How Strong is the Causal Relationship between Globalization and Energy Consumption in Developed Economies? A Country-Specific Time-Series and Panel Analysis

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Abstract
We examine the causal relationship between globalization, economic growth and energy consumption for 25 developed economies using both time series and panel data techniques for the period 1970-2014. Due to the presence of cross-sectional dependence in the panel (countries from Asia, North America, Western Europe and Oceania), we employ the Pesaran (2007) CIPS test to ascertain unit root properties. The Westerlund (2007) cointegration test indicates the presence of a long-run association between globalization, economic growth and energy consumption. Long-run heterogeneous panel elasticities are estimated through the Pesaran (2006) common correlated effects mean group (CMG) estimator and the Eberhardt and Teal (2010) augmented mean group (AMG) estimator. The causality between the variables is examined via Dumitrescu and Hurlin (2012) and, Emirmahmutoglu and Kose (2011) Granger causality tests. The empirical results reveal that, for most countries, globalization increases energy consumption. In the USA and UK globalization is negatively correlated with energy consumption. The causality analysis indicates the presence of the globalization driven energy consumption hypothesis. This empirical analysis suggests insightful policy guidelines for policy makers using globalization as an economic tool to utilize energy efficiently for sustainable economic development in the long-run.

Keywords: Globalization, Energy consumption, Causality

JEL Classification:Q43, F49

1. Introduction

Globalization, broadly defined as a shift to a more integrated world economy, is one of the most important forces shaping economies and societies (Hill, 2006). While it was once the case that most national economies were relatively self-contained, today more and more economies are interconnected. This interconnectedness can occur through economic, societal, or political means. Globalization, through its impact on trade, financial capital flows, and transfer of knowledge and technology can have an enormous impact on economic activity that has both positive and negative impacts on a country's citizens. While the impact of globalization on jobs, knowledge and health are actively studied, other areas, like the impact of globalization on energy consumption are understudied.

There are several reasons why one would be interested in studying the relationship between energy consumption and globalization. Two of the most important reasons are future energy needs, and environmental pollution from carbon dioxide (CO_2) emissions. Energy consumption is directly related to economic activity and increased economic activity requires more energy usage. An increase in energy efficiency can offset some but not all of the increases in energy requirements. High income OECD countries, for example, used 4537 kg of oil equivalent per capita in 1980 and 5103 in 2007[1]. This number has since fallen to 4683 in 2013 as the effects of the 2008-2009 financial crises have slowed global economic activity. The important point is that even with increases in energy efficiency, OECD countries use more energy per capita today than 30 years ago. For most countries, safe and secure energy supply is an important component of

[1] Data sourced for the World Bank World Development Indicators database (http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators)

future economic development. Future energy supply needs depends upon expectations of future energy consumption.

Environmental degradation is another important reason to study the impact of globalization on energy demand. The environmental consequences of trade liberalization have been recently investigated (Copeland and Taylor 1994, 2004, Copeland 2005, Baek et al. 2009). Globalization is considered as an important factor in stimulating energy consumption and hence may impact environmental quality in both developed and developing economies (Baek et al. 2009, Shahbaz et al. 2015, 2016). Approximately 65% of global CO_2 emissions come from the burning of fossil fuels and fossil fuels are the main source of energy[2]. The finding of a strong positive link between globalization and energy consumption would have implications for CO_2 emissions. In this context, a research question arises: how strong is the linkage between globalization and energy consumption? It is therefore important for researchers to examine the impact of globalization on energy consumption through various channels. An earlier study by Baek et al. (2009) emphasized the environmental consequence of trade liberalization in 25 developed and developing countries. However, the recent study by Shahbaz et al. (2016) for the Indian economy also supported the importance of globalization on energy consumption. Hence we may conclude that globalization plays a vital role which can affect energy consumption positively and negatively. It may be the case that foreign investors create new businesses or expand their existing ventures employing sophisticated technology that lowers the usage of energy and thereby reduces their total production costs (Shahbaz et al. 2016). Such a situation indicates an inverse relationship between globalization and energy demand. On the other hand, a positive

[2]https://www3.epa.gov/climatechange/ghgemissions/global.html

relationship between globalization and energy consumption exists if foreign firms in a domestic economy expand the existing business activity or create new business hubs with obsolete or traditional technology that consumes higher volumes of energy and thereby adds to the total costs of production (Shahbaz et al. 2016). Such a possibility is not beneficial for the host country because the operational business activity of foreign firms is producing a loss-loss matrix of lower cost of production and higher loss of environmental quality due to relax environmental policies (Shahbaz et al. 2016).

As far as the impacts of globalization on energy consumption are concerned, its effects on energy consumption can be viewed through the channels of scale, technique and composition effects. Through the scale effect, keeping other things constant, globalization will increase energy consumption because it increases economic activity (Cole, 2006). In addition, when globalization is in the form of trade and capital inflows, globalization enables economies to reduce energy consumption by importing new technology without hampering the economic activity (Antweiler et al. 2001). This is termed as the technique effect of globalization on energy consumption (Dollar and Kraay, 2004). Lastly, the composite effect of globalization on energy consumption occurs when energy consumption decreases with the rise in economic activity (Stern, 2007). Moreover, globalization enables an economy in shifting the production process from agriculture to industry and finally to service sectors. Thereby, production techniques may change as the economy transitions from the industrial sector to the service sector entailingless use of energy and ensuring better environmental quality (Jena and Grote, 2008).

The usage of globalization proxies such as exports, imports, trade, and trade liberalization when examining the association between globalization and energy consumption has provided somewhat mixed empirical results although there is evidence that trade affects energy consumption in both the short and long run. These empirical findings cannot help policy makers in designing comprehensive trade policy that use globalization as a tool for optimal utilization of energy to enhance domestic output. This warrants using a more appropriate indicator of globalization for the investigation of the globalization-energy consumption nexus. This present study contributes to the existing literature in six important ways: (i) We examine the causal relationship between globalization and energy consumption for 25 developed countries (Asia, North America, Western Europe and Oceania) by using a dynamic time series and panel econometric framework by incorporating economic growth as additional determinant of energy consumption. It is desirable to study the energy consumption – globalization relationship for developed economies because developed economies were the first to experience globalization and also developed countries have a longer data set on energy consumption,(ii) We use a new index of globalization developed by Dreher (2006) which explicitly takes into account several important dimensions of globalization (economic, social, and political), (iii) We employ the Pesaran (2007) CIPS test for testing whether cross-sectional dependence is present or not, (iv) The Westerlund (2007) test is applied in order to examine panel cointegration between the series, (v) Long-run heterogeneous panel elasticities are estimated by applying common correlated effects mean group (CMG) estimator and Eberhardt and Teal (2010) augmented mean group (AMG) estimator, and (vi) The causality between the variables is examined via Emirmahmutoglu and Kose (2011) and Dumitrescu and Hurlin (2012) Granger causality approaches. We find that for most of the countries studied, globalization stimulates energy consumption.

The remainder of the paper is structured as follows: Section 2 discusses the related literature. Section 3 highlights the empirical strategy used in the analysis. Section 4 discusses the data set used in the analysis and presents empirical results. Finally, Section 5 concludes with core findings along with added policy implications.

2. Related Literature

Going back to the genesis of the energy and environmental economics literature, several researchers (Shafik and Bandhopadhaya 1992, Panayotou 1993, Seldon and Song 1994, Grossman and Krueger 1991, 1995 and others) have established an empirical relationship between income and environmental pollution and found an inverted U-shaped relationship between these variables. In energy economics, there is a growing literature examining the feedback relationship between energy consumption and economic growth across economies (Ozturk, 2010). In connection to the dynamics of energy consumption linked with economic growth through testing of the Environmental Kuznets curve (EKC) hypothesis, we also find many recent studies that have extended the relationship between economic growth and energy consumption by incorporating financial development and urbanization into the energy demand function (Shahbaz and Lean 2012, Islam et al. 2013, Menegaki and Ozturk 2013). In addition, Baek et al. (2009) have recently examined the environmental consequences of trade liberalization for 25 developed and developing countries and found empirical support for the environmental Kuznets curve hypothesis and pollution heaven hypothesis for developed and developing countries. In line with their findings, the strong support in favor of an environmental Kuznets curve hypothesis for developed countries occurs because trade openness and income cause a change in environmental quality, while for developing countries the pollution heaven hypothesis exists due to causality running from environmental degradation to income and trade openness. Such differences in inferences between developed and developing countries are the main cause of using narrowly defined globalization (e.g. trade liberalization). A very recent study by Shahbaz et al. (2016) shows that accounting for globalization produces a win-win situation for a developing economy like India in terms of higher economic growth and improved environmental quality through reducing energy consumption. The research by Baek et al. (2009) and Shahbaz et al. (2016) provide a solid foundation to extend the energy economics literature. In particular, we are interested in determining the dynamic casual linkage between globalization and energy consumption in 25 developed economies.

Various studies in the existing literature have used different indicators of globalization to examine the relationship between globalization and energy consumption. For instance, Antweiler et al. (2001) used trade openness (exports + imports) as an indicator of globalization and found that trade openness reduces energy demand as the technological effect dominates the composite and scale effects. The adoption of energy saving technology in the production process not only saves energy resources but also enhances domestic production and improves environmental quality. Copeland and Taylor, (2004) also supported the beneficial role of international trade in saving energy and inducing environmental quality through environmental regulations and movement of capital-labor channels. Cole, (2006) investigated the impact of trade liberalization (an indicator of globalization) on per capita energy use for 32 developed and developing countries. He finds that trade can influence energy consumption via a scale effect (increased movement of goods and services on account of trade leads to economic activity and energy usage), a technique effect (trade enables technology transfer from developed to developing countries), and a composite effect (trade can affect the sector composition of an economy). The empirical evidence indicates that trade liberalization is likely to increase per capita energy use.

There are a number of studies that further look at the impact of trade on energy consumption. Narayan and Smyth (2009) investigated the causality between energy consumption, exports (indicator of globalization) and economic growth for MENA region. They reported the feedback effect between economic growth and energy consumption and neutral hypothesis between exports and energy consumption. For a panel of Middle East countries, Sadorsky (2011) finds that in the short run, causality runs from exports to energy consumption while there is a bidirectional link between imports and energy consumption. Long run results show that increases in exports and imports increase energy consumption. In case of South American countries, Sadorsky (2012) investigated the relationships between energy consumption, output and trade and noted that Granger causality runs from energy consumption to imports, and there exists the bidirectional causality between energy consumption and exports in short-run but the feedback effect also exists between energy consumption and trade in long-run. Ozturk and Acaravci, (2012) explored the relationship between economic growth, energy, financial development and trade for Turkish economy. Their results indicated that trade openness leads economic growth that positively affects energy consumption. Lean and Smyth (2010a) investigated the relationship between economic growth, energy consumption and international trade for Malaysia by using multivariate Granger causality tests for the period of 1971-2006. They indicated the presence of unidirectional Granger causality running from exports to energy consumption. Similarly, Lean and Smyth (2010b) found that exports Granger cause of electricity generation. On the contrary, Erkan et al. (2010) found evidence of unidirectional causality running from energy consumption to exports for the Turkish economy. In the case of Shandong (China), Li (2010) reported that energy consumption is a Granger cause of exports. Sami (2011) employed a production function for examining the relationship between energy consumption, exports and economic growth for the Japanese economy. The empirical results find that unidirectional causality exists running from exports to electricity consumption.

Shahbaz et al. (2013a) employed an augmented production function for examining the relationship between energy consumption, economic growth and international trade for the Chinese economy. They found that international trade causes energy consumption. In case of Pakistan, Shahbaz et al. (2013b) used exports as an indicator of globalization to test the relationship between exports and natural gas consumption. Their empirical analysis indicated that natural gas consumption contributes to economic growth and exports. In a similar vein, Dedeoglu and Kaya (2013) examined the relationship between energy consumption, globalization (measures by exports and imports) for 25 OECD countries. Their empirical analysis confirmed the presence of a feedback effect between energy and exports (energy and imports). Shahbaz et al. (2014) employed the heterogeneous Granger causality test to examine the relationship between trade openness and energy consumption for 91 low, middle and high income countries. They empirically documented the U-shaped relationship between trade openness and energy consumption for low and middle income countries but inverted U-shaped relationship is also found for high income countries. They also noted a bidirectional Granger causality relationship between trade openness and energy consumption was confirmed by a non-homogenous causality approach. For African countries, Aïssa et al. (2014) documented that domestic output is stimulated by renewable energy consumption and trade but the neutral effect is observed between trade openness and renewable energy consumption. Shahbaz et al. (2016) used a globalization index (covering economic, social and political aspects of globalization) developed by Dreher (2006) in order to examine the association between globalization and energy consumption for the Indian economy. Their results reported that globalization is one of the key factors of reducing energy demand for India.

3. Methodology Framework

This paper aims to investigate the relationship between globalization and energy consumption using a panel of 25 developed countries. These countries are highly integrated due to economic and financial ties; a country may be impacted by economic shocks or business cycle effects occurring in other countries and vice versa. The empirical evidence may be biased or ambiguous if we ignore economic, financial or cultural ties of states during model specification. Imposing homogeneity restriction on parameters and cross-section-independence across individual units can further least to misleading empirical results. To solve this issue, we apply cross-sectional independence and slope homogeneity tests to decide on the appropriate panel causality approach.

3.1. Cross-sectional Dependence Test

We apply the Langrage multiplier (LM) cross-sectional dependence test which is widely used in the existing applied economics literature to determine whether cross-sectional dependence is present among the panel of countries. This test originated with Breusch and Pagan, (1980). The empirical equation for the LM test is modeled as following:

$$y_{it} = \alpha_i + \beta_i x_{it} + \mu_{it} \qquad (1)$$

for $i = 1, 2, ..., N;\ t = 1, 2, ..., T$

where i indicates cross-section dimension, time dimension is shown by t and x_{it} is a $k \times 1$ vector of impendent variables. In the basic set up of our model the variable y represents energy consumption and the variable x represents globalization. The individual intercepts and slope coefficients across countries are indicated by α_i and β_i. The null hypothesis of no cross-sectional dependence is stated as follows:

$$H_0 : Cov(\mu_{it}, \mu_{jt}) = 0 \qquad for\ all\ t\ and\ \ i \neq j$$

The alternate hypothesis of cross-sectional dependence is given by:

$$H_a : Cov(\mu_{it}, \mu_{jt}) \neq 0 \qquad for\ at\ least\ one\ pair\ of\ i \neq j$$

In order to test the null hypothesis of no cross-sectional dependence, Breusch and Pagan, (1980) introduced the following LM test:

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \qquad (2)$$

where, $\hat{\rho}_{ij}$ indicates the coefficient of pair-wise correlation obtained from OLS (ordinary least square) using equation-1 for each i. The LM test is suitable for relatively small N with adequate large T. Furthermore, the LM test is distributed asymptotic chi-square with $(N(N-1)/2)$ degrees of freedom. The cross-sectional dependence test losses its explanatory power if the population average pair-wise correlation mean is close to zero (Pesaran et al. 2008). The cross-sectional dependence test may accept the null hypothesis if the factor loadings contain zero mean in the cross-section dimension. In order to overcome these issues, Pesaran et al. (2008) modified the LM test by adjusting for these biases. The modified LM test uses accurate mean and variance of the LM statistics. The modified LM test is formulated as following:

$$LM_{adj} = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{Tij}}{\sqrt{v_{Tij}^2}} \quad (3)$$

where, the exact mean and variance of $(T-k)\hat{\rho}_{ij}^2$ are indicated by μ_{Tij} and v_{Tij}^2 tabulated by Pesaran et al. (2008). The LM test is asymptotically distributed as standard normal if the null hypothesis considers first $T \to \infty$ and then $N \to \infty$ as well.

3.2. Slope Homogeneity Test

With the presence of strong cross-sectional dependence, it is possible that every country may have similar dynamics of the economic development process. This leads us to control the cross-sectional heterogeneity while investigating the empirical results. When the panel is heterogeneous, assuming slope homogeneity can result in misleading estimates (Breitung, 2005). The null hypothesis of the slope homogeneity test is $H_0 : \beta_i = \beta_j$ and is tested using an F-test against the alternative hypothesis that $H_a : \beta_i \neq \beta_j$ for all i_s[3]. When the cross-sections are fixed with large time dimensions, independent variables are strictly exogenous with homogenous error variance (Chang et al. 2014). Swamy, (2007) introduced a new test for testing slope homogeneity, the "relating homoscedasticity assumption", by applying a suitable pooled estimator on the dispersion of individual slope estimates. The standard F-test and Swamy test require that N should be fixed relative to T. Pesaran and Yamagata (2008) extended this test for examining slope homogeneity for large panels. The test developed by Pesaran and Yamagata (2008) is suitable if $(N, T) \rightarrow \infty$ by assuming that error terms contain a normal distribution. The modified version of the Swamy test is modeled as following:

$$\tilde{S} = \sum_{i=1}^{N} \left(\hat{\beta}_i - \tilde{\beta}_{WFE}\right)' \frac{x_i' M_\tau x_i}{\tilde{\sigma}_i^2} \left(\hat{\beta}_i - \tilde{\beta}_{WFE}\right) \tag{4}$$

where, the pooled OLS coefficient is denoted by $\hat{\beta}_i$, the weighted fixed effect pooled estimator is $\tilde{\beta}_{WFE}$, the identity matrix is M_τ and an estimate of σ_i^2 is denoted by $\tilde{\sigma}_i^2$. The standard dispersion statistic can be computed by the following formula given below:

$$\bar{\Delta} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - k}{\sqrt{2k}}\right) \tag{5}$$

[3]The null hypothesis is that slope coefficients (no heterogeneity) are homogenous against no homogeneity (heterogeneity).

It is expected that the $\bar{\Delta}$ test contains standard as well as asymptotically normally distribution under the null hypothesis of $(N, T) \to \infty$ and $\sqrt{N/T} \to \infty$ with normal distribution of error terms. The biased adjusted version of the $\bar{\Delta}$ test is modeled as following:

$$\bar{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - E(\bar{z}_{it})}{\sqrt{\text{var}(\bar{z}_{it})}}\right) \quad (6)$$

where, the mean and variance are denoted by $E(\bar{z}_{it}) = k$ and $\text{var}(\bar{z}_{it}) = 2k(T-k-1)/T+1$.

3.3. Panel unit root test

Pesaran (2007) developed a new panel unit root test by augmenting the standard ADF regressions with the cross-section averages of the lagged level and first differences of the individual series. In the presence of N cross-sectional and t time series observation, Pesaran (2007) uses the following simple dynamic linear heterogeneous model:

$$\Delta x_{i,t} = \alpha_i + \rho_i x_{i,t-1} + c_i \bar{x}_{t-1} + d_i \Delta\bar{x} + \varepsilon_{i,t} \quad (7)$$

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

The cross-sectional averages of lagged levels $\bar{x}_{t-1}$ and first differences $\Delta\bar{x}_t$ of individual series capture the cross-sectional dependence via factor structure. Pesaran suggests modifyingequation-7 with appropriate lags in the presence of serially correlated error term. Pesaran (2007) obtains the modified IPS statistics based on the average of individual CADF, which is denoted as cross-sectional augmented IPS (CIPS). This is estimated from:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \qquad (8)$$

where $CADF_i$ is the cross-sectional augmented Dickey-Fuller statistic for the ith cross-sectional unit given by the t-ratio of ρ_i in the CADF regression-1. The distribution of the CIPS statistic is found to be non-standard even for large N.

3.4. Panel Cointegration Test

Granger (1981) pioneered the concept of cointegration in time series data. Cointegration tests were developed by Engle and Granger (1987), Philips and Ouliaris (1990) and Johansen (1988, 1991), among others. Similar to panel unit root tests, extension of time-series cointegration to panel data is also recent. The panel cointegration tests that have been proposed so far can be divided into two groups: the first group of cointegration tests is based on the null hypothesis of cointegration (McCoskey and Kao 1998, Westerlund 2005) while the second group of cointegration tests take no cointegration as the null hypothesis (Pedroni 1999, Kao 1999, Larsson et al. 2001, Groen and Kleibergen 2003).

Four error correction based panel cointegration tests developed by Westerlund, (2007) are employed in the present study. These tests are based on structural dynamics rather than residuals dynamics so that they do not impose any common factor restriction. The null hypothesis of no cointegration is tested via the error correction term in a conditional error correction model. If the null of no error correction is rejected, then the null hypothesis of no cointegration is rejected. The error correction model based on the assumption that all the variables are integrated of order 1 is as follows:

$$\Delta z_{it} = \delta_i' d_i + \theta_i (z_{i(t-1)} - \beta_i' y_{i(t-1)}) + \sum_{j=1}^{m} \theta_{ij} \Delta z_{i(t-j)} + \sum_{j=0}^{m} \phi_{ij} \Delta y_{i(t-j)} + \omega_{it} \quad (9)$$

where, $d_t = (1-t)'$ holds the deterministic components, and $\delta_i' = (\delta_{1i}, \delta_{2i})'$ is the associated vector of parameters. In order to allow for the estimation of the error correction parameter θ_i by least square, (9) can be rewritten as:

$$\Delta z_{it} = \delta_i' d_i + \theta_i (z_{i(t-1)} + \pi_i' y_{i(t-1)}) + \sum_{j=1}^{m} \theta_{ij} \Delta z_{i(t-j)} + \sum_{j=0}^{m} \phi_{ij} \Delta y_{i(t-j)} + \omega_{it} \quad (10)$$

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

$$G_\tau = \frac{1}{N}\sum_{i=1}^{N}\frac{\theta_i}{S.E(\hat{\theta}_i)} \qquad (11)$$

and

$$G_\alpha = \frac{1}{N}\sum_{i=1}^{N}\frac{T\theta_i}{\theta_i^{'}(1)} \qquad (12)$$

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

$$P_\tau = \frac{\hat{\theta}_i}{S.E(\hat{\theta}_i)} \qquad (13)$$

$$P_\alpha = T\hat{\theta} \qquad (14)$$

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

3.5. Panel causality tests

3.5.1. Emirmahmutoglu and Kose (2011) Panel Causality Test

In order to examine whether globalization causes energy consumption or energy consumption cause globalization, we apply the Emirmahmutoglu and Kose (E-K) (2011) panel causality test. This test is based on the Toda and Yamamoto (T-Y) causality procedure that can be applied without testing the integrating properties of the variables. The E-K causality test is applicable if the variables are stationary at I(0) or I(1) or I(0)/I(1)[4]. The analysis of Fisher (1932) is the basis for the formation of the E-K panel causality test. Emirmahmutoglu and Kose, (2011) modified the lag augmented VAR (LA-VAR) approached developed by Toda and Yamamoto, (1995). The E-K panel causality test employs the VAR model at levels using extra *dmax* lags in order to determine Granger causality association between the series in heterogeneous fixed panels. The level VAR model containing k_i + *dmax* lags using heterogeneous mixed panels:

$$x_{i,t} = \mu_i^x + \sum_{j=1}^{k_i + d\max} \mathrm{A}_{11,ij} x_{i,t-j} + \sum_{j=1}^{k_i + d\max} \mathrm{A}_{12,ij} y_{i,t-j} + \mu_{i,t}^x \tag{15}$$

$$y_{i,t} = \mu_i^y + \sum_{j=1}^{k_i + d\max} \mathrm{A}_{11,ij} x_{i,t-j} + \sum_{j=1}^{k_i + d\max} \mathrm{A}_{12,ij} y_{i,t-j} + \mu_{i,t}^y \tag{16}$$

where $i(i = 1, \ldots, N)$ indicates individual cross-sections and $t(t = 1, \ldots, T)$ is time periods while $\mu_{i,}^x$ and μ_i^y are fixed effects vectors. The column vectors of error terms are $\mu_{i,t}^x$ and $\mu_{i,t}^y$ and the lag structure is k_i that is assumed to be predetermined or different for different cross-section units and *demax* indicates the optimal integrating order for each i in the VAR system. The bootstrap

[4] There is no need to test the presence or absence of cointegration between the variables when applying the Toda and Yamamoto (1995) causality test. This methodology uses a two-step approach. In the first step, the lag length of the VAR is determined using standard selection criteria like AIC or SIC. In the second step, the order of the VAR lag length is augmented by a number reflecting the order of integration associated with the variables.

causality procedure developed by Emirmahmutoglu and Kose, (2011) for causality running from x to y is summarized as following:

1. The ADF unit root test is applied in order to determine the appropriate (*dmax*) order of integration of the variables to be used in the VAR system for each cross-section units. The optimal lag order $k_i s$ is chosen following Akaike Information Criterion (AIC) by applying ordinary least square (OLS) to estimate the regression-15.

2. The non-causality hypothesis is empirical tested by re-estimating equation-16 using *demax* and k_i. This process is conducted to calculate for each individual as following:

$$\hat{\mu}_{i,t}^{y} = y_{i,t} - \hat{\mu}_i^{y} + \sum_{j=1}^{k_i + d\max} \hat{A}_{21,\,ij} x_{i,t-j} + \sum_{j=1}^{k_i + d\max} \hat{A}_{22,\,ij} y_{i,t-j} \quad (17)$$

3. We follow the suggestion by Stine, (1987) to centre the residuals as following:

$$\tilde{\mu} = \hat{\mu}_i - (T - k - l - 2)^{-1} + \sum_{t=k+l+2}^{T} \hat{\mu}_t \quad (18)$$

   where, $\hat{\mu} = (\hat{\mu}_{1t}, \hat{\mu}_{2t}, \hat{\mu}_{3t}, ...\hat{\mu}_{Nt})'$, $k = \max(k_i)$ and $l = \max(d\max_i)$. Further, these residuals are developed by using $[\tilde{\mu}_{i,t}]_{N\times T}$. The full column with the replacement of matrix is chosen at a time for preserving cross covariance of errors structure. The bootstrap residuals are indicated by $\tilde{\mu}_t^*$ and $(t = 1, ..., T)$.

4. A bootstrap sample of $\boldsymbol{y_i}$'s is generated i.e.

$$y_{i,t}^{*} = \hat{\mu}_i^{y} + \sum_{j=1}^{k_i + d\max} \hat{A}_{21,ij} x_{i,t-j} + \sum_{j=1}^{k_i + d\max} \hat{A}_{22,ij} y_{i,t-j}^{*} + \mu_{i,t}^{*} \qquad (19)$$

The $\hat{\mu}_i^{y}$, $\hat{A}_{21,ij}$ and $\hat{A}_{22,ij}$ are obtained by using step-3.

5. Further, the Wald test is applied to test the non-causality hypothesis for each individual by replacing $y_{i,t}$ with $y_{i,t}^{*}$. In such situations, we estimate equation-7 in the absence of parameters restriction. The individual *p-values* correspond to the Wald statistics for *ith* cross-section. The Fisher test statistic is calculated as following:

$$\lambda = -2\sum_{i=1}^{N} \ln(p_i) \qquad i = 1, \ldots\ldots, N \qquad (20)$$

The steps 3-5 are repeated 1000 times in order to generate the empirical bootstrap distribution of the Fisher test statistics. An appropriate percentiles sampling distribution is selected to generate bootstrap critical values. Lastly, Emirmahmutoglu and Kose, (2011) argued that LA-VAR approach performs well under the cross-section independence and cross-section dependence. This seems to be acceptable for the entire time period (T) and observations (N).

3.5.2. Dumitrescu and Hurlin (2012) Panel Causality Test

The problem with the Emirmahmutoglu and Kose (2011) bootstrap panel causality test is that it is based on the bivariate Toda-Yamamoto approach. Furthermore, the E-K panel causality testis applicable if the time series length (T) is greater than the number of cross-sections (N). In response to these short comings, Dumitrescu and Hurlin, (2012) developed new panel causality approaches. Their approach is suitable in the absence of the restriction of T>N. Moreover, this approach to panel causality is applicable if all the variables in the panel are stationarity at a common level i.e. I(1).

Dumitrescu and Hurlin, (2012) modified the Granger, (1969) non-causality test for heterogeneous panels assuming fixed estimates. This causality test considers the two heterogeneity dimensions: (i) heterogeneous regression model to be employed for testing causality in Granger sense and (ii) heterogeneous causal associations. We consider the following linear model. The linear specification of the empirical equation is modeled as following:

$$z_{it} = \alpha_i + \sum_{m=1}^{M} \gamma_i^{(m)} z_{i,t-m} + \sum_{m=1}^{M} \beta_i^{(m)} y_{i,t-k} + \varepsilon_{it} \qquad (21)$$

The equation-21 indicates y and z are the series found to be stationary for N individuals in T periods. The intercept and coefficients such as α_i and $\beta_i = (\beta_i^{(1)},.......,\beta_i^{(m)})'$ are fixed in the given time dimension. The autoregressive parameters $\gamma_i^{(m)}$ and regression coefficient estimates $\beta_i^{(m)}$ are assumed to vary across cross-sections. The null hypothesis is ‘no causal relationship exists between the variables' in the panel for any of the cross-section and it is termed as Homogenous Non-Causality (HNC) hypothesis which can be described as following:

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

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

The alternative hypothesis is termed as the Heterogeneous Non-causality (HENC) hypothesis as we specify two sub-groups of cross-section units. The unidirectional causality runs from *y* to *z* in the first sub-group but not in the second sub-group. If there is no causal association from *y* to *z* for the second sub-group then we use a heterogeneous panel data model by assuming fixed estimates of the group for empirical analysis. The alternate hypothesis can be described as following:

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

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

It is assumed that β_i may be sensitive across cross sections with N_1< N individual processes providing neutral effect from y to z. The unknown N_1 determines the condition $0 \leq N_1 / N < 1$. This leads us to propose the average statistics $W_{N,T}^{HNC}$ following (Dumitrescu and Hurlin, 2012). The average statistics $W_{N,T}^{HNC}$ is directly linked to the Homogenous Non-causality (HNC) hypothesis as given below:

$$W_{N.T}^{HNC} = \frac{1}{N}\sum_{i=1}^{N} W_{i,T} \quad (22)$$

where, $W_{i,T}\,(W_{i,T} = \hat{\theta}_i^{'} R^{'} \left[\hat{\sigma}_i^2 R(Z_i^{'} Z_i)^{-1} R^{'}\right] R\hat{\theta}_i)$ are individual Wald statistics for each cross-section unit. The null hypothesis of non-causality reveals that each individual Wald statistic congregates to a chi-squared distribution in the presence of M degree of freedom for $T \to \infty$. This harmonized test statistic $Z_{N,T}^{HNC}$ for $T, N \to \infty$ is written as following:

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2M}}(W_{N,T}^{HNC} - M) \to N(0,1) \quad (23)$$

The harmonized test statistic $Z_{N,T}^{HNC}$ for fixed T samples is given as following:

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2\times K} \times \frac{(T-2K-5)}{(T-K-3)}} \times \left[\frac{(T-2K-3)}{(T-2K-1)} W_{N,T}^{HNC} - K\right] \to N(0,1) \quad (24)$$

where, $W_{N,T}^{HNC} = (1/N)\sum_{1=1}^{N} W_{i,T}$. Dumitrescu and Hurlin (2012) have provided detailed information for these statistics extensively.

4. Data and Results

We use world development indicators (CD-ROM, 2015) as our data source for energy consumption. Annual data from 1970-2014 for energy consumption (kg of oil equivalent) is converted into per capita units using total population. The data on real GDP per capita (constant

2010 US$) is also collected from world development indicators (CD-ROM, 2015). The globalization index is from Dreher (2006) who generated an overall globalization index from three sub-indices i.e. economic globalization, social globalization and political globalization. Economic globalization involves two sub-indexes including (i) actual economic flows (trade, foreign direct investment and portfolio investment) and (ii) restrictions to trade and capital flows (which include restrictions on trade and capital using hidden import barriers, mean tariff rates, taxes on international trade as a share of current revenue and an index of capital controls). Social globalization is measured using personal contact (telephone contact, tourism, foreign population), information flows (internet usage, televisions per 1000 people, trade in newspapers), and data on cultural proximity (number of McDonald's restaurants, number of IKEA stores, trade in books). For political globalization, Dreher (2006) used number of embassies in a country, membership in international organizations, participation in UN secretary council membership and international treaties to generate an index of political globalization. The globalization index is constructed from the three sub-indices, economic, social, and political, which account for 36%, 38%, and 26% respectively of the overall globalization index.

The presence of cross-sectional dependence and slope heterogeneity affect the causal estimates between globalization (G), economic growth (Y) and energy consumption (EC). Consequently, it is important to test the data for these properties. Table-1 shows the results of cross-sectional dependence and slope homogeneity tests. These tests are the Lagrange multiplier (LM) test (Breusch and Pagan, 1980), the cross-sectional dependence test (Peseran et al. 2008) and the LMadj test with the null hypothesis of no cross-sectional dependence. Peseran and Yamagata, (2008) recommended a standardized version of Swamy's test for examining the slope homogeneity in large panels and its biased adjusted version. The results reported in Table-1 also indicate the absence of slope homogeneity and cross-sectional independence. This implies that cross-sectional dependence is present. We confirm the presence of heterogeneity and spatial effect across the panel of 25developed countries.

Table-1: Cross-Sectional Dependence and Slope Homogeneity Analysis

CD_{BP}	5210.61***
CD_{LM}	199.45***
CD	20.513***
LM_{adj}	199.17***
$\tilde{\Delta}$	4271.3***
$\tilde{\Delta}_{adj}$	10.1792***
Note: *** represents significance at 1% per cent level.	

Table-2: Pesaran (2007) Panel Unit Root Test Analysis

	Constant	Constant and trend
Level		
lnEC	-1.093	-0.263
lnG	-1.687	0.165
lnY	-1.872	-0.682
First difference		
ΔlnEC	-17.155***	-16.049***
ΔlnG	-13.560***	-12.749***
ΔlnY	-4.917***	-5.144***
Note: *** indicates rejection of null hypothesis at 1% level.lnEC refers to natural logarithmic of energy consumption while lnG denotes natural logarithmic of overall globalization index covering social, political and economic globalization indexes.		

In order to examine the stationarity properties of globalization and energy consumption, we apply the CIPS unit root test and the reported results are shown in Table-2. We find that globalization and energy consumption contain unit roots according to the constant and constant – trend versions of the test in the presence of cross-sectional dependence. Globalization, economic growth and energy consumption are found stationary in first differences. This implies that globalization, economic growth and energy consumption are integrated of order I(1). The unique order of integration of both variables allows us to apply the error-correction based panel cointegration test developed by Westerlund (2007) to examine whether a long-run relationship between globalization, economic growth and energy consumption is present or not. Table-3 reports the results of panel cointegration tests. We find the null hypothesis of no cointegration can be rejected indicated by group (G_t and G_α at 10% and 1% levels, respectively) and panel statistics (P_t and P_α at 10% and 1% levels, respectively). This supports the hypothesis that globalization, economic growth and energy consumption are cointegrated for a sample of developed countries over the period 1970-2014.

Table-3: Westerlund (2007) Cointegration Test Analysis

	Value	z-value	Robust p-value
G_t	-8.162	-0.952	0.006
G_α	-13.712	-4.054	0.000
P_t	-9.849	-3.762	0.000
P_α	-7.428	-1.628	0.003
Note: Optimal lag/lead length determined by Akaike Information Criterion with a maximum lag/lead length of 2. Width of Bartlett-kernel window set to 3. Number of bootstraps to obtain bootstrapped-values, which are robust against cross-sectional dependencies set to 400.			

The existence of a panel cointegration relationship between globalization, economic growth and energy consumption in 25 developed countries enables us to examine the time series and panel effects of globalization on energy consumption. Table-4 reveals the heterogeneous panel elasticity analysis by applying CMG and AMG[5]. As far as the country specific time series evidence is concerned, we find that globalization has a positive impact on energy consumption in Japan (at 1%), Korea (at 1%), Israel (at 1%), Singapore (at 1%), Canada (at 1%), Austria (at

[5] To conserve space, we have just focused to empirical results between globalization and energy consumption. The rest results are available upon request from authors.

1%), Belgium (at 1%), Finland (at 1%), France (at 1%), Greece (at 1%), Iceland (at 1%), Ireland, Italy (at 1%), the Netherlands (at 1%), Norway (at 1%), Portugal (at 1%), Spain (at 1%), Sweden (at 1%), Switzerland (at 1%), Australia (at 1%) and New Zealand (at 1%). This implies that globalization strongly stimulates energy consumption. On contrary, globalization is negatively linked with energy consumption in USA (at 5%), Denmark (at 5%), Luxembourg (at 1%) and UK (at 10%). This implies that globalization reduces energy consumption may be due to adoption of energy efficient technology. The panel estimates also show the positive link of globalization on energy consumption at 1% and 5% levels of significance.

Table-4: Long-run Heterogeneous Panel Elasticity Analysis

Country	CMG		AMG	
	Coeff.	Z	Coeff.	Z
Japan	0.7302	13.450***	0.4131	3.4142***
Korea	3.7047	26.906***	0.7130	0.6941**
Israel	0.6248	5.7300***	0.0122	0.0726
Singapore	3.2352	15.441***	0.9889	1.9313**
USA	-0.1717	-2.2371*	-0.6083	-3.3023***
Canada	0.6523	7.1907***	0.6143	3.6235***
Austria	0.9718	17.941***	-0.1442	-1.2613
Belgium	0.7133	9.1620***	-0.6292	-3.1823***
Denmark	-0.2133	-2.1591**	-0.2140	-0.8073
Finland	0.8097	15.855***	-0.0483	-0.2441
France	0.6636	15.348***	0.2785	3.4170***
Greece	1.2056	12.319***	-0.0954	-0.8699
Iceland	1.9406	9.1010***	0.1005	0.5980
Ireland	1.3464	11.030***	0.2248	0.7085
Italy	0.7178	17.086***	0.1143	0.9843
Luxembourg	-1.4949	-5.2105***	1.2177	1.6905*
Netherlands	0.2984	3.6358***	-0.6684	-3.2432***
Norway	1.6895	24.188***	0.9717	4.6172***
Portugal	1.6490	17.907***	0.1407	0.7571
Spain	1.0573	17.747***	0.1125	0.6195
Sweden	0.4769	6.0859***	0.8034	2.9701***
Switzerland	0.7333	10.723***	0.5780	2.7696***
UK	-0.1727	-1.6581**	-0.2837	-2.0134***
Australia	0.8528	21.637***	0.3125	2.6056***
New Zealand	1.2227	17.255***	0.2198	0.7653

Panel statistics	1.0856	5.4002***	0.2230	2.1777**
Note: ***, ** and * indicate significance at 1%, 5% and 10% level, respectively. Coeff. = coefficient; CMG = Pesaran (2006) common correlated effects mean group estimator; AMG = Eberhardt and Teal (2010) augmented mean group estimator.				

We further note that although the CMG test accommodates cross-section dependence as well as time-variant unobservable factors, unobservable common factors are treated as a nuisance (Eberhardt and Teal, 2010). The CMG is simply an average of the individual country common-country effects. The CMG estimator is unable to detect differences between temporal and general dynamics which are determined by common and exogenous individual-specific time series factors (Eberhardt and Teal, 2010). Last but not the least, CMG is unable to model spatial patterns that may occur in globalization and energy consumption nexus. The reason is that CMG estimator consistently provides efficient slope estimates without solving the process of spatial error (Eberhardt and Teal, 2010). These issues are covered by applying the augmented mean group estimator (AMG) developed by (Eberhardt and Teal, 2010). As far as the AMG results of Table-4 are concerned, we again note that globalization is positively but significantly linked with energy consumption in case of Japan, Korea, Singapore, Canada, France, Luxemburg, Norway, Sweden, Switzerland and Australia at 1%, 5% and 10% significant levels, respectively. Contrarily, globalization is inversely and significantly linked with energy consumption in the USA (at 1% level), Belgium (at 1% level), Netherlands (at 1% level) and UK (at 5% level) respectively. Globalization has a positive (negative) but insignificant effect on energy consumption in Israel, Greece, Iceland, Ireland, Israel, Italy, Portugal, Spain and New Zealand (Austria, Denmark, Finland, Greece) respectively.

In order to examine the causal relationship between globalization and energy consumption, we have applied Emirmahmutoglu and Kose (2011) panel Granger causality test. The empirical results are shown in Table-5. We find unidirectional causality running from globalization to energy consumption in Korea (at 1%), Singapore (at 5%), USA (at 5%), Austria (at 5%), Greece (at 1%), Italy (at 5%) and Portugal (at 1%) but energy consumption Granger causes globalization in Norway. The neutral effect also exists between globalization and energy consumption for Japan, Israel, Singapore, Canada, Belgium, Denmark, Finland, France, Iceland, Ireland, Luxemburg, Netherlands, Spain, Sweden, Switzerland and Australia respectively. The feedback effect also exists between globalization and energy consumption in New Zealand. The panel estimates reveal the unidirectional causality running from globalization to energy consumption at 1% level of significance.

Table-5: Emirmahmutoglu and Kose (2011) Panel Granger Causality Analysis

Null Hypothesis	G_t does not Granger cause E_t			E_t does not Granger cause G_t		
	$G_t \neq E_t$			$E_t \neq G_t$		
Individual statistics						
Country	k_i	W_i	p_i	k_i	W_i	p_i
Japan	1	0.1399	0.6671	2	0.7801	0.6605
Korea	1	14.762***	0.0000	1	2.0380	0.3818
Israel	2	0.4618	0.7497	2	0.3883	0.8854
Singapore	3	5.0262**	0.0458	1	0.5693	0.4469
USA	1	6.0137**	0.0316	1	0.4903	0.4766
Canada	1	0.0097	0.8594	2	2.4206	0.3233
Austria	2	4.9901**	0.0262	1	0.0160	0.8426
Belgium	1	0.4252	0.4924	1	0.2073	0.6225
Denmark	1	0.0614	0.7535	1	0.0069	0.8733
Finland	1	0.6437	0.4078	3	0.0298	0.8092
France	1	0.0000	0.9225	1	0.5533	0.4524
Greece	2	11.942***	0.0010	1	0.4388	0.4980
Iceland	1	0.7578	0.3725	2	0.8695	0.3568
Ireland	1	0.0872	0.7209	1	0.5132	0.4673
Italy	1	7.0873**	0.0182	1	0.0435	0.7850
Luxembourg	1	0.0807	0.7284	1	0.6690	0.4134

Netherlands	2	1.1614	0.2778	2	4.0736	0.2917
Norway	1	0.0011	0.9095	1	4.8371*	0.0391
Portugal	1	16.004***	0.0000	2	5.0554	0.2044
Spain	1	0.9612	0.3205	1	0.7904	0.3772
Sweden	2	0.0022	0.8975	1	0.2795	0.5769
Switzerland	1	1.1657	0.2769	1	0.2715	0.5825
UK	1	3.2710	0.1087	2	0.9565	0.6122
Australia	1	0.4521	0.4803	1	1.9360	0.1802
New Zealand	2	8.0338**	0.0091	2	5.5976**	0.0281
Panel test statistics						
Fisher test value				Fisher test value		
97.183***				41.094		
Bootstrap critical values:				Bootstrap critical values:		
1%: 89.076				1%: 80.862		
5%: 74.284				5%: 69.759		
10%: 62.873				10%: 58.874		
Note: ***, ** and * show significance at 1%, 5% and 10% levels respectively.						

Table-6: Dumitrescu and Hurlin (2012) Granger Causality Analysis

Null Hypothesis	G_t does not Granger cause E_t			E_t does not Granger cause G_t		
	$G_t \neq E_t$			$E_t \neq G_t$		
Individual statistics						
Country	k_i	W_i	p_i	k_i	W_i	p_i
Japan	2	22.063***	0.0000	1	11.652***	0.0000
Korea	1	3.9638*	0.0624	2	2.6778	0.1079
Israel	1	5.8148*	0.0876	2	2.5778	0.1143
Singapore	2	5.6203*	0.0962	1	1.9213	0.1693
USA	2	6.5272**	0.0486	1	2.9202	0.2410
Canada	2	3.0441	0.1031	1	4.4421**	0.0176
Austria	1	0.9656	0.5866	1	1.7479	0.1886
Belgium	2	0.9571	0.5889	1	0.8753	0.3386
Denmark	1	0.8229	0.6259	1	5.4264*	0.0343
Finland	1	1.5807	0.4433	2	2.4385	0.1241
France	2	10.527***	0.0026	1	0.7102	0.3836
Greece	1	5.8723**	0.0185	1	1.9660	0.1774
Iceland	3	3.3618	0.3481	1	0.1381	0.6580
Ireland	1	2.3229	0.1328	1	0.1414	0.6552
Italy	1	1.5113	0.2192	1	0.4900	0.4590
Luxembourg	2	9.3822**	0.0307	1	0.4532	0.4740
Netherlands	2	0.7643	0.6428	1	15.542***	0.0004
Norway	1	13.653***	0.0007	2	6.7621*	0.0606
Portugal	3	1.7886	0.1864	1	5.4421*	0.0871
Spain	1	0.3099	0.5419	1	1.2768	0.2558
Sweden	3	8.6532**	0.0249	1	0.8753	0.3387

Switzerland	1	7.8721**	0.0366	3	1.6894	0.1956
UK	1	9.6362**	0.0109	1	19.033***	0.0000
Australia	1	18.527***	0.0003	2	3.7135	0.1679
New Zealand	3	22.643***	0.0001	1	16.653***	0.0000
Panel test statistics						
W^{Hnc}	7.8734***			7.0652***		
W_{NT}^{Hnc}	32.5170***			14.6283***		
W_{N}^{Hnc}	5.5007***			5.5392***		
Note: ***, ** and * show significance at 1%, 5% and 10% levels respectively.						

In order to test the robustness of causality results, we apply the D-H panel causality test developed by Dumitrescu and Hurlin (2012). The results are shown in Table-6 and we note the presence of feedback effect i.e. bidirectional causal relationship between globalization and energy consumption in case of Japan, Norway, the UK and New Zealand. Globalization Granger causes energy consumption is validated in case of Korea, Israel, Singapore, USA, France, Luxemburg, Sweden, Switzerland and Australia, respectively. The unidirectional causality is found running from energy consumption to globalization is confirmed for the case of Canada, Demark and Netherlands. The neutral effect i.e. no causal relationship exists between globalization and energy consumption in case of Austria, Belgium, Finland, Iceland, Ireland, Italy and Spain. The Dumitrescu and Hurlin (2012) panel causality statistics indicate that globalization causes energy consumption and in resulting, energy consumption causes globalization in Granger sense i.e. globalization and energy consumption are interdependent.

5. Concluding Remarks and Policy Suggestions

Recently, the literature on empirically examining the causal linkage between globalization, energy consumption and environmental quality in the context of developing countries like India has emerged as a new branch of research in energy economics (Shahbaz et al. 2015, 2016). To our knowledge, there has been no systematic analysis of the causal linkage between globalization and energy consumption for developed countries of the world. Motivated by this research gap, we examine the relationship between globalization and energy consumption for 25 developed countries using a new measure of globalization and time series and panel data techniques for the period 1970-2014 by incorporating economic growth as additional and control determinant of energy consumption. In doing this, our study fills a research gap in the extant literature of energy economics by analyzing the role of globalization on the dynamics of energy consumption.

Moreover, understanding the causal linkage between globalization and energy consumption in advanced economies is important because the shocks to globalization and energy consumption in these countries have substantial ramifications for both the advanced economies and the economy of other developed and developing countries. For instance, without incorporating the role of globalization on energy consumption future planning for a safe and secure energy supply is made more difficult. The impact of globalization on energy consumption also has environmental implications. While it is widely agreed that globalization increases economic activity and wealth, these benefits need to be viewed in the context of how globalization affects energy consumption because increases in fossil fuel energy consumption lead to higher emissions of CO_2 emissions. Higher CO_2 through its effects on climate change will affect the health and well-being of not only present but future generations.

In response to these concerns we study globalization and energy consumption for 25 developed countries using time series and panel data techniques for the period 1970-2014. Our panel includes the data of countries from Asia, North America, Western Europe and Oceania. Unit root properties of the variables are examined by applying Pesaran (2007) CIPS test to accommodate cross-sectional dependence. The presence of long-run association between globalization and energy consumption is ascertained by applying Westerlund (2007) cointegration test. The long-run heterogeneous panel elasticities are estimated by using Pesaran (2006) common correlated effects mean group (CMG) estimator and Eberhardt and Teal (2010) augmented mean group (AMG) estimator. The causality between the variables is examined via applying Dumitrescu and Hurlin (2012) and, Emirmahmutoglu and Kose (2011) Granger causality test.

The empirical results indicate the presence of cointegration between globalization and energy consumption in 25 developed countries. In line with the time series analysis, we find that globalization is positively linked with energy consumption in the case of Japan, Korea, Singapore, Canada, Belgium, France, Luxemburg, Netherlands, Norway, Sweden, Switzerland and Australia, while globalization decrease energy consumption in the USA and UK. Globalization has neutral impact on energy consumption in Austria, Greece, Iceland, Ireland, Italy, Portugal, Spain, New Zealand, Denmark and Finland. The long run heterogeneous panel elasticity estimates also show the positive effect of globalization on energy consumption. We find unidirectional causality running from globalization to energy consumption in case of Korea, USA, Austria, Greece, Italy, Portugal, UK and New Zealand, while energy consumption Granger causes globalization in Norway only. The neutral effect exists for Japan, Israel, Singapore, Canada, Belgium, Denmark, Finland, France, Iceland, Ireland, Luxemburg, Netherlands, Spain, Sweden, Switzerland and Australia. The panel Granger causality estimates also reveal the unidirectional causality running from globalization to energy consumption.

The findings of this study add some worthy policy suggestions. We find that globalization is positively linked with energy consumption in 12 developed countries (approximately 50% of total sample countries used in the analysis), indicating that greater opening up or exposure of these economies to the rest of the world via trade and capital flows may not help them in reducing their energy demand in the process of economic activity. Despite growing economic globalization, the producers in these economies may not have changed their production techniques and therefore outdated production techniques require greater amounts of energy consumption. From a policy perspective, it can be suggested that these economies need to be aware of the positive impact of globalization on energy consumption. Otherwise these countries will face greater long-term environmental consequences of increased energy consumption in terms of climate change and global warming. In addition, an interesting finding is that in a few developed countries like the USA and the UK, globalization decreases energy consumption. This finding has key policy implications, both the USA and the UK are largely benefitted by reducing the usage of energy in the process of economic activity along with passing globalization. This becomes possible on their part because of utilizing energy-saving advanced technology in the process of economic activity through wholesale globalization with tough enforcement of environmental regulations. The UK and USA both experienced large decreases in energy intensity relative to the other countries in our sample that may help to explain this result.

The panel findings also bear some policy implications as unidirectional causality is found running from globalization to energy consumption, for all countries, indicating that globalization plays a vital role in the dynamics of energy consumption. If any environmental policy is designed by policy makers and implemented by governments of these countries without incorporating the role of globalization on energy consumption in augmented energy demand function, then in line with the recent empirical arguments of Baek et al. (2009) and Shahbaz et al. (2015) these countries will have to face the severe environmental consequences of globalization in the long-run. Hence from a policy perspective, we suggest that policy makers in these economies should not underestimate the significant role of globalization in energy demand function while formulating and implementing environmental policy (see Shahbaz et al. 2016).

Overall our findings suggest that advanced economies are not going to free themselves from the constraints of energy resources if they continue to demand energy for long-run economic growth especially in the presence of globalization. This finding is not consistent with the seminal argument of Hansen-Prescott (2002) resource model in which they have argued that society has freed itself from the constraint of resource limitations. Thus it is easy to refute the Hansen-Prescott resource model as our finding is not consistent with their key argument. Furthermore our results are consistent with the recent finding of Stern and Kander (2010) for Sweden in which they have argued that the economy is still constrained by energy resources in the presence of modern growth theory. In order for globalization to be desirable for both economic growth and environmental quality a different approach to energy usage most be implemented. Energy efficiency, a reduction in energy usage, fuel switching, and technological innovations all provide alternative ways to increase economic growth without harming environmental quality and ecological balance (Smulders and de Nooij 2003, Csereklyei et al. 2014).

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