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Do gross domestic product changes have asymmetric effect on India's energy use?

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ABSTRACT
The existing literature on the linkage between Gross Domestic Product (GDP) and energy use in both industrialized and developing economies usually assumes that the impacts of gross domestic product changes are symmetric. In this study, we utilized nonlinear autoregressive distributed lag (NARDL) model and test whether or not the effect of variations in the gross domestic product on energy use is symmetric or asymmetric from the context of India. Using time series data over 1971-2014, the findings depict that the change in the gross domestic product has a symmetric effect on energy use both in short-run and the long-run. Our conclusions infer that there is no asymmetrical association between GDP and energy use, leading to support the symmetric impact of GDP on energy use.

Keywords
GDP, Energy use, NARDL, India, Asymmetric

JEL Classification
E10; N75;O13;Q43

1. Introduction

Along with globalization, energy becomes the most important inputs in the process of economic development. Consequently, not only the demand for energy has increased but also a dependency on energy has rapidly risen in both developed and developing countries (Ghali & El-Sakka, 2004). Although the demand for energy in third world economies is even now considerably lower than the global standards, there has been an upturn equivalent to industrial growth and levels of income. Moreover, the elasticity coefficient computed to indicate the association between economic growth and energy use both in strong and weak economies assume values approximately equal to one, which infers that a one percent upsurge in economic growth leads increase energy use by 100 percent in developing economies (Kapusuzoglu & Karan, 2012). Besides, the elasticity coefficient estimated between the demand for energy use and GDP is relatively less than one for developing economies. The difference between developed and developing economies from the

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perspective of the association between the demand for energy (energy use) and economic growth generally stems from the continuously escalating need for energy in emerging economies (Dorsman *et al.*, 2012).

India as the world second most populous country, while consuming only six percent of the globe's primary energy and three-quarters of energy use are met by fossil fuels. Since 2000, the demand for primary energy use has nearly increased by two times and also the potential for further fast growth is relatively high. In addition to this, the targeted policy interventions and economic growth in India have lifted more than millions out of tremendous poverty, however, per capita energy use is still close to one-third of the world average and at least 240 million masses have no access to use of electricity. In this situation, even with expanding concentration on subsidy reform and energy efficiency, there are reasons to anticipate continued rapid expansion in energy demand (IEA, 2015). Thus, India being a third-largest big economy; is growing swiftly and policies are in a position to continue with the country's growing and modernization of its manufacturing. In this sense, the increase in India's gross domestic product is a prime driver of energy trends (Bakirtas & Akpolat, 2018). The primary energy use of India between 2010 and 2016 are depicted in Figure 1. Data for the figure is obtained from Statista, 2018.

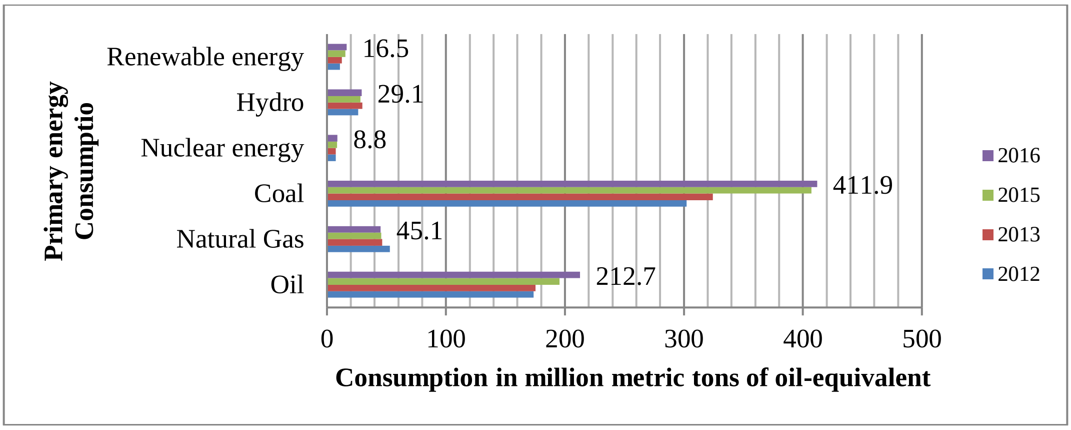

Figure 1: Primary energy use in India between 2010 and 2016, by fuel in million metric tons of oil equivalent.

In 2016, the demand for renewable energy, hydro, nuclear energy, coal, natural gas, and oil were 16.5, 29.1, 8.8, 411.9, 45.1 and 212.7 million metric tons, respectively. Contrariwise, Figure 2 shows the position of India's energy use with respect to total top 5 emerging economies (BRICS)' aggregate energy use.

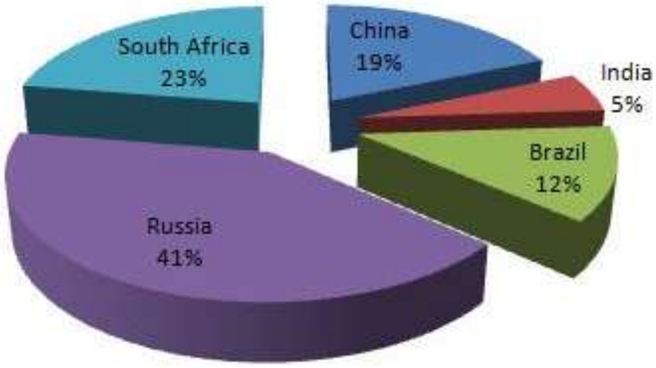

Figure 2: Energy use share of each BRICS member nations with respect to the total energy use of BRICS

Two approaches that explain the reasons behind the existence of the nexus between economic growth and energy uses are the neoclassical and the ecological approaches. The neoclassical approach primarily considers the structure of the economy as a closed system. Goods are produced by employing labor, capital and are exchanged between sellers and buyers. In this course, the higher gross domestic product is intended to be attained by raising the human capital and labor inputs. Moreover, this approach postulates that rise in the capital, labor quality and technological advancement will also contribute to attaining economic growth. The neoclassical growth model involves three typical models. The first model sort out changes in technology, the second with natural resources and the last model combine the first two models (Barro, 1998; Stern & Cleveland, 2004; Ockwell, 2008). On the other hand, the ecological approach regard energy as an underlying determinant that permitting economic production (Dorsman *et al.,* 2012). There exists a disagreement on the association between energy use and economic growth in the existing literature. Some of this literature include (Longxing *et al.*, 2011; Chen *et al.,* 2012; Mulali *et al.,* 2013; Muhammad *et al.*, 2015; Irwan *et al.,* 2015; Faisal *et al.,* 2015; Bennouna & Hebil, 2016; Bah & Azam, 2017; Shahbaz *et al.*, 2017; Muhammad *et al.*, 2018; Mahalingam & Orman, 2018; Cai *et al.*, 2018).

It is noteworthy to mention that very few studies have concentrated on investigating the asymmetrical impact of GDP on energy use in India. Therefore, this is the first study that attempts to inspect the asymmetry arises due to change in gross domestic product and also dissect its effect on energy use from the perspective of India.

The remaining paper is divided into three sections. Part two establish a nonlinear ARDL model. Part 3 elaborates the estimated findings, while part 4 ends up with conclusions.

2. Research methods

Following the methodology of (Shin *et al.*, 2013) the relationships between positive and negative components energy use and GDP are represented by the following long-run regression:

$$EU_t = \vartheta_0 + \vartheta_1^+ GDP_t^+ + \vartheta_2^- GDP_t^- + \varepsilon_t \tag{1}$$

where EU is energy use integrating of order one, GDP represents gross domestic product integrating of order one, $\vartheta = \vartheta_0, \vartheta_1^+, \vartheta_2^-)$ is a vector of long-run unknown parameters. It is noted that ϑ_1^+ represent coefficients of the positive component of GDP and ϑ_2^- indicated the negative component of GDP. While $GDP_t = GDP_0 + GDP_t^+ + GDP_t^-$ .Where GDP_t^+ and GDP_t^- are partial sum process of positive and negative variation in GDP_t follow as;

$$GDP_t^+ = \sum_{j=1}^{t} \Delta GDP_j^+ = \sum_{j=1}^{t} \max\left(\Delta GDP_j, 0\right), GDP_t^- = \sum_{j=1}^{t} \Delta GDP_j^- = \sum_{j=1}^{t} \min\left(\Delta GDP_j, 0\right) \tag{2}$$

The Equation 2 is a simple modelling to inspect asymmetrical behaviour among variables included in the model. This modelling was first employed by (Schorderet, 2001) from the perspective of the nonlinear nexus between unemployment and output.

Following (Shin et al., 2013), Equation 1 can be fitted in an ARDL setup under the context of (Pesaran et al., 2001) as:

$$\Delta EU_t = \varsigma_0 + \varsigma_1 EU_{t-i} + \varsigma_2^+ GDP_{t-i}^+ + \varsigma_3^- EU_{t-i}^- + \sum_{i=1}^{p} \Theta_i \Delta EU_{t-i} + \sum_{i=0}^{m} (\varpi_i^+ \Delta GDP_{t-i}^+ + \varpi_i^- \Delta GDP_{t-i}^-) + \epsilon_t \tag{3}$$

where p and m are lag orders. $\sum_{i=0}^{m} \varpi_i^+$ estimates the short-run possible response of GDP increases on the energy use emissions while $\sum_{i=0}^{m} \varpi_i^-$ measures the short run impact of GDP reduction on CO_2 emissions. Hence, in this setup, along with asymmetric long-term association, the asymmetric short-run impact of variations in GDP on energy use is also captured.

The error correction model (ECM) of the Equation 3 is depicted as:

$$\Delta EC_t = \sum_{i=1}^{p} A_i \Delta EU_{t-i} + \sum_{i=1}^{m} (\eta_i^+ \Delta GDP_{t-i}^+ + \eta_i^- \Delta GDP_{t-i}^-) + \Upsilon_i ECT_{t-i} + \rho_t \tag{4}$$

where A_i, depicts short-run coefficient and η_i^+, η_i^- indicate short-run adjustment symmetry. While Υ_i indicates the coefficient of error correction term.

We follow the following steps and procedures in order to estimate NARDL model. In step 1, we test each series for an order of integration with the help of Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) Unit Root tests (Dickey & Fuller, 1979; Phillips & Perron , 1988; Elliott, et al., 1996). In the second step, we estimate Equation 3, using the standard OLS procedure. In step 3, the Bound testing technique is carrying out to test the existence of a long-run association between variables (Shin, et al., 2013; Pesaran, et al., 2001). This technique is based on the Wald F test having the null hypothesis of H_0 (HYP1): $\varsigma_1 = \varsigma_2^+ = \varsigma_3^- = 0$ and the null hypothesisH_0: $\varsigma_1 \neq \varsigma_2^+ \neq \varsigma_3^- \neq 0$. In the fourth step, the possible existence of relationship between GDP and energy use in the long-run and short-run asymmetries in established. Furthermore, we also estimated the symmetric increasing "dynamic multiplier effects" of one percent difference in GDP_{t-i}^+ and GDP_{t-i}^- respectively as:

$$K_b^+ = \sum_{j=0}^{b} \frac{\partial EU_{t\_j}}{\partial GDP_{t-1}^+}, \quad K_b^- = \sum_{j=0}^{b} \frac{\partial EU_{t\_j}}{\partial GDP_{t-1}^-}, \quad b = 1,2,3 \ldots \ldots \tag{5}$$

It is noted that as $b \to \infty$, $K_b^+ \to \vartheta_1^+$ and $K_b^- \to \vartheta_1^-$.

In the last step, the following two hypotheses are tested against alternative hypothesis:

H_0: (HYP2): $-\,{}^{\varsigma_2^+}/_{\varsigma_1} = -\,{}^{\varsigma_3^-}/_{\varsigma_1}$(No long Run asymmetrical relationship)

H_1: $-\,{}^{\varsigma_2^+}/_{\varsigma_1} \neq -\,{}^{\varsigma_3^-}/_{\varsigma_1} \neq 0$ (Long Run asymmetrical relationship)

H_0: (HYP3): $-\,{}^{\varpi_i^+}/_{\Theta_i} = -\,{}^{\varpi_i^-}/_{\Theta_i}$(No short Run asymmetrical relationship)

H_1: $-\,{}^{\varpi_i^+}/_{\Theta_i} \neq -\,{}^{\varpi_i^-}/_{\Theta_i}$(Short Run asymmetrical relationship)

The results of these hypotheses and empirical model are presented in the next section.

3. Results and discussion

This study used secondary data on energy use in kg oil equivalent and gross domestic product in current US dollar. All the data series have been compiled from the WDI (2018), World Bank Database. The data range used in this study is 1971-2014. As an important condition of time series data, ADF and PP unit root tests are utilized to check the unit root in variables. The estimated results in Table 1 infer that both energy use and GDP are nonstationary at levels but become stationary only at first difference under the 0.001 level of significance. Moreover, the estimated outcomes of PP validated that all the designated variables can be labelled under the I(1) process.

Table 1: ADF and PP unit root test

Variables	Level		First difference	
	ADF	**PP**	**ADF**	**PP**
EU	3.749478	3.619111	-4.814941**	-5.042372**
GDP	0.032307	-0.006617	-5.954680**	-5.973082**

* depicts significance at 5%

The main difference between linear ARDL and nonlinear ARDL is that the nonlinear ARDL capture asymmetries arise from the positive and negative shocks of macroeconomic variables. On the other hands, linear ARDL do not account asymmetrical relationship among variables. Thus, we start our analysis from the positive and negative components of GDP. Figure 3 depicted the positive and negative shocks of GDP and its effect on energy use.

Our main objective is to compute whether or not the effect of a variation in GDP on India's energy use is asymmetric or symmetric. Table 2 presents the result of estimated non-linear ADRL coefficients of short-run as well as the long-run. The reported result of short-run coefficients is positive for GDP increases as well as for GDP decreases. As such, the projected elasticities of GDP increase (decrease) relating to energy use is 0.033 (0.0334), infers that a 1% growth (reduction) in GDP is expected to rise (decline) energy use by 0.033% (0.0334%). It is further inferred that the estimated rise in coefficient of GDP is highly significant, nevertheless, the coefficient of GDP decreases is statistically insignificant. Keeping in view, the variations in the significance level and the directions of reported elasticities, the difference in GDP indicates towards an asymmetric effect in the short-run of Indian energy uses.

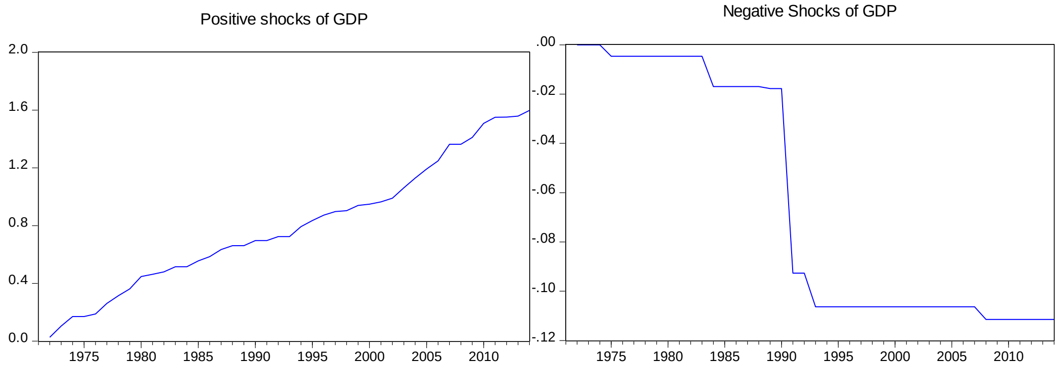

Figure 3: Positive & negative components of GDP

Though, the reported result of Wald test indicates that the null hypothesis of symmetry should be accepted. In contrast, the result of long run divulge that the two estimates are positive. For example, the expansions/reductions in the elasticity of GDP relating to energy use is 0.375 (0.379), recommending that increase/decrease of one percent change in GDP is likely to increase (decrease) energy use by 0.375% (0.379%).

Table 2: Results of short-run and long-run NARDL equation

Variable	Short run coefficient	Std. error	t-statistic
C	0.210570*	0.122684	1.716355
$LEU(-1)$	-0.088130*	0.051533	-1.710170
GDP^{+}	0.032951***	0.011565	2.849271
GDP^{-}	0.033371	0.035813	0.3572
ECT(-1)	-0.088130	0.007487	-11.77051
Variable	**Long run coefficient**	**Std. error**	**t-statistic**
GDP^{+}	0.373890***	0.103710	3.605138
GDP^{-}	0.378662	0.528090	0.717039
C	2.389308***	0.021840	4.598309
NARDL bound test			
$\mathrm{F-statistic\ (HYP1)} = 32.16222$	$[\mathrm{LB} = 2.63, \mathrm{UB} = 3.35 \text{ at } 10\%]$ $[\mathrm{LB} = 3.1, \mathrm{UB} = 3.87 \text{ at } 5\%]$ $[\mathrm{LB} = 3.55, \mathrm{UB} = 4.38 \text{ at } 1\%]$		

*** and * represent 1% and 10% significance level, respectively.

The estimations provided in equation (3) are statistically significant, which indicates a "co-integration" relationship between the explained variables in the model. Thus, it is important to conduct a "co-integration" for the association between GDP and energy use. The most common test for this is to evaluate and compare the upper critical value to the estimated F-statistic value as suggested by the Pesaran, Shin, and Smith (2011). When we follow this procedure, the assessed F-statistic is 32.16 and the one percent and five percent upper critical value is 3.55 (4.38). Henceforth, our study strongly accepts that there is a long-run cointegration association between variables.

Table 3: Testing hypothesis of asymmetrical effect

Null hypothesis	F-statistic	Probability
Long run symmetries (HYP2)	1.0156	0.2455
Short run symmetries (HYP3)	1.9761	0.4912

*** and * indicate that the null hypothesis is accepted at 1% and 10% level of significant

Besides, the previous estimation results we got in Equation 3 do not suffer the spurious regression issue. Another form of validating long-run relationship is that the equilibrium takes when the error-correction coefficient should not only negative but also significant. In reality, we get the negative coefficient of ECT (-0.088), and this is also statistically significant at 1% levels. Thus, our estimated results provide an evidence of supporting co-integration.

Table 4: Results of short and long-run ARDL equations

Variable	Short run coefficient	Std. error	t-statistic
C	-0.145726***	0.030242	-4.818702
$LEU(-1)$	-0.088478**	0.039997	-2.212100
GDP	0.032999***	0.010578	3.119425
ECT(-1)	-0.088478***	0.007517	-11.77049
Variable	**Long run coefficient**	**Std. error**	**t-statistic**
GDP	0.372958***	0.057021	6.540666
C	-1.647040**	0.619384	-2.659140
NARDL bound test			
$\mathrm{F-statistic} = 43.98235$	$[\mathrm{LB} = 3.02, \mathrm{UB} = 3.51 \text{ at } 10\%]$		
	$[\mathrm{LB} = 3.62, \mathrm{UB} = 4.16 \text{ at } 5\%]$		
	$[\mathrm{LB} = 4.18, \mathrm{UB} = 4.79 \text{ at } 1\%]$		

*** and ** represent 1% and 5% significance level

After validating the symmetric relationship between GDP and energy use, we estimate a linear ARDL model. The estimated outcomes of linear ARDL are reported in Table 4. The findings show that there exist short-run and long-run positive relationships between GDP and energy use. Ultimately, to validate and confirm our estimated model, we carry out several diagnostic tests for the residuals of our data. Table 5 signifies the estimated values of different diagnostic tests. All the results of diagnostic tests divulge that our model is free of any statistical problem.

Table 5: Validation tests

Test	Test-statistic	Probability
White test	2.891395	0.7167
LM test	0.860972	0.6502
Ramsay reset test	0.495172	0.4858
CUSUM	Stable	0.05
CUSUM square	Stable	0.05

4. Conclusion

Changes in the Gross Domestic Product are expected to have asymmetric effects on energy use. However, the previous literature on the nexus between GDP and energy used not directly test the asymmetry hypothesis in their works of research. Thus, the current study is conducted to test whether or not the effect of changes in the gross domestic product on energy use is asymmetric from the perspective of India, currently one of the top emerging economies among developing countries and third largest end user of energy in all over the world. The findings of nonlinear ARDL validate that variations in GDP have an asymmetric effect on energy use in both short-run and the long-run. In other words, the asymmetry of changes in GDP is not observed in both short-run and long-run.

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