energy consumption.
Keywords: Trade, Energy, Causality

Introduction

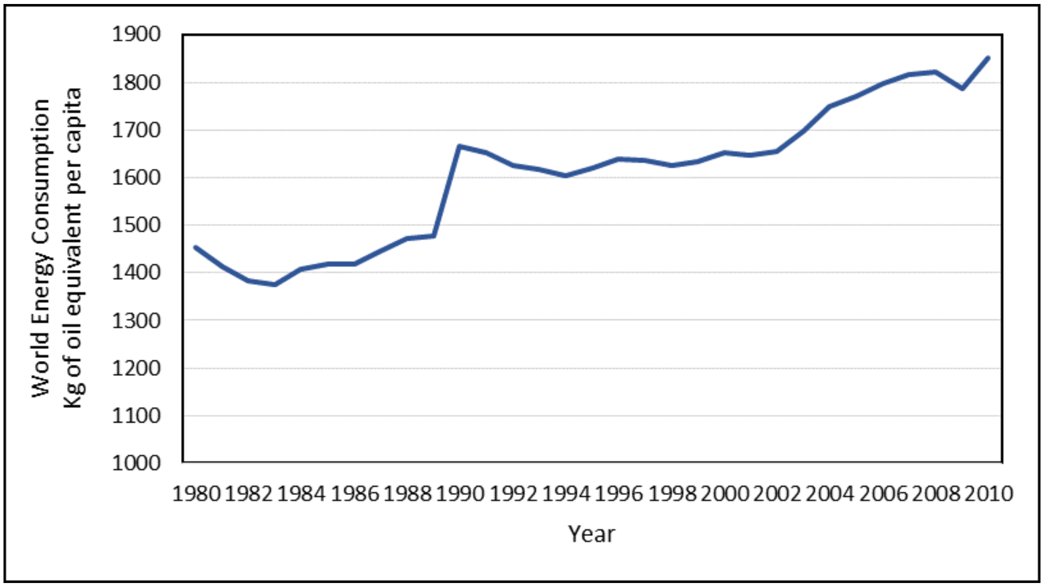
Trade liberalization has affected the flow of trade (goods and services) between developed and developing countries. The Heckscher-Ohlin trade theory reveals that under free trade, developing countries would specialize in the production of those goods that are produced by relatively abundant factors of production such as labor and natural resources. Developed countries would specialize in the production of those goods that are produced by human capital and manufactured capital-intensive activities. Trade openness entails movement of goods produced in one country for either consumption or further processing to other country. Production of those goods is not possible without the effective use of energy. Trade openness affects energy demand via scale effect, technique effect and composite effect. Other things being same, trade openness increases economic activities, thus stimulate domestic production and hence economic growth. A surge in domestic production reshapes energy demand because of expansion in domestic production commonly refers as scale effect. Such scale effect is caused by trade openness. Economic condition of the country and extent of relationship between economic growth and trade openness determine the impact of trade openness on energy consumption (Shahbaz et al. 2013; Cole, 2006). Trade openness enables developing economies to import advance technologies from developed economies. The adoption of advanced technology lowers energy intensity. The economic consequences of advance technologies implementations consume less energy and produce more output that is usually referred as technique effect (Arrow, 1962). Composite effect reveals that with the use energy intensive production as economic development i.e. shift from agriculture to industry. In initial stages of economic development, since economy is based largely on agriculture sector, thus the use to energy consumption is relatively less. As economy starts shifting from agriculture to industry, the use of energy consumption increases. Arrow

(1962) calls it positive composite effect. Finally, following maturity stage of economic development, shifts in industry to service consume less energy consumption which implies that energy intensity is lowered because of composite effect.

Energy affects trade openness via various channels. Firstly, energy is an important input of production because machinery and equipments in the process of production require energy. Secondly, exporting or importing manufactured goods or raw material requires energy to fuel transportation. Without adequate energy supply, trade openness will be adversely affected. Consequently, energy is an important input in trade expansion and adequate consumption of energy is essential to expanding trade via expanding exports and imports. The relationship between trade openness and energy consumption is important. If energy plays its key role to flow exports or imports then any policies aiming at reduction energy consumption such as energy conservation policies will negatively impact the flow of exports or imports and hence, reduce the benefit of trade openness. The bidirectional causal relationship between trade openness and energy consumption suggests in adopting energy expansion policies because energy consumption stimulates trade openness and as result, trade openness affects energy consumption (Sadorsky, 2011). The energy conservation policies will not have an adverse effect on trade openness if causality is running from trade openness to energy consumption or neutral effect exists between trade openness and energy consumption (Sadorsky, 2011).

Energy consumption in the world increases parallel to technological development, increase in trade and population growth. The world average energy consumption was 1454 Kg of oil equivalent per capita in 1980 while the amount increased to 1852 Kg of oil equivalent per capita in 2010 (see Figure-1). According to American Energy Information Administration (EIA) and to the International Energy Agency (IEA), the worldwide energy consumption will on average continue to increase by 2% per year.

Figure-1: **World Energy Consumption per Capita**



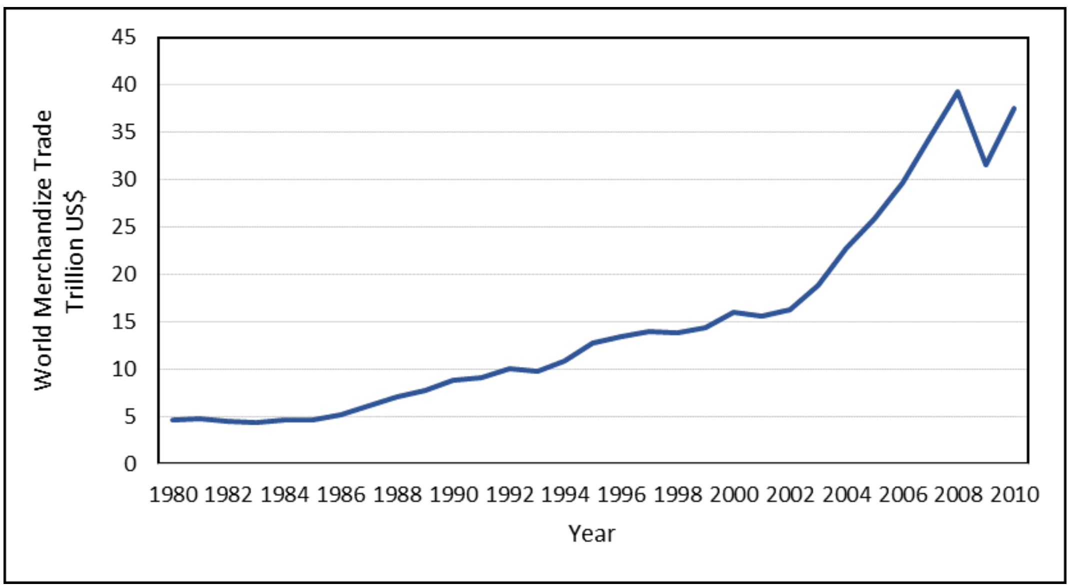
Source: World Development indicators (CD-ROM, 2012)

Between 1980 and 2006, energy consumption has increased but the change of different fuel consumption structure varies by region. Coal has the largest increase in all fuel consumption of the world, accounting for 30.4% of total increase; Asia and Oceania contributed 97.7% of total coal increase between 1980 and 2006. During the same period, natural gas ranks the second in all fuel consumption in total energy consumption, accounting for 28.7%, Asian and Oceania still contributed the largest part, 24% of total gas increase, Eurasia, Europe and Middle East contributed about 17% to 20% by each. Oil was the third fuel in total consumption, accounting for 21.5%. Asia and Oceania still was the biggest contributor; about 67.9% of increase in oil consumption came from this region. The nuclear power has increased by 10.7% of total increase, mainly is contributed by Europe, North America and, Asia and Oceania where more new nuclear reactors have been started. Hydropower has developed in Asia and Oceania and Central and, South America, because of their abundant hydro resources. And these two regions contribute 80% of global hydropower increase. However, global industry sector has reduced its share of total energy use from 33% in 1980 to 27% in 2006 because most developed countries used less energy in industry by improvement in energy efficiency, technology development and major production structure changes.

Growth in world energy consumption reached 5.6% in 2010, the highest growth rate since 1973. Energy consumption in OECD countries grew by 3.5% while non-OECD countries by 7.5% in 2010. Chinese energy consumption grew by 11.2% and China surpassed the United States as the world's largest energy consumer. Oil remains the world's leading fuel in 2010, accounted for 33.6% of global energy consumption. World natural gas consumption grew by 7.4% in 2010, the most rapid increase since 1984. The United States had the world's largest increase in consumption, rising by about 5.6% in 2010. Asian countries also registered large increase of about 10.7%, led by a 21.5% increase in India. Coal consumption grew by 7.6% in 2010, the fastest global growth since 2003. The share of coal in world energy consumption is 29.6%, larger than 25.6% of ten years ago. China consumed 48.2% of world coal and accounted for nearly two-third of global coal consumption. The use of modern renewable energy sources including wind, solar, geothermal, marine, modern biomass and hydro continued to grow rapidly and accounted for 1.8% of world energy consumption in 2010, up from 0.6% in 2000. Energy use in transport sector increased very rapidly during the recent years due to rapid economic development and population growth. Over the past 30 years, energy use in transport sector has doubled. Transport sector accounts for 25% of world energy consumption in 2010 (International Energy Agency, 2012).

The volume of merchandize trade among countries has been rapidly increasing for last two decades due to globalization. Global merchandize trade (exports plus imports of goods) was US$ 3.8 trillion in 1980 but it is amounted to US$ 37 trillion in 2010 (see Figure-2).

Figure-2: World Merchandize Trade



Source: World Development indicators (CD-ROM, 2012)

In 2006, merchandize exports in volume term increased among regions. Exports from North America and Asia grew faster than imports. The growth rate of Asian export was 13% while imports grew by 9%. Europe recorded balanced export and import growth of 7%. For South and Central America, the Commonwealth of Independent States, Africa and the Middle East, import growth was larger than exports. This pattern is linked to more favorable in terms of trade due to increases in commodity prices in the past few years. The global economies faced negative trade shock in 2009. This negative trade shock was mainly due to massive contraction of global demand that reduced commodity prices in all regions of the world. The trade shock was strongest in transition economies and the economies of Western Asia and Africa. However, the similar situation does not exist in 2010. All WTO regions experienced double-digit increase in the dollar value of both exports and imports in 2010 due to rise in prices of fuel and other commodities. The top merchandise exporters in 2010 was China (US$ 1.58 trillion) followed by United States (US$ 1.28 trillion), Germany (US$ 1.27 trillion), Japan (US$ 770 billion) and Netherlands (US$ 572 billion). The leading merchandize importers in 2010 were United States (US$ 1.97 trillion), China (US$ 1.40 trillion), Germany (US$ 1.07 trillion), Japan (US$ 693 billion) and France (US$ 606 billion) (Source: World Trade Report, 2011).

There are few studies that examined the relationship between energy consumption and economic growth (Masih and Masih 1996, Yang 2000, Narayan et al. 2008), energy consumption and exports (Narayan and Smyth 2009, Lean and Smyth 2011, Halicioglu 2010; Shahbaz et al. 2013a). However, the relationship between trade openness and energy consumption is still under studied. The objective of this study is to fill this gap by investigating the relationship between trade openness and energy consumption using global data of 91 high, middle and low-income countries for the period 1980-2010. The pooled mean group and mean group models are used to show non-linear relationship between trade openness and energy consumption. Test for establishing the long-run relationships between variables are carried out by using the panel cointegration approach developed by Larsson et al. (2001) while test for causality is conducting by using a modified version of Granger causality test developed by Hurlin and Venet, (2001).

The rest of the paper is organized as follows: section 2 gives a brief review of empirical studies, section 3 presents the methodology and data source, section 4 presents the results and discussion and section 5 gives the review the conclusion and policy implications.

2. Literature Review

There is an extensive literature available on the relationship between economic growth and energy consumption. Energy consumption is an important factor of production like capital and labor and it affects economic growth. After the end of 1970s energy crisis, many studies (e.g. Kraft and Kraft 1978, Akarca and Long 1979 and 1980, Yu and Choi 1985) exposed that energy consumption is positively correlated with economic growth. However, empirical evidence provided by Zahid (2008), Amirat and Bouri (2010), Noor and Siddiqi (2010), Apergis and Payne (2010) is conflicting about direction of causality. For instance, Nondo and Kahsai (2009) investigated the long-run relationship between total energy consumption and economic growth for a panel of 19 African countries. They applied Levine et al. (2005), Im et al. (2003) and Hadri (2005) panel unit root tests to test the integrating properties of real GDP and total energy consumption. Their analysis indicated that both the variables are cointegrated for long run relationship confirmed by Pedroni (1999) panel cointegration approach. Moreover, they noted that economic growth is cause of energy consumption in long run as well as in short run. Noor and Siddiqi (2010) investigated the causal relationship between per capita energy consumption and per capita GDP in five South Asian countries namely Bangladesh, India, Nepal, Pakistan and

Sri Lanka. They applied panel unit root tests IPS, LLC and MW, and Pedroni cointegration as well as Kao residual cointegration approaches. They reported that energy consumption enhances economic growth. Their causality analysis reveals that economic growth Granger causes energy consumption in South Asian countries[1].

There are few studies investigating the relationship between trade openness and energy consumption. For instance, Cole (2006) examined the relationship between trade liberalization and energy consumption. Cole (2006) used data of 32 countries and found that trade liberalization promotes economic growth which boosts energy demand. Moreover, trade liberalization stimulates capitalization which in results affects energy consumption. Jena and Grote, (2008) investigated the impact of trade openness on energy consumption. They noted that trade openness stimulates industrialization via scale effect, technique effect, composite effect and comparative advantages effect which affect energy consumption. Narayan and Smith (2009) examined the causal relationship between energy consumption and economic growth by incorporating exports as an indicator of trade openness in production function for a panel of six Middle Eastern countries namely Iran, Israel, Kuwait, Oman Saudi Arabia and Syria. They applied panel unit root test, panel cointegration and panel causality tests. Their analysis confirmed the presence of cointegration relationship between variables. Furthermore, they reported that that a short-run Granger causality exists running from energy consumption to real GDP and from economic growth to exports but neutral effect is found between exports and energy consumption.

[1] Payne, (2010) and Ozturk, (2010) presented comprehensive survey studies on the relationship between economic growth and energy consumption.

Later on, Sadorsky (2011) examined the causal relationship between total energy consumption and trade openness. The panel means group cointegration and panel Granger causality approaches for the panel of 8 Middle Eastern countries namely, Bahrain, Iran, Jordan, Oman, Qatar, Saudi Arabia, Syria and UAE. The empirical evidence reported that that long run relationship exists between the variables. Sadorsky found that that 1 percentage increase in real per capita GDP increases per capita energy consumption by 0.62%. A 1% increase in real per capita exports increases per capita energy consumption by 0.11% while 1% increases in real per capita imports increases per capita energy consumption by 0.04%. Panel Granger causality analysis revealed that exports Granger cause energy consumption and the feedback is found between imports and energy consumption in short run. Similarly, the bidirectional causality exists between GDP and energy consumption in short run. Sadorsky (2012) used production function to investigate the relationship between trade openness and energy consumption in South American countries namely Argentina, Brazil, Chile, Ecuador, Paraguay, Peru, and Uruguay over the period of 1980-2007. The panel cointegration developed by Pedroni (2004), fully modified ordinary least squares (FMOLS) and the VECM Granger causality approaches were applied. The empirical evidence confirmed the presence of cointegration for long run relationship between the variables. The relationship between exports and energy consumption is bidirectional and imports Granger causes energy consumption in short run. Using data of 52 developed and developing economies, Ghani (2012) explored relationship between trade liberalization and energy demand. The results indicated that trade liberalization has insignificant impact on energy consumption but after a certain level of capital per labor, trade liberalization affects energy consumption.

Hossain, (2012) examined the relationship between electricity consumption and exports by adding foreign remittances and economic growth as additional determinants in SAARC countries namely Pakistan, India and Bangladesh. The author reported the no causality between exports and electricity demand. Dedeoğlu and Kaya, (2013) investigated the relationship between exports, imports and energy consumption by incorporating economic growth as additional determinant of trade openness and energy consumption using data of the OECD countries. They applied the panel cointegration technique developed Pedroni, (2004) and use the Granger causality developed by Canning and Pedroni (2008). Their analysis showed the cointegration between the variables. They also noted that economic growth, exports and imports have positive impact on energy consumption. Their causality analysis revealed that the relationship between exports (imports) and energy consumption is bidirectional.

3. Estimation Strategy

Panel unit roots

We apply Levine et al. 2002 (LLC), Im et al. 2003 (IPS), Maddala and Wu, (1999) (MW, ADF) and Maddala and Wu, (1999) (MW, PP) panel unit root tests to check the stationarity properties of the variables. These tests apply to a balanced panel but the LLC can be considered a pooled panel unit root test, IPS represents as a heterogeneous panel test and MW panel unit root test is non-parametric test.

3.1. LLC Unit Root Test

Levin et al. (2002) developed a number of pooled panel unit root tests with various specifications depending upon the treatment of the individual specific intercepts and time trends. This test imposes homogeneity on the autoregressive coefficient that indicates the presence or absence of unit root problem while the intercept and the trend can vary across individual series. LLC unit root test follows ADF regression for the investigation of unit root hypothesis as given below step by step:

1. Implement a separate ADF regression for each country:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{it-1} + \sum_{j=1}^{p_i} \alpha_{i,j} \Delta y_{i,t-j} + \varepsilon_{i,t} \qquad (1)$$

The lag order p_i is allowable to across individual countries. The appropriate lag length is chosen by allowing the maximum lag order and then uses the t-statistics for *ij b* to determine if a smaller lag order is preferred.

2. Run two separate regressions and save the residuals $\tilde{\eta}_{it}, \tilde{\mu}_{i,t-1}$

$$\Delta y_{i,t} = \lambda_i + \sum_{j=1}^{p_i} \gamma_{i,t-j} \Delta y_{i,t-j} + \eta_{i,t} \Rightarrow \tilde{\eta}_{it} \qquad (2)$$

$$y_{i,t-1} = \partial_i + \sum_{j=1}^{p_i} \ell_{i,t-j} \Delta y_{i,t-j} + \mu_{i,t-1} \Rightarrow \tilde{\mu}_{i,t-1} \qquad (3)$$

LLC procedure suggests standardized the errors $\tilde{\eta}_{it}, \tilde{\mu}_{i,t-1}$ by the regressing the standard error the ADF equation provided above:

$$\tilde{\eta}_{it} = \frac{\tilde{\eta}_{it}}{\hat{\sigma}_{\varepsilon i}}, \tilde{\eta}_{it-1} = \frac{\tilde{\eta}_{i,t-1}}{\hat{\sigma}_{\varepsilon i}} \qquad (4)$$

3. Regression can be run to compute the panel test statistics following equation-5:

$$\tilde{\eta}_{it} = \alpha \tilde{\eta}_{i,t-1} + \nu_{i,t} \qquad (5)$$

The null hypothesis is as follows: $H_{\circ} : \rho_1,.. = ...\rho_n = \rho = 0$ and alternate hypothesis is

$H_A : \rho = ...\rho_n = \rho < 0$.

3.2. IPS Unit Root Test

Im, Pesaran and Shin (IPS), (2003) introduced a panel unit root test in the context of a heterogeneous panel. This test basically applies the ADF test to individual series thus allowing each series to have its own short-run dynamics. But the overall t-test statistic is based on the arithmetic mean of all individual countries' ADF statistic. Suppose a series (TR_{ti}, EC_{ti}) can be represented by the ADF (without trend).

$$\Delta x_{i,t} = \varpi_j + \varpi_i x_{i,t-1} + \sum_{j=1}^{p_i} \phi_{i,j} \Delta x_{i,t-j} + \nu_{i,t} \qquad (6)$$

After the ADF regression has different augmentation lags for each country in finite samples, the term $E(t_T)$ and $\text{var}(t_T)$ are replaced by the corresponding group averages of the tabulated values of $E(t_T, P_i)$ and $\text{var}(t_T, P_i)$ respectively. The IPS test allows for the heterogeneity in the value ϖ_i under the alternative hypothesis. This is more efficient and powerful test than usual single time series test. The estimable equation of IPS unit root test is modeled as following:

$$t_{NT} = \frac{I}{N}\sum_{i=1}^{N} t_{i,t}(P_i) \qquad (7)$$

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:

$$\mathrm{A}_{\bar{t}} = \frac{\sqrt{N(T)}[\bar{t}_T - E(t_T)}{\sqrt{\operatorname{var}(t_T)}} \qquad (8)$$

As t_{NT} 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. When the ADF has different augmentation lags (P_i) the two terms $E(t_T)$ and $\operatorname{var}(t_T)$ in the equation above are replaced by corresponding group averages of the tabulated values of $E(t_T, P_i)$ and $\operatorname{var}(t_T, P_i)$ respectively[2].

[2] Karlsson and Lothgren, (2000) demonstrate the power of panel unit root tests by Monte Carlo simulation. The null of all these tests is that each series contains a unit root and thus is difference stationary. However, the alternative hypothesis is not clearly specified. In LLC the alternative is that all individual series in the panel are stationary. In IPS the alternative is that at least one of the individual series in the panel is stationary. They conclude that the "presence or absence of power against the alternative where a subset of the series is stationary has a serious implications for empirical work. If the tests have high power, a rejection of the unit root null can be driven by few stationary series and the whole panel may inaccurately be modelled as stationary. If, on other hand, the tests have low power it may incorrectly concluded that the panel contains a common unit root even if a majority of the series is stationary'' (p. 254). The simulation results reveal that the power of the tests (LLC, IPS) increases monotonically with: (1) an increased number (N) of the series in the panel; (2) an increased time series dimension (T) in each individual series; (3) increased proportion of stationary series in the panel. Their Monte Carlo simulations for N = 13 and T = 80 reveal the power of the test is 0.7 for LLC tests and approaching unity for the IPS tests.

3.3. MW Unit Root Test

The Fisher-type was developed by Maddala and Wu, (1999) which pools the probability values obtained from unit root tests for every cross-section *i*. This is a non-parametric test and has a chi-square distribution with 2nd degree of freedom where *n* is number of countries in a panel. The test statistic is given by:

$$\lambda = -2\sum_{i=1}^{n}\log_e(p_i) \sim \chi^2_{2n}(d.f.) \qquad (9)$$

Where, p_i is probability value from ADF unit root tests for unit *i*. The MW unit root test is superior to IPS unit root test because MW unit root test is sensitive with lag length selection in individual ADF regressions. Maddala and Wu, (1999) performed Monte Caro simulations to prove that their test is more advanced than the test developed by IPS (2003).

3.4. The Likelihood-based Panel Cointegration Test

The panel LLL trace test statistics is actually derived from the average of individual likelihood ratio cointegration rank trace test statistics from the panel individuals. The multivariate cointegration trace test of Johanson (1988, 1995) is engaged to investigate each individual cross-section system autonomously, in that way, allowing heterogeneity in each cross-sectional unit root for said panel. The process of data generation for each of the groups is characterized by following heterogeneous VAR (p_i) model:

$$Y_{i,t} = \sum_{j=1}^{p_i} \Lambda_{i,j} Y_{i,t-j} + \varepsilon_{i,t} \qquad (10)$$

Where $i = 1,......, N; t = 1,.......T$

For each one, the value of $Y_{i,-j+1},......Y_{i,0}$ is considered fixed and $\varepsilon_{i,t}$ are independent and identically distributed (normally distributed): $\varepsilon \sim N_K(0, \Omega_i)$, where Ω_i is the cross-correlation matrix in the error terms: $\Omega_i = E(\varepsilon_{i,t}, \varepsilon_{i,t}^{'})$. The equation-10 can be modified in vector error correction model (VECM) model as given below:

$$\Delta Y_{i,t} = \Pi_i Y_{i,t-1} + \sum_{j=1}^{p_i - 1} \Gamma_{i,j} \Delta Y_{i,t-j} + \varepsilon_{i,j} \qquad (11)$$

Where $\Pi_i = \Lambda_{i,1} + ... + \Lambda_{pi} - 1$ and $\Gamma_{i,j} = \Lambda_{i,j} - \Lambda_{i,j-1}, \Pi_i$ is of order $(k \times k)$. If Π_i is of reduced rank: rank $(\Pi_i) = r_i$, which can be de-composed into $\Pi_i = ab^{'}$, where α_i and β_i are of order $(k \times r_i)$ and of full rank column rank that represents the error correction form. The null hypotheses of panel LLL (2001) rank test are:

$$H_{\circ} = rank(\Pi_i) = r_i \leq r \quad \text{for all } i = 1,....., N \text{ against}$$

$$H_a = rank(\Pi_i) = k \qquad \text{for all } i = 1,....., N$$

The procedure is in sequences like individual trace test process for cointegration rank determination. First, we test for $H_{\circ} = rank(\Pi_i) = r_i \leq r, r = 0$, if null hypothesis of no cointegration is accepted, this shows that there is no cointegration relationship

$(rank(\Pi_i) = r_i = 0)$ in all cross-sectional groups for said panel. If null hypothesis is not accepted then null hypothesis $r = 1$ is tested. The sequence of procedure is not disconnected and continued until null hypothesis is accepted, $r = k - 1$, is rejected. Accepting the hypothesis of cointegration $r = 0$ along with null hypothesis of rank $(\Pi_i) = r \leq 0(0 < r < k)$ implies that there is at least one cross-sectional unit in panel which has rank$(\Pi_i) = r > 0$. The likelihood ratio trace test statistic for group *i* is as following;

$$LR_{iT}\{H(r)/H(k) = -2\ln Q_{iT}(H(r)/H(k) = -T\sum_{l=r+1}^{p}\ln(1-\lambda_{li}^{'}) \qquad (12)$$

Where $\lambda_l^{'}$ is the l^{th} largest eigen value in the i^{th} cross-section unit. The LR-bar statistic is calculated as the average of individual trace statistics:

$$L\bar{R}_{iT}[H(r)/H(k)] = \frac{1}{N}\sum_{i=1}^{n}LR_{iT}[H(r)/H(k)] \qquad (13)$$

Finally, modified version of above equation is defined as:

$$\lambda_{L\bar{R}}[H(r)/H(k) = \frac{\sqrt{N}(L\bar{R}_{NT}[H(r)/H(k)] - E(Z_k))}{\sqrt{VAR(Z_k)}} \qquad (14)$$

Where $E(Z_k)$ and $Var(Z_k)$ are mean and variance of the asymptotic trace statistics, which can be obtained from simulation. The LLL (2001) prove the central limit theorem for the standard

LR-bar statistic that under the null hypothesis, $\lambda_{L\bar{R}} \Rightarrow N(0,1)$ as N and $T \to \infty$ in such a way that $\sqrt{NT}^{-1} \to 0,$ under the assumption that there is no cross-correlation in the error terms, that is give below:

$$E(\varepsilon_{i,t)} = 0 \text{ and } E(\varepsilon_{i,t}, \varepsilon_{j,t}) = \begin{cases} \Omega_i \\ 0 \end{cases} \text{for } i = j, i \neq j$$

LLL (2001) note that $T \to \infty$ is needed for each of the individual test statistic to converge to its asymptotic distribution, while $N \to \infty$ is needed for the central limit theorem.

3.5. Panel Causality Test

Hurlin and Venet, (2001) extended the Granger (1969) causality test for panel data models with fixed coefficients. The estimable equation for empirical estimation is modeled as following:

$$y_{i,t} = \sum_{K=1}^{P} \gamma^{(K)} y_{i,t-K} + \sum_{K=0}^{P} \beta_i^{(K)} x_{i,t-K} + v_{i,t} \tag{15}$$

With $P \in N^*$ and $v_{i,t} = \partial_i + \varepsilon_{i,t}$, where $\varepsilon_{i,t}$ are *i.i.d* $(O, \sigma^2_\varepsilon)$. In contrast to Nair–Reichert and Weinhold (2001), assume that the autoregressive coefficients $\gamma^{(k)}$ and the regression coefficients slopes $\beta_i^{(k)}$ are constant $\Omega k \varepsilon [1, p]$. Also assume that parameters $\gamma^{(k)}$ are identical for all individuals, whereas the regression coefficients slopes $\beta_i^{(K)}$ could have an individual dimension. Hurlin and Venet (2001), consider four principal cases following equation-15:

3.6. Homogenous Non-Causality Test

Initially the homogenous non-causality (HNC) hypothesis has been discussed. Conditionally to the specific error components of the model, this hypothesis assumes no prevalence of any individual causality association:

$$\forall i \in [1, N] \; E\left(y_{i,t} / \overline{y}_{i,t}, \alpha_i\right) = E\left(y_{i,t} / \overline{y}_{i,t}, \overline{x}_{i,t}, \alpha_i\right) \quad (16)$$

In equation-15, the corresponding test[3] is defined by:

$$H_o : \beta_i^{(K)} = 0 \;\; \forall_i \in [1, N], \forall k \in (1, p) \quad (17)$$

$$H_a : \exists (i, k) / \beta_i^{(K)} \neq 0$$

In order to test these N_p linear restrictions, for this Wald Statistic employed:

$$F_{hnc} = \frac{(RSS_2 - RSS_1)/(Np)}{RSS_1 / [NT - N(1+p) - p]} \quad (18)$$

Where, RSS_2 indicates the restricted sum of squared residual obtained under H_0 and RSS_1 corresponds to the residual sum of squares of equation-15. If the realization of this statistic is not significant, the homogeneous non-causality hypothesis is accepted. This result implies that the variable X is not causing Y in finite sample set in all countries. The non-causality result is then totally homogenous that stops for further empirical exercise.

[3] Here, we do not consider instantaneous non-causality hypothesis.

3.7. Homogenous Causality Test

Secondly, homogenous causality (HC) hypothesis takes place, in which there exist N causality relationships:

$$\forall i \in [1, N] \ E\left(y_{i,t} / \overline{y}_{i,t}, \alpha_i\right) \neq E\left(y_{i,t} / \overline{y}_{i,t}, \overline{x}_{i,t}, \alpha_i\right) \quad (19)$$

In this case, suppose that the N individual predictors, obtained conditionally to $\overline{Y}_{i,t}, \overline{X}_{i,t}$ and α_i, are the same:

$$\forall (i, j) \in [1, N] \ E\left(y_{i,t} / \overline{y}_{i,t}, \overline{x}_{i,t}, \alpha_i\right) = E\left(y_{i,t} / \overline{y}_{j,t}, \overline{x}_{j,t}, \alpha_j\right) \quad (20)$$

Two configurations could appear, if we reject hypothesis of non-homogenous causality. The first one corresponds to the overall causality hypothesis (homogenous causality hypothesis) and occurs if all the coefficients β_i^K are identical for all *k*. The second one, who is the more plausible, is that some coefficients β_i^K are different for each individual. Thus, after the rejection of the null hypothesis of non homogenous causality, the second step of the procedure consists in testing if the regression slope coefficients associated to $x_{i,t-k}$ be identical. This test corresponds to a standard homogeneity test. Formally, the homogenous causality hypothesis test is as following:

$$H_o : \forall k \in [1, p] \ / \beta_i^k = \beta^k \ \forall i \in [1, N] \quad (21)$$

$$H_a : \exists k \in [1, p], \exists (i, j) \in [1, N] / \beta_i^k \neq \beta_j^k$$

The homogenous causality hypothesis implies that the coefficients of the lagged explanatory variable $x_{i,t-k}$ are identical for each lag k and different from zero. Indeed, if we have rejected, in the previous step, the non-homogenous causality hypothesis $\beta_i^K = 0 \ \forall(i,k)$, this standard specification test allows testing the homogenous causality hypothesis. In order to test the homogenous causality hypothesis, F-statistic is calculated by applying the given mechanism:

$$F_{hc} = \frac{(RSS_3 - RSS_1)/[p(N-1)}{RSS_1 / [NT - N(1+p) - p]} \tag{22}$$

where, RSS_3 corresponds to the realization of the residual sum of squares obtained in equation-15 when one imposes the homogeneity for each lag k of the coefficients associated to the variable $x_{i,t-k}$. If the F_{hc} statistics with $P(N-1)$ and $NT - N(1+P) - P$ degrees of freedom is not significant, the homogenous causality hypothesis is accepted. This result implies that the variable X is causing Y in the N countries of the samples, and that the autoregressive processes are completely homogenous.

3.8. Heterogeneous Causality Test

Third case is relevant to the heterogeneous causality hypothesis. Under HEC hypothesis, it is assumed that it exists at least one individual causality relationship (and at the most N), and second that individual predictors, obtained conditionally to $\overline{y}_{i,t}, \overline{x}_{i,t}, \overline{\lambda}_t$ and, α_i are heterogeneous.

$$\exists i \in [1,N] \ \ E(y_{i,t} / \overline{y}_{i,t}, \alpha_i) \neq E(y_{i,t} / \overline{y}_{i,t}, \overline{x}_{i,t}, \alpha_i) \tag{23}$$

$$\exists(i,\, j)\ \in[1, N]\, E(y_{i,t}\ /\ \overline{y}_{i,t}, \overline{x}_{i,t}, \alpha_i) \neq E(y_{j,t}\ /\ \overline{y}_{j,t}, \overline{x}_{j,t}, \alpha_j) \qquad (24)$$

3.9. Heterogeneous Non-causality Test

Finally, heterogeneous non- causality hypothesis assumes that there exists at least one and at the most N−1 equalities of the form:

$$\exists i \in[1, N]\ \ E(y_{i,t}\ /\ \overline{y}_{i,t}, \alpha_i) = E(y_{i,t}\ /\ \overline{y}_{i,t}, \overline{x}_{i,t}, \alpha_i) \qquad (25)$$

The third step of the procedure consists in testing the heterogeneous non-causality hypothesis (HENC). In doing so, the mechanism is given below:

$$H_o : \exists i \in[1, N]\ /\ \forall k \in[1, p]\ \beta_i^K = 0 \qquad (26)$$

$$H_a : \forall i\ \varepsilon\, [1, N], \exists k\ \varepsilon\, [1, N]\ /\ \beta_i^K \neq 0$$

This test is proposed to test this last hypothesis with two nested tests. The first test is an individual test realized for each individual. For each individual i = 1… N, test the nullity of all the coefficients of the lagged explanatory variable $x_{i,t-k}$. Then, for each i, test the hypothesis $\beta_i^K = 0, \forall k \in[1, p]$. For that, compute N statistics:

$$F_{hene}^{i} = \frac{(RSS_{2,i} - RSS_1)\ /\ p}{RSS_1\ /\left[NT - N(1+2p) + p\right]} \qquad (27)$$

where, $RSS_{2,i}$ corresponds to the realization of the residual sum of squares obtained in model (15), when one imposes the nullity of the *k* coefficients associated to the variable $x_{i,t-k}$ only for the individual *i*. A second test of the procedure consists in testing the joint hypothesis that there is no causality relationship for a sub-group of individuals. Let us respectively denote I_c and I_{nc} the index sets corresponding to sub-groups for which there exists a causal relationship and there does not exist a causal relationship. In other words, we consider the following model $\forall t \in [1, T]$:

$$y_{i,t} = \sum_{k=1}^{p} \gamma_i^k y_{i,t-k} + \sum_{K=0}^{p} \beta_i^k x_{i,t-k} + v_{i,t} \qquad (28)$$

with

$$\beta_i^K \neq 0 \;\; for\; i \in \; I_c$$
$$\beta_i^K = 0 \;\; for\; i \in \; I_{nc}$$

Let $n_c = \dim(I_c)$ and $n_{nc}=\dim(I_{nc})$. Suppose that $n_c/n_{nc} \rightarrow \theta < \infty$ as n_c and n_{nc} tend to infinity. One solution to test the HENC hypothesis is to compute the Wald statistic.

$$F_{henc} = \frac{(RSS_4 - RSS_1)/(n_{nc}\, p)}{RSS_1 / \left[NT - N(1+p) - n_c\, p\right]} \qquad (29)$$

where RSS_4 corresponds to realization of the residual sum of squares obtained from equation-15 when one imposes the nullity of the *k* coefficients associated to the variable $x_{i,t-k}$ for the n_{nc} individuals of the I_{nc} sub-group. If the HENC hypothesis is accepted, it implies that there exists a sub-group of individual for which the variable *x* does not cause the variable *y*. The dimension of this sub-group is then equal to n_{nc}. On the contrary, if the HENC hypothesis is rejected, it implies that there exists a causality between *x* and *y* for all individual of the panel.

3.10 Data and Data Sources

The 91 countries are selected for the estimation of causality between energy consumption and trade openness on the basis of data availability[4]. The study covers the period 1980-2010. All necessary data for the sample period are obtained from World development Indicators (CD-ROM, 2012). Energy consumption in kg of oil equivalent per capita is used to measure energy consumption, real export (US$) plus real imports (US$) divided by population is measure trade openness. Both variables are used in their natural logarithmic form.

4. Empirical Results and their Discussions

The results of ADF unit root test in the presence of intercept and, intercept and trend reported in Table-1 suggest that all the series are non-stationary at their level form, but stationary at first difference. This implies that real trade per capita (TR_t) and energy consumption per capita (EC_t) are integrated at I(1) for each country in our sample.

Table-1: ADF Unit Root Test

Country/ Variable	Level		1st Difference		Country /Variable	Level		1st Difference	
	Intercept	Trend & Intercept	Intercept	Trend & Intercept		Intercept	Trend & Intercept	Intercept	Trend & Intercept
Algeria					**Angola**				
TR_t	0.4189	-0.8701	-3.8052**	-5.1733*	TR_t	1.5123	-0.5634	-3.5182**	-4.5661*
EC_t	-0.6407	-1.4528	-5.8948*	-5.2814*	EC_t	-1.6214	-1.5625	-3.2417**	-5.9735*
Argentina					**Australia**				
TR_t	-1.0531	-3.0792	-5.2571*	-5.0271*	TR_t	0.3937	-2.6913	-4.3756*	-4.5020*

[4] The selection of countries is restricted with availability of data. The names of countries are listed in appendix-A

EC_t	-0.8932	-2.8109	-3.6245**	-3.6308**	EC_t	0.1996	-2.7783	-4.1198*	-4.2963**
Austria					**Albania**				
TR_t	-0.5524	-2.4505	-3.2985**	-3.5066***	TR_t	-0.7642	-1.6930	-4.4905*	-4.9971*
EC_t	-0.1863	-2.5139	-4.6619*	-4.4885*	EC_t	-1.5043	-1.2434	-3.0995**	-3.2659***
Bangladesh					**Belgium**				
TR_t	0.6132	-3.0994	-3.9199*	-3.9065**	TR_t	-0.5282	-2.2922	-3.0316**	-3.5863***
EC_t	1.0205	-2.3929	-4.6232*	-5.1651*	EC_t	-1.9601	-2.6871	-3.5797**	-3.5434***
Benin					**Bolivia**				
TR_t	-0.3299	-2.3450	-4.9286*	-5.0471*	TR_t	0.2859	-1.3079	-2.9710***	-4.3259**
EC_t	-1.9601	-2.6871	-3.5797**	-3.5434***	EC_t	-1.4582	-2.1065	-3.5069**	-3.4382***
Botswana					**Brazil**				
TR_t	-1.4420	-2.4192	-3.9853*	-4.0636**	TR_t	1.1870	-2.1045	-4.5757*	-4.8461*
EC_t	-1.0734	-1.3623	-3.0628**	-5.6302*	EC_t	-0.9027	-2.4494	-3.1364**	-3.7495**
Brunei Darussalam					**Bulgaria**				
TR_t	-0.3508	-1.4825	-3.6958**	-5.7109*	TR_t	-0.4585	-0.4585	-2.7263***	-4.3906**
EC_t	-1.9429	-3.1187	-3.7129**	-3.6122***	EC_t	-1.3805	-2.2254	-3.3030**	-3.9770**
Canada					**China**				
TR_t	-1.9408	-2.4400	-4.9088*	-5.2583*	TR_t	0.1074	-2.1102	-4.8452*	-4.8994*
EC_t	-2.0028	-3.1663	-3.7820*	-3.7348**	EC_t	0.6452	-2.0721	-2.9494**	-3.2235***
Chili					**Congo Dem Rep**				
TR_t	-0.7908	-2.4845	-5.5118*	-5.3639*	TR_t	-2.5579	-2.8169	-3.9579*	-3.8466**
EC_t	0.3533	-2.8041	-2.9216***	-4.6043*	EC_t	-0.6483	-1.9564	-4.2579*	-4.1745**
Colombia					**Costa Rica**				
TR_t	-0.0635	-2.6416	-3.1969**	-4.5686*	TR_t	-0.2737	-2.3264	-3.6127**	-3.5250***
EC_t	-1.1615	-1.4324	-4.8072*	-4.8553*	EC_t	-0.2865	-0.3390	-3.2568**	-3.8902**
Congo Rep					**Cameroon**				
TR_t	-1.5302	-2.7516	-3.9847*	-3.8813**	TR_t	-1.5618	-2.9541	-2.7506***	-5.6762*
EC_t	-1.2094	-0.5212	-3.2900**	-3.4620***	EC_t	-1.0496	-1.0088	-3.6118**	-4.1561**
Cote D'Ivoire					**Cyprus**				
TR_t	0.2225	-1.9929	-3.6169**	-3.8302**	TR_t	-0.4131	-1.6628	-3.3912**	-3.3175***
EC_t	-0.9567	-1.7444	-3.9964*	-4.8263*	EC_t	-1.5058	-0.5346	-3.3796**	-3.8715**
Cuba					**Dominican Rep**				
TR_t	-1.8938	-1.6057	-2.7562***	-3.9406**	TR_t	-0.5985	-2.1949	-5.3140*	-5.2511*
EC_t	-1.4306	-2.8859	-2.9979**	-2.9527***	EC_t	-0.9124	-1.6794	-3.9453*	-3.8494**
Denmark					**Egypt**				
TR_t	-0.0910	-2.3117	-3.2089**	-3.5203***	TR_t	0.5745	-2.7622	-2.7713***	-3.6586**
EC_t	-2.0518	-2.7916	-3.7190**	-3.6570**	EC_t	-1.0024	-2.4033	-3.5517**	-3.3564***
Ecuador					**Ethiopia**				

TR_t	0.7030	-2.0413	-3.4003**	-3.9494**	TR_t	-0.0839	-1.2336	-4.3298*	-4.6814*
EC_t	-0.1665	-1.1361	-3.3996**	-4.2587**	EC_t	-1.4764	-1.9549	-3.2659**	-3.8596**
El Salvador					**France**				
TR_t	-0.0745	-2.2870	-3.4843**	-3.3700***	TR_t	-0.4312	-2.3780	-3.2569**	-3.6901**
EC_t	-0.0416	-1.7824	-2.8539***	-3.7315**	EC_t	-1.3933	-1.7466	-4.2313*	-4.6509*
Finland					**Ghana**				
TR_t	-0.6923	-2.7347	-3.7078**	-3.5774***	TR_t	-1.7857	-1.5640	-5.0802*	-5.4612*
EC_t	-2.3395	-2.7686	-4.3644*	-4.1951**	EC_t	-1.0468	-1.0777	-4.1390*	-4.2675**
Gabon					**Guatemala**				
TR_t	-0.9361	-2.7341	-3.9640*	-4.2463**	TR_t	0.7712	-3.0441	-3.3703**	-3.6195**
EC_t	-2.2723	-1.0959	-3.5525**	-4.5870*	EC_t	-1.3829	-2.0519	-3.3144**	-3.4552***
Greece					**Honduras**				
TR_t	0.5889	-2.8057	-3.5020**	-3.6567**	TR_t	-2.0091	-3.1213	-3.8804*	-4.4064*
EC_t	-1.8250	-2.0913	-4.5134*	-5.0303*	EC_t	-1.0752	-2.0968	-4.1316*	-4.7148*
Hong Kong Sar China					**Hungary**				
TR_t	-1.1785	-1.3189	-2.6850***	-3.8314**	TR_t	1.7100	-1.6508	-3.2192**	-4.3836**
EC_t	-2.2905	-2.1313	-4.1514*	-4.6741*	EC_t	-1.5879	-1.6464	-4.2076*	-4.1344**
Iceland					**India**				
TR_t	-0.0669	-2.9149	-3.9574*	-3.6995**	TR_t	1.8877	-0.6580	-3.0276**	-3.8732**
EC_t	1.3877	-1.0638	-2.6858***	-4.4322*	EC_t	-0.0584	-2.1698	-3.4824**	-3.3593***
Indonesia					**Iran**				
TR_t	0.2339	-2.9163	-3.0756**	-3.2696***	TR_t	-1.8514	-3.1574	-3.9574*	-3.8381**
EC_t	-0.8880	-1.1027	-3.0141**	-5.4069*	EC_t	-1.7349	-2.6435	-4.8904*	-4.8000*
Ireland					**Israel**				
TR_t	-0.3663	-2.9986	-3.4761*	-4.3522**	TR_t	0.2725	-3.0813	-4.7457*	-4.6242*
EC_t	-0.7152	-1.7686	-2.8905***	-3.9752**	EC_t	-1.3830	-1.3627	-2.6706***	-3.9254**
Italy					**Jamaica**				
TR_t	-0.4589	-2.1827	-3.0526**	-3.6232**	TR_t	-0.9943	-1.0985	-3.0749**	-3.3349***
EC_t	-0.6640	-0.6640	-3.7542*	-3.5772***	EC_t	-0.5598	-2.9249	-2.9871***	-3.9866**
Japan					**Jordan**				
TR_t	-0.5783	-1.5631	-3.7380*	-3.7787**	TR_t	1.6131	-1.0977	-3.5064**	-4.1582**
EC_t	-1.5272	-0.7059	-2.9823***	-3.4728**	EC_t	-1.6982	-2.4034	-3.9477*	-3.7925**
Kenya					**South Korea**				
TR_t	0.9276	-2.3376	-3.6645**	-4.5061*	TR_t	-0.4298	-2.3466	-3.7693*	-3.7279**
EC_t	-1.8363	-3.0614	-3.3529**	-3.3313***	EC_t	-1.1716	-1.7710	-3.3229**	-3.2994***
Kuwait					**Morocco**				
TR_t	-0.9690	-2.0366	-4.6979*	-5.2502*	TR_t	-0.9696	-2.0819	-4.3410*	-4.1784**
EC_t	-2.3481	0.4619	-4.8638*	-5.8653*	EC_t	-0.9635	-2.1519	-5.0387*	-5.2066*

Luxembourg					**Nepal**				
TR_t	-0.2836	-2.2064	-4.9548*	-4.8930*	TR_t	-2.3691	-1.8741	-3.7489*	-4.3319*
EC_t	-2.3473	-2.3293	-4.0122*	-5.6876*	EC_t	0.4621	-1.3866	-3.7507*	-4.3404*
Mexico					**Mozambique**				
TR_t	0.2913	-2.4058	-3.8353*	-3.8029**	TR_t	0.3713	-0.5526	-3.1407**	-3.3170***
EC_t	0.2726	-1.6751	-4.5094*	-5.8401*	EC_t	-2.2439	-1.5365	-3.5940**	-3.7322**
Netherland The					**New Zealand**				
TR_t	-1.4168	-3.2000	-3.8649*	-3.9471**	TR_t	-1.0605	-2.9833	-5.2135*	-5.1376*
EC_t	-2.4361	-2.8255	-5.0101*	-4.9431*	EC_t	-1.7181	-0.4779	-3.0886**	-3.3346***
Nicaragua					**Nigeria 62**				
TR_t	-0.4710	-1.1263	-3.3732**	-3.3756***	TR_t	-0.1775	-2.4375	-3.5531**	-3.9467**
EC_t	-1.5720	-1.9819	-4.6927*	-4.9537*	EC_t	-1.7124	-2.4091	-4.8954*	-4.7717*
Norway					**Oman**				
TR_t	-1.1537	-2.6473	-4.9267*	-4.7619*	TR_t	0.5709	-1.9620	-4.7076*	-5.4118*
EC_t	-1.4857	-2.6535	-3.7932*	-3.6945**	EC_t	-1.6655	-1.1611	-3.2912**	-3.8308**
Pakistan					**Panama**				
TR_t	-0.8509	-1.5699	-3.6078**	-3.7826**	TR_t	-0.0274	-2.9196	-3.6502**	-3.7050**
EC_t	-0.7991	-1.2641	-3.6304**	-3.6256**	EC_t	-1.4526	-2.1700	-3.5667**	-3.5796***
Paraguay					**Peru**				
TR_t	-1.0733	-1.8795	-3.3666**	-3.2948***	TR_t	0.9379	-1.2987	-4.1376*	-4.8637*
EC_t	-1.9243	-1.5327	-3.4150**	-3.5757***	EC_t	-2.4168	-1.6216	-3.0831**	-3.8628**
Philippines					**Portugal**				
TR_t	0.0850	-2.4948	-2.9139***	-4.0941**	TR_t	-0.9716	-1.9043	-3.1984**	-3.7547**
EC_t	-1.0685	-0.8958	-2.7434***	-5.7293*	EC_t	-1.4205	-0.5693	-3.0971**	-3.4068***
Senegal					**Saudi Arabia**				
TR_t	0.3681	-1.9134	-3.9852*	-4.0835**	TR_t	-1.1196	-3.0603	-2.9303***	-3.8555**
EC_t	-2.0357	-1.7417	-3.7402*	-4.0870**	EC_t	-0.4166	-2.4292	-4.3369*	-4.4657*
Sweden					**South Africa**				
TR_t	-0.2027	-3.2173	-3.6094**	-3.5278***	TR_t	-0.1611	-2.2382	-3.3540**	-3.5337***
EC_t	-2.3509	-2.2029	-3.7852*	-4.1207**	EC_t	-2.4185	-2.7120	-3.9703*	-3.8643**
Spain					**Switzerland**				
TR_t	-2.6228	-2.9807	-2.9065***	-3.9750**	TR_t	-0.5370	-2.1945	-3.0437**	-3.6199**
EC_t	0.3351	-2.5762	-3.3364**	-3.6564**	EC_t	-2.1958	-2.3868	-3.8958*	-4.1728**
Sudan					**Thailand**				
TR_t	0.9521	-0.2051	-2.6364***	-3.7561**	TR_t	-0.6347	-1.8510	-2.9256***	-3.8709**
EC_t	0.0171	-1.6685	-4.6910*	-5.0355*	EC_t	-0.6523	-2.1115	-2.9460***	-3.2717***
Syrian Arab Rep					**Trinidad and Tobago**				
TR_t	0.7897	-2.2773	-3.2714**	-3.7719**	TR_t	1.0311	-0.9596	-2.8083**	-4.8930*

EC_t	-1.3196	-0.1094	-3.9862*	-4.2562**	EC_t	1.4450	-0.9133	-3.1422**	-3.4384***
Togo					**Turkey**				
TR_t	-1.6974	-2.0971	-3.2771**	-3.4455***	TR_t	-0.4813	-3.1314	-4.9825*	-4.7570*
EC_t	-0.6940	-2.2815	-3.7204**	-3.6245**	EC_t	-1.0464	-2.1727	-3.6186**	-3.5759***
Tunisia					**United Arab Emirates**				
TR_t	0.2968	-2.9650	-2.6946***	-3.8919**	TR_t	1.1937	-2.0504	-2.7599***	-3.7995**
EC_t	-0.0885	-2.2401	-3.8989*	-3.6826**	EC_t	-2.4012	-1.6495	-3.6501**	-4.0875**
United Kingdom					**United States**				
TR_t	0.2412	-3.2119	-2.7876***	-3.2986***	TR_t	-0.5591	-2.7876	-4.2063*	-3.9376**
EC_t	-1.7197	-0.5494	-3.4085**	-4.1409**	EC_t	-2.4541	-1.7094	-5.8708*	-5.6874*
Uruguay					**Vietnam**				
TR_t	-0.1814	-2.6080	-3.0855**	-3.7887**	TR_t	-1.2282	-2.2356	-5.6683*	-5.7772*
EC_t	-2.3534	-3.0691	-4.1359*	-4.1451**	EC_t	1.6287	-0.7176	-3.7120**	-4.7837*
Venezuela R.B.De					**Zimbabwe**				
TR_t	0.1327	-2.2907	-3.9118*	-4.8369*	TR_t	-1.6008	-1.6471	-3.1144**	-3.4239***
EC_t	-1.8629	-1.8146	-3.5727**	-3.4811***	EC_t	-1.1851	-2.0258	-4.1822*	-4.2352**
Zambia					Note: *, ** and *** denote significant at 1%, 5% and 10% levels respectively.				
TR_t	0.7516	0.3288	-3.4925**	-4.2436**					
EC_t	-1.5577	-0.5170	-3.8687*	-4.4820*					

The unit root test results set the stage for Johansen cointegration approach. The results are presented in Table-2. We find the acceptance of null hypothesis i.e. no cointegration in case of Angola, Brazil, Bulgaria, Cameroon, Congo Dem Rep, Congo Rep, Israel, Italy, Kenya, South Korea, Kuwait, Nicaragua, Pakistan, Panama, Philippines, Sudan, Tunisia, Turkey, Zambia and Zimbabwe. We find two cointegrating vectors in case of Benin, Saudi Arabia, Cyprus, Denmark, Ecuador, Ghana, Indonesia, Luxemburg and Paraguay and for the rest of countries, we find one cointegrating vector. The existence of one or two cointegrating vectors confirms the presence of cointegration between the variables. This shows that trade openness and energy consumption have long run relationship over selected period of time i.e. 1980-2010.

Table-2: Johansen Cointegration Test

Country	Likelihood ratio	5%critical value	P-value	Country	Likelihood ratio	5%critical value	P-value
Algeria				**Angola**			
$R = 0$	34.8179*	25.8721	0.0030	$R = 0$	18.4636	25.8721	0.3136
$R \leq 0$	5.09129	12.5179	0.5833	$R \leq 0$	7.45470	12.5179	0.2995
Argentina				**Australia**			
$R = 0$	27.1434**	25.8721	0.0346	$R = 0$	29.8304**	25.8721	0.0152
$R \leq 0$	6.42493	12.5179	0.4083	$R \leq 0$	8.00144	12.5179	0.2516
Austria				**Albania**			
$R = 0$	27.04634*	25.8721	0.0094	$R = 0$	33.7549*	25.8721	0.0042
$R \leq 0$	4.400725	12.5179	0.1968	$R \leq 0$	7.23212	12.5179	0.3209
Bangladesh				**Belgium**			
$R = 0$	28.7918*	25.8721	0.0210	$R = 0$	26.6517**	25.8721	0.0400
$R \leq 0$	4.95061	12.5179	0.6035	$R \leq 0$	7.11880	12.5179	0.3323
Benin				**Bolivia**			
$R = 0$	41.7722*	25.8721	0.0003	$R = 0$	66.8464*	25.8721	0.0000
$R \leq 0$	15.0975*	12.5179	0.0181	$R \leq 0$	13.1493	12.5179	0.0392
Botswana				**Brazil**			
$R = 0$	27.4591**	25.8721	0.0315	$R = 0$	13.7969	25.8721	0.6743
$R \leq 0$	6.463937	12.5179	0.4038	$R \leq 0$	3.11117	12.5179	0.8631
Brunei Darrulsalm				**Bulgaria**			
$R = 0$	29.4351**	25.8721	0.0172	$R = 0$	21.5356	25.8721	0.1578
$R \leq 0$	9.58154	12.5179	0.1474	$R \leq 0$	3.88762	12.5179	0.7583
Cameroon				**Canada**			
$R = 0$	24.3665	25.8721	0.0761	$R = 0$	26.8541**	25.8721	0.0377
$R \leq 0$	9.47495	12.5179	0.1531	$R \leq 0$	12.1440	12.5179	0.0577
Chili				**China**			
$R = 0$	31.5805*	25.8721	0.0087	$R = 0$	25.9354**	25.8721	0.0491
$R \leq 0$	8.96315	12.5179	0.1826	$R \leq 0$	8.62820	12.5179	0.2045
Colombia				**Congo Dem Rep**			
$R = 0$	26.9458**	25.8721	0.0367	$R = 0$	11.5926	25.8721	0.8392
$R \leq 0$	7.87041	12.5179	0.2624	$R \leq 0$	3.06221	12.5179	0.8691
Congo Rep				**Saudi Arabia**			
$R = 0$	13.0347	25.8721	0.7355	$R = 0$	35.8987*	25.8721	0.0020
$R \leq 0$	2.38065	12.5179	0.9406	$R \leq 0$	17.0467*	12.5179	0.0082
Costa Rica				**Cote D Ivories**			
$R = 0$	26.6582**	25.8721	0.0399	$R = 0$	27.6100**	25.8721	0.0301
$R \leq 0$	5.27551	12.5179	0.5573	$R \leq 0$	4.79881	12.5179	0.6254
Cuba				**Cyprus**			
$R = 0$	35.5558*	25.8721	0.0023	$R = 0$	29.5951**	25.8721	0.0164
$R \leq 0$	8.0965	12.5179	0.2439	$R \leq 0$	12.9237**	12.5179	0.0427
Denmark				**Dominican Rep**			
$R = 0$	36.5301*	25.8721	0.0016	$R = 0$	41.7294*	25.8721	0.0003
$R \leq 0$	13.6372**	12.5179	0.0324	$R \leq 0$	9.29973	12.5179	0.1627

Ecuador				**Egypt**			
$R=0$	49.3521*	25.8721	0.0000	$R=0$	35.8685*	25.8721	0.0021
$R\le 0$	13.7689**	12.5179	0.0307	$R\le 0$	6.10382	12.5179	0.4472
El Salvador				**Ethiopia**			
$R=0$	35.1654*	25.8721	0.0026	$R=0$	30.3543**	25.8721	0.0129
$R\le 0$	12.2436	12.5179	0.0555	$R\le 0$	5.16437	12.5179	0.5729
Finland				**France**			
$R=0$	26.9650**	25.8721	0.0365	$R=0$	34.3356*	25.8721	0.0035
$R\le 0$	6.82323	12.5179	0.3633	$R\le 0$	6.76451	12.5179	0.3697
Gabon				**Ghana**			
$R=0$	30.0153*	25.8721	0.0144	$R=0$	35.1224*	25.8721	0.0027
$R\le 0$	11.7234	12.5179	0.0676	$R\le 0$	14.1094**	12.5179	0.0268
Greece				**Guatemala**			
$R=0$	28.2878**	25.8721	0.0245	$R=0$	29.5195**	25.8721	0.0168
$R\le 0$	8.29920	12.5179	0.2282	$R\le 0$	10.5420	12.5179	0.1046
Honduras				**Hong Kong**			
$R=0$	26.0812**	25.8721	0.0471	$R=0$	37.9506*	25.8721	0.0010
$R\le 0$	10.9387	12.5179	0.0905	$R\le 0$	7.72672	12.5179	0.2748
Hungary				**Iceland**			
$R=0$	44.9969*	25.8721	0.0001	$R=0$	38.8020*	25.8721	0.0007
$R\le 0$	8.98506	12.5179	0.1813	$R\le 0$	5.81125	12.5179	0.4847
India				**Indonesia**			
$R=0$	26.1574**	25.8721	0.0461	$R=0$	31.2241*	25.8721	0.0098
$R\le 0$	4.72569	12.5179	0.6361	$R\le 0$	12.2892**	12.5179	0.0546
Iran				**Ireland**			
$R=0$	37.4250*	25.8721	0.0012	$R=0$	34.3030*	25.8721	0.0035
$R\le 0$	9.92483	12.5179	0.1306	$R\le 0$	7.14944	12.5179	0.3292
Israel				**Italy**			
$R=0$	24.6479	25.8721	0.0704	$R=0$	17.09164	25.8721	0.4081
$R\le 0$	4.03627	12.5179	0.7368	$R\le 0$	4.836427	12.5179	0.6200
Jamaica				**Japan**			
$R=0$	29.4438**	25.8721	0.0172	$R=0$	39.5565*	25.8721	0.0006
$R\le 0$	7.55742	12.5179	0.2900	$R\le 0$	10.5050	12.5179	0.1060
Jordan				**Kenya**			
$R=0$	33.1366*	25.8721	0.0052	$R=0$	17.3930	25.8721	0.3862
$R\le 0$	3.17938	12.5179	0.8545	$R\le 0$	6.66917	12.5179	0.3803
South Korea				**Kuwait**			
$R=0$	27.3817**	25.8721	0.0322	$R=0$	28.2335**	25.8721	0.0250
$R\le 0$	8.74030	12.5179	0.1970	$R\le 0$	9.24276	12.5179	0.1659
Luxemburg				**Mexico**			
$R=0$	40.8911*	25.8721	0.0003	$R=0$	48.3444*	25.8721	0.0000
$R\le 0$	19.2744*	12.5179	0.0032	$R\le 0$	6.1009	12.5179	0.4476
Morocco				**Mozambique**			
$R=0$	29.1988**	25.8721	0.0186	$R=0$	31.0356**	25.8721	0.0104
$R\le 0$	6.63904	12.5179	0.3837	$R\le 0$	10.8260	12.5179	0.0943
Nepal				**Netherland The 62**			

$R = 0$	27.6112**	25.8721	0.0301	$R = 0$	26.4791**	25.8721	0.0420
$R \leq 0$	2.17146	12.5179	0.9572	$R \leq 0$	11.6056	12.5179	0.0707
New Zealand				**Nicaragua**			
$R = 0$	28.1404**	25.8721	0.0257	$R = 0$	11.8624	25.8721	0.8214
$R \leq 0$	8.54960	12.5179	0.2100	$R \leq 0$	2.8651	12.5179	0.8922
Nigeria				**Norway**			
$R = 0$	31.4737*	25.8721	0.0090	$R = 0$	28.8942**	25.8721	0.0204
$R \leq 0$	8.19985	12.5179	0.2358	$R \leq 0$	10.5826	12.5179	0.1031
Oman				**Pakistan**			
$R = 0$	26.4988**	25.8721	0.0418	$R = 0$	18.0948	25.8721	0.3376
$R \leq 0$	8.58027	12.5179	0.2078	$R \leq 0$	3.5568	12.5179	0.8048
Panama				**Paraguay**			
$R = 0$	21.1596	25.8721	0.1728	$R = 0$	35.5854*	25.8721	0.0023
$R \leq 0$	8.20377	12.5179	0.2355	$R \leq 0$	14.3679*	12.5179	0.0242
Peru				**Philippines**			
$R = 0$	26.0875**	25.8721	0.0470	$R = 0$	10.9235	25.8721	0.8795
$R \leq 0$	8.41322	12.5179	0.2198	$R \leq 0$	1.93863	12.5179	0.9723
Portugal				**South Africa**			
$R = 0$	12.4912	25.8721	0.7769	$R = 0$	31.1438**	25.8721	0.0100
$R \leq 0$	3.69726	12.5179	0.7854	$R \leq 0$	4.3126	12.5179	0.6965
Spain				**Sudan**			
$R = 0$	35.3192*	25.8721	0.0025	$R = 0$	20.9619	25.8721	0.1811
$R \leq 0$	10.2042	12.5179	0.1182	$R \leq 0$	7.2129	12.5179	0.3228
Sweden				**Switzerland**			
$R = 0$	31.8140*	25.8721	0.0081	$R = 0$	27.5750**	25.8721	0.0304
$R \leq 0$	6.4377	12.5179	0.4068	$R \leq 0$	7.2930	12.5179	0.3149
Syrian Arab Rep				**Thailand**			
$R = 0$	29.8728**	25.8721	0.0150	$R = 0$	39.8339*	25.8721	0.0005
$R \leq 0$	11.4533	12.5179	0.0748	$R \leq 0$	6.4373	12.5179	0.4069
Togo				**Trinidad and Tobago**			
$R = 0$	48.6538*	25.8721	0.0000	$R = 0$	27.7872**	25.8721	0.0286
$R \leq 0$	5.0368	12.5179	0.5911	$R \leq 0$	9.6121	12.5179	0.1459
Tunisia				**Turkey**			
$R = 0$	44.0057*	25.8721	0.0001	$R = 0$	30.0648**	25.8721	0.0141
$R \leq 0$	16.1203**	12.5179	0.0120	$R \leq 0$	6.6956	12.5179	0.3773
United Kingdom				**United Arab Emirates**			
$R = 0$	44.3407*	25.8721	0.0001	$R = 0$	33.2987*	25.8721	0.0049
$R \leq 0$	7.7262	12.5179	0.2748	$R \leq 0$	6.3311	12.5179	0.4194
Uruguay				**United States**			
$R = 0$	35.8733*	25.8721	0.0020	$R = 0$	31.4441*	25.8721	0.0091
$R \leq 0$	5.38711	12.5179	0.5418	$R \leq 0$	1.6455	12.5179	0.9861
Venezuela R. B. De				**Vietnam**			
$R = 0$	30.9671**	25.8721	0.0106	$R = 0$	26.1699**	25.8721	0.0459
$R \leq 0$	12.8779**	12.5179	0.0435	$R \leq 0$	8.0407	12.5179	0.2484
Zambia				**Zimbabwe**			
$R = 0$	30.39876**	25.8721	0.0127	$R = 0$	24.9006	25.8721	0.0657

$R \leq 0$	2.449747	12.5179	0.9345	$R \leq 0$	10.0065	12.5179	0.1269
Senegal				Note:* and ** denotes rejection of null hypothesis at 1% and 5% levels of significance respectively.			
$R = 0$	31.1438**	25.8721	0.0100				
$R \leq 0$	4.3126	12.5179	0.6965				

Table-3: Panel Unit Root Test

IPS TEST				
	Level		**1st Difference**	
Variables	**Intercept**	**Trend &Intercept**	**Intercept**	**Trend &Intercept**
TR_t	10.5763	-1.1019	-19.8147*	-16.6784*
EC_t	2.5184	0.6182	-21.5562*	-17.8725*
LLC TEST				
	Level		**1st Difference**	
Variables	**Intercept**	**Trend &Intercept**	**Intercept**	**Trend &Intercept**
TR_t	5.6390	-0.4516	-19.1851*	-16.5538*
EC_t	1.7180	3.4397	-16.4287*	-13.5677*
MW(ADF) TEST				
	Level		**1st Difference**	
Variables	**Intercept**	**Trend &Intercept**	**Intercept**	**Trend &Intercept**
TR_t	30.9469	182.3521	366.570*	296.0253*
EC_t	164.2160	200.3711	563.351*	445.5541*
MW(PP) TEST				
	Level		**1st Difference**	
Variables	**Intercept**	**Trend &Intercept**	**Intercept**	**Trend &Intercept**
TR_t	32.2558	178.6561	1064.9488*	895.8082
EC_t	169.0261	196.1862	1471.0689*	1282.0323*
Note: * denote rejection of null hypothesis at 1% significance level.				

This ambiguity in the results based on single country study prompts us to apply panel cointegration approach[5]. For this purpose, we apply panel unit root tests to check for stationary properties of the series. The results based on the LLC, IPS, MW (ADF) and MW (PP) unit root tests with constant and, constant and trend are reported in Table-3. The tests show that all variables are found to be non-stationary at level. At first difference, all the series are integrated

[5] In some countries we could not find cointegration while in rest countries we found the existence of cointegration between the variables.

i.e. I(1). This unique order of integration of the variables helps us to apply Johansen panel cointegration approach to examine long run relationship between the variables for selected panel.

Table-4: Panel Cointegration Test

Hypotheses	**Likelihood ratio**	**1% critical value**
$R = 0$	5.9035*	2.45
$R \leq 0$	0.9523	
Note:* denote rejection of null hypothesis at 1% significance level.		

The results are reported in Table-4. We find that maximum likelihood ratio i.e. 5.9035 is greater than critical value at 1% level of significance. This leads us to reject the null hypothesis of no panel cointegration between the variables. We may conclude that the panel cointegration exists between trade openness and energy consumption in sampled countries. The Table-5 show that trade openness affects energy consumption in high, middle and low-income countries. In high-income countries, we find that the relationship between trade openness and energy consumption is inverted U-shaped. This implies that initially trade openness is positively linked with energy consumption and after a threshold level, it declines energy demand due to adoption of energy efficient technology. This indicates that a 1 percent increase in trade openness raises energy demand by 0.860 percent and negative sign of nonlinear term of trade openness corroborates the delinking of energy consumption as trade openness is at optimal level. In case of middle and low income countries, relationship between trade openness and energy consumption is U-shaped which reveals that trade openness decreases energy consumption initially but energy consumption is increased with continues process of trade openness. In middle-income countries, trade openness stimulates industrialization, which raises energy demand (Cole, 2006). It is argued by Ghani, (2006) that low-income countries are unable to reap optimal fruits of trade liberalization because these economies are lacking in utilizing energy efficient technology to enhance domestic production.

Table-5: Panel Cointegration Estimates

Variables	Pooled Mean Group (PMG)	Mean Group (MG)	Hausman Test[6]
High Income Panel[7]			
TR_t	0.860* (0.000)	1.315** (0.041)	3.31 (0.191)
TR^2_t	-0.015* (0.000)	-1.688** (0.054)	
Middle Income Panel			
TR_t	-0.023** (0.014)	-0.191*** (0.063)	1.45 (0.484)
TR^2_t	0.003* (0.000)	0.116** (0.043)	
Low Income Panel			
TR_t	-1.493* (0.000)	-2.827** (0.023)	1.68 (0.321)
TR^2_t	0.0387* (0.000)	0.114** (0.030)	
Note: *, ** and *** show significance at 1%, 5% and 10% levels respectively.			

Table-6: Non-Homogenous and Homogenous Causality

Dependent variables	**Non-homogenous causality**		**Homogenous causality**	
	$\ln TR_t$	$\ln EC_t$	TR_t	EC_t
$\ln TR_t$	–	Causality exists*	–	No Causality
$\ln EC_t$	Causality exists*	–	Causality exists*	–
Note: * represent significance at 1% level.				

The presence of cointegration between the series leads us to investigate the direction of causality. In doing do, we have applied homogeneous and non-homogenous panel causality and results are reported in Table-6. The results of non-homogenous causality reveal the feedback hypothesis

[6] Hausman test indicate that PMG model is preferred over PG model
[7] A graph is provide in Appendix for high income countries

between trade openness and energy consumption as bidirectional causal relationship is confirmed between both the series. We find that trade openness Granger causes energy consumption confirmed by homogeneous causality (see Table-6).

Our results of non-homogenous causality validated the presence of *feedback effect*, as trade openness and energy consumption are interdependent. The unidirectional causality is found running from trade openness to energy consumption. This validates the presence of *trade-led-energy hypothesis* confirmed by homogenous causality approach. This ambiguity in results would not helpful in policymaking point of view and leads us to apply homogenous and non-homogenous causality approach using data of low, middle and high-income countries. This will not only help us in obtaining results region-wise but also enable us to design a comprehensive trade and energy policy for sustained economic growth and better living standard. In doing so, we have investigated the homogenous and non-homogenous causal relationship separately for high, middle and low-income countries. The results are reports in Table-7. In high income countries, non-homogenous causality reports the unidirectional causality running from trade openness to energy consumption but feedback effect is confirmed by homogenous causality between both variables. The relationship between trade openness and energy consumption is bidirectional for middle and low-income countries confirmed by homogenous and non-homogenous causality approaches.

Table-7: Homogenous and Non-homogenous Causality

	Homogenous Causality		**Non-homogenous Causality**	
Variables	**High Income Countries**			
	TR_t	$\ln EC_t$	TR_t	EC_t

TR_t	–	Causality exists*	-	No causality
EC_t	Causality exists*	–	Causality exists*	
Variables	**Middle Income Countries**			
	TR_t	$\ln EC_t$	TR_t	EC_t
TR_t	–	Causality exists*		Causality exists*
EC_t	Causality exists*	–	Causality exists*	
Variables	**Low Income Countries**			
	TR_t	$\ln EC_t$	TR_t	EC_t
TR_t	–	Causality exists*		Causality exists*
EC_t	Causality exists*	–	Causality exists*	
Note: * represent the significance at 1% level.				

Table-8: Heterogeneous Causality

Country	**Variables**	TR_t	EC_t
Algeria	TR_t	-	No Causality
	EC_t	Causality exists*	-
Angola	TR_t	-	No Causality
	EC_t	Causality exists*	-
Argentina	TR_t	-	No Causality
	EC_t	Causality exists*	-
Australia	TR_t	-	No Causality
	EC_t	Causality exists*	-
Austria	TR_t	-	No Causality
	EC_t	No Causality	-
Albania	TR_t	-	Causality exists*
	EC_t	Causality exists***	-
Bangladesh	TR_t	-	Causality exist***
	EC_t	No Causality	-
Belgium	TR_t	-	No Causality
	EC_t	No Causality	-
Benin	TR_t	-	Causality exist**
	EC_t	No Causality	-
Bolivia	TR_t	-	No Causality
	EC_t	No Causality	-

Botswana	TR_t	-	No Causality
	EC_t	Causality exists*	-
Brazil	TR_t	-	No Causality
	EC_t	Causality exists*	-
Brunei Darussalam	TR_t	-	No Causality
	EC_t	No Causality	-
Bulgaria	TR_t	-	No Causality
	EC_t	No Causality	-
Cameroon	TR_t	-	No Causality
	EC_t	No Causality	-
Canada	TR_t	-	No Causality
	EC_t	No Causality	-
Chile	TR_t	-	No Causality
	EC_t	Causality exist*	-
China	TR_t	-	Causality exist*
	EC_t	No Causality	-
Colombia	TR_t	-	No Causality
	EC_t	No Causality	-
Congo Dem Rep	TR_t	-	No Causality
	EC_t	No Causality	-
Congo Rep	TR_t	-	No Causality
	EC_t	No Causality	-
Costa Rica	TR_t	-	No Causality
	EC_t	Causality exist*	-
Cote D'Ivoire	TR_t	-	Causality exist***
	EC_t	Causality exist*	-
Cuba	TR_t	-	Causality exist*
	EC_t	No Causality	-
Cyprus	TR_t	-	Causality exist**
	EC_t	Causality exist*	-
Denmark	TR_t	-	No Causality
	EC_t	No Causality	-
Dominican Rep	TR_t	-	No Causality
	EC_t	No Causality	-
Ecuador	TR_t	-	Causality exist*

	EC_t	No Causality	-
Egypt	TR_t	-	Causality exist***
	EC_t	Causality exist*	-
El Salvador	TR_t	-	No Causality
	EC_t	Causality exist*	-
Ethiopia	TR_t	-	Causality exist*
	EC_t	No Causality	-
Finland	TR_t	-	Causality exist*
	EC_t	Causality exist*	-
France	TR_t	-	Causality exist*
	EC_t	No Causality	-
Gabon	TR_t	-	Causality exist***
	EC_t	Causality exist*	-
Ghana	TR_t	-	No Causality
	EC_t	Causality exist*	-
Greece	TR_t	-	Causality exist*
	EC_t	No Causality	-
Guatemala	TR_t	-	Causality exist*
	EC_t	No Causality	-
Honduras	TR_t	-	Causality exist**
	EC_t	Causality exist*	-
Hong Kong	TR_t	-	Causality exist*
	EC_t	Causality exist***	-
Hungary	TR_t	-	No Causality
	EC_t	No Causality	-
Iceland	TR_t	-	No Causality
	EC_t	No Causality	-
India	TR_t	-	No Causality
	EC_t	Causality exist*	-
Indonesia	TR_t	-	Causality exist*
	EC_t	No Causality	-
Iran	TR_t	-	No Causality
	EC_t	No Causality	-
Ireland	TR_t	-	No Causality
	EC_t	No Causality	-

Israel	TR_t	-	No Causality
	EC_t	No Causality	-
Italy	TR_t	-	No Causality
	EC_t	Causality exist*	-
Jamaica	TR_t	-	Causality exist*
	EC_t	Causality exist*	-
Japan	TR_t	-	No Causality
	EC_t	Causality exist*	-
Jordan	TR_t	-	No Causality
	EC_t	Causality exist*	-
Kenya	TR_t	-	No Causality
	EC_t	No Causality	-
South Korea	TR_t	-	No Causality
	EC_t	No Causality	-
Kuwait	TR_t	-	Causality exist*
	EC_t	Causality exist*	-
Luxemburg	TR_t	-	No Causality
	EC_t	No Causality	-
Mexico	TR_t	-	No Causality
	EC_t	Causality exist*	-
Morocco	TR_t	-	Causality exist*
	EC_t	Causality exist*	-
Mozambique	TR_t	-	Causality exist*
	EC_t	No Causality	-
Nepal	TR_t	-	No Causality
	EC_t	Causality exist**	-
The Netherlands	TR_t	-	Causality exist*
	EC_t	No Causality	-
New Zealand	TR_t	-	No Causality
	EC_t	No Causality	-
Nicaragua	TR_t	-	Causality exist*
	EC_t	No Causality	-
Nigeria	TR_t	-	No Causality
	EC_t	No Causality	-
Norway	TR_t	-	Causality exist*

	EC_t	Causality exist*	-
Oman	TR_t	-	No Causality
	EC_t	Causality exist*	-
Pakistan	TR_t	-	No Causality
	EC_t	Causality exist*	-
Panama	TR_t	-	Causality exist*
	EC_t	Causality exist*	-
Paraguay	TR_t	-	Causality exist***
	EC_t	No Causality	-
Peru	TR_t	-	Causality exist***
	EC_t	No Causality	-
Philippines	TR_t	-	Causality exist***
	EC_t	No Causality	-
Portugal	TR_t	-	No Causality
	EC_t	Causality exist**	-
Saudi Arabia	TR_t	-	Causality exist**
	EC_t	Causality exist*	-
Senegal	TR_t	-	No Causality
	EC_t	No Causality	-
South Africa	TR_t	-	No Causality
	EC_t	No Causality	-
Spain	TR_t	-	No Causality
	EC_t	No Causality	-
Sudan	TR_t	-	No Causality
	EC_t	Causality exist*	-
Sweden	TR_t	-	Causality exist***
	EC_t	No Causality	-
Switzerland	TR_t	-	Causality exist*
	EC_t	No Causality	-
Syria	TR_t	-	No Causality
	EC_t	No Causality	-
Thailand	TR_t	-	No Causality
	EC_t	Causality exist*	-
Togo	TR_t	-	Causality exist***
	EC_t	Causality exist***	-

Trinidad and Tobago	TR_t	-	Causality exist*
	EC_t	No Causality	-
Tunisia	TR_t	-	No Causality
	EC_t	No Causality	-
Turkey	TR_t	-	No Causality
	EC_t	Causality exist*	-
United Kingdom	TR_t	-	No Causality
	EC_t	No Causality	-
United Arab Emirates	TR_t	-	Causality exist*
	EC_t	No Causality	-
Uruguay	TR_t	-	Causality exist*
	EC_t	Causality exist*	
Unites States	TR_t	-	Causality exist*
	EC_t	Causality exist*	-
Venezuela	TR_t	-	Causality exist*
	EC_t	No Causality	-
Vietnam	TR_t	-	No Causality
	EC_t	No Causality	-
Zambia	TR_t	-	Causality exist*
	EC_t	No Causality	-
Zimbabwe	TR_t	-	No Causality
	EC_t	No Causality	-
Note: *, ** and *** represent significance at 1%, 5% and 10% levels respectively.			

The results of heterogeneous causality reported in Table-7 suggest the feedback relationship between trade openness and energy consumption i.e. bidirectional causality exists in case of Albania, Cote D'Ivoire, Cyprus, Egypt, Finland, Gabon, Honduras, Hong Kong, Kuwait, Morocco, Norway, Panama, Saudi Arabia, Togo, Uruguay and Unites States. Energy consumption Granger causes trade openness in case of Bangladesh, Benin, China, Cuba, Ecuador, Ethiopia, France, Greece, Guatemala, Indonesia, Mozambique, The Netherlands, Nicaragua, Paraguay, Philippines, Sweden, Switzerland, Trinidad and Tobago, United Arab Emirates, Venezuela and Zambia.

The unidirectional causality is found running from trade openness to energy consumption. This validates the trade-led-energy hypothesis in case of Algeria, Angola, Argentina, Australia, Botswana, Brazil, Chili, Costa Rica, El Salvador, Ghana, India, Italy, Japan, Jordan, Mexico, Nepal, Oman, Pakistan, Portugal, Sudan, Thailand and Turkey. The neutral effect between trade openness and energy consumption i.e. no causality exists between both the variables. This includes Austria, Belgium, Bolivia, Brunei Darussalam, Bulgaria, Cameroon, Canada, Colombia, Congo Democratic Republic, Congo Republic, Denmark, Dominican Republic, Hungary, Iceland, Iran, Ireland, Israel, Kenya, South Korea, Luxemburg, New Zealand, Nigeria, Senegal, South Africa, Spain, Syria, Tunisia, United Kingdom, Vietnam and Zimbabwe.

5. Concluding Remarks and Future Directions

This paper explores the relationship between trade openness and energy consumption using data of 91 heterogeneous (high, middle and low income) countries over the period of 1980-2010. In doing so, we have applied time series as well as panel unit root tests to examine the integrating properties of the variables. Similarly, to examine cointegration between the variables, we have applied single country as well as panel cointegration approaches. The homogenous and non-homogenous causality approaches are applied to examine the direction of causality between the variables in high, middle and low-income countries. Heterogeneous causality approach has also been applied to examine between trade openness and energy consumption at country level analysis.

Our results indicated that our variables are integrated at I(1) confirmed by time series and panel unit root tests and same is inference is drawn about cointegration between trade openness and energy consumption. The pooled mean group estimation analysis reveals an inverted-U shaped relationship in high income countries and vice versa in middle and low income countries. The causality analysis confirms the existence of feedback effect between trade openness and energy consumption in middle and low income countries but bidirectional causality is confirmed by homogenous causality approach in high income countries but non-homogenous causality approach indicates unidirectional causality running form trade openness to energy consumption. Heterogeneous causality exposes that in 18% of sampled countries, the feedback effect exists while 24% show that trade openness causes energy consumption. A 24% sample countries show that trade openness causes energy consumption and rest of sample countries confirms the presence of neutral effect between trade openness and energy consumption.

Overall, our results expose that the feedback effect exists between trade openness and energy consumption, which suggests in exploring new and alternative sources of energy to reap optimal fruits of trade. Trade openness stimulates industrialization that in resulting affects economic growth. This channel of trade affects energy demand via economic growth. Similarly, insufficient energy supply impedes economic growth, which affects exports as well as imports, and as results energy consumption will be declined. Trade openness also is a source of transferring advanced technologies i.e. energy efficient technology from developed countries to developing economies. Our findings confirm that the relationship between trade openness and energy consumption is U-shaped. This suggests that middle and low-income countries should import energy efficient technologies from developed economies to lower energy intensity. This will not be possible if developed countries do not promote those technologies and lower profits for countries, which do not have access to required amounts of capitals. Further, if this situation is founded, it will have a global positive impact as it will save natural resources for future generations and it will reduce environmental pollution.

This paper can be augmented for future research by incorporating financial development, industrialization, urbanization in energy demand function following Shahbaz and Lean, (2012) in case of low, middle and high-income countries. The semi-parametric panel approach proposed by Baltagi and Lu, (2002) could be applied to investigate the impact of financial development, industrialization, trade openness and urbanization on energy consumption using global level data. Using global level data, trade openness, financial development, industrialization, urbanization and CO_2 emissions nexus could be investigated by applying heterogamous panel under cross-sectional dependence framework.

Reference

1. Akarca, A.T., and Long, T.V. (1979). Energy and employment: a time series analysis of the causal relationship. Resources and Energy, 5, 326-331.
2. Akarca, A.T., and Long, T.V. (1980). On the relationship between energy and GNP: a re-examination. Journal of Energy and Development, 5, 326-331.
3. Amirat, A., Bouri, A. (2010), Energy and economic growth: the Algerian case.
4. Apergis N. and Payne E.J. (2010). Energy consumption and growth in South America: Evidence from a panel error correction model. Energy Economics, 32, 1421-1426.
5. Arrow, K. J. (1962). The economic implications of learning by doing. The Review of Economic Studies, 29, 155-173.
6. Baltagi, B.H., Li, D., (2002). Series estimation of partially linear panel data models with fixed effects. Annals of Economics and Finance 3, 103-116.
7. Canning, D., and Pedroni, P., (2008). Infrastructure, long-run economic growth and causality tests for cointegrated panels. Manchester School, 76, 504-527.
8. Cole, M. A., (2006). Does trade liberalization increase energy use? Economics Letters, 92, 108-112.
9. Dedeoğlu, D., Kaya, H., (2013). Energy use, exports, imports and GDP: New evidence from the OECD countries. Energy Policy, 57, 469-476.

10. Ghani, G. M., (2012). Does trade liberalization affect energy consumption? Energy Policy, 43 (4), 285-290.
11. Granger, C.W.J. (1969). Investigating causal relations by econometric models and cross-spectral methods. Econometrica, 37, 424-438.
12. Halicioglu, F., (2011). A dynamic study of income, energy and exports in Turkey. Energy, 36, 3348–3354.
13. Hossain, Md. S., (2012). Multivariate Granger causality between economic growth, electricity consumption, exports and remittances for the panel of three SAARC countries. Global Journal of Management and Business Research, 12, 41-54.
14. Hurlin, C. and Venet, B., (2001). Granger causality tests in panel data models with fixed Coefficients, 12th (EC)2 Conference on Causality and Exogeneity in Econometrics, Core Louvain – Ia – Neuve.
15. Im, K.S., Pesaran, M.H. and Shin, Y. (2003). Testing unit roots in heterogeneous panels. Journal of Econometrics, 115, 53-74.
16. Jena, P. R. and Grote, U. (2008). Growth-trade-environment nexus in India. Economics Bulletin, 17, 1-17.
17. Johansen, S., (1988). Statistical analysis of cointegration vectors. Journal of Economic Dynamics and Control, 12, 231-254.
18. Johansen, S., (1995). A statistical analysis of cointegration for I(2) variables. Econometric Theory, 11, 25-59.
19. Karlsson, S., and Lothgren, M., (2000). On the power and interpretation of panel unit root tests. Economics Letters, 66, 249-255.
20. Kraft, J., Kraft, A., (1978). On the relationship between energy and GNP. Journal of Energy and Development, 3, 401-403.
21. Larsson, R., Lyahagen, J. and Lothgren, M., (2001). Likelihood-based cointegration tests in heterogeneous panels. Econometrics Journal, 4, 109-142.
22. Lean, H.H. and Smyth, R., (2010). On the dynamics of aggregate output, electricity consumption and exports in Malaysia: evidence from multivariate Granger causality tests. Applied Energy, 87, 1963-1971.
23. Levin, A., Lin, C-F. and Chu, C-S. J. (2002). Unit root tests in panel data: asymptotic and finite-sample properties. Journal of Econometrics, 108, 1-24.
24. Maddala, G.S., and Wu, S., (1999). A comparative study of unit root tests with panel data and new simple test. Oxford Bulletin of Economics and Statistics, 631-652.
25. Masih, A. M. M. and Masih, R., (1996). Energy consumption, real income and temporal causality results from a multi-country study based on cointegration and error correction modeling techniques. Energy Economics, 18, 165-183.
26. Nair-Reichert, U. and Weinhold, D. (2001). Causality tests for cross-country panels: a new look at FDI and economic growth in developing countries. Oxford Bulletin of Economics and Statistics, 63, 153-171.
27. Narayan, P. K., Narayan, S., Prasad, A., (2008). A structural VAR analysis of electricity consumption and real GDP: evidence from the G7 countries. Energy Policy, 36, 2765-2769.
28. Narayan, P.K. and Smyth, R., (2009). Multivariate Granger causality between electricity consumption, exports and GDP: evidence from a panel of Middle Eastern countries. Energy Policy, 37, 229-236.

29. Nondo C. and Kahsai M. (2009). Energy consumption and economic growth: evidence from COMESA countries. Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Atlanta, Georgia, January 31-February 3, 2009.
30. Noor S. and Siddiqi M.W. (2010). Energy consumption and economic growth in South Asian countries: a cointegrated panel analysis. International Journal of Human and Social Sciences, 5, 921-926.
31. Ozturk, I. (2010). A Literature Survey on Energy-Growth Nexus. Energy Policy, 38(1), 340-349.
32. Payne, J., 2010. A survey of the electricity consumption-growth literature. Applied Energy 87, 3723-3731.
33. Pedroni, P. (1999). Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors, Oxford Bulletin of Economics and Statistics, Special Issue, 61: 653-670.
34. Pedroni, P. (2004). Panel Cointegration: Asymptotic and Finite Samples Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis, Econometric Theory, 20: 597-625.
35. Sadorsky, P., (2011). Trade and energy consumption in the Middle East. Energy Economics, 33, 739-749.
36. Sadorsky, P., (2012). Energy consumption, output and trade in South America. Energy Economics, 34, 476-488.
37. Shahbaz, M. and Lean, H. H., (2012). Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. Energy Policy 40, 473-479.
38. Shahbaz, M. Khan, S. and Tahir, M. I. (2013b). The dynamic links between energy consumption, economic growth, financial development and trade in China: fresh evidence from multivariate framework analysis. Energy Economics, 40, 8-21.
39. Shahbaz, M. Lean, H. H. and Farooq, A. (2013a). Natural gas consumption and economic growth in Pakistan. Renewable and Sustainable Energy Reviews, 18, 87-94.
40. Yang, H. Y., (2000). A note on the causal relationship between energy and GDP in Taiwan. Energy Economics, 22, 309-317.
41. Yu, E. S. H. and Choi, J. Y. (1985). The causal relationship between energy and GNP: an international comparison. Journal of Energy and Development, 10, 249-272.
42. Yu, E. S. H., Choi, J. Y. (1985) The Causal Relationship between Energy and GNP: An International Comparison. *Journal of Energy and Development* 10(2): 249-272.
43. Zahid, K., (2008). Energy-GDP relationship: a casual analysis for the five countries of South Asia. Applied Econometrics and International Development, 8, 167-180.

Appendix-A
List of World Countries

High Income Countries	**Middle Income Countries**	**Low Income Countries**
Angola	Algeria	Bangladesh
Australia	Argentina	Benin
Austria	Bolivia	Congo Dem Rep
Albania	Botswana	Ethiopia
Belgium	Brazil	Kenya
Brunei Darussalam	Bulgaria	Mozambique

Canada	Cameroon	Nepal
Cyprus	Chile	Togo
Denmark	China	Zimbabwe
Finland	Colombia	
France	Congo Rep	
Greece	Costa Rica	
Hong Kong	Cote D’Ivoire	
Hungary	Cuba	
Iceland	Dominican Rep	
Israel	Ecuador	
Italy	Egypt	
South Korea	El Salvador	
Kuwait	Gabon	
Luxemburg	Ghana	
The Netherlands	Guatemala	
New Zealand	Honduras	
Norway	India	
Oman	Indonesia	
Portugal	Iran	
Saudi Arabia	Ireland	
Spain	Jamaica	
Sweden	Japan	
Switzerland	Jordan	
Trinidad and Tobago	Mexico	
United Kingdom	Morocco	
United Arab Emirates	Nicaragua	
Unites States	Nigeria	
	Pakistan	
	Panama	
	Paraguay	
	Peru	
	Philippines	
	Senegal	
	South Africa	
	Sudan	
	Syria	
	Thailand	
	Tunisia	
	Turkey	
	Uruguay	
	Venezuela	
	Vietnam	
	Zambia	