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

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INTRODUCTION

Trade liberalisation 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 specialise in the production of those goods that are produced by relatively abundant factors of production such as labour and natural resources. Developed countries would specialise in the production of those goods that are produced by human capital and manufactured in 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 stimulates domestic production and hence economic growth. A surge in domestic production increases energy demand , which is commonly referred 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 advanced technologies from developed economies. The adoption of advanced technology lowers energy intensity. The use of advanced technologies result in less energy consumption and more output that is usually referred to as technique effect [Arrow (1962)]. Composite effect reveals the shift of production structure from agriculture to industry with the use of energy intensive production techniques. In initial stages of economic development economy is based largely on agriculture sector, thus the use of energy is relatively less. As economy starts shifting from agriculture to industry, the energy consumption increases. Arrow (1962) calls it positive composite effect. Finally, at the later stage of economic development,

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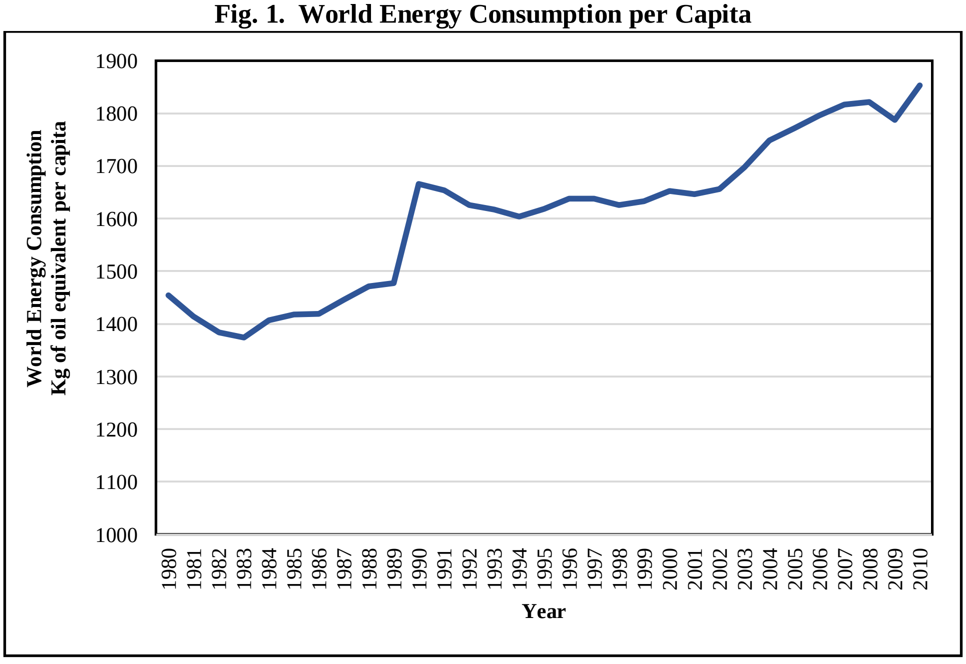
economic structure shifts from industry to services, there is less energy consumption, which implies that energy intensity is lowered because of composite effect.

Energy affects trade openness via various channels. First, energy is an important input of production because machinery and equipment in the process of production require energy. Second, export or import of manufactured goods or raw material require 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 expand trade via expanding exports and imports. The relationship between trade openness and energy consumption is important. Since energy plays a key role to promote exports or imports hence policies aiming at reduction of 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 that energy expansion policies should be adopted because energy consumption stimulates trade openness and 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 if neutral relationship 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, which increased to 1852 Kg of oil equivalent per capita in 2010 (see Figure 1). According to American Energy Information Administration (EIA) and the International Energy Agency (IEA), the worldwide energy consumption will on average continue to increase by 2 percent per year.

Fig. 1. World Energy Consumption per Capita

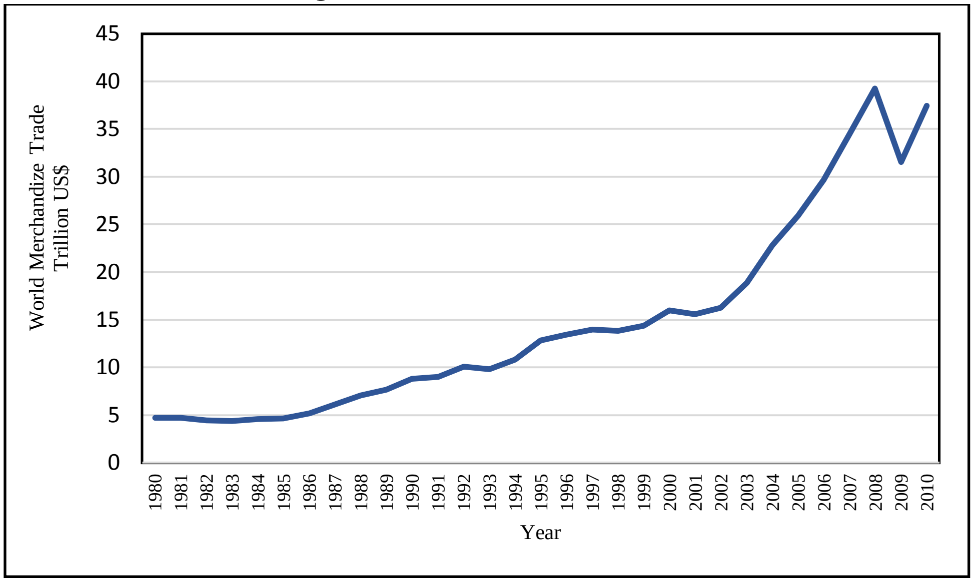


Source: World Development Indicators (CD-ROM, 2012).

Between 1980 and 2006, energy consumption has increased but fuel consumption structure varies by region. Coal has the largest share in fuel consumption of the world, accounting for 30.4 percent of total increase; Asia and Oceania contributed 97.7 percent of total coal increase between 1980 and 2006. During the same period, natural gas ranks second in total energy consumption, accounting for 28.7 percent, Asian and Oceania still contributed the largest part, 24 percent of total gas increase, Eurasia, Europe and Middle East contributed about 17 percent and 20 percent respectively. Oil ranked as the third fuel in total consumption, accounting for 21.5 percent. Asia and Oceania still were the biggest contributors; accounting for about 67.9 percent of increase in oil consumption. The nuclear power contributed about 10.7 percent to total increase, the increase was mainly 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 percent to global hydropower increase. However, global industry sector has reduced the use of total energy from 33 percent in 1980 to 27 percent 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 percent in 2010, the highest growth rate since 1973. Energy consumption in OECD countries grew by 3.5 percent while in non-OECD countries by 7.5 percent in 2010. Chinese energy consumption grew by 11.2 percent and China surpassed the United States as the world's largest energy consumer. Oil remained the world's leading fuel in 2010, and accounted for 33.6 percent of global energy consumption. World natural gas consumption grew by 7.4 percent in 2010, the most rapid increase since 1984. The United States witnessed the world's largest increase in consumption, which rose by about 5.6 percent in 2010. Asian countries also registered large increase of about 10.7 percent, led by a 21.5 percent increase in India. Coal consumption grew by 7.6 percent in 2010, the fastest global growth since 2003. The share of coal in world energy consumption is 29.6 percent, more than 25.6 percent of ten years ago. China consumed 48.2 percent 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 percent of world energy consumption in 2010, up from 0.6 percent 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 percent of world energy consumption in 2010 [International Energy Agency (2012)].The volume of merchandise trade among countries has been rapidly increasing for last two decades due to globalisation. Global merchandise trade (exports plus imports of goods) was US$ 3.8 trillion in 1980 but it amounted to US$ 37 trillion in 2010 (see Figure 2).

Fig. 2. World Merchandise Trade



Source: World Development Indicators (CD-ROM, 2012).

In 2006, merchandise exports in volume terms increased among regions. Exports from North America and Asia grew faster than imports. The growth rate of Asian export was 13 percent while imports grew by 9 percent. Europe recorded balanced export and import growth of 7 percent. For South and Central America, the Commonwealth of Independent States, Africa and the Middle East, import growth was larger than exports. This pattern is attributed to more favourable 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 were 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 merchandise 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 a 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 understudied. 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 conducted by using a modified version of Granger causality test developed by Hurlin and Venet (2001).

The rest of the paper is organised 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 conclusions 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 labour 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 a few studies investigating the relationship between trade openness and energy consumption. For instance, Cole (2006) examined the relationship between trade liberalisation and energy consumption. Cole (2006) used data of 32 countries and found that trade liberalisation promotes economic growth, which boosts energy demand. Moreover, trade liberalisation stimulates use of capital intensive techniques, which in turn affects energy consumption. Jena and Grote (2008) investigated the impact of trade openness on energy consumption. They noted that trade openness stimulates industrialisation 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

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

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 relationship is found between exports 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 were used for the panel of 8 Middle Eastern countries namely, Bahrain, Iran, Jordan, Oman, Qatar, Saudi Arabia, Syria and UAE. The empirical evidence reported 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 percent. A 1 percent increase in real per capita exports increases per capita energy consumption by 0.11 percent while 1 percent increase in real per capita imports increases per capita energy consumption by 0.04 percent. 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 cause energy consumption in short run. Using data of 52 developed and developing economies, Ghani (2012) explored relationship between trade liberalisation and energy demand. The results indicated that trade liberalisation has insignificant impact on energy consumption but after a certain level of capital per labour, trade liberalisation 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 by Pedroni (2004) and used 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 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) We use a separate ADF regression for each country:

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

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

(2) We run two separate regressions and save the residuals $\tilde{\eta}_{it}, \tilde{\mu}_{i,t-1}$

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

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

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

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

(3) Regression can be run to compute the panel test statistics following Equation 5:

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

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).

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

After the ADF regression has different augmentation lags for each country in finite samples, the term $E(t_T)$ and $\mathrm{var}(t_T)$ are replaced by the corresponding group averages of the tabulated values of $E(t_T, P_i)$ and $\mathrm{var}(t_T, P_i)$ 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 follows:

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

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 follows:

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

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 $\mathrm{var}(t_T)$ in the equation above are replaced by corresponding group averages of the tabulated values of $E(t_T, P_i)$ and $\mathrm{var}(t_T, P_i)$ respectively.[2]

3.3. MW Unit Root Test

The Fisher-type test 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-

[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 hypothesis is that all individual series in the panel are stationary. In IPS the alternative hypothesis 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 hypothesis 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 the 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.

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:

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

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 to the 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 of the panel individuals. The multivariate cointegration trace test of Johanson (1988, 1995) is applied 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 characterised by the following heterogeneous VAR (p_i) model:

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

Where $i = 1,\ldots\ldots N; t = 1,\ldots\ldots T$

For each one, the value of $Y_{i,-j+1},\ldots\ldots Y_{i,0}$ 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 of the error terms: $\Omega_i = E(\varepsilon_{i,t},\varepsilon'_{i,t})$. The Equation 10 can be modified as vector error correction model (VECM) as given below:

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

Where $\Pi_i = \Lambda_{i,1} + \ldots\ldots + \Lambda_{pi} - 1$ 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 column rank that represents the error correction form. The null hypotheses of panel LLL (2001) rank test are:

$H_\circ = rank(\Pi_i) = r_i \leq r$ for all $i = 1,\ldots\ldots N$ against

$H_a = rank(\Pi_i) = k$ for all $i = 1,\ldots\ldots N$

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, or 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;

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

Where λ'_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:

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

Finally, modified version of above equation is defined as:

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

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) proves the central limit theorem for the standard LR-bar statistic, according to which 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 given 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) notes 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:

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

With P∈N* and $v_{i,t} = \partial_i + \varepsilon_{i,t}$, where $\varepsilon_{i,t}$ are $i.i.d$ (O,σ^2_ε). In contrast to Nair–Reichert and Weinhold (2001), we assume that the autoregressive coefficients $\gamma^{(k)}$ and the regression coefficients slopes $\beta_i^{(k)}$ are constant $\Omega k \varepsilon [1, p]$. We 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. Conditional to the specific error components of the model, this hypothesis assumes no prevalence of any individual causality association:

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

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

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

In order to test these N_p linear restrictions Wald Statistic is employed:

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

Where RSS_2 indicates the restricted sum of squared residuals. RSS_1 corresponds to the residual sum of squares of equation-15. If the realisation 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. If the non-causality result is totally homogenous then further empirical exercise is stopped.

3.7. Homogenous Causality Test

Secondly, homogenous causality (HC) hypothesis is proven, in which there exist N causality relationships:

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

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

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

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

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

second one is more plausible, which 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 of testing if the regression slope coefficients associated to $x_{i,t-k}$ are identical. This test corresponds to a standard homogeneity test. Formally, the homogenous causality hypothesis test is as following:

$$H_o : \forall k \in [1, p] \ / \beta_i^k = \beta^k \ \forall i \in [1, N] \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (21)$$
$$H_a : \exists k \in [1, p], \exists\,(i, j) \ \in [1, N] / \beta_i^k \neq \beta_j^k$$

The homogenous causality hypothesis implies that the coefficients of the lagged explanatory variables $x_{i,t-k}$ 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:

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

where, RSS_3 corresponds to the realisation 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 there exists at least one individual causality relationship (and at the most N), and second that individual predictors, obtained conditional to the fact that $\overline{y}_{i,t}, \overline{x}_{i,t}, \overline{\lambda}_t$ and, α_i are heterogeneous.

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

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

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:

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

The third step of the procedure consists of testing the heterogeneous non-causality hypothesis (HENC). The following equation explains this mechanism:

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

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

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

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

where, $RSS_{2,i}$ corresponds to the realisation 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 of 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} as 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 $\forall t \in [1, T]$:

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

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.

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

where RSS_4 corresponds to realisation 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 individuals 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 individuals 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

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

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 exports (US$) plus real imports (US$) divided by population are used to 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, 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.

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.

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 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.

The results are reported in Table 4. We find that maximum likelihood ratio i.e. 5.9035 is greater than critical value at 1 percent 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 shows 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

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

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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*
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**

Continued—

Table 1—(*Continued*)

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*

Continued—

Table 1—(*Continued*)

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**

Continued—

Table 1—(*Continued*)

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***

Continued—

Table 1—(*Continued*)

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									
TR_t	0.7516	0.3288	–3.4925**	–4.2436**					
EC_t	–1.5577	–0.5170	–3.8687*	–4.4820*					

Note: *, ** and *** denote significant at 1 percent, 5 percent and 10 percent levels respectively.

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

Continued—

Table 2—(*Continued*)

Colombia				**Congo Dem Rep**			
R = 0	26.9458**	25.8721	0.0367	*R* = 0	11.5926	25.8721	0.8392
R ≤ 0	7.87041	12.5179	0.2624	*R* ≤ 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 ≤ 0	2.38065	12.5179	0.9406	*R* ≤ 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 ≤ 0	5.27551	12.5179	0.5573	*R* ≤ 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 ≤ 0	8.0965	12.5179	0.2439	*R* ≤ 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 ≤ 0	13.6372**	12.5179	0.0324	*R* ≤ 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 ≤ 0	13.7689**	12.5179	0.0307	*R* ≤ 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 ≤ 0	12.2436	12.5179	0.0555	*R* ≤ 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 ≤ 0	6.82323	12.5179	0.3633	*R* ≤ 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 ≤ 0	11.7234	12.5179	0.0676	*R* ≤ 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 ≤ 0	8.29920	12.5179	0.2282	*R* ≤ 0	10.5420	12.5179	0.1046

Continued—

Table 2—(*Continued*)

Honduras				**Hong Kong**			
R = 0	26.0812**	25.8721	0.0471	*R* = 0	37.9506*	25.8721	0.0010
R ≤ 0	10.9387	12.5179	0.0905	*R* ≤ 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 ≤ 0	8.98506	12.5179	0.1813	*R* ≤ 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 ≤ 0	4.72569	12.5179	0.6361	*R* ≤ 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 ≤ 0	9.92483	12.5179	0.1306	*R* ≤ 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 ≤ 0	4.03627	12.5179	0.7368	*R* ≤ 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 ≤ 0	7.55742	12.5179	0.2900	*R* ≤ 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 ≤ 0	3.17938	12.5179	0.8545	*R* ≤ 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 ≤ 0	8.74030	12.5179	0.1970	*R* ≤ 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 ≤ 0	19.2744*	12.5179	0.0032	*R* ≤ 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 ≤ 0	6.63904	12.5179	0.3837	*R* ≤ 0	10.8260	12.5179	0.0943

Continued—

Table 2—(*Continued*)

Nepal				**Netherland The 62**			
R = 0	27.6112**	25.8721	0.0301	*R* = 0	26.4791**	25.8721	0.0420
R ≤ 0	2.17146	12.5179	0.9572	*R* ≤ 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 ≤ 0	8.54960	12.5179	0.2100	*R* ≤ 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 ≤ 0	8.19985	12.5179	0.2358	*R* ≤ 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 ≤ 0	8.58027	12.5179	0.2078	*R* ≤ 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 ≤ 0	8.20377	12.5179	0.2355	*R* ≤ 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 ≤ 0	8.41322	12.5179	0.2198	*R* ≤ 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 ≤ 0	3.69726	12.5179	0.7854	*R* ≤ 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 ≤ 0	10.2042	12.5179	0.1182	*R* ≤ 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 ≤ 0	6.4377	12.5179	0.4068	*R* ≤ 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 ≤ 0	11.4533	12.5179	0.0748	*R* ≤ 0	6.4373	12.5179	0.4069

Continued—

Table 2—(*Continued*)

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							
$R = 0$	31.1438**	25.8721	0.0100				
$R \leq 0$	4.3126	12.5179	0.6965				

Note: * and ** denote rejection of null hypothesis at 1 percent and 5 percent levels of significance respectively.

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Table 3

Panel Unit Root Test

IPS TEST				
	Level		1st Difference	
Variables	Intercept	Trend and Intercept	Intercept	Trend and 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 and Intercept	Intercept	Trend and 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 and Intercept	Intercept	Trend and 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 and Intercept	Intercept	Trend and Intercept
TR_t	32.2558	178.6561	1064.9488*	895.8082
EC_t	169.0261	196.1862	1471.0689*	1282.0323*

Note: * Denotes rejection of null hypothesis at 1 percent significance level.

Table 4

Panel Cointegration Test

Hypotheses	Likelihood Ratio	1% Critical Value
$R = 0$	5.9035*	2.45
$R \leq 0$	0.9523	

Note: *Denotes rejection of null hypothesis at 1 percent significance level.

Table 5

Panel Cointegration Estimates

Variables	Pooled Mean Group (PMG)	Mean Group(MG)	Hausman Test[6]
	High Income Panel[7]		
TR_t	0.860*	1.315**	3.31
	(0.000)	(0.041)	(0.191)
TR^2_t	–0.015*	–1.688**	
	(0.000)	(0.054)	
	Middle Income Panel		
TR_t	–0.023**	–0.191***	1.45
	(0.014)	(0.063)	(0.484)
TR^2_t	0.003*	0.116**	
	(0.000)	(0.043)	
	Low Income Panel		
TR_t	–1.493*	–2.827**	1.68
	(0.000)	(0.023)	(0.321)
TR^2_t	0.0387*	0.114**	
	(0.000)	(0.030)	

Note: *, ** and *** show significance at 1 percent, 5 percent and 10 percent levels respectively.

Table 6

Non-Homogenous and Homogenous Causality

	Non-homogenous Causality		Homogenous Causality	
Dependent Variables	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: *Represents significance at 1 percent level.

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 continuous process of trade openness. In middle-income countries, trade openness stimulates industrialisation, which raises energy demand [Cole (2006)]. It is argued by Ghani (2006) that low-income countries are unable to reap optimal fruits of trade liberalisation because these economies are lacking in utilisation of energy efficient technology to enhance domestic production.

The presence of cointegration between the series leads us to investigate the direction of causality. In doing so, 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 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).

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

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 be helpful in policy-making 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 standards. 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 confirms 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	
	High Income Countries			
Variables	ln 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			
	ln 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			
	ln TR_t	ln EC_t	TR_t	EC_t
TR_t	_	Causality Exists*		Causality Exists*
EC_t	Causality Exists*	_	Causality Exists*	

Note: *Represents the significance at 1 percent 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	–

Continued—

Table 8—(*Continued*)

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*	–

Continued—

Table 8—(*Continued*)

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***	–

Continued—

Table 8—(*Continued*)

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 percent, 5 percent and 10 percent 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 relationship between trade openness and energy consumption i.e. no causality exists between both the variables for 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 relationship 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, however non-homogenous causality approach indicates unidirectional causality running form trade openness to energy consumption. Heterogeneous causality exposes that in 18 percent of sampled countries, the feedback effect exists while 24 percent show that trade openness causes energy consumption and rest of sample countries confirm the presence of neutral relationship between trade openness and energy consumption.

Overall, our results demonstrate 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 industrialisation that in turn 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 a result energy consumption decreases. 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 prices for countries, which do not have access to required amounts of capital. Further, it will have a positive impact on the world economy 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, industrialisation, urbanisation 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, industrialisation, trade openness and urbanisation on energy consumption using global level data. Using global level data, trade openness, financial development, industrialisation, urbanisation and CO_2 emissions nexus could be investigated by applying heterogamous panel under cross-sectional dependence framework.

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	

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Comments

Paper gives a good comparison among the high, middle and low income countries in terms of energy usage. Few comments which can improve the paper are; inclusion of the role of mediating/moderating variable which is production through which energy has causal relationship between trade openness. Baron and Kenny (1986)[8] gives a good technique of using moderating/mediating variable. Battery of tests is estimations are done in the paper but authors are very miser to explain the results. Since the panel data estimation is done to obtain the estimates therefore there is no need for single country regression or if authors have different objective in their mind then they did not explain it in the text. The paper says that 25 percent of the sample countries have positive association between energy and trade openness, what would author infer from this result. Since the data is from 1980-2010, thus I would recommend to apply a structural break test on the variables.

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[8]Reuben M. Baron and David A. Kenny (1986) "The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations". *Journal of Personality and Social Psychology*, Vol. 51, No. 6, 1173-1182.