Globalisation, Economic Growth and Energy Consumption in the BRICS Region: The Importance of Asymmetries

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Abstract: This paper examines the asymmetric impact of globalisation and economic growth on energy consumption in BRICS countries, applying the NARDL bounds approach to explore the presence of asymmetric cointegration across variables. The empirical results reveals that energy consumption is positively and negatively affected by the positive and negative globalisation shocks, respectively. A positive shock in economic growth promotes energy consumption, while a negative shock reduces energy consumption.

Keywords: Globalisation, Growth, Energy

JEL Classification: F1, O4, Q4

1. Introduction

The economic structure of the BRICS region is characterised by a huge share of labour force in agricultural sector and only a small portion in the services sector. The region's share of world trade and investment is smaller than its share of GDP: it has a total GDP of US$16.92 trillion (i.e., 23% of the world GDP). The region's total trade volume is US$7.7 trillion, and its share of total world trade is up to 18%. In the last decade, the BRICS countries have more than doubled their share of world exports. Currently, BRICS exports accounted for 19% of total world exports, while in the previous decade, intra-BRICS trade grew from US$93 billion to US$224 billion (163%). FDI inflows are approximately US$595 billion, while Brazil's exports to other BRICS countries increased by 202%, from US$14.25 to 43.05 billion. Imports increased by 249%, from US$10.84 to US$ 37.87 billion. In 2015, Brazil recorded a positive trade balance of US$5.1 billion with BRICS countries.

In the Chinese economy, gross savings is as high as 54% of GDP, and gross investment is 48% of GDP, implying that the country experiences net capital outflows. This elevated investment has played a vital role in the uninterrupted economic growth over the years. China is a comparatively more export-oriented country, as exports and imports share 29% and 25% of GDP, respectively; India experiences a negative trade balance, with imports being 25% and exports 18% of GDP. However, India has somehow remained balanced in terms of savings and investments, as gross savings are 35% and investments are 36% of GDP. Russia, Brazil and South Africa's gross savings and investment are far lower than those in China and India.

Based on recent statistics (Enerdata, 2015), world energy consumption increased slightly from 1.8% in 2012 to 1.9% in 2013; it was 1.6% in 2011. In the BRICS countries, energy demand has risen at a slow pace, from an annual average growth rate of 5.6% over the period from 2000-2011; it was 3.5% in 2013 (Enerdata, 2015)[1]. Energy demand was recorded as the highest in China among the BRICS countries. China's portion of global energy consumption was reported as 22% in 2013; it was 12% in 2000. The share of global energy consumption by BRICS countries was as high as 40% in 2013, compared to 25% in 2000. Figure-1 illustrates that the growth rate of energy consumption in the BRICS countries was the highest in the world in 2013, as a result of both increased economic growth and demographic trends that are expected to maintain the pressure on energy demand.

[1]http://www.enerdata.net/enerdatauk/press-and-publication/enerdata-actualities/events.php

[Insert Figure 1 about here]

BRICS countries will likely develop further in the near future. If growth trends remain stable over the next decade, both China and India will boost their collective share in world output to over 40%. The current shift in production activities will continue to move to Asia as a consequence of comparative advantages. The Chinese economy has the potential to regain its strong position as an emerging market economy and innovative power. The future growth potential of the BRICS, as well as the ease of trading and engaging in foreign direct investment, strongly depends on globalisation, which opens up economies through the expansion of trade and investment activities. Nevertheless, to continue the growth process and to keep the pace of trade and investment activities, countries require a considerable amount of energy. Through globalisation, countries can also transfer advanced technologies and technical knowledge for the efficient use of conventional energy at production and consumption levels. Developing countries are required to access advanced technologies and technical knowledge because they do not have enough funding to spend on innovative and energy-saving technologies.

Globalisation may have favourable and unfavourable effects on energy consumption demand: it is a means of enhancing economic growth and welfare by eliminating cross-border restrictions on trade and investment with trading partners. If overseas firms establish new businesses or expand their existing ones and utilise more advanced technologies, energy consumption may shrink and ultimately reduce their overall costs. Meanwhile, these practices will impact the existing firms in the host country, as they strive to adopt the latest methods of production and conserve energy use. In contrast, globalisation may increase energy consumption because the objective of foreign firms is not to conserve energy, while their ultimate goal is to maximise their profits in the host country. Furthermore, the effect of globalisation on energy consumption can be analysed in three modes: the scale effect, the technique effect, and the composition effect.

Through the scale effect channel, with all other factors remaining constant, globalisation will boost economic activity and, thus, increase energy consumption (Cole, 2006). As far as the technique effect is concerned, globalisation enables countries to reduce energy consumption by importing advanced technology that enables economic activities (Antweiler et al., 2001; Dollar and Kraay, 2004). Finally, the composition effect of globalisation on energy consumption occurs when energy consumption declines with growth in economic activity (Stern, 2007). Furthermore, globalisation allows an economy to shift its production activities from farming to manufacturing and, finally, to the services sector. In this manner, production methods might be modified as the economy evolves from the manufacturing to the services sector, energy demand is reduced and environmental quality is improved (Jena and Grote, 2008).

The recent econometric literature (Shin et al., 2014) highlights that factors such as structural reforms, policy shifts, real and financial shocks, and regional and global imbalances may affect the variables under consideration and, hence, induce asymmetries in their dynamic relationships. Thus, it does not seem unreasonable that these factors may have induced changes in the type of relationship across the relevant variables. Additionally, given that asymmetry and non-linearity are two important stylised facts of many economic time series, a non-linear model that characterises short-run and long-run linkages between globalisation, economic growth and energy consumption is deemed appropriate. Practically, assuming a strictly linear relationship in the presence of significant asymmetries can lead to inefficient and biased results, which invalidate the usefulness of the linear specification. Notably, economic and financial development depend mainly on macroeconomic factors (e.g., business cycles, monetary policy adjustments, and product market regulations), while energy consumption seems to be more sensitive to specific conditions in the domestic and global energy markets. To accommodate both the short-run and long-run asymmetries in the dynamic relationship, the analysis makes use of the multivariate non-linear ARDL (NARDL) framework proposed by Shin et al. (2014).

This paper contributes to the existing literature by examining the asymmetric relationship between globalisation, economic growth and energy consumption using data from the BRICS countries for the 1970-2015 period. Although an enormous amount of literature investigates the impact of trade openness on energy consumption, no study so far has used any comprehensive measure of globalisation that encompasses the economic, social and political dimensions in the BRICS. In particular, economic globalisation emphasises an increase in international trade and foreign direct investment flows between the origin country and its partners. As a result, both trade and investment activities will increase energy consumption. Social globalisation represents the flow of information and cultural proximity through personal contacts. It enables individuals to share information and to learn the best practices established in other countries in various areas and sectors of the economy and, in turn, to follow similar energy conservation, production and consumption practices in the home economy. Finally, political globalisation consists of information on the number of embassies and membership in major international tasks and agreements. A country that is more politically globalised is expected to be engaged in international agreements and working groups aimed at reducing the effects of climate change. The existing literature hypothesizes that memberships in international organizations tend to improve both environmental performance and the probability of joining international environmental treaties (Bernauer et al. 2010, Spilker, 2012, 2013, Ward 2006). With respect to environmental agreements, Bernauer and Colleagues (2010) offer proof that countries that are already component of a larger network of international organizations also behave more cooperatively when it comes to environmental agreements. Since IOs tend to discourage environmentally damaging behaviour, allow for intervention and problem solving, the sharing of information and the generation of regulations and confidence, countries that are members to more general international organizations tend to join more environmental treaties. Conversely, Spilker and Koubi (2016), demonstrate that international organizations membership does not affect environmental agreements sanction[2]. In doing so, countries will try to establish global standards to address mutual interests, such as climate change, carbon emissions and other greenhouse gases. Given that most greenhouse gases come from burning fossil fuels, a country's commitment to reducing carbon emissions directly affects its energy use pattern. However, due to variations in the level of economic interest across countries on issues such as global warming and climate change, certain countries politicise the issue by giving priority to other economic and social issues, which makes them reluctant to sign international environmental agreements and adopt fewer pollution-producing strategies, while increasing their levels of energy consumption.

The remainder of this paper is structured as follows: Section 2 reviews the current literature, while Section 3 presents the theoretical framework and the econometric approaches. The data description is detailed in Section 4, while Section 5 presents the empirical results. Finally, conclusions and policy implications are reported in Section 6.

[2] There is at least one exception to the general rule where a highly politically globalized is not supporting international regulations of environment. This exception is the United States under the current Trump administration which withdrew from COP 21 recently.

2. Literature review

The literature is growing in the field of energy economics, which investigates the link between energy consumption and economic growth across global economies (Ozturk, 2010). Ozturk (2010) presents a comprehensive assessment of the recent literature on the issue and ultimately observes that no consensus can be reached on the direction of causality between energy consumption and economic growth. The empirical findings presented in the literature since the seminal paper by Kraft and Kraft (1978) have been mixed or conflicting. The results depend on the sample of countries, the time span under analysis and the estimation methodologies used. Certain studies find evidence in favour of causality from GDP to energy consumption (Kraft and Kraft, 1978), while for others, no causal relationship is found (Yu and Choi, 1985; Yu and Hwang, 1984); other studies document the presence of reverse causality from energy consumption to GDP (Lee, 2005). Alam and Butt (2002) note a bidirectional causal relationship between energy consumption and economic growth[3]. Araç and Hasanov (2014) considered the role of asymmetries while investigating energy-growth nexus by applying Generalized Impulse Response Functions (GIRFs) for Turkish economy. Their empirical analysis reveals that positive and negative shock in energy consumption affect economic growth positively and negatively but negative shock in energy consumption has dominant effect.

The current literature also includes numerous studies that have highlighted the extent of the relationship between economic growth and energy consumption by incorporating a number of control variables, such as financial development and urbanisation (Shahbaz and Lean, 2012; Islam et al., 2013; Menegaki and Ozturk, 2013). Similarly, the study by Alam et al. (2007) provides evidence that population growth, economic development and urbanisation are the principal forces driving increases in energy demand, while these increases have a profound effect

[3]Alam and Butt (2001) study the factor analysis for changes in energy intensity and energy consumption in Pakistan. Their results show that increases in aggregate energy intensity are due primarily to the structural effect, while increases in aggregate energy consumption are due to both the activity and the structural effect. Therefore, there may have been an inefficient use of energy in the country due to changes in its economic structure and economic activities. By applying the decomposition approach, Alam and Butt (2000) provide some insight into the changes in the economic structure and energy efficiency that occurred in Pakistan over the 1960-1998 period. They find that the cyclical component of the aggregate energy intensity index, due to the changes in economic output, decreases the efficiency of energy use by 9 percent per year, while the trend component, which is due to changes in consumer preferences and technology improvements, leads to increases in energy efficiency by 2.4 per cent per annum. Alam (2002) analyses the efficiency of electricity consumption in the industrial sector in Pakistan using the multi-level decomposition model. In the case of the industrial sector, aggregate electricity intensity decreased over the 1960-1998 period, indicating improvements in the efficiency of electricity use in the industrial sector.

on the growth of CO_2 emissions, leading to global warming[4]. Various studies in the literature have used different indicators of globalisation to investigate the relationship between globalisation and energy consumption. For instance, Antweiler et al. (2001) use trade openness (exports + imports) as an indicator of globalisation and find that it reduces energy demand, as the technological effect dominates the composition and scale effects. The work by Copeland and Taylor (2004) also supports the beneficial role of international trade in saving energy and inducing environmental quality through environmental regulations and movements of the capital-labour channel. Cole (2006) investigates the impact of trade liberalisation (i.e., an indicator of globalisation) on per capita energy use for 32 developed and developing countries and finds that trade openness can influence energy consumption via the scale effect (i.e., increased movements of traded goods and services, leading to higher economic activity and energy usage), the technique effect (i.e., trade enables technology transfers from developed to developing countries), and the composite effect (i.e., trade can affect the sector composition of the economy). The empirical evidence indicates that trade liberalisation is likely to increase per capita energy use. Narayan and Smyth (2009) investigate causality between energy consumption, exports and economic growth for Iran, Israel, Kuwait, Oman, Saudi Arabia, and Syria. Their empirical results confirm the feedback hypothesis, according to which energy consumption and exports have favourable effects on economic growth.

Fora panel of eight Middle Eastern economies, Sadorsky (2011) discovers short-run unidirectional causality from exports to energy consumption and bidirectional causality between imports and energy consumption. In the case of seven South American countries, Sadorsky (2012) finds a long-run association between energy consumption, economic output and trade. He further reports unidirectional causal relationship running from energy consumption to imports and bidirectional causality between energy consumption and exports in the short run. Ozturk and Acaravci (2012) explore the relationship between economic growth, energy consumption, financial development and trade for the Turkish economy and find that trade openness leads economic growth that positively affects energy consumption. Lean and Smyth (2010a) examine the association across economic growth, energy consumption and international trade in Malaysia

[4] Alam and Butt (2002) investigate the causal links between energy consumption and economic growth by incorporating capital and labour as input factors in Pakistan. Their empirical analysis finds a strong long-run nexus across energy consumption, economic growth, capital, and labour. However, unidirectional causality runs from energy consumption to economic growth. Additionally, capital formation Granger causes both energy consumption and economic growth.

by using multivariate Granger causality tests spanning the 1971-2006 period. They point to the presence of unidirectional causation from exports to energy consumption. In a similar attempt, Lean and Smyth (2010b) establish that exports cause electricity generation in Malaysia. By contrast, the study by Erkan et al. (2010) introduces the idea that unidirectional causality exists from energy consumption to exports for the Turkish economy. In the case of Shandong (China), Li (2010) reports that exports cause energy consumption, while Sami (2011) employs a production function to determine the connection between energy consumption, exports and economic growth for the Japanese economy. His results show that unidirectional causality runs from exports to electricity consumption. Additionally, Hossain (2012) examines the relationship between exports and energy consumption for three South Asian economies (i.e., Bangladesh, India and Pakistan) for the 1976–2009 period and finds support for the validity of the neutrality hypothesis.

Shahbaz et al. (2013a) employ an augmented production function to evaluate the link between energy consumption, economic growth and international trade for the Chinese economy and find that international trade causes energy consumption. For the case of Pakistan, the study by Shahbaz et al. (2013b) use exports as the indicator of globalisation to test the relationship between exports and natural gas consumption. Their findings illustrate that natural gas consumption contributes to enhancing both economic growth and exports. For a panel of 25 OECD economies, Dedeoglu and Kaya (2013) scrutinise the link involving energy consumption and globalisation (measured by exports and imports). Their empirical results confirm the presence of the response effect of energy consumption on exports and imports. In the study by Shahbaz et al. (2014), a heterogeneous causality test is utilised to inspect the relationship connecting trade openness and energy consumption for 91 low-, middle- and high-income economies. These authors empirically estimate a U-shaped association between trade openness and energy consumption for low- and middle-income countries, while an inverted U-shaped relationship is found for high-income countries. They also illustrate bidirectional causality between trade openness and energy consumption. For the case of African countries, Aïssa et al. (2014) recognise that domestic output is stimulated by renewable energy consumption and trade. Subsequently, Nasreen and Anwer (2014) examine the trade energy-growth nexus using panel cointegration for 15 Asian countries. After finding evidence of panel cointegration, they further reveal that energy consumption positively impacts economic growth and trade openness, while the feedback hypothesis is observed only between trade openness and energy demand. A recent study by Shahbaz et al. (2016) shows that accounting for globalisation generates a win-win situation for a developing economy such as India in terms of higher economic growth and improves environmental quality by reducing energy consumption. Research by Baek et al. (2009) and Shahbaz et al. (2016) provide further analysis to extend the energy economics literature.

3. The model and data

This study explores the association between globalisation and energy consumption by incorporating economic growth and capital as potential determinants in the energy demand function for each BRICS country. The functional form of the model yields:

$$E_t = f(G_t, Y_t, K_t) \tag{1}$$

We transform all variables into natural logarithms for efficient and consistent empirical results. The empirical equation of the energy demand function is modelled as follows:

$$\ln E_t = \beta_1 + \beta_2 \ln G_t + \beta_3 \ln Y_t + \beta_4 \ln K_t + \varepsilon_t \tag{2}$$

where $\ln$ is the natural-log, E_t is energy consumption (per capita), G_t is globalisation index borrowed from Dreher (2006), Y_t is economic growth (measured by real GDP per capita in US$) and K_t is capital (measured by real gross fixed capital formation in US$). ε_t is the residual term which is assumed to have a normal distribution.

The data on energy consumption (kg of oil equivalent) and real GDP (constant 2010 US$) and real gross fixed capital formation (constant 2010 US$) are obtained from world development indicators (CD-ROM, 2016) spanning the 1970-2015 period. The total population series is also employed to convert energy consumption, real GDP and real gross fixed capital formation into per capita units. The composite globalisation index developed by Dreher (2006) includes three sub-indices: economic globalisation, social globalisation and political globalisation. Economic globalisation comprises two sub-indices: (i) actual economic flows (i.e., trade, foreign direct investment and portfolio investment) and (ii) restrictions to trade and capital flows (i.e., tariff and non-tariff restrictions and the index of capital controls). Social globalisation can be quantified by using personal contacts (i.e., telephone contact, tourism, and foreign population), information flows (i.e., internet usage, televisions per 1000 people, and trade in newspapers), and data on cultural proximity (i.e., number of McDonald's restaurants, number of IKEA stores, and trade in books). Political globalisation is measured by the number of embassies in a country, membership in international organisations, participation in the UN secretary council, and membership in international agreements. The globalisation index is generated with the weights of 36%, 38%, and 26% for the economic, social, and political indices, respectively (http://globalization.kof.ethz.ch/)[6].

4. Methodological framework

4.1. The BDS test for non-linearity

The Brock-Dechert-Scheinkman (hereafter BDS) test of Brock et al. (1987) is used to examine the nonlinearity in the relationship between time series variables. Precisely, the following hypothesis is tested to explore the non-linearity in the relationship as defined in Equation (1):

H_0: The residuals of the model are independently and identically distributed.

H_1: The residuals of the model are not independently and identically distributed or there is non-linearity in the relationship.

The test utilises the concept of spatial correlations based on chaos theory. Suppose we have a time series as follows:

$$\{x_i\} = [x_1, x_2, x_3, \dots, x_N] \tag{3}$$

[5]The previous literature used many proxies for globalization, e.g., exports, imports, trade, and trade intensity, to estimate the link between globalization and energy consumption; however, these studies presented inconclusive results. These proxies cannot assist policy makers to formulate comprehensive trade policies that apply globalization as an instrument for more favourable utilization of energy to augment domestic output. To this end, it is necessary to use more suitable indicators of globalization for the investigation of the globalization-energy consumption nexus.

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We select a value of m (embedding dimension) and embed the time series by taking each m successive points in the series into m-dimensional vectors. Thus, a scalar time series is convened into a series of vectors with overlapping entries.

$$\begin{aligned} x_1^m &= (x_1, x_2, \dots, x_m) \\ x_2^m &= (x_2, x_3, \dots, x_{m+1}) \\ &\vdots \\ x_{N-m}^m &= (x_{N-m}, x_{N-m+1}, \dots, x_N) \end{aligned} \qquad (4)$$

Next, the correlation integral – a measure of the spatial correlation among the points –is calculated by adding the number of pairs of points (i, j), where $1 \leq i \leq N$ and $1 \leq j \leq N$, in the m-dimensional space that are "close" in the sense that the points are within a radius or tolerance ε of each other.

$$C_{\varepsilon,m} = \frac{1}{N_m(N_m - 1)} \sum_{i \neq j} I_{i,j;\varepsilon} \qquad (5)$$

where, $I_{i,j;\varepsilon}=1$, if $\left\| x_i^m - x_j^m \right\| \leq \varepsilon$ otherwise = 0

According to Brock et al. (1987), for the dimensions (m) between two and five, the time series is *i.i.d.*

$$C_{\varepsilon,m} \approx [C_{\varepsilon,1}]^m \qquad (6)$$

when the ratio $\frac{N}{m} > 200$. The values of $\frac{\varepsilon}{\sigma}$ range between 0.5 and 2 (Lin, 1997) if the quantity $[C_{\varepsilon,m} - (C_{\varepsilon,1})^m]$ has an asymptotic normal distribution with a zero mean and a variance $V_{\varepsilon,m}$ defined as:

$$V_{\varepsilon,m} = 4[K^m + 2\sum_{j=1}^{m-1} K^{m-j} C_\varepsilon^{2j} + (m-1)^2 C_\varepsilon^{2m} - m^2 K C_\varepsilon^{2m-2}] \qquad (7)$$

where $K = K_{\varepsilon} = \frac{6}{N_m(N_m - 1)(N_m - 2)} \sum_{i<j<N} h_{i,j,N;\varepsilon}$; $h_{i,j,N;\varepsilon} = \frac{[I_{i,j;\varepsilon} I_{j,N;\varepsilon} + I_{i,N;\varepsilon} I_{N,j;\varepsilon} + I_{j,i;\varepsilon} I_{i,N;\varepsilon}]}{3}$

Hence, the null hypothesis of independence can be tested using the BDS test statistic as follows:

$$BDS_{\varepsilon,m} = \frac{\sqrt{N}[C_{\varepsilon,m} - (C_{\varepsilon,1})^m]}{\sqrt{V_{\varepsilon,m}}} \tag{8}$$

4.2. The NARDL bounds testing approach for cointegration

Most of the previous studies have examined the long-run relationship between variables in a linear setting and assuming a strict linearity among the variables. Recent literature highlights that variables may have a nonlinear long-run relationship and therefore, the true nature of association might not be fully reflected through linear models (see e.g., Park and Phillips (2001), Saikkonen and Choi (2004), Escribano et al. (2006) and Bae and de Jong (2007), among others). Schorderet (2001, 2003) proposes a bivariate asymmetric cointegrating regression, while Granger and Yoon (2002) later proposed that the positive and negative components of the explanatory variables may have a differential effect on the dependent variable. Following their proposition, many studies decomposed the variables into the respective positive and negative shocks and provided evidence in favour of dynamic asymmetry among different economic variables (see e.g., Borenstein et al. 1997, Lee 2000, Viren 2001, Bachmeier and Griffin 2003, among others). Following this ample support provided by the literature, the general form of asymmetric long-run relationship is represented below:

$$y_t = \beta^+ x_t^+ + \beta^- x_t^- + u_t, \tag{9}$$

where, β^+ and β^- are the associated long run parameters. The time series x_t is a k x 1 vector of regressors decomposed as:

$$x_t = x_0 + x_t^+ + x_t^-, \tag{10}$$

where positive $x_t^+ x$ and negative $x_t^- x$ partial sum processes of change in x_t can be calculated as follows:

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} \max(\Delta x_j, 0) \text{ and } x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \min(\Delta x_j, 0) \quad (11)$$

Shin et al. (2014) utilised the concept of cumulative positive and negative partial sums in the Auto-Regressive Distributed Lag (ARDL) framework[7] proposed by Pesaran et al. (2001) as follows:

$$y_t = \sum_{j=1}^{p} \phi_j y_{t-j} + \sum_{j=0}^{q} (\theta_j^{+'} x_{t-j}^+ + \theta_j^{-'} x_{t-j}^-) + \varepsilon_t \quad (12)$$

where, ϕ_j is the autoregressive parameter, θ_j^+ and θ_j^- $\theta_j^+ + \theta_j^-$ are the asymmetric distributed lag parameters, and ε_t is the error term assumed to be normally distributed with a zero mean and constant variance. According to Shin et al. (2014), the modified asymmetric error correction model can be estimated as follows:

$$\Delta y_t = \rho y_{t-1} + \theta^+ x_{t-1}^+ + \theta^- x_{t-1}^- + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{j=0}^{q} (\varphi_j^+ \Delta x_{t-j}^+ + \varphi_j^- \Delta x_{t-j}^-) + e_t, \quad \text{for} j = 1, \ldots, q \quad (13)$$

where, the $\theta^+ = -\rho\beta^+$ and $\theta^- = -\rho\beta^-$.

Practically, the NARDL estimation and hypothesis testing requires the same procedure as in the linear ARDL model. First, the error-correction model in equation-13 is estimated using standard ordinary least squares (OLS) regression. Then, the presence of long-run association between the

[7] The ARDL framework can simultaneously resolve the problem of residual serial correlation and endogenous regressors if an appropriate lag order of the ARDL (p, q) model is selected (Pesaran and Shin, 1998). The degree to which any endogeneity is corrected in the asymmetric ARDL framework depends on the integration order of the decomposed series x_t^+ and x_t^-x, i.e., I(I). If the decomposed cumulative sums are I(d), then the correction is better for values of d closer to 1.

variables is ascertained through modified F-test, using the bounds testing procedure advanced by Pesaran et al. (2001), which refers to the joint null $\rho = \theta^{+} = \theta^{-} = 0$ in equation-13. Following Shin et al. (2014), we utilise both the *F*-statistic, denoted by F_{PSS}, and *t*-statistic proposed by Banerjee et al. (1998), denoted by t_{BDM}). Next, the existence of long-run and short-run asymmetries is ascertained by applying the Wald tests; we examine for long-run symmetry $\theta^{+} = \theta^{-}$ and for short-run asymmetry as either of the two (i) $\sum_{j=0}^{q} \varphi_j^{+} = \sum_{j=0}^{q} \varphi_j^{-}$) or (ii) $\varphi_j^{+} = \varphi_j^{-}$ for all $j = 1, \dots, q$.

Finally, according to Fousekis et al. (2016), the paths of asymmetric adjustments and the duration of the disequilibrium following a positive or a negative shock on the system can provide very useful information regarding asymmetry patterns. These short-run and long-run asymmetry paths can be presented through the cumulative dynamic multiplier effect on y_t for a unit change in x_t^{+} and x_t^{-}, respectively, as follows:

$$m_h^{+} = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^{+}}, \qquad m_h^{-} = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^{-}}, \qquad h = 0,1,2, \dots \dots \tag{14}$$

Note that as $h \to \infty$, then $m_h^{+} \to \beta^{+}$ and $m_h^{-} \to \beta^{-}$, where β^{+} and β^{-} are calculated as $\beta^{+} = -\theta^{+}/\rho$ and $\beta^{-} = -\theta^{-}/\rho$, respectively. The NARDL model to be estimated in the framework of our study takes the following form:

$$\begin{aligned} \Delta lnE_t = {} & \mu + \rho \, lnE_{t-1} + \theta_1^{+} lnG_{t-1}^{+} + \theta_1^{-} lnG_{t-1}^{-} + \theta_2^{+} lnY_{t-1}^{+} + \theta_2^{-} lnY_{t-1}^{-} + \theta_3^{+} lnK_{t-1}^{+} \\ & + \theta_3^{-} lnK_{t-1}^{-} + \sum_{i=1}^{p-1} \alpha_i \, \Delta \, lnE_{t-i} + \sum_{i=0}^{q} \pi_{1,i}^{+} \Delta lnG_{t-1}^{+} + \sum_{i=0}^{q} \pi_{1,i}^{-} \Delta lnG_{t-1}^{-} \\ & + \sum_{i=0}^{q} \pi_{2,i}^{+} \Delta lnY_{t-1}^{+} + \sum_{i=0}^{q} \pi_{2,i}^{-} \Delta lnY_{t-1}^{-} + \sum_{i=0}^{q} \pi_{3,i}^{+} \Delta lnK_{t-1}^{+} + \sum_{i=0}^{q} \pi_{3,i}^{-} \Delta lnK_{t-1}^{-} + \varepsilon_t \end{aligned} \tag{15}$$

where the definitions of the variables are the same as in equation-2. In turn, lnG^{+}, lnG^{-},lnY^{+}, lnY^{-}, lnK^{+} and lnK^{-} are the partial sums of positive and negative changes in each of the explanatory variables, respectively.

5. Empirical results

The descriptive statistics of the time series variables are reported in Table 1. For the Brazilian economy, capital is more volatile than economic growth, globalisation and energy consumption, while energy consumption is less volatile than globalisation, economic growth and capitalisation in Russia. In India, a high standard deviation is found for capital, while economic growth, globalisation and energy consumption are less volatile. Chinese economic growth is less volatile than Chinese capitalisation. Moreover, in China, energy consumption is more volatile than globalisation. Overall, capital has high volatility in the Chinese economy. Finally, energy consumption is less volatile than economic growth, globalisation and capital. The Jarque-Bera test reveals that energy consumption (Russia and China) and globalisation (Brazil, India and China) are non-normally distributed. The non-normality of data due to higher skewness and kurtosis values implies fat-tailed behaviour, which can be regarded as an early indication of asymmetries in the time series; however, to identify the possible asymmetries in a relationship, a thorough analysis is required, i.e., through the BDS test.

[Insert Table 1 about here]

Next, we apply the BDS non-linearity test developed by Brock et al. (1996) to determine if non-linearity is present in the dynamic relationship, as defined in equation-1. The empirical results are shown in Table 2. We document that the null hypothesis of linearity is rejected for the majority of series, implying that non-linearity is present, recommending the use of a non-linear approach for the empirical analysis. The issue of non-normality is addressed by applying the asymmetric ARDL test, which captures both short-run and long-run asymmetries in a relation (Shin et al. 2014).

[Insert Table 2 about here]

To examine the presence of long-run associations between the variables, we apply the non-linear ARDL (NARDL) developed by Shin et al. (2014). This modelling approach requires that the variables should be stationary at I(1) or I(0)/I(1). To ensure that all the variables are integrated at I(1) or I(0)/I(1), we apply ADF, PP and KPSS unit root tests. The results show unit root problems in the levels of the variables with intercepts and trends, but they are found stationary in first differences[8]. The findings imply that all the variables have a unique order of integration, i.e., I(1).

The traditional unit root tests may provide ambiguous empirical results because they do not accommodate structural breaks that stem the time series. The ignorance of structural breaks in the series may suggest that the null hypothesis is true when it is actually false, as a result of the low explanatory power associated with these unit root tests. This issue can be controlled by applying the structural break unit root test developed by Kim and Perron (2009), which examines the null hypothesis of a structural break point in the trend at an unspecified date. The outcomes of this test with a single unknown structural break are presented in Table 3[9]. The results show that the time series are integrated of order one, i.e., I(I), in the presence of structural breaks. The structural breaks occur for energy consumption in the years 2003, 1984, 2004, 2002 and 2007 in the case of Brazil, Russia, India, China and South Africa, respectively. These structural breaks in energy consumption are the outcome of various energy policies implemented in these economies. After first differencing, all the variables are found to be stationary, confirming that energy consumption, globalisation, economic growth and capital have a unique order of integration, i.e., I(1).

[Insert Table 3 about here]

The unique order of integration of the variables leads us to apply the NARDL bounds testing approach to explore the presence of an asymmetric relationship between energy consumption, globalisation, economic growth and capital. The results are reported in Table 4. The reported R-squared values indicate that 82.76%, 93.42%, 59.44%, 76.79% and 74.32% of energy consumption in Brazil, Russia, India, China and South Africa, respectively, is explained by globalisation, economic growth and capital[10]. The Durbin Watson (DW) statistic turns are close

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[8]We do not report these results in order to conserve space, but they are available upon request from the authors.

[9]We have considered both intercepts and trends when applying the ADF structural break unit root test.

[10] It should be noted that in order to select the final NARDL specification, we followed the general-to-specific approach. The preferred specification, is chosen by starting with max p = 2 max q = 2 and dropping all insignificant stationary regressors. The inclusion of insignificant lags, in practice, is likely to lead to in accuracies in the estimation and may introduce noise into the dynamic multipliers.

to the value of 2 for all the cases, indicating the absence of auto-correlation in the residual of the energy demand function. Furthermore, there are no serial correlation issues or heteroskedasticity in the residuals of estimated values, as the test statics i.e. χ^2_{SC} and χ^2_{HC}, respectively, fail to reject their respective null hypotheses at the usual significance levels. The Ramsey reset test (χ^2_{FF}) confirms the well-designed functional form of the empirical models, supporting the reliability and the stability of the empirical estimates. The results also indicate that the PSSF-statistic is greater than the upper critical bound at the 1% level of significance for the BRICS countries. The t-statistics (T_{BDM}) suggested by Banerjee et al. (1998) are significant at a 1% level of significance, confirming the asymmetric long-run relationship between energy consumption, globalisation, economic growth and capital over the 1970-2015 period. Finally, the Wald test statistics indicate the presence of short-run and long-run asymmetries in the energy demand function.

[Insert Table 4 about here]

The long-run Analysis

A positive globalisation shock significantly reduces energy consumption in Brazil and Russia, while energy consumption is positively affected by a negative globalisation shock in Brazil and South Africa[11]. The association between negative globalisation shocks and energy consumption is also negative (statistically significant) in the cases of Russia and China. In India, globalisation (negative and positive shocks) negatively affects energy consumption. Overall, globalisation positively (negatively) affects energy consumption in Brazil and South Africa (Russia, India and China). These empirical findings are consistent with those by Shahbaz et al. (2016) and Khalid et al. (2016), who report that globalisation reduces energy demand in India and China. In case of India, Shahbaz et al. (2016) applied bounds testing approach to cointegration between energy demand and its determinants in India. They found that overall globalization (economic globalization) has negative and significant effect on energy consumption but social and political

[11] Decrease or negative shock in globalization can be assessed in following ways: "Globalization decreases when countries erect barriers to trade such as tariffs, quotas etc as well as decrease in the cross border capital flows, issuing regulations they restrict the follow of information by countries. Furthermore, globalization has had its moment and could already be in decline, steadily replaced by its successor: a new age driven by advanced robotics, artificial intelligence and additive manufacturing. These technologies stand to dramatically lower the costs of production as they become more prevalent throughout the manufacturing process.

globalization reduce energy demand insignificantly. The causality analysis indicates the presence of feedback effect between globalization (economic, social and political globalization) and energy consumption. Similarly, Khalid et al. (2016) employed energy demand function to investigate the relationship between globalization and energy demand by adding financial development and trade openness as additional determinants for Chinese. They applied ARDL bounds testing approach and reported that globalization (economic, social and overall globalization) adds to energy demand but political globalization is positively but insignificantly linked with energy consumption. The empirical findings by Shahbaz et al. (2016) and Khalid et al. (2016) may be biased. These studies ignore the role of asymmetries stemming from globalization and energy demand due to the implementation of energy and trade reforms in India and China. However, it is important to note that negative globalisation shocks have more profound negative impacts.

Energy consumption is positively affected by positive and negative economic growth shocks in Russia. The positive and negative shocks in economic growth have a negative and positive impact on energy consumption in China and South Africa, respectively. The impact of economic growth (positive and negative shocks) on energy consumption is positive for the Indian economy. In the case of Brazil, energy consumption is negatively (positively) affected by positive (negative) shocks in economic growth. Shahbaz and Lean (2012) note that economic growth promotes energy consumption via industrialisation in Tunisia. In the study by Shahbaz et al. (2015), it is reported that economic growth affects energy consumption directly via scale and urbanisation effects. These authors suggest that economic growth leads to trade openness, which stimulates energy demand.

A positive shock in capital positively affects energy consumption in Brazil, India and China. Energy consumption is negatively affected by negative shocks stemming from capital in the case of South Africa. In the Chinese economy, according to Shahbaz et al. (2013b), capitalisation affects energy demand via industrialisation and economic growth.

<u>The short-run Analysis</u>

Positive and negative globalisation shocks reduce energy demand in the Chinese economy. Energy consumption is inversely affected by lagged and positive globalisation shocks in the Brazilian economy. Furthermore, second-lagged positive globalisation shocks decrease energy consumption in Russia and India but increase it in China and South Africa. Negative shocks in globalisation lead energy demand in Russia and India. Lagged negative globalisation shocks increase (reduce) energy consumption in Russia and Brazil (China).

Positive shocks stemming from economic growth increase energy consumption in Brazil. Lagged positive shocks in economic growth add to energy demand in South Africa. Energy consumption is positively and negatively affected by second-lagged positive economic growth shocks in Russia and South Africa. Negative economic growth shocks decrease energy demand in Russia, China and South Africa, while energy consumption is positively affected by lagged negative economic growth shocks in Brazil, China and South Africa. Positive shocks stemming from capital promote energy consumption in Brazil, while energy consumption is positively and negatively affected by positive and negative capital shocks in Brazil. Finally, energy demand is positively and negatively influenced by lagged negative capital shocks in India and Russia[12].

The analysis also employs multiple dynamic adjustments. The outcomes are presented in graphs that plot the cumulative dynamic multipliers. These multipliers display the patterns in which economic growth adjusts to its new long-term equilibrium following a negative or a positive unitary shock in globalisation, economic growth and capital. The estimated dynamic multipliers are based on the best-fitting NARDL model selected by the Akaike information criterion. The positive (continuous black line) and negative (dashed black line) changes capture the adjustment of energy consumption to positive and negative shocks in the variables under discussion at a given forecast horizon. The asymmetric curve (continuous red line) represents the difference between the dynamic multipliers associated with positive and negative shocks i.e., $m_h^+ - m_h^-$. This curve is displayed along with its lower and upper bands (dotted red lines) at the 95% confidence interval and presents a measure of the statistical significance of asymmetry at any horizon h.

Figure 2 shows the adjustment pattern of energy consumption to a unitary negative and positive change in globalisation, economic growth and capital for the Brazilian economy. The cumulative effect of positive and negative globalisation shocks on energy consumption is positive. The effect of negative globalisation shocks dominates the effect of positive globalisation shocks on energy consumption. A positive globalisation shock affects energy

[12]The stability of NARDL estimates is tested by applying the CUSUM of square (CUSUMSQ) proposed by Brown et al. (1975). The results are reported in Figure 1 and show that the plots of CUSUMSQ are between the critical bounds at the 5% significance level, indicating the reliability of the NARDL parameters.

consumption negatively. The asymmetric response in energy consumption due to positive and negative globalisation shocks is significant, which confirms that economic growth overall positively impacts energy demand. In the long run, negative economic growth shocks have a stronger impact on energy consumption than positive ones, i.e., -0.0239 vs. 0.3151. A positive association is noted between capital and energy consumption. The effect of positive shocks (in capital) dominates the effect of negative shocks (in capital) on energy demand. The significant and asymmetric response to capital shocks in terms of energy consumption is also noted.

[Insert Figure 2 about here]

In the Russian economy (Figure 3), the association between globalisation and energy consumption is negative and significant. Positive and negative globalisation shocks affect energy consumption negatively, i.e., negative shocks have a larger impact on energy consumption than positive shocks. The asymmetric association between globalisation and energy consumption is statistically significant. Energy consumption responds positively to positive and negative shocks in economic growth. The effect of negative economic growth shocks exceeds that of positive shocks, but this effect turns out to be positive and statistically significant. The relationship between economic growth and energy demand is asymmetric and significant. The linkage between positive and negative shocks in capital and energy consumption is negative but statistically insignificant. The cumulative effect of positive and negative capital shocks on energy consumption is asymmetric in the long run, but it is statistically insignificant.

[Insert Figure 3 about here]

In India, positive globalisation shocks influence energy consumption insignificantly, while energy consumption responds negatively and significantly to negative globalisation shocks (Figure 4). Energy consumption is insignificantly affected by negative and positive economic growth shocks. Energy consumption responds positively and significantly to negative capital shocks. The relationship between globalisation (economic growth) and capital and energy consumption is asymmetric and statistically significant.

[Insert Figure 4 about here]

As shown in Figure 5, the cumulative effect of globalisation and economic growth on energy consumption is negative and asymmetric in China. Positive and negative economic growth shocks affect energy consumption in China positively and negatively, respectively. This finding confirms that the association between economic growth and energy consumption is asymmetric and significant. Energy consumption is positively and significantly affected by positive capital shocks.

[Insert Figure 5 about here]

In South Africa, the cumulative effect of globalisation (economic growth) and energy consumption is positive and significant. The negative shock stemming from globalisation and economic growth promotes energy consumption significantly and asymmetrically. Negative capital shocks are inversely linked with energy consumption, while positive capital shocks have a positive but statistically insignificant effect on energy consumption, which validates the finding that capital overall negatively and asymmetrically affects energy consumption (Figure 6).

[Insert Figure 6 about here]

6. Policy implication of Discussion

The empirical findings of this study contribute valuable policy implications and recommendations. The findings that globalisation had unfavourable effects on energy consumption in Brazil and South Africa and favourable ones in India, China and Russia demonstrate that stronger trade and investment flows, closer social relationships and better political strategies across economies can reduce the demand for energy due mostly to the awareness of energy-efficient technologies. Despite rising economic globalisation, the producers in Brazil and South Africa might not use advanced production techniques; therefore, they consume larger amounts of energy for their production activities. The unfavourable impacts of globalisation on energy use and resulting higher environmental costs via augmented energy consumption may occur in the form of natural disasters and global warming and, hence, must be given proper attention.

Regarding the effect of capital on energy consumption is concerned, the findings revealed that capitalisation increased energy consumption in the majority of the BRICS countries. These countries should adopt energy conservation policies, invest in innovative energy-saving capital and machineries, and apply clean and 'green' technologies for production and consumption purposes. A transfer from inferior to higher-quality energy sources is expected not only to trim total energy consumption; it may also reduce environmental impact of energy use. An obvious example would be a shift from coal use to natural gas use. Natural gas is a cleaner burning energy source and produces less carbon emissions per unit of energy derived. Similarly, hydro and wind energy could also have fewer environmental impacts. The environmental impact of energy use may also change over time due to technological innovations that reduce emissions of various pollutants or other environmental impacts associated with an energy source. Therefore, despite the strong connection between energy consumption and economic growth, the environmental impact of growth can be reduced through several channels. In addition, if there are restrictions to adopting clean energy sources and to technologically transforming old technologies, the potential reduction in environmental intensity of economic production is ultimately limited.

Finally, reducing energy consumption through consumer life style changes, that is, using pricing and taxation to discourage the use of energy-intensive devices and encouraging the use of energy-conserving devices, is highly desirable. To be successful, these strategies must link both suitable supply and end-use technologies. Policy agents must convert these strategies into policies. Complete hardware plus 'software'— policies, management, financing, training, and institutions-solutions are essential for the deployment of energy as an instrument of sustainable development.

7. Conclusion

Globalisation performs an imperative role as an instrument linking growing economies, while it affects environmental degradation due primarily to the immense use of energy in both production and consumption activities in both advanced and developing economies. According to Shahbaz et al. (2015), "… *our effort is hopefully worthy of empirical investigation in a threatening* *environment of climate change and global warming*". Given that the environmental costs of globalisation are considered to be greater for a diverse and connected world than for a segmented world, the behaviour of the energy demand function has been investigated by incorporating globalisation (using the index that encompasses three different dimensions of globalisation), economic growth and capital as positional determinants of energy consumption in the BRICS. To this end, the NARDL cointegration approach was applied, which accommodates asymmetries stemming from time series. The robustness of the NARDL analysis was also examined by applying the multiple dynamic adjustment approach.

The results indicate the presence of asymmetric cointegration across energy consumption, globalisation, economic growth and capital. Additionally, the long-run impact of determinants on energy consumption was found to be heterogeneous in the BRICS. Positive (negative) globalisation shocks significantly decreased (increased) energy consumption in Brazil and Russia (Brazil and South Africa). Energy consumption declined with negative globalisation shocks in Russia and China.

In India, globalisation (both negative and positive shocks) reduced energy consumption levels. Comparing both positive and negative shocks, the analysis concluded that globalisation increases (decreases) energy consumption in Brazil and South Africa (Russia, India and China).

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Table-1. Descriptive Statistics

Variable	Statistics	Brazil	Russia	India	China	South Africa
$\ln E_t$	Mean	6.9436	8.7118	5.9433	6.8130	7.8573
	Median	6.8952	8.5435	5.9116	6.6871	7.8797
	Maximum	7.3123	9.3621	6.4572	7.8231	7.9993
	Minimum	6.6763	8.2894	5.5927	6.1689	7.6536
	Std. Dev.	0.1674	0.3466	0.2591	0.4768	0.0806
	Skewness	0.6437	0.5418	0.4320	0.7112	-0.7359
	Kurtosis	2.5057	1.8026	2.1037	2.3487	3.0227
	Jarqu-Bera	3.4080	4.7812	2.8417	4.4877	3.8827
	Probability	0.1819	0.0915	0.2415	0.1060	0.1435
$\ln G_t$	Mean	3.9144	3.7569	3.5671	3.6299	3.8711
	Median	3.9504	3.8340	3.5521	3.7145	3.7087
	Maximum	4.0997	4.2085	3.9442	4.1122	4.1746
	Minimum	3.6533	3.0217	3.2082	3.0090	3.6085
	Std. Dev.	0.1611	0.4011	0.2847	0.4252	0.2406
	Skewness	-0.2739	-0.2981	0.0458	-0.1835	0.2260
	Kurtosis	1.5093	1.6236	1.2954	1.3340	1.1886
	Jarqu-Bera	4.5190	4.1245	5.3420	5.3351	6.2446
	Probability	0.1044	0.1271	0.0691	0.0694	0.0440
$\ln Y_t$	Mean	8.3711	8.7755	6.1902	6.5378	8.7992
	Median	8.3420	8.7868	6.0699	6.4613	8.7892
	Maximum	8.6904	9.5164	7.1686	8.3081	8.9371
	Minimum	8.0367	8.0964	5.5754	5.0706	8.6719
	Std. Dev.	0.1648	0.4133	0.4900	1.0428	0.0814
	Skewness	0.4254	0.0857	0.5133	0.1606	0.2580
	Kurtosis	2.5930	2.0341	2.0192	1.7256	1.9614
	Jarqu-Bera	1.5940	1.7642	3.6959	3.1664	2.4097
	Probability	0.4506	0.4139	0.1575	0.2053	0.2997
	Mean	6.7812	7.7194	4.7558	5.3872	7.0094

	Median	6.7360	7.3565	4.5530	5.4235	7.0448
	Maximum	7.1777	9.4003	5.9797	7.5503	7.3999
	Minimum	6.4990	6.1201	3.8798	3.1977	6.5894
	Std. Dev.	0.1842	1.0617	0.6880	1.3043	0.2438
	Skewness	0.6212	0.1615	0.5017	0.0845	-0.0366
	Kurtosis	2.6237	1.6125	1.9192	1.7844	1.6642
	Jarqu-Bera	3.0200	3.7207	3.9874	2.7610	3.2062
	Probability	0.2209	0.1556	0.1361	0.2514	0.2012

Table-2. BDS Non-linearity Tests

Variable	BDS-Statistic	Prob.
Brazil		
$\ln E_t$	0.0340**	0.0215
$\ln G_t$	0.0003	0.9814
$\ln Y_t$	0.1084	0.3056
$\ln K_t$	-0.0222**	0.0224
Russia		
$\ln E_t$	0.0406**	0.0187
$\ln G_t$	0.0273***	0.0667
$\ln Y_t$	0.0290**	0.0515
$\ln K_t$	0.0045	0.7297
India		
$\ln E_t$	-0.0236***	0.0806
$\ln G_t$	0.0330**	0.0243
$\ln Y_t$	-0.0052	0.6140
$\ln K_t$	-0.0112	0.2894
China		
$\ln E_t$	-0.0222***	0.0800
$\ln G_t$	0.0404**	0.0189
$\ln Y_t$	-0.0014	0.8066
$\ln K_t$	-0.0123	0.5109
South Africa		
$\ln E_t$	0.0320**	0.0244
$\ln G_t$	0.0083	0.9483
$\ln Y_t$	0.0042	0.5539
$\ln K_t$	0.0052	0.6224
Note: **: p≤0.05; ***: p≤0.10.		

Table-3. Unit Root Analysis with Structural Breaks

Variables	ADF Test at Level		ADF Test at 1st diff.	
	Statistics	Break Date	Statistics	Break Date
Brazil				
$\ln E_t$	-2.224	2003	-6.1590*	1990
$\ln G_t$	-3.3423	1988	-6.4114*	1991
$\ln Y_t$	-2.4110	2004	-5.2707*	1983
$\ln K_t$	-3.2885	2009	-5.7314*	1983
Russia				
$\ln E_t$	-2.5061	1984	-7.2424*	1994
$\ln G_t$	-2.1728	1991	-7.1298*	2000
$\ln Y_t$	-2.3434	1982	-5.0755*	1994
$\ln K_t$	-3.8984	1989	-4.7670**	1992
India				
$\ln E_t$	-0.0676	2004	-6.7438*	2003
$\ln G_t$	-2.6515	1987	-8.2561*	1988
$\ln Y_t$	1.0194	1993	-7.0459*	1993
$\ln K_t$	-1.0386	2003	-7.2898*	2004
China				
$\ln E_t$	-2.9937	2002	-6.4333*	2003
$\ln G_t$	-2.1311	1989	-9.8454*	1990
$\ln Y_t$	-0.5305	1983	-4.4151**	1983
$\ln K_t$	-3.1569	1991	-6.2463*	1989
South Africa				
$\ln E_t$	-2.2103	2007	-6.9442*	2003
$\ln G_t$	-2.8480	1994	-5.4243*	1995
$\ln Y_t$	-3.5068	2003	-4.8414**	1992
$\ln K_t$	-3.2229	1984	-5.4726*	1986

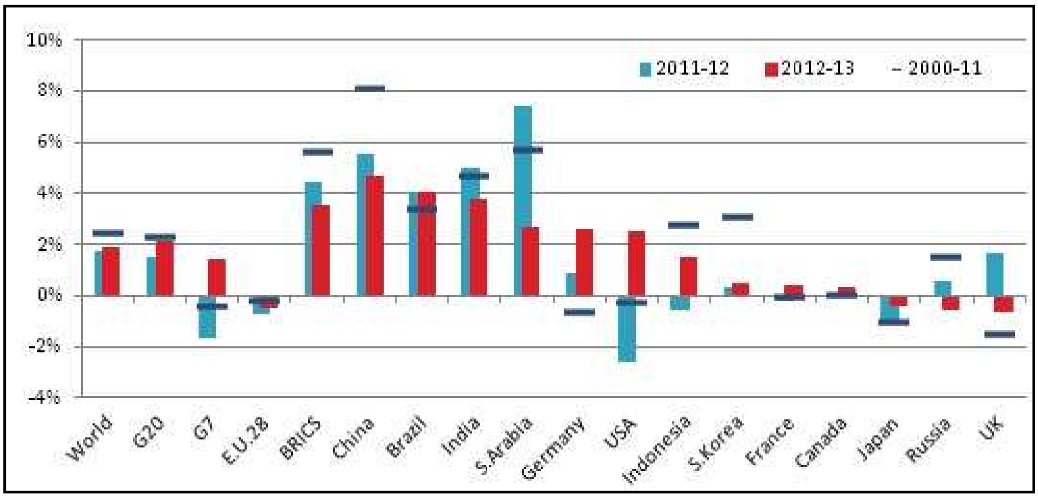
Significance Level				
CV 1%	-4.949133			
CV 5%	-4.443649			
CV 10%	-4.193627			
Note: *: p≤0.01; **: p≤0.05.				

Table-4. NARDL Cointegration Analysis

Dependent Variable: $\Delta \ln E_t$										
	Brazil		**Russia**		**India**		**China**		**South Africa**	
Constant	4.4179***	(1.0229)	1.5856***	(1.5982)	2.9571***	(0.9138)	1.7551***	(0.5219)	1.8349**	(0.7978)
$\ln E_{t-1}$	-0.6872***	(0.1591)	-1.1246***	(0.1696)	-0.5232***	(0.1622)	-0.3023***	(0.0842)	-0.2309**	(0.1039)
$\ln G_t^+$	-0.2234***	(0.0694)	-0.1288*	(0.0778)	-0.0444**	(0.0542)	0.0431	(0.0967)	-0.0940	(0.0863)
$\ln G_t^-$	1.0092***	(0.2530)	-3.5498***	(0.6466)	-1.9137***	(0.5780)	-1.7928*	(0.9112)	3.1379***	(0.7488)
$\ln Y_t^+$	0.0239*	(0.0170)	0.6841*	(0.3386)	0.1159	(0.1057)	-0.2720***	(0.0806)	-0.6598	(0.5619)
$\ln Y_t^-$	0.3151*	(0.0049)	0.8221***	(0.1544)	0.0144	(0.1174)	0.9411*	(0.5679)	1.2249**	(0.5023)
$\ln K_t^+$	0.3909***	(0.0755)	-0.2959	(0.2060)	0.0878*	(0.0478)	0.2780***	(0.0532)	0.2003	(0.1999)
$\ln K_t^-$	-0.1341	(0.1413)	-0.0235	(0.0236)	0.1855	(0.1837)	0.2733	(0.1842)	-0.8258***	(0.2133)
D_t	0.0351**	(0.0159)	-0.0006	(0.0117)	0.0190	(0.0125)	0.0821***	(0.0238)	0.0767**	
$\Delta \ln E_t$	0.1944	(0.1298)							-0.3327**	(0.1566)
$\Delta \ln E_{t-1}$	0.2705**	(0.1004)							-0.3344*	(0.1664)
$\Delta \ln E_{t-2}$	0.3855**	(0.1389)	-0.3149*	(0.1667)	0.1637*	(0.0919)				
$\Delta \ln G_t^+$					-0.1814*	(0.1136)				
$\Delta \ln G_{t-1}^+$	-0.3169**	(0.1370)								
$\Delta \ln G_{t-2}^+$			-1.0431*	(0.5912)	-1.1556*	(0.5646)	1.2829*	(0.7545)	2.2381**	(0.8201)
$\Delta \ln G_t^-$	0.5873	(0.4114)	1.4765**	(0.5397)	1.4265*	(0.8584)	1.5778**	(0.7108)		
$\Delta \ln G_{t-1}^-$	0.4642**	(0.2126)	0.6710***	(0.1860)			-0.3548**	(0.1677)		
$\Delta \ln Y_t^+$			0.5751**	(0.2467)						
$\Delta \ln Y_{t-1}^+$									1.2534**	(0.4927)
$\Delta \ln Y_{t-2}^+$			0.7039***	(0.1622)					-0.9153*	(0.5028)
$\Delta \ln Y_t^-$			-0.2286**	(0.0983)			-1.3394*	(0.7069)	-1.3747**	(0.6314)
$\Delta \ln Y_{t-1}^-$	0.1685*	(0.0893)					0.2327***	(0.0778)	0.6100***	(0.1719)
$\Delta \ln K_t^+$	-0.1940***	(0.0656)			-0.2306***	(0.0617)				
$\Delta \ln K_{t-1}^+$			-0.1434**	(0.0610)	0.5176**	(0.2325)				
$\Delta \ln K_t^-$					0.4421**	(0.1629)	-0.6689***	(0.2317)	0.4292*	(0.2285)
R^2	0.8276		0.9342		0.5944		0.7679		0.7432	
Adj-R^2	0.7055		0.8977		0.4677		0.7157		0.5614	
D-W Test	1.9618		2.163		2.3414		2.1781		2.4908	
χ^2_{SC}	3.0483		2.6253		1.7735		2.1367		2.1889	
χ^2_{HC}	0.5588		2.2328		0.9335		0.3832		0.7315	
χ^2_{FF}	0.9307		2.0295		2.3841		0.2434		0.2381	
L_G^+	-0.3217	[0.0048]	-0.1139	[0.0866]	-0.1674	[0.1103]	0.6555	[0.0555]	-0.4070	[0.3007]

L_G^-	0.4198	[0.0981]	-3.1579	[0.0000]	-2.6969	[0.0002]	-9.2378	[0.0000]	13.5914	[0.0451]
L_Y^+	0.2434	[0.0396]	0.6073	[0.0569]	0.1739	[0.3708]	-0.9405	[0.0314]	-2.8578	[0.3451]
L_Y^-	0.9825	[0.0136]	0.7335	[0.0000]	0.0891	[0.6959]	0.7687	[0.6967]	5.3056	[0.0543]
L_K^+	0.4061	[0.0004]	-0.2626	[0.1701]	0.2526	[0.0612]	0.8314	[0.0069]	0.8674	[0.3892]
L_K^-	-0.2770	[0.0556]	-0.0215	[0.1796]	0.1094	[0.7209]	1.7580	[0.0290]	-3.5770	[0.0684]
$W_{LR,G}$	3.2688***		42.7059*		17.3330*		32.2349*		4.4340**	
$W_{LR,Y}$	3.2489***		10.1456*		0.1201		0.6916		1.9049	
$W_{LR,K}$	13.3289*		1.6059		0.1976		4.4453**		2.9044**	
$W_{SR,G}$	4.1265**		15.9713*		0.5045		8.3665*		10.6434*	
$W_{SR,Y}$	2.6362***		20.6383*		0.2998		6.6091*		3.0625***	
$W_{SR,K}$	5.2113**		2.4043		2.5714**		14.8548*		7.8381*	
F_{PSS}	9.3640*		7.6616*		6.5665*		8.8337*		6.0740**	
T_{BDM}	-4.9124*		-6.8275*		-4.6544*		-4.6667*		-4.6789*	
CUSUMSQ	Stable		Stable		Stable		Stable		Stable	

Notes: The superscripts "+" and "-" denote positive and negative variations, respectively. L^+ and L^- are the estimated long-run coefficients associated with positive and negative changes, respectively, defined by $\hat{\beta} = -\theta / \rho$. χ^2_{SC}, χ^2_{FF} and χ^2_{HET} denote LM tests for serial correlation, normality, functional form and heteroscedasticity, respectively. W_{LR} and W_{SR} represent the Wald test for the null of long- and short-run symmetry for the respective variables. F_{PSS} shows the statistic of the Pesaran et al. (2001) bounds test. T_{BDM} denotes the statistic of Banerjee et al. (1998). Figures in brackets show p-values. *: p≤0.01; **: p≤0.05; ***: p≤0.10.



Source: Enerdata (2015)

Fig. 1. Growth of energy consumption across the major world economies (%/year)

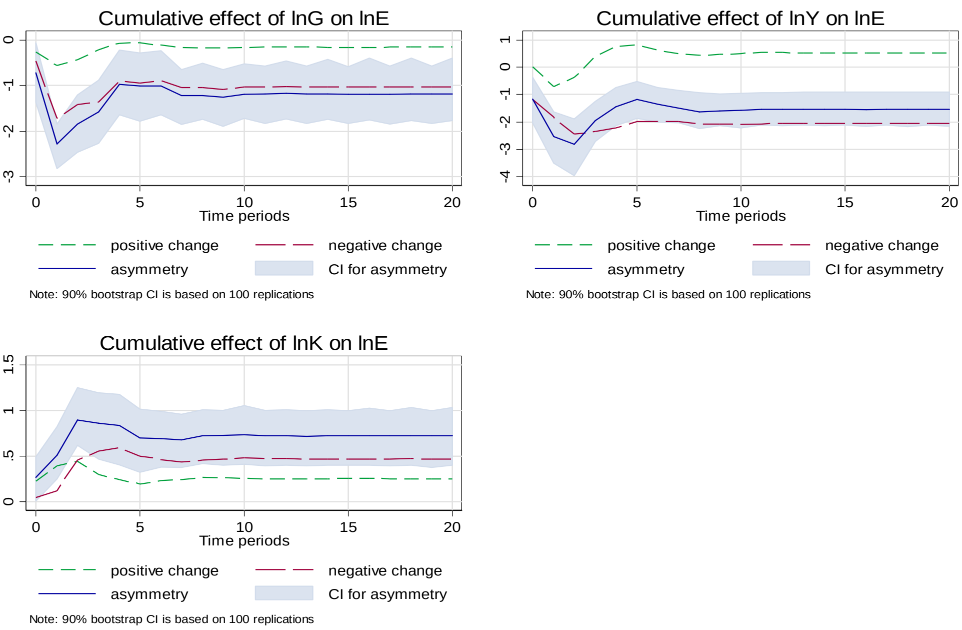


Fig. 2. Cumulative dynamic multipliers for Brazil

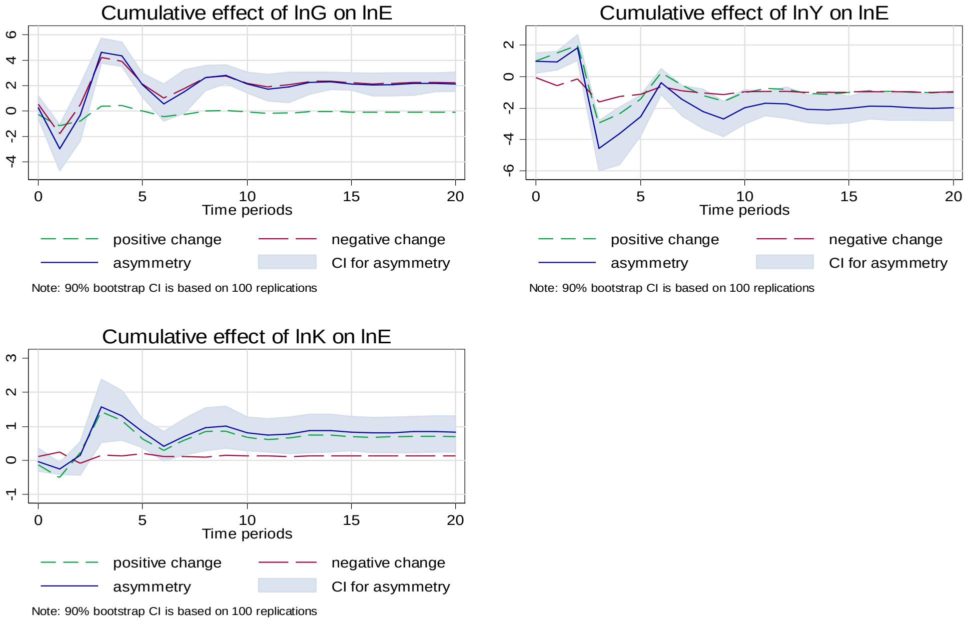


Fig. 3. Cumulative dynamic multipliers for Russia

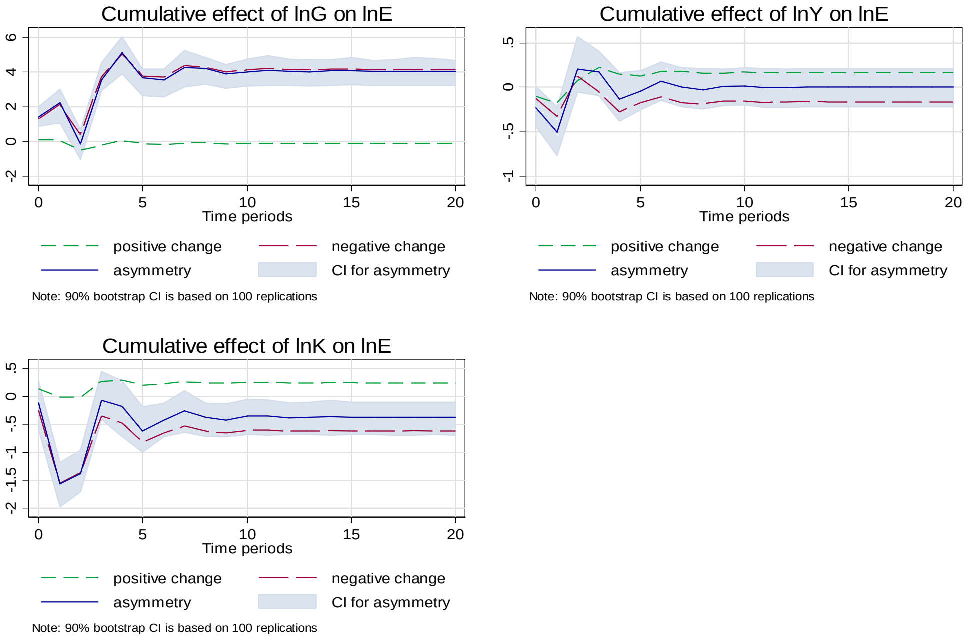


Fig. 4. Cumulative dynamic multipliers for India

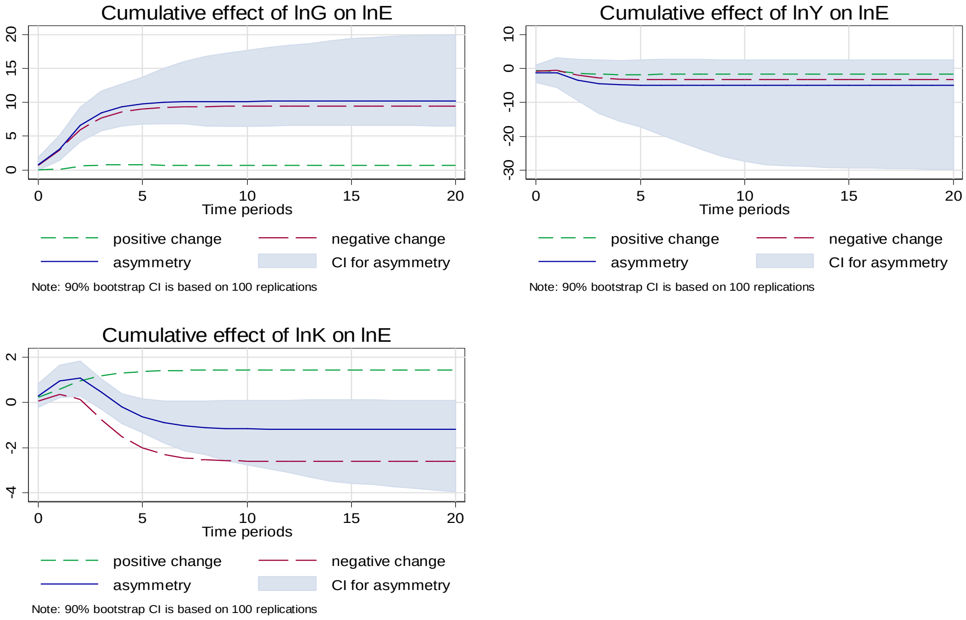


Fig. 5. Cumulative dynamic multipliers for China

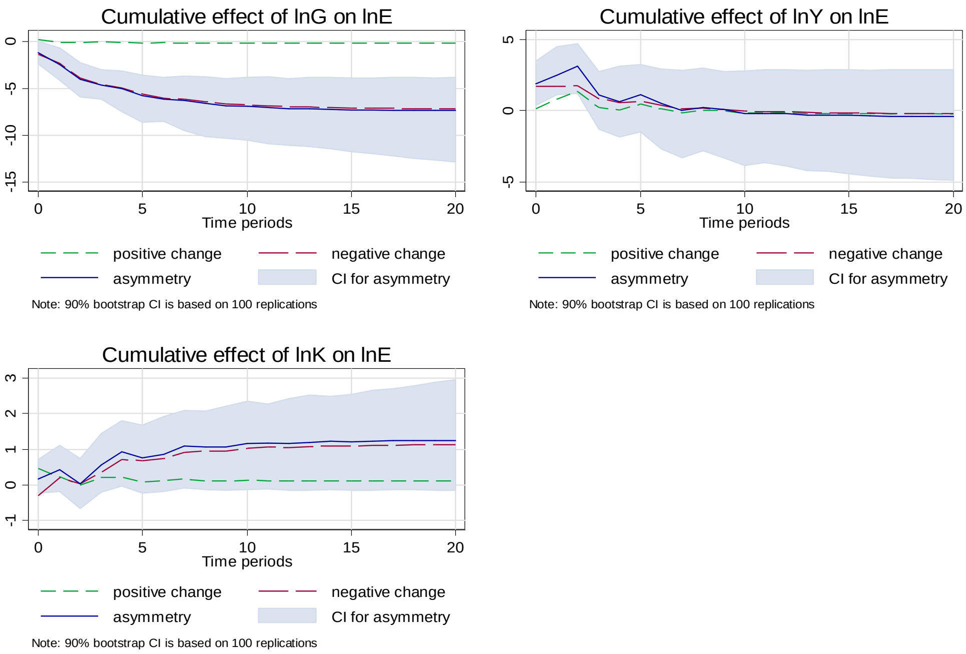


Fig. 6. Cumulative dynamic multipliers for South Africa