Decomposing Scale and Technique Effects of Economic Growth on Energy Consumption: Fresh Evidence in Developing Economies

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Abstract: This study contributes by investigating the association between scale, technique and composition effects on energy consumption by considering financial development, oil prices and globalization as potential determinants of economic growth and energy demand. We have applied recent cointegration considering cross-sectional dependence and structural breaks introduced by Westerlund and Edgerton (2008). Furthermore, FMOLS, DOLS and Cup-FMOLS are applied to examine impact of scale effect, technique effect, composition effect, financial development, oil prices and economic globalization on energy consumption. The empirical results show that variables are cointegrated for long run relationship. Scale effect and technique effect are negatively and positively linked with energy consumption. Composition effect and economic globalization stimulate energy demand. Contrarily, financial development and oil prices decline energy consumption. This empirical analysis helps policy makers of developing economies in designing their comprehensive environmental policy for sustainable economic development in long-run.

Keywords: Scale and Technique Effects, Globalization, Energy Consumption
JEL Classifications: E44, F6, P48

I. Introduction

Growing population, rising economic growth and increasing demand for energy will put tremendous pressure on the use of energy as well as on the existing natural resources in the imminent years, particularly in the developing and emerging economies (for more details, see OECD 2012, Wolfram et al. 2012). In the context of mounting pressure on natural resources exploitation while advancing economic growth, it appears to be pressing long-run challenges facing developing nations in the world. The key challenge for developing economies is the emergence of negative externality arising from massive use of energy affecting the long-run economic growth potential by undermining health, damaging human capital accumulation, and affecting human welfare and environmental quality (Boppart 2014, Voigt et al. 2014). Given that a central inquiry in the environmental economics literature arises: How does economic growth affect energy consumption in developing economies? How does economic growth affect carbon emissions in developing economies? The first question has been the subject of concentrated empirical research in the context of developing economies, but the second question remains far from rich literature for developing nations following the novel work of Grossman and Krueger (1991, 1995)[1]. The EKC hypothesis has an optimistic policy implication in the sense that countries exhibiting EKC can inevitably rise out of their ecological predicaments (Beckerman 1992, Bartlett and Graddy 2000). In such line, Mohapatra and Giri (2015) recently pointed out that for developing economies, "grow now with higher energy consumption, and clean up latter" is the objective. Hence, EKC hypothesis cannot be generalized for developing economies. Moreover, the EKC approach has often been criticized for its failure to produce fruitful insights into the efficiency of energy use.[2] In this context, the issue surrounding the dynamic effects of economic growth on energy demand appears to be a relevant one and hence it has motivated researchers to study on the practical implications of EKC hypothesis for developing countries.

However, improving energy efficiency has received growing attention by policy makers and governments in developing countries as a primary element for ensuring sustainable development, as it can encounter the energy poverty issue, while addressing both climate change and loss of environmental quality (Mohapatra and Giri 2015). Moreover, efficiency corrections in energy utilization can alone target 31% of global emissions reductions that are necessary to halve increasing emissions by 2050 compared to 2009 levels (IEA, 2012a). Though such projection appears to be promising despite prominent surge in overall output and energy use (Allcott and Greenstone, 2012, and IEA, 2012b), but the probable efficiency increases do not continue to be large in various sectors of emerging and developing economies. In this connection, a key question is what drives increasing energy consumption or energy demand in response to economic development in developing countries.

The nature of developing countries is to grow at the massive use of energy and thereby increasing the intensity of energy or the use of energy rather than reducing it without thinking on the betterment of long-run environmental quality. This indicates that complementarity exists in energy-growth association. For instance, government in developing countries through energy tax

[1]An inverted U-shaped relationship between pollution level and income has been emphasized in their analysis. Such relationship is called as Environmental Kuznets Curve (EKC) hypothesis.

[2]The energy-gross domestic product is a measure of energy intensity of the economy. It is the amount of necessary energy for creating a unit of output. The variation of this element shows the degree of energy intensiveness for the economy (Keppler et al. 2007). Energy intensity is also a reciprocal of energy efficiency (Mohapatra et al. 2016).

measures normally intends to reduce energy use in production process, to work towards betterment of environmental quality, and to diminish its reliance on imports for the sake of stabilizing external imbalances. In view of this phenomenon, we intend to look into the drivers of energy demand in 66 developing economies over 1990-2017, by triangulating the scale, technique, and composition effects, within the broader framework of EKC hypothesis. The empirical analysis on the energy-growth nexus may be helpful for reducing greenhouse gas emissions via optimizing energy consumption in economic activities. The greater and constant global efforts between developed and developing countries is required to solve the energy security and rising poverty problems in a climate changing environment of the present age. To the best of our knowledge, we have not found any attempt in exploring the dynamic scale, technique and composition effects of economic growth on energy consumption in case of developing economies. Thereby, there are multifaceted contributions of this study in the literature of energy economics: (i) This study contributes to the existing literature by investigating the association between scale, technique and composition effects on energy consumption. The potential roles of financial development, energy prices and globalization are also considered in energy demand function to avoid the specification problem. (ii) For checking the integration property of the variables, second generation unit root tests[3] are applied. (iii) The cointegration approach considering cross-sectional dependence and structural breaks developed by Westerlund and Edgerton (2008) is applied to examine cointegrating association between energy consumption and its determinants. (iv) The impact of scale effect, technique effect, composition effect, financial development, energy prices and economic globalization on energy consumption is examined by applying FMOLS, DOLS and Cup-FMOLS. (v) The rolling window heterogeneous panel causality is employed to test the direction of causality between energy consumption and its determinants. We find that scale effect and technique effect have negative and positive effect on energy consumption. Composition effect and economic globalization add in energy demand. On contrary, financial development and energy prices decline energy consumption. This panel analysis will help policymakers of developing economies in devising their energy policies in an inclusive manner for ensuring sustainable development.

II. Literature Review

Influenced by the EKC hypothesis, a substantial body of empirical literature has been tested across countries and over time in the various time series and panel settings. The literature on energy-growth nexus in developing countries is extensive during the past twenty years, but paints a slightly confusing picture (Masih and Masih, 1996a, b, Asafy-Adjaye 2000, Yang 2000, Lee, 2005a, b, Shahbaz et al. 2012a, Shahbaz 2015, Ahmed et al. 2016, Shahbaz and Sinha 2019). Since these studies yield contradictory results, the applicability of policing part emerging from their findings are limited. For instance, few studies find the unidirectional causality running from energy consumption to economic growth (Masih and Masih 1998, Asafy-Adjaye 2000, Yang 2000, Fatai et al. 2004, Lee, 2005, Keppler 2007). The rest of the studies also report bidirectional and mixed findings (Yu and Choi 1985, Glasure and Lee 1998, Soytas and Sari 2003, Jumbe 2004, Morimoto and Hope 2004, Oh and Lee 2004, Paul and Bhattacharya 2004, Ambapour and Massamba 2005, Keppler 2007, Shahbaz and Lean 2012, Shahbaz et al. 2012, Shahbaz et al. 2016).

[3]These tests account for cross-sectional dependence and structural breaks stemming in the series.

According to the literature of energy and environmental economics, EKC hypothesis has certain shortcomings of not deciding the drivers of increasing energy consumption at different stages of economic development mostly in the context of developing countries. In such line, it is again important to identify the main drivers of increasing energy demand or energy intensity in developing economies. Enhancements in energy utilization in course of economic development in advanced nations could be due to the introduction of cleaner production technologies and innovative avenues of capital equipment or due to the changing structure of the economic activity. If *technique effect* is dominant over *scale effect* in reducing energy demand in developed economies, policies reassuring technology trades, environmental-friendly economies of scale, and experiential learning effects via globalization process could aim at reproducing comparable drifts in developing economies. This still displays above-average energy intensity levels at each and every stages of production level. From a strategic standpoint, it is indicative that both developing and developed countries need to strengthen their international environmental agreements and policy design via *technique effect* rather than *scale effect*. This is because technology transfers via trade openness or effective use of technologies in the process of production turn out to be worthy one for reducing energy intensity without hampering growing trend of sustainable economic development and quality of desirable environment. Then it is advisable for policy makers in developing countries to give top priority on *technique effect* which is emerging from the process of production rather than promoting the larger participation of developing countries with advanced nations not only for reducing energy use but also caring about the quality of environment (Dasgupta et al. 2002, Carson 2010, Aldy et al. 2010, Sandeep et al. 2016). To this end, the way out from increasing energy consumption while advancing economic growth of developing countries need to relook at or augment their production process via structural change and the use of less-energy intensive technology. Such effect is called as *composite effect* that emerges from the course of economic development (Keppler et al. 2007).

The studies on the linkage between economic development and energy elasticity or energy intensity are few. For instance, Zilberfarb and Adams (1981) using a panel data set of 47 developing countries find that energy-income elasticity is higher in response to one unit change in the income level. This implies that a unit increase in income level leads to increase in use of energy to the extent of 1.35, indicating that the various levels of economic development require greater amounts of energy use to stimulate production process. This finding is similar and consistent with the finding of Ang (1987). Ang (1987) using 1975 data for both developed and developing countries find that energy-income elasticity is constantly higher for developing countries in compared to the case of developed countries. This finally shows that economic development is necessarily required at the expense of energy consumption. In a similar vein, a recent few papers also analyzed how energy intensity of OECD and other developed economies converge (Greening et al. 1998, Alcântara and Duarte 2004, Mulder and De Groot 2012). The findings of these studies are found mixed and inconclusive on the energy demand-growth nexus. As long as the dynamic effects of economic growth on energy demand are concerned, we only find two studies (Keppler et al. 2007, Voigt et al. 2014). Keppler et al. (2007) using a panel of 44 countries over 1950-1999 examined causal linkage between economic development and energy consumption for developed and developing countries. They have found that income elasticity of energy demand is stronger for developing countries than developed countries. Luzzati and Orsini (2009) applied parametric and semi-parametric approaches to examine relationship between economic growth and energy consumption for 113 countries over the period of 1971-2004. Their empirical analysis does not support for the existence of energy Kuznets curve. Using data of 158 developed and developing countries, Nguyen-Van (2010) applied parametric regression to assess the income-energy association and validated the existence of energy Kuznets curve i.e. energy consumption catalyzes income growth, and after the threshold level, energy demand falls with further increase in income per capita.

Moreover, Voigt et al. (2014) using a panel data of 40 major economies over the period 1995-2007, find that improvements in use of energy at country level are due to the dominance of technological change over the structural change, indicating that latter one is less important in energy efficiency. They also find that the industry mix was the main driver of energy intensity reduction for few countries, such as Japan, the United States, Australia, Taiwan, Mexico and Brazil. At the global level, their findings depict that aggregate energy efficiency improved mostly due to technological change. Similarly, Van Benthem (2015) examined the linkage between economic growth and energy intensity by applying ordinary least square (OLS) for 76 developing economies. The results approve the presence of presence of S-shaped between the variables. Menegaki et al. (2015) applied Arellano-Bond-Bover estimator model to examine relationship economic growth and energy consumption (renewable energy consumption) by considering technology, education and demography as additional factors in energy demand function over 1990-2010. Their results show the existence of U-shaped relationship between economic growth and energy consumption i.e. energy consumption declines initially but start to rise with an increase in economic growth with the passage of time. They also noted that education and technology decline energy consumption. Pablo-Romero and Jesús, (2016) used data of Latin America and the Caribbean regions for examining the presence of energy Kuznets curve over the period of 1990-2011. They applied panel data approaches and found the absence of environmental Kuznets curve. Similarly, Burke and Csereklyei (2016) investigated the nexus between energy consumption and GDP for 132 developed and developing economies for 1960-2010. They employed sectoral approach using panel and cross-sectional data. Their empirical exercise confirmed the energy-growth association to be U-shaped. For Chinese economy, Hao et al. (2016) applied Spatial Durbin Model (SDM) using data of 29 provinces for 1995-2012 for examining association between coal consumption and economic growth. They also extended coal demand function by adding population density and urbanization as additional factors. Their empirical analysis reveals the presence of energy (coal) Kuznets curve. They noted population density and urbanization add coal demand significantly and insignificantly. In case of Bangladesh, Hasan and Mozumder (2016) used Household Income and Expenditure survey (HIES) to investigate whether relationship between electricity (other sources of energy) consumption and economic growth is U-shaped or inverted-U shaped. Using HIES data of 2010, their results indicate that electricity consumption (other energy sources) decline with an increase in income but after threshold point, electricity consumption (other energy sources) increases with further increase in income. This segment of result assures the existence of U-shaped association for income-electricity consumption (other energy sources) nexus. It was also noted that urbanization catalyzes energy consumption.

Furthermore, in case of EU27 countries, Pablo-Romero et al. (2018) examined the relationship between economic growth and energy consumption in transportation for the period of 1995-2009. They applied feasible generalised least squares (FGLS) to investigate whether energy Kuznets curve exists or not by considering agriculture employment as additional factor influencing transportation energy demand. Their empirical analysis indicates that energy Kuznets curve is not validated but increase in agriculture employment has positive effect on house transport energy consumption[4]. Zhang et al. (2018) used provincial data for examining the association between energy consumption and economic growth in China for the period of 1978-2015. By adopting ARDL bounds testing approach, they reported the presence of cointegration between the variables in most of provinces. Their empirical evidence confirmed linear relationship between energy consumption and economic growth in majority of provinces. In some provinces, growth-energy association is inverted-U or inverted-N which confirms the presence of peak of energy consumption. Pablo-Romero et al. (2018) investigated whether energy Kuznets curve hypothesis is validated in transition economies or not. They applied first differenced models of DOLS and FMOLS to inspect growth-energy (residential) association by considering rural population, population density, transition index and services as additional determinants of energy demand. Their empirical results indicated the invalidation of energy Kuznets curve i.e. EKC but rural population and population density have positive effect on energy consumption. On contrary, transition index and services decline energy consumption. Using provincial data over the period of 1996-2013 for Chinese economy, Dong and Hao (2018) applied the Generalised Method of Moments (GMM) to investigate linkages between economic growth and electricity consumption by considering urbanisation, secondary industrial value-added and trade openness as additional determinants of energy (electricity) demand. Their empirical results support for the presence of inverted-U shaped association between economic growth and electricity consumption. Furthermore, they note that urbanisation, secondary industrial value-added and trade openness affect electricity consumption positively. Borozon (2018) investigated whether energy (electricity) Kuznets curve exists for European Union or not for the period of 2005-2016 by considering education, taxation, poverty and climate change as additional determinants of electricity demand. By employing System Generalised Method of Moments (SYS-GMM) and found inverted-U shaped EKC for economic growth and electricity consumption association. Their empirical analysis further shows insignificant effect of poverty and education on electricity consumption but tax and climate change increase electricity demand[5].Using annual data for 1965-2016 and applying the LMDI decomposition approach, Chai et al. (2019) examined the energy-growth nexus for coal consumption. Their results unveil that energy consumption rises with economic growth initially up to a certain level, beyond which energy consumption falls with further economic growth, thereby demonstrating an inverted-U shaped relationship. This confirms the presence of energy Kuznets curve in China. On contrary, Dong et al. (2019) applied extended production function to investigate energy-growth association by taking capital, FDI, population density as additional factors of energy demand and hence, economic growth. By means of panel data approaches, they found the variables to be cointegrated. Their results also indicate the absence of energy Kuznets curve for China.

Concluding, it is noted that existing studies on economic growth-energy consumption nexus investigating whether energy Kuznets curve exists or not are inconclusive. This ambiguity in

[4] The inclusion energy prices has not affected empirical results.

[5] Rehermann and Pablo-Romero (2018) investigated transportation energy – economic growth nexus using data for Latin American and Caribbean regions for the period of 1990-2014. By applying FGLS and GMM approaches, they noted the presence of N-shaped association transportation energy consumption and economic growth. Their empirical analysis further reports the significant role of trade, population density and urbanization on transportation energy consumption.

empirical findings may be due to misspecification such as inclusion and exclusion of relevant variables affecting energy demand in developing economies. Majority of existing studies use population density, urbanization, rural population, education, tax, climate change etc. consider additional determinants of energy demand while investigating the presence of energy Kuznets curve. Financial development and economic globalization are potential determinants of economic growth and hence, energy demand. Sardosky (2010) indicated that energy consumption is impacted by financial development, and this association is moderated directly via economic growth and indirectly via consumer, business and wealth effects. Similarly, economic globalization might have an impact on energy consumption via scale, technique and composition effects (Jena and Grote, 2008). Inclusion of financial development and economic globalization in energy demand function may affect energy Kuznets curve as well. Given the discussion of literature review, it is clear that no study is available in developing countries context using advanced panel technique in exploring the dynamic effects of scale effect, technique effect, composition effect, financial development, energy prices and economic globalization on energy consumption. As per our understanding of the literature, the present study appears to be the first one to the existing literature and contributes worthy policy implications for developing countries facing multiple challenges in the present ages.

III. Theoretical Framework

The present study explores the association among scale, technique and composition effects by assuming financial development and economic globalization as possible factors of economic growth and energy demand. Financial development possibly will affect energy consumption through income effect, consumer effect and wealth effect (Shahbaz and Lean, 2012). The developed financial sector attracts foreign direct investment as well as provides financial resources to investors at cheaper cost for using energy efficient and advanced technology in production process which not only speeds up economic growth but also reduces energy demand (Frankel and Rose 2002). Globalization permits emerging economies to import energy-efficient production technologies from developed countries to enhance their production level, which in resulting, affects energy consumption and environmental quality as well (Shahbaz et al. 2016). Following above discussion, the general functional form of energy demand function is given to examine effect of scale effect, technique effect, composition effect, financial development, energy prices and economic globalization in the following equation:

$$E_{i,t} = f(Y_{i,t}, Y^2_{i,t,}, K_{i,t}, F_{i,t}, G_{i,t}, P_{i,t}) \quad (1)$$

The variables have been transformed into their natural logarithms. The mathematical version of our theoretical model is as per the following:

$$\ln E_{i,t} = \alpha_1 + \underbrace{\alpha_2 \ln Y_{i,t} + \alpha_3 \ln Y^2_{i,t}}_{Scale\ and\ Technique\ Effects} + \underbrace{\alpha_4 \ln K_{i,t}}_{Composite\ Effect} + \underbrace{\alpha_5 \ln F_{i,t}}_{Finance\ Effect} + \underbrace{\alpha_6 \ln G_{it}}_{Globalization\ Effect} + \underbrace{\alpha_7 \ln P_{i,t}}_{Energy\ Prices\ Effect} + \mu_{i,t} \quad (2)$$

where, $\ln E_{i,t}$ is natural log of energy consumption, $\ln Y_{i,t}$ ($\ln Y^2_{i,t}$) is natural log of real GDP per capita (square of real GDP per capita) measure for scale effect (technique effect), $\ln K_{i,t}$ is log transformed capital-labor ratio as proxy for composition effect, $\ln F_{i,t}$ is financial development proxies by natural log of real domestic credit to private sector per capita, $\ln G_{i,t}$ is for natural log of KOF index of economic globalization and $\ln P_{i,t}$ indicates natural log of energy prices measures by consumer price index. We expect that linkages of scale effect and technique effect with energy consumption is negative and positive if $\alpha_2 > 0$ and $\alpha_3 < 0$. It reveals that scale effect at initial stages of economic development raises energy consumption but at latter stages of economic development, technique effect dominates scale effect and lowers energy consumption. This positive and negative effects of scale and technique effects is referred to as Energy Kuznets Curve i.e. inverted-shaped relation[6]. We expect $\alpha_4 > 0$ is composition effect i.e. structure of economy is capital-intensive otherwise $\alpha_4 < 0$[7]. Financial sector development declines energy consumption via allocation of financial resources in energy efficient projects. So, we expect $\alpha_5 < 0$ otherwise $\alpha_5 > 0$ if financial sector allocates financial resources to firms without monitoring either firms care about energy efficient technologies for production. We expect $\alpha_6 < 0$ if economic globalization lowers energy consumption otherwise globalization raises energy demand and $\alpha_6 > 0$. $\alpha_7 < 0$ shows negative effect of energy prices on energy demand otherwise $\alpha_7 > 0$[8].

The data for real Gross Domestic Product (constant 2010 US$), energy use (kt of oil equivalent), real domestic credit to private sector (constant 2010 US$), real gross fixed capital formation (constant 2010 US$), and labor force are assembled from the World Bank database (World Bank, 2018). Economic globalization data is taken from Dreher (2006)[9]. Economic globalization index encompasses ratio of net foreign income to GDP, mean tariff rate, import restrictions, ratio of tax on trade flow to revenue and capital account barriers. We collect data for 66 developing countries for the period of 1990-2017. Population (total) is used to translate the model parameters into per capita terms, excluding consumer price index. The selection of countries is based on data availability.

IV. Statistical Methodologies

IV.I. Cross-Sectional Dependence Test

The examination of cross-sectional dependence (CD) in the panel data is of utmost importance, as presence of the same might produce biased and inconsistent results (Phillips and Sul, 2003). In reality, countries are connected with each other via different channels, e.g. economic, social, political, bilateral trade, and board sharing. These forms of associativity among the countries

[6]We follow Cole (2006) and Ling et al. (2015) who real GDP per capita and real GDP per capita square as measures of scale effect and technique effect.

[7]Cole (2006), Tsurumi and Managi (2010) and Ling et al. (2015) suggested to use capital-labor ratio as measure of composition effect although Panayotou (1997) suggested to use industrial contribution to GDP as proxy of composition effect.

[8]The absence of data on energy prices leads us to find an alternative measure. Mahadevan and Asafu-Adjaye (2007) suggested to use consumer price index as a proxy affecting economic growth and energy consumption. It is argued by Hoa (1993) that in developing economies, various energy sources are used at different prices by industries and residents. Energy-intensive industries may have subsidies on energy prices and therefore, industries consume energy at different energy prices in developing economies. So, consumer prices index is an attractive alternative of energy prices (Hondroyiannis et al. 2002, Chanran et al. 2010).

[9]http://globalization.kof.ethz.ch/

might result in CD among the model variables. To address the same, we use CD test developed by Chudik and Pesaran (2015). The following equation is used by CD test to examine the presence of CD in the data.

$$CD = \sqrt{2T/N(N-1)}\left\{\sum_{i=0}^{N-1}\sum_{j=i+1}^{N}\rho_{ij}\right\} \tag{3}$$

where, N indicate the cross-sections in panel, T represents the time span, ρ_{ij} is correlation coefficient of unit i and j. Under the null hypothesis of weak cross-sectional dependence, the statistic is asymptotically distributed.

IV.II. Cointegration Test with Structural Breaks

The cointegration test of Westerlund and Edgerton (2008) can accommodate the structural break along with cross-sectional dependence and has employed the procedure involved in the LM unit root test, which was devised by Schmidt and Philipps (1992). The null hypothesis of this test is the absence of cointegration among the data, against the alternate hypothesis of cointegration in the presence of structural breaks.

$$y_{it} = A_i + \mu_i t + a_i D_{it} + x'_{it} B_i + (D_{it} x_{it})' b_i + \epsilon_{1_{it}} \tag{4}$$

$$x_{it} = x_{it-1} + \epsilon_{2_{it}} \tag{5}$$

where, cross-sections are denoted by $i = 1,\ldots N$, time series is denoted by $t = 1, \ldots T$, x_{it} is the set of independent covariates, D_{it} is the dummy variable indicating the presence of structural break, (A_i, a_i) and (B_i, b_i) *are* model intercepts and slopes before and after structural break, respectively, and ε_{it} is normally distributed error term allowing the cross-sectional dependence among the unforeseen conjoint factors C_t.

$$\epsilon_{1_{it}} = \rho'_i C_t + m_{it} \tag{6}$$

$$C_{it} = \omega_j C_{jt-1} + n_{it} \tag{7}$$

$$\varphi_i(L)\Delta m_{it} = \varphi_i \Delta m_{it-1} + p_{it} \tag{8}$$

where, $\varphi_i(L) = 1 - \sum_{i,j}\varphi_{ij}L^j$ is a scalar polynomial with lag length L, and ρ_i is the vector of factor loading parameters. Therefore, the test statistics reported by Westerlund and Edgerton's (2008) cointegration test are given by:

$$LM_\varphi(i) = T\hat{\varphi}_i(\hat{r}_i/\hat{\sigma}_i) \tag{9}$$

$$LM_\tau(i) = \hat{\varphi}_i/SE(\hat{\varphi}_i) \tag{10}$$

where, $\hat{\varphi}_i$ is the estimated value of φ_i with standard error of $\hat{\sigma}_i$, and $\hat{r}^2{}_i$ is the estimated long run variance of m_{it}.

IV.III. Long Run Estimators

It is necessary to determine the long run association between the variables in the model. Further, it is required for: (a) to understand the elasticity of dependent variables with respect to independent variables, (b) the strength of the association, and (c) understanding whether the association is valid for long-run. While these assessments are carried out, we also need to check for cross-sectional dependence and endogeneity among the model variables. The long run estimators have been chosen while keeping these factors in mind. Pedroni (2001a, b) employed the fully modified ordinary least square (FMOLS) technique for solving the problem related to the existence of endogeneity between regressors through the following equation:

$$W_{i,t} = \alpha_i + \beta_i X_{i,t} + \varepsilon_{i,t} \quad (11)$$
$$\forall_t = 1, \dots, T, \; i = 1, \dots, N$$

and proposed that $W_{i,t}$ and $X_{i,t}$ are cointegrated with slopes β_i, wherein $\beta_i$may be heterogeneous across i. Thereby, the following association will be attained:

$$W_{i,t} = \alpha_i + \beta_i X_{i,t} + \sum_{k=-K_i}^{K_i} \gamma_{i,k} \Delta X_{i,t-k} + \varepsilon_{i,t} \quad (12)$$
$$\forall t = 1, \dots, T, \; i = 1, \dots, N$$

We considered $\xi_{i,t} = (\hat{\varepsilon}_{i,t}, \Delta X_{i,t})$ and $\Omega_{i,t} = lim_{T\to\infty} E\left[\frac{1}{T}\left(\sum_{i=1}^{T} \xi_{i,t}\right)\left(\sum_{i=1}^{T} \xi_{i,t}\right)\right]$ as the long covariance for this vector process, which can be decomposed into $\Omega_i = \Omega_i^0 + \Gamma_i + \Gamma_i^{'}$, where Ω_i^0 is the contemporaneous covariance and $+\Gamma_i^{'}$ is a weighted sum of autocovariance. The panel FMOLS estimator is given as:

$$\hat{\beta}_{FMOLS}^{*} = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\sum_{i=1}^{T}\left(X_{i,t} - \bar{X}_i\right)^2\right)^{-1}\left(\sum_{i=1}^{T}\left(X_{i,t} - \bar{X}_i\right) W_{i,t}^{*} - T_{\hat{\gamma}_i}\right)\right] \quad (13)$$

where, $W_{i,t}^{*} = W_{i,t}^{*} - \bar{W}_i - \frac{\hat{\Omega}_{2,1,i}}{\hat{\Omega}_{2,2,i}} \Delta X_{i,t} \; and \; \hat{\gamma}_i = \hat{\Gamma}_{2,1,i} + \hat{\Omega}_{2,1,i}^{0} - \frac{\hat{\Omega}_{2,1,i}}{\hat{\Omega}_{2,2,i}}\left(\hat{\Gamma}_{2,2,i} + \hat{\Omega}_{2,2,i}^{0}\right)$.

However, while estimating the long-run elasticities, cross-sectional dependence should be taken into consideration, and in this pursuit, we have used continuously updated fully modified (Cup-FM) estimation method to determine the long-run elasticities of the variables. These tests were introduced by Bai et al. (2009). These methods evaluate the slope parameters which include the unobserved joint trends together, following a recursive mechanism. It permits cross-sectional dependence and endogeneity. Moreover, these estimation methods are robust to mixed I(1)/I(0) factors and regressors. Further, the parameters and loadings are computed in recursion until convergence. Thus, we can formulate it as follows:

$$\left(\hat{\beta}_{Cup}, \hat{F}_{Cup}\right) = \arg\min \frac{1}{nT^2} \sum_{i=1}^{n} (y_i - x_i\beta) M_F (y_i - x_i\beta) \quad (14)$$

where, $M_F = I_T - FF'/T^2$, I_T and F show the identity matrix of dimension T, and the covert common factors assumed in the error term. Therefore, the initial estimates are allocated to F, and it continues until convergence.

IV.IV. Rolling Window Heterogeneous Panel Causality

Incidence of cointegrating association suggests the likelihood of causal relationship. To identify causality among the model parameters, we applied the Dumitrescu and Hurlin's (2012) causality test using the rolling window estimation procedure devised by Balcilar et al. (2018). First, we will discuss the Dumitrescu and Hurlin's (2012) causality test. The panel causality test of Dumitrescu and Hurlin (2012) was performed for each of cross-sections from which the test statistic averages have been generated. This test allows heterogeneity across cross-sections. This approach considers two different statistics: *Wbar-statistic* takes the average of test statistics, and *Zbar-statistic* shows a standard (asymptotic) normal distribution. These two statistics provide the standardized version of the statistics and is easier to compute. These statistics use lag 2 specification by Schwarz information criteria (SIC) while obtaining *W*bar-statistic and *Zbar*-statistics, and this lag specification allows desegregation of common factors in cross-sectional covariance. This test suggests homogeneous non-causality hypothesis by allowing heterogeneity in the causal association. Under the alternate hypothesis, it is allowed for a subgroup of individuals to have no causal association, and another subgroup of individuals, for which one variable Granger causes other variable. Hence, the null hypothesis is defined as:

$$H_0: \beta_i = 0;\ \forall_i = 1,2,\ldots,N$$

In this equation, β_i continues as $\beta_i = \left(\beta_i^{(1)}, \beta_i^{(2)}, \ldots\ldots\ldots \beta_i^{(k)}\right)$ and can alter across groups. The test further allowed some of the individual vectors β_i to be equal to 0 (non-causality assumption). In the null hypothesis, there are $N_1 < N$ individual processes with no causality from x to y. Following is the alternate hypothesis:

$$\begin{aligned} H_1: \beta_i &= 0; \qquad \forall i = 1,2,\ldots,N_1 \\ \beta_i &\neq 0; \qquad \forall i = N_1 + 1,\ldots,N \end{aligned}$$

where, for $N_1 \in \mathbb{R}$, $0 \leq N_1/N < 1$,as $N_1 = N$ signifies noncausality for the panel members. Contrariwise, $N_1 = 0$ signifies existence of causality for all the panel members. Therefore, under the null hypothesis, x is not causally associated with y across the cross-sections of the panel. Hence, in this regard, homogeneous result is obtained in relation to causality. To test the null hypothesis, Wald statistics ($W_{i,T}$) are calculated for each cross-section, followed by averaging for the panel Wald statistic ($W_{N,T}^{HNC}$). Further, the Dumitrescu-Hurlin (2012) proposed the use of Z_N^{HNC} statistic for $T<N$.

$$Z_N^{HNC} = \frac{\sqrt{N\left[W_{N,T}^{HNC} - N^{-1}\sum_{i=1}^{N} E(W_{i,T})\right]}}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(W_{i,T})}} \qquad (15)$$

This study utilizes rolling window causality method to encapsulate the variations in causal association among the model variables. Following Balcilar et al. (2018), we have divided the subsamples into $t = ŧ - 1 + l, ŧ - 1, ŧ, ŧ = l, l + 1, T$, where l is the rolling window. Keeping the standard errors of the estimation at 95% significance level, the limits of the rolling window can be denoted as per the following:

Upper limit = $\widehat{\beta_{W_{\iota,T}}} + 1.96 * \epsilon_W$ (16)

Lower limit = $\widehat{\beta_{W_{\iota,T}}} - 1.96 * \epsilon_W$ (17)

Here, $\widehat{\beta_{W_{\iota,T}}}$ is the bootstrapped regression coefficient, and ϵ_W is the standard error of regression. For the panel, Upper limit > $\widehat{W_{\iota,T}}$ > Lower limit. The strength of the causal association can be defined as the slope of the regression, i.e. value of $\widehat{\beta_{W_{\iota,T}}}$.

V. Discussion of Results

Summary statistics of the model parameters and the correlation analysis are reported in Table-1. It depicts that volatility of energy consumption ($\ln E_{i,t}$) is greater than volatility stems in economic globalization ($\ln G_{i,t}$). Composition i.e. capital-labor ratio ($\ln KL_{i,t}$) volatility is less than volatility in financial development ($\ln F_{i,t}$). Energy prices ($\ln P_{i,t}$) are more volatile compared to scale and technique effects i.e. $\ln Y_{i,t}$ and $\ln Y_{i,t}^2$[10]. The correlation analysis indicates that correlation of scale effect and technique effect with energy consumption is negative and positive respectively. Composition effect is directly correlated with energy consumption. The correlation between financial development and energy consumption is negative. Economic globalization is positively linked with energy demand. The correlation between energy prices and energy consumption is negative.

[10]The correlation figures reveal negative (positive) correlation among scale effect (technique effect) and energy consumption. Composition effect and economic globalization are positively correlation with energy consumption. The correlation of financial development and oil prices is negative with oil prices. Composition effect and financial are positively correlated with scale and technique effects. Economic globalization is inversely correlation with scale and technique but positively linked with composition and financial development. The correlation of oil prices with scale and technique effects is negative but positive correlation exists between oil prices, composition effect, financial development and economic globalization.

Table-1: Summary Statistics and Correlation

Variables	$\ln E_{i,t}$	$\ln Y_{i,t}$	$\ln Y_{i,t}^2$	$\ln K_{i,t}$	$\ln F_{i,t}$	$\ln G_{i,t}$	$\ln P_{i,t}$
Mean	6.6333	7.8236	62.0809	7.1620	6.4071	3.8634	3.9864
Median	6.5679	7.9212	62.7457	7.2179	6.6211	3.9041	4.3212
Maximum	8.5850	9.6197	92.5399	9.4114	9.7378	4.3804	6.1114
Minimum	4.7490	5.6213	31.5992	2.9301	0.3056	2.7660	-18.491
Std. Dev.	0.7368	0.9339	14.4373	1.0604	1.5893	0.2792	1.4127
Skewness	0.3738	-0.2344	-0.0450	-0.4458	-0.5055	-0.7961	-6.4511
Kurtosis	2.6074	2.1068	2.0363	2.7664	3.2719	3.6698	73.1640
Sum	11621.55	13706.99	108765.7	12547.89	11225.25	6768.701	6984.186
Sum Sq. Dev.	950.5971	1527.399	364973.7	1969.120	4422.982	136.5390	3494.818
$\ln E_{i,t}$	1.0000						
$\ln Y_{i,t}$	-0.3670	1.0000					
$\ln Y_{i,t}^2$	0.2607	0.9999	1.0000				
$\ln K_{i,t}$	0.1613	0.4520	0.4520	1.0000			
$\ln F_{i,t}$	-0.0717	0.2186	0.2186	0.1152	1.0000		
$\ln G_{i,t}$	0.0696	-0.0269	-0.0269	0.0557	0.0192	1.0000	
$\ln P_{i,t}$	-0.01746	-0.1276	-0.1276	0.1332	0.3027	0.3320	1.0000

The correlation matrix demonstrates that the data is free from multi-collinearity between the variables, as coefficients of correlation for each pair are small. For further assurance, we have also estimated variance inflating factor and tolerance which are used to detect multicollinearity between the variables. The perfect linear combination of independent variables already exists if value of tolerance is small and vice versa. The impact of collinearity between the variables is investigated by applying variance inflation factor which is 1/tolerance whose value should be greater or equivalent to 1. The presence of multicollinearity is confirmed if value of variance inflating favor exceeds 10, which increases the instability of α and β coefficients. The empirical results of variance inflating factor and tolerance are reported in Table-2 using simple and orthogonal transformation of the variables. Before transformation, we noted that values of variance inflating factor are high in case of $\ln Y_{i,t}$ and $\ln Y_{i,t}^2$ but tolerance is also very small for both variables. This shows the presence of multi-collinearity of these variables with other independent variables in the regression model. In case of $\ln E_{i,t}$, $\ln KL_{i,t}$ and $\ln F_{i,t}$ are 2.56, 5.08 and 4.37 respectively. The value of tolerance is also small for $\ln E_{i,t}$, $\ln KL_{i,t}$ and $\ln F_{i,t}$ i.e. 0.3903, 0.1968 and 0.2286. This also validates the presence of collinearity which may be an issue for empirical analysis. We transformed all the variables into orthogonal form. The results confirm that values of variance inflating factor is almost equal to for all the variables. Estimates of tolerance for all the variables are almost 1 or equal to 1. It is concluded that absence of collinearity or multicollinearity is confirmed by variance inflating factor and tolerance as well.

Table-2: Variance Inflation Factors (VIF) and Tolerance

Variables	Before Transformation		After Transformation	
	VIF	Tolerance	VIF	Tolerance
$\ln E_{i,t}$	2.56	0.3903	1.16	0.8617
$\ln Y_{i,t}$	286.70	0.0035	1.12	0.8910
$\ln Y_{i,t}^2$	272.59	0.0037	1.03	0.9735
$\ln K_{i,t}$	5.08	0.1968	1.00	1.0000
$\ln F_{i,t}$	4.37	0.2286	1.07	0.9304
$\ln G_{i,t}$	1.47	0.6794	1.38	0.7221
$\ln P_{i,t}$	1.30	0.7682	1.00	1.0000

Table-3: Traditional Unit Root tests

Variables	Levin-Lin-Chu		Im-Pesaran-Shin	
	Level	1st Differential	Level	1st Differential
$\ln E_{i,t}$	0.2633	-13.9242[a]	4.3782	-20.4846[a]
$\ln Y_{i,t}$	1.4688	-13.5874[a]	13.6400	-15.9934[a]
$\ln Y_{i,t}^2$	2.4453	-13.4914[a]	15.0265	-15.8566[a]
$\ln K_{i,t}$	-0.5731	-15.4977[a]	2.9550	-18.8697[a]
$\ln F_{i,t}$	10.2016	-12.6184[a]	2.9648	-17.7360[a]
$\ln G_{i,t}$	6.5831	-14.1860[a]	0.2385	-21.8298[a]
$\ln P_{i,t}$	11.6917	-15.2599[a]	1.3457	-11.5903[a]
Note: a significance at 1%				

In order to determine integrating properties of the variables, we have applied LLC and IPS panel unit root tests developed by Levin et al. (2002) and Im et al. (2003). The empirical results of LLC and IPS tests are shown in Table-3. It can be seen that at level, all the variables demonstrate nonstationary property with intercept and time trend. After first difference, energy consumption, scale effect, technique effect, composition effect, financial development, economic globalization and energy prices are found stationary, i.e. the variables show first order of integration. The results provided by traditional unit root tests are ambiguous, as these procedures do not account for the cross-sectional dependence and structural breaks stemming in panel data. To solve this issue, we apply Chudik and Pesaran (2015) CD test to examine either variables contain cross-sectional dependence or not. The results are recorded in Table-4. The exact information of presence or absence of cross-sectional dependence may lead us further for consistent and robustness empirical analysis. We find that all the variables reject null hypothesis of no cross-sectional dependence. This confirms the presence of cross-sectional dependence in sampled countries due to trade, foreign direct investment, portfolio investment, international tourism, foreign remittance, regional integration. It can be inferred that all the variables contain cross-sectional dependence problem. This validates that for example, shock stems in international trade in one country may have impact on other country. Similarly, shocks in energy consumption, scale and technique effects (economic growth), composition effect, financial development, economic globalization, and energy prices in one country may affect other sampled countries. In such situation, we apply panel unit root test accommodating information of cross-sectional dependence in panel data. It is necessary to examine, whether presence of cross-sectional dependence affect integrating properties of the variables or not.

Table-4: Cross-Sectional Dependence test

Variables	*Statistic*	*p-value*	*Variables*	*Statistic*	*p-value*
$\ln E_{i,t}$	236.848	0.000	$\ln F_{i,t}$	236.124	0.000
$\ln Y_{i,t}$	236.867	0.000	$\ln G_{i,t}$	236.727	0.000
$\ln Y_{i,t}^2$	236.536	0.000	$\ln P_{i,t}$	223.714	0.000
$\ln K_{i,t}$	234.500	0.000			

We chose Breitung (2000) and Herwartz and Siedenburg (2008) panel unit root tests, which consider the incidence of cross-sectional dependence in the panel data. The empirical results are reported in Table-5, and they show that, all model parameters remain non-stationary at level, considering cross-sectional dependence. This confirms that shocks stemming in energy consumption, scale and technique effects, composition effect, financial development, economic globalization and energy prices are permanent. In such situation, long run growth, finance and trade policies are effective for energy demand. The variables are static after first differential, which validates that energy consumption, scale effect, technique effect, composition effect, financial development, energy prices and economic globalization are integrated to first order, in presence of cross-sectional dependence.

Table-5: Unit Root Analysis with Cross-Sectional Dependence

Variables	Herwartz and Siedenburg (2008)		Breitung (2000)	
	Level	1st Differential	Level	1st Differential
$\ln E_{i,t}$	2.5310	-3.2799[a]	8.8813	-13.8241[a]
$\ln Y_{i,t}$	2.6756	-2.3168[b]	18.8259	-7.3774[a]
$\ln Y_{i,t}^2$	2.4372	-2.5058[a]	19.1370	-7.4245[a]
$\ln K_{i,t}$	1.1531	-2.3885[a]	8.5197	-9.3852[a]
$\ln F_{i,t}$	2.0732	-3.1882[a]	10.4780	-9.4368[a]
$\ln G_{i,t}$	0.7246	-3.8309[a]	4.4295	-13.4693[a]
$\ln P_{i,t}$	1.2503	-1.6494[b]	20.7076	-2.6516[b]
Note: a significance at 1%. b significance at 5%.				

Table-6: Westerlund and Edgerton (2008) Cointegration test

Model	No Shift		Mean Shift		Regime Shift	
	Statistic	p-value	Statistic	p-value	Statistic	p-value
LM_τ	-15.545	0.000	-2.808	0.002	-2.501	0.006
LM_ϕ	-22.305	0.000	-4.116	0.000	-4.301	0.000
Note: models are run with maximum 5 factors						

Several panel cointegration tests are available to examine cointegration between the variables proposed by Pedroni (2000, 2001) and, Westerlund (2007). The problem with these panel cointegration tests is that such cointegration tests are unable to account structural breaks and cross-sectional dependence in sampled countries in panel data. These structural breaks and cross-sectional dependence in the data occur because of implementation of macroeconomic, energy, finance and trade policies, i.e. measures. In such situation, presence of breaks and cross-sectional dependence may affect cointegration relationship between the variables in sample countries. To solve this issue, we apply Westerlund and Edgerton (2008) panel unit cointegration test taking into account structural breaks and cross-sectional dependence in the data. This panel cointegration test also solves the issue of heteroskedastic, serially correlated errors and unit specific time trends locating at different dates for different units. The empirical results of Westerlund and Edgerton (2008) panel unit cointegration test are reported in Table-6. In this pursuit, we use three cointegration models with (a) no shift, (b) mean shift, and (c) regime shift. The statistics i.e. LM_τ and LM_ϕ of Westerlund and Edgerton (2008) panel unit cointegration test reject the null of no cointegration and accept alternate hypothesis of cointegration between the variables. Based on the results, it can be inferred that energy consumption, scale and technique effect (economic growth), composition effect, financial development, economic globalization and energy prices have cointegration relationship for the period of 1990-2017.

Now, if we look at the structural breaks appearing in the data for countries (Table-7), then we can see that those years are somewhat associated with crude oil prices movements, which had an impact on economic growth pattern of 66 developing countries. In the year 1995, prices growth became positive for the first time in this entire study period. Subsequently, in 2000, prices growth reached the peak, followed by a sharp decline in 2001. Again, having a big dip in 2009, prices moved up in 2010, followed by a decline in 2011. This was the year, when the Arab Spring issue came into existence, and it affected the global crude oil supply. Moreover, it had an impact on geopolitical scenario. This was also the year of Greek Debt crisis. While talking about the geopolitical crisis, Lebanon war took place in the year 2006, and this was also the year, when secretarial violence in Iraq was started. These events had impacted the economic growth pattern of such developing economies from geopolitical and from oil supply perspectives.

Table-7: Assessments of Structural Breaks

Country	Mean Shift	Regime Shift
Albania	2012	2012
Algeria	2014	2014
Armenia	2011	2011
Azerbaijan	2011	2004
Bangladesh	2014	2011
Benin	2014	2014
Bolivia	2011	2009
Botswana	2011	2010
Brazil	2005	2005
Bulgaria	2005	2005
Cambodia	1995	1995
Cameroon	1995	1995
Chile	1995	1995
China	2006	2006
Colombia	2006	1995
Congo, Dem. Rep.	2006	1995
Congo, Rep.	2006	2006
Costa Rica	2006	1996
Côte d'Ivoire	2012	1997
Dominican Republic	2006	1998
Ecuador	2006	1996
Egypt	2006	2006
El Salvador	2006	2006
Gabon	2010	2006
Ghana	2010	1999
Guatemala	2010	1996
Haiti	2006	2006
Honduras	2012	2006
India	2012	2012
Indonesia	2012	2003
Iran	2012	2002
Jamaica	2012	2012
Jordan	2012	2012
Kazakhstan	2012	2012
Kenya	2010	2010
Macedonia	2010	2012
Malaysia	2010	2010
Mexico	2010	2010
Moldova	2010	2010
Morocco	2010	2010
Namibia	2010	2012

Nepal	2010	2012
Nigeria	2010	1996
Pakistan	2010	1995
Panama	2010	2010
Paraguay	2010	1993
Peru	2010	2010
Philippines	2010	1993
Romania	2010	1995
Russia	2010	1993
Senegal	2011	1993
Serbia	2011	2011
South Africa	2011	1993
Sri Lanka	2011	1995
Sudan	2011	2011
Tajikistan	2000	1994
Tanzania	2011	2000
Thailand	2011	2011
Togo	2000	1995
Tunisia	2011	1993
Turkey	2000	2000
Ukraine	2000	2000
Uruguay	2000	2000
Vietnam	1994	2001
Yemen	2011	2011

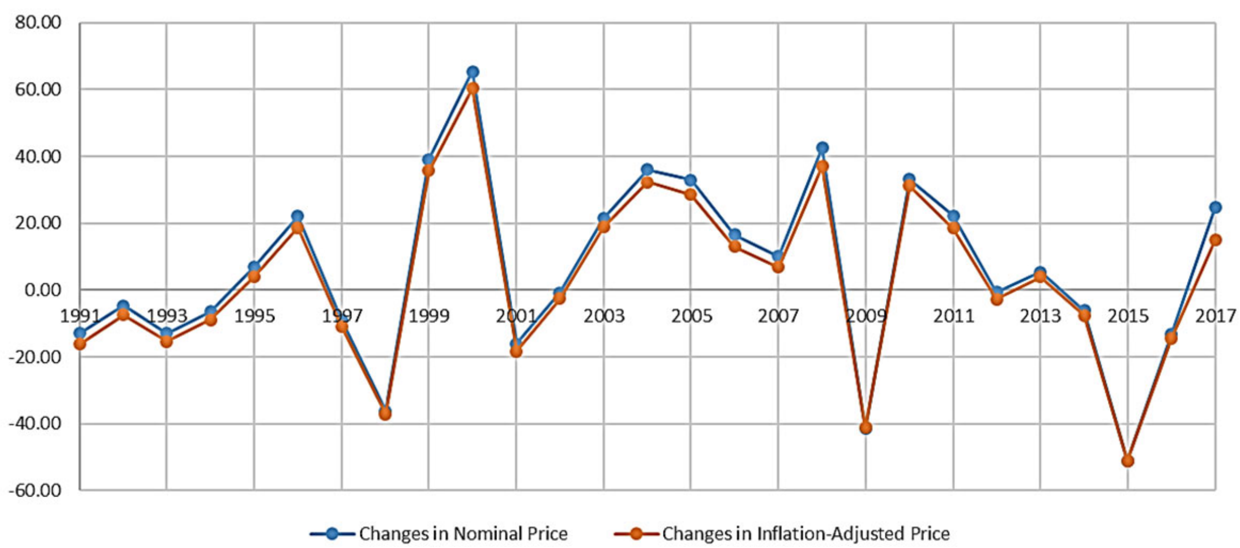


Figure-1: Changes in Crude Oil Prices (1991-2017)
Source: US Bureau of Labor Statistics

After validating the presence of cointegrating association between energy consumption and its elemental factors, FMOLS, DOLS and Cup-FMOLS are employed to examine the impact of scale effect, technique effect, composition effect, financial development, economic globalization and energy prices on energy consumption. The empirical results are detailed in Table-8. We find that scale effect reduces energy consumption. A 1% increase in scale effect i.e. real GDP per capita declines energy consumption by 5.4940-6.6186% keeping all else is same. The negative scale effect implies that economic expansion is declining energy demand. This phenomenon might be justified in light of the pattern of economic growth in developing nations. As fossil fuel in the primary source of energy in such countries, rise in greenhouse gas emissions can be evident. Rising environmental concern has gradually forced such developing nations to shift from fossil fuel to renewable energy solutions, and therefore, the demand for fossil fuel-based energy has come down. This segment of evidence is in line with Tsurumi and Managi (2010), Nguyen-Van (2010), Deichmann et al. (2018), and Zhang et al. (2018), in terms of the negative impact of scale effect on energy consumption. Contrarily, according to Cole (2006), this association is found to be positive in case of 32 developed and developing countries, indicating that economic expansion to be accompanied with higher energy demand. The technique effect has positively affected energy consumption. Considering ceteris paribus, 0.1635-0.9332% increase in energy consumption is due to 1% increase in technique effect. This shows that changes in methods used to enhance domestic output are ineffective which increases energy demand as output grows. Further, it implies the adoption of technology consumes more energy compared to previous production technology. Implementation of less effective environmental policies also encourages investors for acceptance of energy intensive production process to increase endogenous production (Tsurumi and Managi 2010, Ling et al. 2015). This situation can be attributed to the situation of renewable energy implementation scenario in developing nations. Compared to developed counterparts, research and development towards the discovery of alternate sources of energy are at a nascent stage, and therefore, rising demand of energy is catered by fossil fuel-based energy sources. In view of this, environmental policies in the developed nations are compelled to take a backseat, as the trade-off between economic growth and ecological sustainability is a major problem being encountered by the policymakers. Similarly, Cole (2006) for 32 developed and developing countries, Tsurumi and Managi (2010) for 292 developing and developed economies, Deichmann et al. (2018) for 137 countries, Zhang et al. (2018) for China who also reported the positive effect of technique effect on energy demand[11].

The impact of composition effect on energy demand is positive and significant at 5% level. We note that a 1% increase in composition effect leads energy consumption by 0.0142-0.0861%. The composition effect is reflection of the structure of the economy. Developing economies are in stage of developmental transformation from agrarian to industrial, and this transformation

[11]This negative and positive effects of $\ln Y_{i,t}$ and $\ln Y_{i,t}^2$ on energy consumption show the presence of U-shaped growth-energy demand nexus. It implies that economic growth declines energy consumption initially but after a threshold level, energy consumption is accompanied with economic growth at later stages of economic development. This U-shaped energy-growth nexus is in the similar lines with Menegaki et al. (2015), Burke and Csereklyei (2016), Hasan and Mozumder (2016), Pablo-Romero et al. (2018). On contrary, Nguyen-Van (2010), Pablo-Romero and Jesús, (2016), Hao et al. (2016), Dong and Hao (2018), Borozon (2018), Chai et al. (2019), Dong et al. (2019) confirm the presence of energy Kuznets curve while Van Benthem (2015) validated S-shaped relationship between economic growth and energy consumption.

demands more energy (Cole, 2006). The high capital-labor i.e. composition effect is positively linked with energy consumption which indicates that capital applied for producing domestic output is energy intensive. This further confirms that capital-labor ratio could not capture technique effect in developing economies yet. This segment of empirical results are similar with Cole (2006), Tsurumi and Managi (2010) and Ling et al. (2015) who reported that higher capital-labor ratio leads energy consumption in developed and developing economies. On contrary, Chintrakarn and Millimet (2008) noted that composition effect has negative effect on energy consumption in developing country like Pakistan.

Our findings demonstrate that financial development dampens energy consumption. All else is same, 0.2126-0.6422% decline in energy consumption is led by 1% increase in financial development. These nations are characterized by high capital-labor ratio, therefore, developing economies strive to achieve high productivity by employing technological advancements. Therefore, newer firms being opened up will tend to have less reliance on energy consumption, whereas the existing firms will try to achieve energy efficiency. With domestic credit available to private sector, government is essentially encouraging new entrepreneurship ventures, which will continue to have less reliance on energy consumption for having a low operating cost. This might result in lowering in energy consumption with further rise in financial development. The dampening consequence of financial development on energy consumption is in the similar lines with Topcu and Payne (2017), who used three indicators of financial development i.e. banking sector, stock market, and bond market indices. They note that stock market development leads to decline in energy demand in 32 developed countries. Similarly, Shahbaz et al. (2016) also reported that financial development is leads to decline in energy consumption in Indian economy. Destek (2018) also support our empirical findings by reported that financial development declines energy demand in emerging economies. The contradictory results have been reported by Sadorsky (2010) for emerging economies, Shahbaz and Lean (2012) in Tunisian context, Islam et al. (2013) in Malaysian context, Komal and Abbass (2015) for Pakistan, Liu et al. (2017) for China, Mahalik et al. (2017) for Saudi Arabia who indicated that financial development stimulates energy demand via consumer, business and economic activities. Similarly, Sadorsky (2011), Coban and Topcu (2013) found that financial development positively impacts energy intensity via consumer, business and wealth effects, and it was found for Central and Eastern European Frontier and EU countries, respectively. The relationship between globalization and energy demand is direct and significant. A 1% rise in globalization (economic) can make energy consumption to increase by 0.0958-0.2728%. It is noted that economic globalization may affect energy consumption by stimulating trade activities, attracting FDI, portfolio investment, and inward remittances in developing economies. This empirical evidence is consistent with Shahbaz et al. (2016, 2018a, b), in terms of the impact of globalization in stimulating energy demand by activating economic activity in India, top-globalized and developed economies. On the contrary, Saud et al. (2018) reported the negative effect of globalization on energy demand in Chinese economy. The association between energy prices and energy consumption is negative and statistically significant 1% and 5% respectively. This unveils that a 1% increase in energy prices declines energy demand by 0.1370-0.4616%.

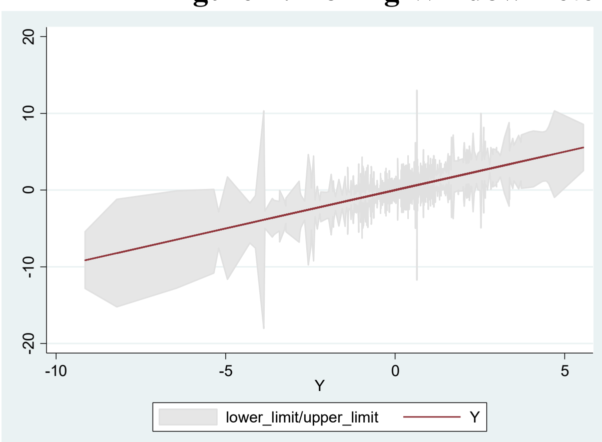
Table-8: Results of Dynamic Long Run estimates

Variables	FMOLS	DOLS	Cup-FMOLS
$\ln Y_{i,t}$	-6.6186[a]	-5.5603[a]	-5.4940[a]
$\ln Y_{i,t}^2$	0.6644[a]	0.9332[a]	0.1635[a]
$\ln K_{i,t}$	0.0861[b]	0.0225[b]	0.0142[b]
$\ln F_{i,t}$	-0.2126[b]	-0.6007[b]	-0.6422[a]
$\ln G_{i,t}$	0.0958[a]	0.2728[a]	0.1463[a]
$\ln P_{i,t}$	-0.1370[a]	-0.4136[a]	-0.4616[c]
Form of EKC	U-shaped	U-shaped	U-shaped
Note: a significance at 1%; b significance at 5%; c significance at 10%			

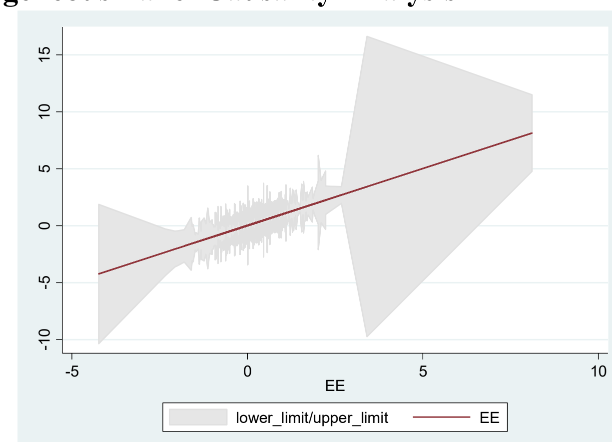
For bringing forth additional insights to empirical analysis, rolling window heterogeneous panel causality analysis has been employed to study the nature of causal association between demand of energy and its determinants. The empirical results are shown in Figure-1. It can be seen from the causality results that scale effect and technique effect i.e. economic growth has a strong causal effect on consumption of energy, compared to other direction of causality indicating causality is running from scale and technique effects to energy consumption. This indicates that the economies are in developing phase, and therefore, the level of industrialization is supposedly high resulting high demand of energy, and consequent high consumption of energy, coexisting with poor environmental protection policies. This level of industrialization can be seen majorly in the secondary sector, i.e. heavy manufacturing sector. These sectors are gradually upholding their productivity by incorporating technological advancements and continuous research and development activities. Now, these sectors are being characterized by capital-intensive sectors. For the attainment of higher productivity, reliance on energy consumption rises, and this is visible from the strong unidirectional causal association running from composition effect i.e. capital-labor ratio to energy consumption, whereas the other side of the causality has been found to be weak.

We have also found the bidirectional causal association i.e. feedback effect found between energy consumption and financial development. This segment of results indicates that when financial development via domestic credit to private sectors catalyzes energy consumption. Flow of credit is impacted via industrial growth brought forth by energy consumption. For developing economies, sustainability of the industrialization is ensured by governments via extension of their support through different financing mechanisms, whereas this financing mechanism also calls for the sustainability of industrialization. Since the industrialization is largely catalyzed by consumption of commercial energy, therefore it might be said that financial development i.e. channelizing government credit to private sector and energy consumption are interdependent. This empirical evidence is consistent with Shahbaz and Lean (2012), Islam et al. (2013) and Aslan et al. (2014) for Tunis, Malaysia and Middle Eastern countries. Contrarily, according to Mahalik et al. (2017), causality runs from financial development to energy consumption in Saudi Arabia. A feedback loop is present between economic globalization and energy consumption. It signifies that on one hand, economic globalization is having a direct impact on energy consumption, and in resulting, energy consumption is acting as a catalyst for economic globalization. For the developing economies, it might be said that economic globalization is one of the major catalysts of industrialization and at the same time, continuous consumption of energy has allowed many sectors to open-up in wake of globalization, and thereby, multiplying the impact of economic globalization. The feedback nature of energy consumption-economic globalization nexus is found to be similar with Shahbaz et al. (2016) for Indian economy, whereas Shahbaz et al. (2018a) reported the globalization-led energy consumption hypothesis in emerging economies. Similarly, Shahbaz et al. (2018b) identified that globalization is a major factor behind energy consumption in Ireland and Netherlands. Lastly, we find that energy prices cause energy consumption in Granger sense. This shows that changes in energy prices might affect energy consumption in developing economies. As rise in energy prices can consequently reduce energy consumption, therefore, energy prices-led energy consumption hypothesis is validated in developing countries.

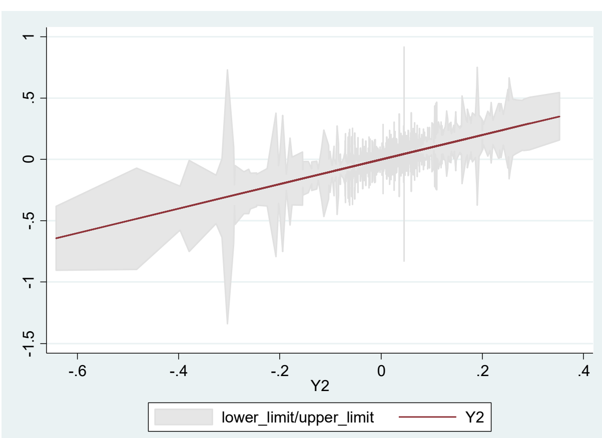
Figure-2: Rolling Window Heterogeneous Panel Causality Analysis



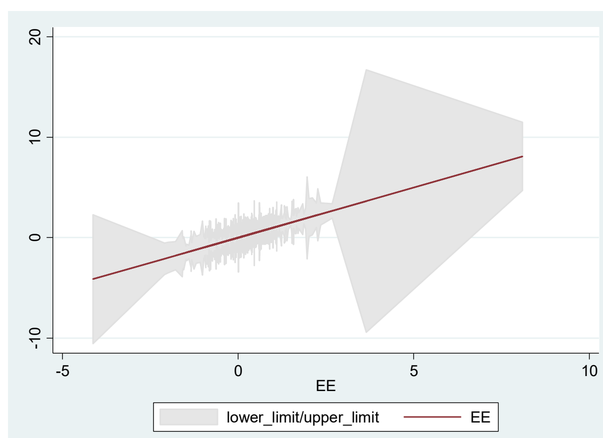
H0: $\ln E_{i,t}$ has no causal impact on $\ln Y_{i,t}$



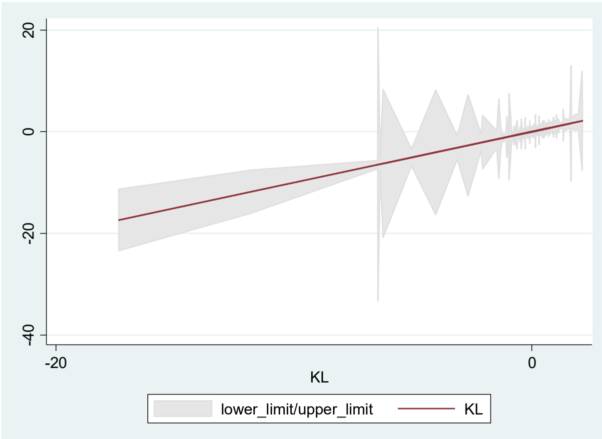
H0: $\ln Y_{i,t}$ has no causal impact on $\ln E_{i,t}$



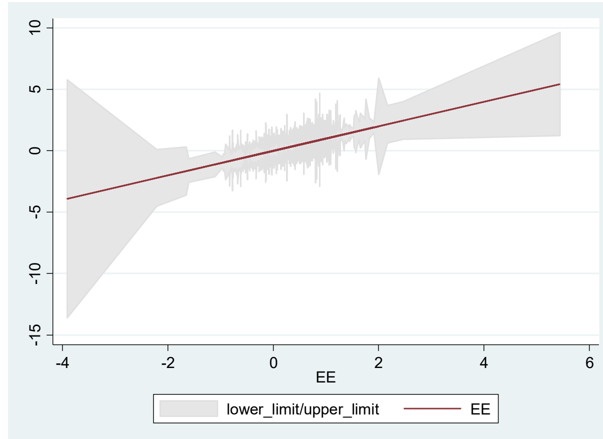
H0: $\ln E_{i,t}$ has no causal impact on $\ln Y_{i,t}^2$



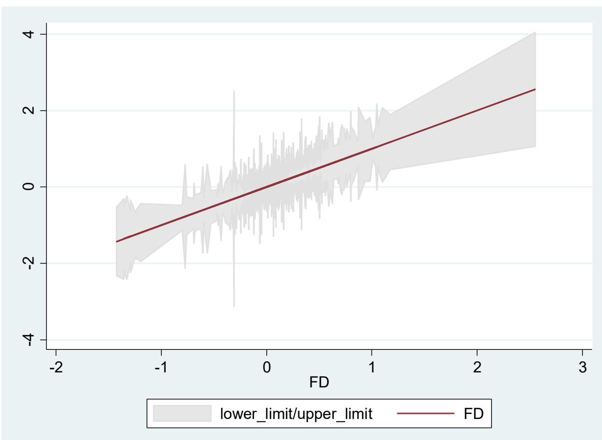
H0: $\ln Y_{i,t}^2$ has no causal impact on $\ln E_{i,t}$



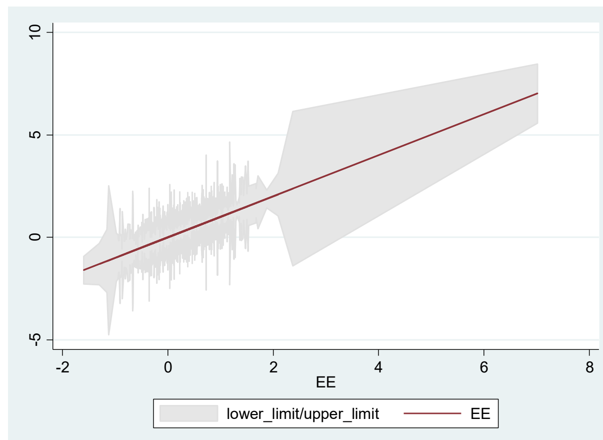
H$_0$: $\ln E_{i,t}$ has no causal impact on $\ln K_{i,t}$



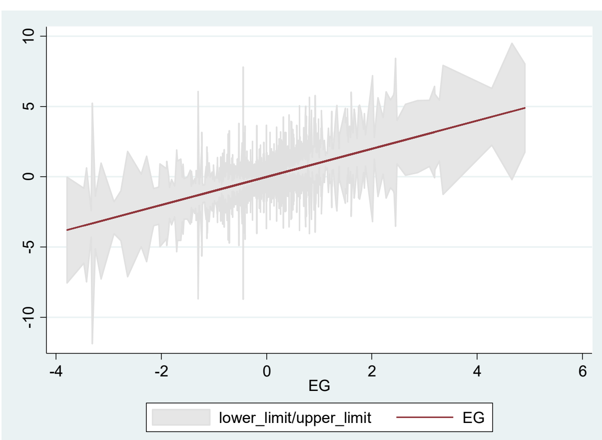
H$_0$: $\ln K_{i,t}$ has no causal impact on $\ln E_{i,t}$



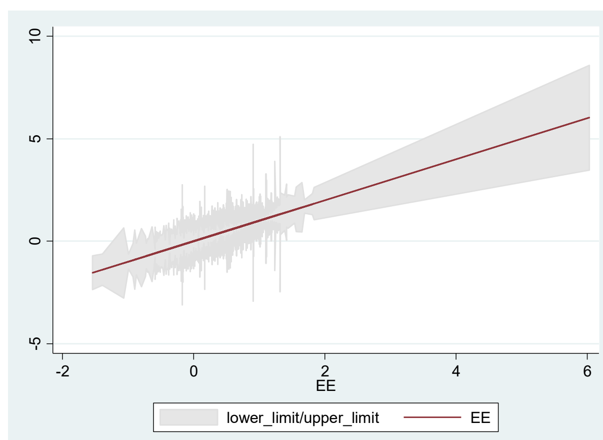
H$_0$: $\ln E_{i,t}$ has no causal impact on $\ln F_{i,t}$



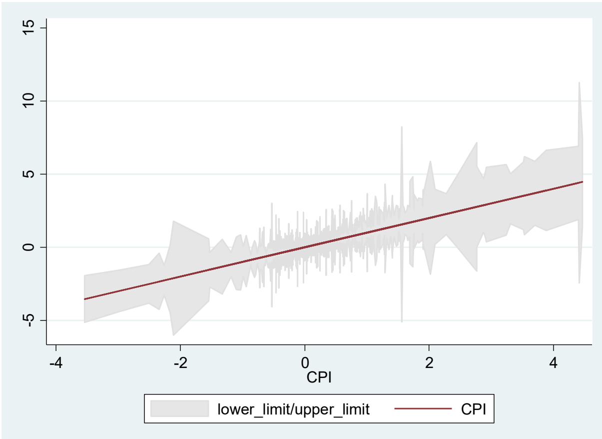
H$_0$: $\ln F_{i,t}$ has no causal impact on $\ln E_{i,t}$

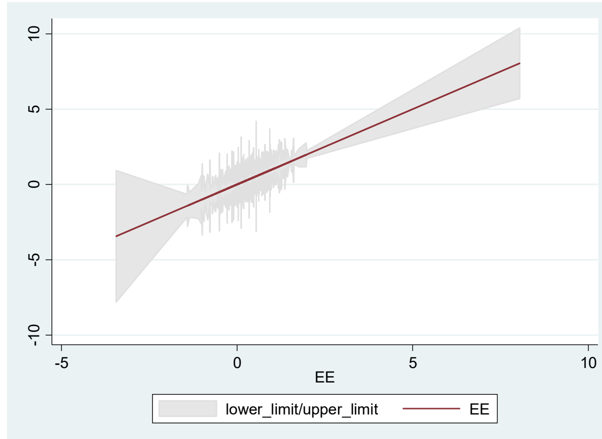


H$_0$: $\ln E_{i,t}$ has no causal impact on $\ln G_{i,t}$



H$_0$: $\ln G_{i,t}$ has no causal impact on $\ln E_{i,t}$





H$_0$: $\ln E_{i,t}$ has no causal impact on $\ln P_{i,t}$

H$_0$: $\ln P_{i,t}$ has no causal impact on $\ln E_{i,t}$

VI. Conclusion and Policy Directions

We have investigated the association of scale, technique and composition effects with energy consumption by considering the potential role of financial development, energy prices and economic globalization in energy demand function to avoid the specification problem. Second generation unit root tests are applied for examining the stationarity properties of the variables. The cointegration approach developed by Westerlund and Edgerton (2008) is employed to inspect the cointegration relationship between the variables. The FMOLS, DOLS and Cup-FMOLS are applied to check the impact of scale effect, technique effect, composition effect, financial development, energy prices and economic globalization on energy consumption. The causal association among the variables is analyzed by employing the rolling window heterogeneous panel causality test.

We find the evidence of cointegration between energy consumption and its hypothesized determinants. Furthermore, scale effect declines energy consumption but technique effect is positively linked with energy demand. The relationship between composition effect and energy consumption is positive. Financial development and energy prices have negative effect on energy consumption. Economic globalization upshots rise in demand of energy. Results of the causality tests divulge that scale and technique effects (economic growth) cause the consumption of energy, respectively. Composition effect causes energy demand. The feedback association is found between financial development and energy consumption, and economic globalization and energy consumption, respectively. Energy price is seen to have causal impact on energy consumption.

As these economies are still at the developing phase, policymakers in developing countries should strive for discovery of alternate energy solutions, so that their dependence on traditional fossil fuel-based energy solutions can be reduced, and these nations can safeguard themselves from energy price fluctuations. The energy demand in developing economies is high due to rise in industrialization, therefore a complete transformation from nonrenewable to alternate energy sources can be harmful for the sustainability of long run economic growth pattern. Continuous use of fossil fuel-based resources will not only hamper environmental quality but will also have an adverse influence on health condition of workforce, and thus, economic growth pattern will be hampered. This is when the shift from scale to composition effect should be considered by policymakers, and in this pursuit, role of financial development i.e. domestic credit to industries should be recognized. Therefore, such nations shift should be phase-wise in nature, in keeping with gradual financial channeling towards the discovery and implementation of alternate and renewable energy sources. In doing so, financial development via credit channeling will not only help the discovery of alternate energy sources, but also will discourage the firms to utilize the traditional forms of energy in production processes. The subsidies provided for using the fossil fuel-based sources should be removed gradually, and in that way, supply of credit for renewable energy discovery and implementation might be smoother. Moreover, following economic globalization route, developing economies can also move towards technology transfer from developed economies in the pursuit of renewable energy solutions. This technology transfer should be continued till developing economies can become self-sufficient in developing renewable energy solutions endogenously. At the same time, economic globalization should also help in developing tertiary sector, i.e. service sector, so that the reliance on renewable energy solutions can be enhanced. In order to bring forth more effectiveness to these policy measures, governments of developing nations should encourage people-public-private partnerships to disseminate the environmental awareness, ways to achieve energy efficiency, and benefits of renewable energy solutions. Contained by a citizen-driven demand-induced regime, formulation of energy policies for shifting energy sources can prove to be more effective, and in that way, energy demand demonstrated by technique effect can be compensated by renewable energy solutions. Following this route, economic growth achieved by developing nations can be sustainable.

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