



EXAMINED THE ENERGY-LED GROWTH HYPOTHESIS IN INDIA: EVIDENCE FROM TIME SERIES ANALYSIS

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ABSTRACT

The present study examined the linkage between energy consumption and economic growth in India using the annual time series data covering the period from 1970-71 to 2011-12. The study used Gross Domestic Product as a proxy for economic growth and energy consumption (oil equivalent per capita). The empirical findings of the study suggest that there is both the short run and the long run relationship exist between energy consumption and economic growth. The Granger causality result confirms that there is unidirectional causality running from economic growth to energy consumption. That means the study support the conservation hypothesis. The impulse response result of the study suggests that India requires an alternative source of energy for faster economic growth. The variance decomposition of the study concluded that the rapid growth of the economy depends on the heavy energy consumption. From the policy recommendation point of view, the energy policy of India should give more importance to find out the alternative source of energy supply in order to meet the growing demand for energy. Moreover, to achieve sustainable energy conservation and macroeconomics stable India should follow the energy efficiency and self-sufficiency in energy production for faster economic growth.

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Keywords: Energy, Growth hypothesis, Cointegration, India and error correction.

JEL Classification: Q40, Q43.

Contribution/ Originality

This study is one of the few studies which have examined the relationship between energy consumption and economic growth in the case of India. The contribution of this study is twofold to the existing literature. Firstly, the study employed advance time series analysis in order to verify the linkage between the variables. Secondly, this study examined the energy-led growth hypothesis in the context of India prior to this no study has done in this context. The empirical findings of the study confirms that the study support the “conservation hypothesis”. The findings also suggest that India should find out the alternative source of energy supply to meet the growing demand for energy.

1. INTRODUCTION

The nexus between energy consumption and economic growth has been the subject of considerable academic research over the past few decades. The broad reason of studying energy is that energy play a focal role in the current debate of energy-led growth hypothesis. As we know economic growth is closely linked to energy consumption since higher level of energy consumption leads to higher economic growth. However, efficient utilisation of energy resources requires a higher level of economic growth. In literature, the relationship between energy consumption and economic growth has attracted attention of researchers in different countries for a long time.

Taking into account certain factors like Environmental quality reduction, rapid growth of population, High energy requirement for the soaring production to meet the growing demand in the economy, increasing worldwide energy price and reduce dependency from foreign energy resources, the importance of the subject to design efficient and practical policies is beyond question. The relationship between energy consumption and economic growth is a controversial issue which is evident from the number of empirical studies.

From the very commencement, [Kraft and Kraft \(1978\)](#) investigated the causal relationship between energy consumption and economic growth covering the sample period from 1947-1974. The study found that unidirectional causality running from energy consumption to GNP growth in the United States. [Akarca and Long \(1980\)](#) found that a causal relationship does not exist between energy consumption and economic growth when, the study period is concise merely by 2 years. [Ozturk \(2010\)](#) examined the relationship taking into consideration about 100 studies with a roughly uniform distribution and concluded that four obtainable outcomes, namely unidirectional causality from energy consumption to growth, unidirectional causality from growth in energy consumption, bidirectional causality and neutrality.

Over the years, much research has been done to determine the key factors impacting on economic growth, an energy being a new factor for growth but, no single study have not included in the traditional growth models ([Stern, 2011](#); [Pirlogea and Cicea, 2012](#)). We have seen most of the studies have explained growth and economic activity on the way of the production function. If we look at the new classical models we could observe that capital, labour and land treated as the primary factors of production, while energy is used as an intermediate input finally produced by the

primary factors of production. In addition to, new classical economist like (Solow, 1974) assumes that capital and energy are perfectly substitutable. A reduction in energy consumption does not, under state of affairs of economic efficiency, which results in a reduction in economic growth. These analyses have led to an importance in the conventional growth theory on the primary inputs, and in Fastidious, labour and capital, other given that land is treated as a subcategory of capital. Whereas, energy has played a minor role in economic production in the conventional theory of growth.

Ecological economist is strongly criticised to the new classical growth theory, which is beached in the biophysical theory of the role of the energy. According to the law of thermodynamics a certain quantity of energy is required to carry out the transformation of matter. Though we know all production process deals with the transformation or movement of matter, therefore, energy is necessary for economic production and as a result economic growth. Moreover, some econometric studies, like (e.g (Apostolakis, 1990)) have used different functional forms to estimate elasticities of substitution between capital and energy. The above studies indicated that energy and capital are, at best weak, complements and substitutes.

From the above analysis, we observed that energy is a vital input in the production process, seeing as it is used in other economic activities. In the Morden times climate change and energy security become a key issue in recent decades. Given changes in energy policies to investigate the caused relationship between energy consumption and economic growth has become a compelling area.

From an economic point of view, the energy consumption and economic growth have two important aspects. (i) High dependency of economic growth on energy. (ii) Economic growth promotes advance energy technology, utilisation of energy and large scale development. Various studies, like (e.g (Akarca and Long, 1979;1980; Masih and Masih, 1996;1997;1998; Glasure and Lee, 1998)) have shown (I) the relationship between energy consumption and economic growth varies depending on the categorisation of (Developed, developing and underdeveloped) countries. (ii) The relationship varies at different times in the same country. This divergence results from a number of factors like (i) structure and stages of economic development. (ii) The use of different econometric methods (iii) Variation of the analysis time horizon. (iv)The type and number of variable inclusion in the process (Yu and Choi, 1985; Ferguson *et al.*, 2000; Toman and Jemelkova, 2003; Karanfil, 2009; Payne, 2010).

Moreover, the available literature on the relationship between energy consumption and economic growth has suffered two foremost drawbacks; (i) Lack of mixture of energy based and conventional models as a result of different theoretical based approach on economic growth (i.e. Conventional growth theory vs. Ecological-Economics view point). (ii) Omission of important variables from the models.

In this present study, we attempt to include these issues by investigating the relationship between energy consumption and economic growth in the case of India. Where, relatively less researched in this area has been conducted. However, the contribution of this study to the literature

is twofold. Firstly, the study has used advance time series analysis in order to verify the linkage between energy consumption and economic growth. Secondly, the study has examined the energy-led growth hypothesis in the context of India prior to this no study has done in this context.

This paper is organised as follows, review of literature is in the section 2, variable description and period of study is considered in section 3. Methodology has been dealt with section 4. The empirical results are discussed in section 5 and concluding remarks are conferred in section 6.

2. REVIEW OF LITERATURE

There have been lots of study done on the causal relationship between energy consumption and economic growth. This study area becomes a key issue after the oil crisis in the 1970's to the more recent concern on energy prices, impact of environmental policy, energy security and reduction of greenhouse gases. The casual relationship between energy consumption and economic growth gives inconsistent and mixed results. The present study motivated on international studies first before moving to Indian studies.

The first study on energy and economic growth back to the late 1970's done by [Kraft and Kraft \(1978\)](#). They investigated the causal relationship between GNP and Energy on the U.S data from the period 1947 to 1974. The study found that increased GNP leads to increase energy consumption on U.S. [Akarca and Long \(1979\)](#) investigated the relationship between energy consumption and economic growth for U.S using employment to substitute for growth. By using annual data from the period 1950 to 1970 the study found that increased energy consumption leads to higher level of employment. [Akarca and Long \(1980\)](#) using a different data set and different methodology (i.e Sims Causality Test) found no causal relationship between GNP and energy consumption. [Akarca and Long \(1979\)](#); [Erol and Yu \(1987a\)](#); [Murray and Nan \(1992\)](#) examined the relationship between energy consumption and economic growth by using employment to substitute for economic growth and employed Sims causality method for the monthly U.S data cumulated from the period 1970 to 1984 and found no causal relationship between energy consumption and employment.

[Erol and Yu \(1987b\)](#) examined the causal relationship between energy consumption and real GNP for Canada, France, Germany, U.K, Italy and Japan. By employing Granger and Sims causality methods they found that there is a bidirectional causality between the two variables for Japan and no causal relationship between the two for the U.K and France. Whereas, increased in GNP leads to increased energy consumption in the case of Germany and Italy and vice-versa for Canada. [Murray and Nan \(1992\)](#) studied the relationship energy consumption and employment by employing Granger causality method for the U.S data from 1974 to 1988. The study found that increased employment results in increased energy consumption.

The above studies are based on the faith of bivariate causality test of output or employment and energy consumption. As we know the general problem of a bivariate analysis is omitted of relevant variables, which leads to misleading statistical results ([Stern, 2000](#); [Payne, 2010](#)). To avoid the above problem, [Yu and Hwang \(1984\)](#); [Stern \(1993\)](#) combined supplementary variables in their analysis for the case of U.S. [Yu and Hwang \(1984\)](#) by employing the employment when

investigating the relationship between energy consumption and GNP, they found that increased employment leads to increased energy consumption for the U.S. Stern (1993) investigated the relationship between energy consumption and GNP by adding employment and capital in the analysis and found that no causal relationship between energy consumption and GNP.

In the above studies, out dated OLS methodology was used by some studies to conduct statistical test and estimate parameter. This OLS method does not take into account the non-stationarity of the variables and the possibility of endogeneity of regressors, both of which generates spurious regressions (Granger and Newbold, 1974). In the past decade with the advances in the time series techniques such as Johansen and Juselius (1990) cointegration and Error Correction Model have been applied to investigate the relationship between energy consumption and economic growth. Glasure and Lee (1998) investigated the relationship between energy consumption and real GDP by applying Engle-Granger cointegration and Error Correction Model in the context of South Korea and Singapore. The study found that there is a bidirectional causality between energy consumption and real GDP growth. Francis *et al.* (2007) examined the relation between the energy consumption and real GDP growth for Jamaica, Haiti, Tobago and Trinidad. The empirical result suggests that there is a bidirectional causality between two. Yet Cheng and Lai (1997) found unidirectional causality relationship between real GDP to energy consumption and energy consumption to employment in the context of Taiwan. Studies like, Yu and Jin (1992); Cheng (1996); Paul and Bhattacharya (2004) and Pirlogea and Cicea (2012) all these studies added measures of labour and capital in the context of a production framework model. Paul and Bhattacharya (2004) examined the bidirectional relationship between two. Yu and Jin (1992) and Cheng (1996) investigated no long run and causal relationship between energy consumption and economic growth. Most of the studies deal with the causal relationship between energy consumption and economic growth employing aggregate energy consumption data. Which, could cover the differential impact links with different types of energy consumption. Yang (2000a;2000b); Yoo and Kim (2006); Jinke *et al.* (2008) and Pirlogea and Cicea (2012) investigated the impact of different disaggregated of energy consumption like electricity, Natural gas, Coal by different sectors. Again, they found that there is no agreement on the causal relationship between energy consumption and economic growth within and across countries. Some studies have employed disaggregated measures of energy consumption by sector and by source among the majority of the studies are bivariate model, Masih and Masih (1996); Soytas and Sari (2003); Yoo (2005;2006a;2006b;2006c); Yoo and Jung (2005); Chen *et al.* (2007) and Zachariadis (2007) included energy, employment and output. Other studies added measure of labour and capital, such as Stern (2000); Ghali and El-Sakka (2004); Oh and Lee (2004a;2004b); Paul and Bhattacharya (2004); Soytas and Sari (2006a;2007); Yuan *et al.* (2008). Masih and Masih (1997;1998) and Asafu-Adjaye (2000) included consumer prices. Glasure (2002) incorporated real money supply, dummy variable oil price shock and real government expenditure. There are certain studies found contradictory and inconsistent results (Masih and Masih, 1996;1997;1998) investigated no causal relationship between energy consumption and economic growth in the

context of Malaysia, Philippines and Singapore while, bidirectional causality takes place between the two in South Korea, Pakistan and Taiwan. Furthermore, they examined that increased energy consumption cause's growth In India, Sri Lanka and Thailand, when economic growth leads to increased energy consumption in Indonesia. Stern (2000) examined greater energy consumption leads to growth in the United States, While Soyatas and Sari (2003) found no causal relationship in the United States, Canada, Poland, and Indonesia, the United Kingdom and Bidirectional causality in Turkey and Argentina. Unidirectional causality with high energy consumption leads to increased GDP Japan, France and West Germany and causality with increased GDP, leading to increased energy consumption in South Korea and Italy. In contrast to the studies like Soyatas and Sari (2003); Ghali and El-Sakka (2004) examined the bidirectional relationship between energy consumption and growth in Canada. Oh and Lee (2004a;2004b) concluded that inconsistent result in the case of Korea when using different models and data set. The Engle-Granger/Johansen-Juselius cointegration methods and consistent error-correction model have been highly used to study a causal relationship between energy consumption and economic growth, these approaches have been criticised due low power and small sample size deals with unit root tests (Harris and Sollis, 2003). A recent study has used the Autoregressive Distributed Lag Model (ARDL) and Bound testing approach, with the Toda and Yamamoto (1995) long run causality test, which can be done regardless whether the variables possess a unit root and whether cointegration occurs among the variables. Altinay and Karagol (2005) examined the relationship between electricity consumption and economic growth by employing Dolado-Lutkepohl test in the case of Turkey. The study found that there is a unidirectional causality runs from electricity consumption to Higher GDP growth. Lee (2006) by employing Toda-Yamamoto methodology, he found that no causal relationship between energy consumption and real GDP per capita in the case of Sweden, Germany and the United States; and bidirectional causality between the energy consumption and real per cpaital GDP in the United States; high energy consumption leads to real GDP per capita in Canada, Switzerland and Belgium; and increases in real GDP per capita boost to greater energy consumption in Italy, France and Japan. Zachariadis (2007) Examined the relationship between energy consumption and economic growth by applying ARDL bound test and Toda-Yamamoto test in the context of France, Canada, Itlay, Germany, United Kingdom, Japan and the united states. The result found an inconsistent and conflicting result due to the adoption of different methodology. Bowden and Payne (2010) examined the causal relationship between the disaggregated processes by sector and real GDP in United States by employing Toda and Yamamoto causality test. The study includes employment variables and real gross fixed capital formation in their model and concluded that no causal relationship between real GDP and commercial energy consumption; and unidirectional causality, with industrial non-renewable energy consumption leads to an increase in real GDP. Sari *et al.* (2008) studied the causal relationship between disaggregated measures energy consumption and industrial production by employing ARDL bound test. The result found that unidirectional causality runs from industrial production to energy consumption, apart from coal consumption, which found to lead growth.

Moreover, a different approach that concern with the low power and size properties of small samples related to a conventional cointegration and unit root test in the panel cointegration tests. The panel study provides additional power by combining the time series and cross section data permitting for the heterogeneity across countries, Lee (2005); Chen *et al.* (2007); Narayan and Smyth (2005); Lee and Chang (2008); Lee *et al.* (2008) and Payne (2010) employed this approach. Lee (2005) using real gross capital formation in the analysis and suggest that unidirectional causality, the highest increase in energy consumption leads to real GDP growth for the developing countries panel. Yet Chen *et al.* (2007) examined the relationship between electricity consumption and real GDP for countries like Hong Kong, Indonesia, Korea, India, Malaysia, Singapore, Thailand, China, The Philippines and Taiwan. The study suggests that there is a bidirectional causality runs between electricity consumption and real GDP for all countries. Mehrara (2007) studied real GDP per capital growth leads to commercial energy consumption for the oil exporting countries through a panel study. Lee *et al.* (2008) examined by directional causality between the two variables. Lee and Chang (2008) investigated by incorporating real gross fixed capital formation and labour force and concluded unidirectional causality runs from energy consumption to real GDP growth for Asian countries, APEC countries. Huang *et al.* (2008) examined mixed results on the impact of electrify and non-electricity on economic growth in a global panel (East/the pacific region/South Asian, Central Asian region and Europe, the Caribbean region and Latin America, and Sub-Saharan, Middle Eastern region and North America). Sharma (2010) examined the relationship, includes inflation, trade, energy, capital stock and labour force for the same country. Behera (2015) examined the relationship between energy consumption and economic growth in the context of India covering the period from 1970 to 2011. By employing Granger causality and variance decomposition analysis the study found that there is a mixed relationship between energy consumption and economic growth.

Paul and Bhattacharya (2004) examined a recent study by applying alternative econometric time series models such as; Engle-Granger, Granger causality test and Johnsen's multivariate cointegration technique in the context of India covering the sample period from 1950 to 1996. The study found that in the long run economic growth leads to economic growth, but the standard Granger causality test shows that energy consumption leads to economic growth. Ghosh (2002) examined the total petroleum products consumption and economic growth in India for the period 1970 to 2002. The study found that there is a long run relationship between the two variables. Moreover, here it is found that the above studies try to relate the aggregate energy consumption and economic growth in India, but there may be practical difficulties in aggregating the different forms of real energy consumption as their units of measurement is different. The conversion of measurement is depends on the productivity and quality of energy. Thus, the present study is different from the earlier studies in relation with various forms of energy consumption and economic growth. As a consequence of this study, which will help to formulate different policy strategies forms of energy demands. Earlier studies have taken aggregate energy consumption or if there is a disaggregation, they are considered some forms of energy consumption and leaving the

most vital component of energy like electricity.

However, from the above review of literature we have found four major findings of the causal relationship between energy consumption and economic growth. These result are deals with four hypothesis like conservation hypothesis, Growth Hypothesis, Feedback hypothesis and Neutrality hypothesis. The conservation hypothesis refers to a unidirectional causality running from economic growth to energy consumption. Which holds that economic growth causes energy consumption as the economy grows rapidly, energy demand for different sectors of the economy increases. However, the Growth hypothesis argues that energy consumption that causes economic growth, from the econometric view point a unidirectional causality running from energy consumption to economic growth. This argument states that economic growth is dependent on energy consumption. The third hypothesis talks about the bidirectional causal relationship between energy consumption and economic growth. That means both economic growth and energy consumption causes each other. This hypothesis otherwise known as ‘feedback hypothesis.’ The last hypothesis is known as neutrality hypothesis which represents the absence of causal relationship between energy consumption and economic growth in either direction. In other words, energy conservation policies have little or no effect on economic growth and the change of economy may not affect the consumption of energy resources.

Review of Literature on Indian Context

Author	Year	Country	Period	Findings
Masih and Masih	1996	India	1955-1990	No causality
Cheng	1999	India	1952-1995	GDP → Energy
Asafa and Adjayae	2000	India , Indonesia and Turkey	1973-1995	GDP← Energy
Ghosh	2002	India	1950-1997	GDP→ Energy
Soytas and Sari	2003	India other G7 countries		No causality
Paul and Bhattacharya	2004	India	1950-1996	GDP ↔ Energy
Chen et al.	2004	India, Malaysia and Korea	1971-2001	GDP→ Energy
Fatai et al.	2004	India and Indonesia	1960-1990	GDP← Energy
Ghosh	2009	India	1970-2006	GDP→Electricity
Imran and Siddiqui	2010	Bangladesh and India	1971-2008	GDP→ Energy
Imran and Siddiqui	2010	India and Pakistan	1971-2008	GDP→ Energy
Behera, J	2015	India	1970-2011	Mixed

3. VARIABLE DESCRIPTION AND PERIOD OF STUDY

The present study used the annual time series data taking the sample period from 1970-71 to 2011-12. The data source is cumulated from the World Bank, World Development Indicators (WDI). This study used Gross Domestic Product as a proxy for economic growth and Energy consumption (kg oil equivalent per capital). All the variables in this study used the natural logarithm form.

4. METHODOLOGY

In order to examine the dynamic relationship between energy consumption and economic growth in India, the study used standard time series methodology. Before performing the time series methodology for estimating the variables, the study conduct unit root test (both ADF and PP test) to examine the time series properties of the variables and to avoid bias and spurious results. Moreover, so as to check the long run and the short run relationship between the variables the study also employed Johanson cointegration and error correction model respectively. To verify the direction of causality in order to support the energy-led growth hypothesis the study used Granger causality followed by VAR impulse response and variance decomposition tests.

5. EMPIRICAL ANALYSIS

Before undertaking anytime series analysis of the data, it would be useful to the broad trends and behaviours of the variables, which will help to interpret the result well. Proper time series plots are drawn below for the variables.

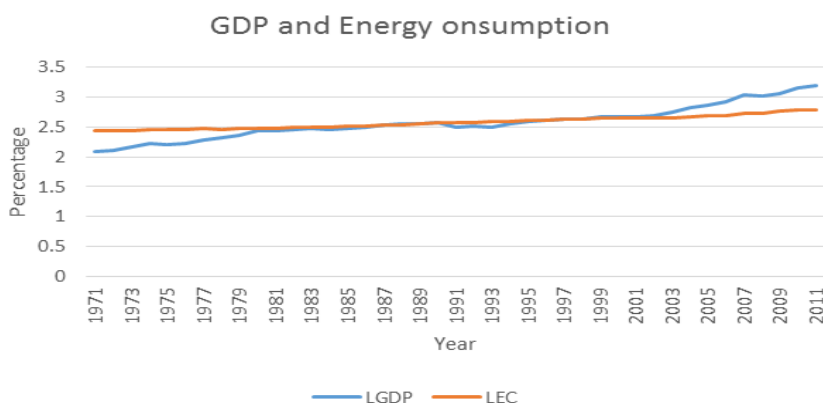


Figure-1. GDP and Energy Consumption 1971-2011

5.1. Descriptive Statistics

As we know the importance of descriptive statistics rests in their as tools for interpreting and analysing data. The summary statistics are present in the following Table-1.

Table-1. Descriptive Statistics

	LEC	LGDP
Mean	2.574	2.569
Median	2.570	2.548
Maximum	2.787	3.187
Minimum	2.440	2.081
Std. Dev.	0.102	0.274
Skewness	0.417	0.421
Kurtosis	2.138	2.803
Jarque-Bera	2.457	1.282
Probability	0.292	0.526

The summary of statistical movements of all the variables is presented in the table-1, from the table it can be observed that, the coefficient of the skewness, an indicator used in the distribution analysis as a sign of asymmetry for all the variables are greater than zero. The result also reveals that the average mean of both energy consumption and economic growth rate are almost same for the sample period. The kurtosis coefficients, a measure of thickness of the tail of the distribution is positive.

5.2. Correlation Matrix

In order to find out the pair wise degree of association among the variables, the study used the correlation matrix. The correlation results are shown below in the table-2.

Table-2. Correlation Matrix

Variables	LEC	LGDP
LEC	1.00	
LGDP	0.96	(0.00)
	[22.05]	
	(0.00)	

Note: ‘[]’ denotes t values and ‘()’ indicates p values

From the table-2, it is observed that there is a high degree of correlation exist between energy consumption and economic growth. The initial result of this correlation matrix indicates the growth hypothesis as expected.

5.3. Unit Root Test

Stationarity test plays a significant role in the time series econometric analysis. In this study to examine the stationarity properties of the time series data the study employed both Augmented Dickey Fuller and Phillip Perron test. The stationarity test helps to avoid bias and spurious result, which leads to misleading conclusions. To eliminate this problem the study conducted the unit root test in following table-3.

Table-3. Unit Root Test

	ADF		PP	
	Level	First Difference	Level	First Difference
LGDP	0.85	-5.69*	0.68	-5.76*
	(0.99)	(0.00)	(0.99)	(0.00)
LEC	3.17	-5.05*	3.25	-5.15*
	(1.0)	(0.00)	(1.00)	(0.00)

Note: () parenthesis indicates, p-values, ‘**’ and ‘***’ indicates variables are significance at 1% and 5% level of significance.

The reported result in the table 3 reveals that the Augmented Dickey Fuller (ADF) and Phillip Perron (PP) test. The result of the unit root test shows that the null hypothesis of the unit root can’t

be rejected in all variables in the level. However, the hypothesis of a unit root is rejected in the first difference at the convenient significant level. Which indicates that all variables are integrated of degree one I (1). That means all the variables have achieved stationary after first difference.

5.4. Cointegration Test

In the time series analysis stationarity of the variable plays an important role. Before proceed to check the long run relationship among the variables it is essential to check the stationarity test of the variables in order to avoid bias and spurious result. Once the order of integration is defined it is useful to check the long run relationship among the variables. To study the economic interrelationship among the variables cointegration test is widely used in the empirical literature.

The study used the [Johansen \(1991; 1988\)](#) maximum likelihood test to check the cointegration among the variables. The details of the test are shown below.

$$\Delta Y = \mu + \gamma_1 Y_{t-1} + \gamma_2 X_{t-2} + \dots + \gamma_{k-1} X_{t-k+1} + \pi Y_{t-k} + \varepsilon_t \dots \dots \dots (1)$$

Where Y_t is an 5×1 vector of the first order integrated [i.e., $I(1)$] variables; γ_i are 5×5 coefficient matrices; ε_t is a vector of normally and independently distributed error terms. The existence of cointegrating vectors (r) implies π is rank-deficient. To identify the number distinct cointegrating vectors the test obtained trace statistics and the maximal eigenvalue tests derived by [Johansen \(1991\)](#). Appropriate critical values are tabulated in [Osterwald-Lenuin \(1992\)](#). If π is of rank r ($0 < r < 5$), then it can be decomposed as: $\pi = \alpha\beta'$, where α ($5 \times r$) and β ($5 \times r$); and the equation (1) can be rewritten as:

$$\Delta Y = \mu + \gamma_1 Y_{t-1} + \gamma_2 X_{t-2} + \dots + \gamma_{k-1} X_{t-k+1} + \alpha(\beta' Y_{t-k}) + \varepsilon_t \dots \dots \dots (2)$$

The rows of β are interpreted as the distinct cointegrating vectors whereby $t k Y - \beta'$ from linear stationary processes. The error correction coefficient is α' (loading factor) that indicates the speed of adjustment towards the long run relationship. In the equation (2), β vector is unrestricted. Without there is a unique cointegrating vectors (i.e. $r=1$), the matrix of cointegration vectors cannot defined long run economic relationships. This is because any liner combination of cointgerating vectors forms another liner stationary relationship. Therefore, the VAR can be defined as

$$\Delta Y = \mu + \pi Y_{t-p} + \sum_{i=1}^{k-1} A_i \Delta Y_{t-i} + \varepsilon_t \dots \dots \dots (3)$$

And from the residual vectors, we construct two likelihood ratio test statistics. The first one is trace test, which is shown in the equation (4)

$$\lambda_{Tra} = -\gamma \sum_{i=r+1}^n \text{Log}(1 - \hat{\lambda}_i) \dots \dots \dots (4)$$

Where, $\hat{\lambda}_{r+1}, \dots, \hat{\lambda}_n$, are $(n-r)$ smallest estimated Eigen values. The null hypothesis is to test that there are at most r unique cointegration vectors. The other test statistics is the maximal eigenvalue test, represented in the equation (5)

$$\lambda_{Max} = -\gamma \text{Log}(1 - \hat{\lambda}_i) \dots \dots \dots (5)$$

The null hypothesis for this test is that there are r cointegrating vectors in Y_t . For both tests, the alternative hypothesis is that there are $g > r$ cointegration vectors in Y_t . Johansen and Juselius (1990) suggested that the trace test may lack power relative to the maximal eigenvalue test. Nevertheless, the trace test is more robust to the non-normality of errors. In the above table 3 reported that the data series of energy consumption and economic growth are stationary after first difference. Therefore, the study employed Johansen’s cointegration is conducted to examine the long run relationship between energy consumption and economic growth. The result of the cointegration are presented below. As we know the estimation procedure of Johansen and Juselius (1990) cointegration test is based on Maximum Likelihood estimation with a VAR model. Hence, before the application of VAR model, the selection of lag length is important. The AIC, SIC, FPE, LR and HQ statistics can be applied to determine the VAR order lag length. (i.e. lag length k). The resulting lag structure is reported in the following table-4. Here the optimal lag length is chosen one.

Table-4. VAR Lag Order Selection Criterion

Lag	Log L	LR	FPE	AIC	SC	HQ
0	82.77598	NA	4.88e-05	-4.251368	-4.165179	-4.220702
1	214.6770	242.9756*	5.83e-08*	-10.98300*	-10.72443*	-10.89100*
2	216.4578	3.092949	6.57e-08	-10.86620	-10.43526	-10.71287
3	220.5317	6.646841	6.58e-08	-10.87009	-10.26677	-10.65543

Note: ‘*’ denotes Lag Order Selected by the Criterion

LR: Sequential Modified LR Test Statistics (each test at 5% Level)

FPE: Final Prediction Error

AIC: Akaike Information Criterion

SC: Schwarz Information Criterion

HQ: Hannan Quinn Information Criterion

Table-5. Cointegration Test

Unrestricted Cointegration Rank Test (Trace)				
Null Hypothesis	Eigenvalue	Trace Statistics	0.05 Value	Critical Prob.**
$r = 0^*$	0.350	19.067	15.494	0.013
$r \leq 1$	0.005	2.224	3.841	0.135
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Null Hypothesis	Eigenvalue	Max-Eigen Statistics	0.05 Value	Critical Prob.**
$r = 0^*$	0.350	16.843	14.264	0.019
$r \leq 1$	0.055	2.224	3.841	0.135

Note: * denotes the rejection of the hypothesis at the 0.05 level of significance and ** indicates P-values.

The above table 5 reported the cointegration result, in which the null hypothesis of no cointegration is rejected at the conventional 0.05 level of significance and concluded that there is a long run relationship exist between the variables. Where, the trace statistics and Eigen value

indicates strong evidence of one cointegrating vector. So we have one cointegration vector in the variables of our study.

5.5. Error Correction Test

As we know the beauty of the error correction model is determined both the short run and long run relationship among the variables. Here the study conducted the error correction test to know about the short run dynamics and speed of adjustment of the variables in the long run relationship. The result of error correction test shown in the following table 6.

Table-6. Error Correction Test

Error Correction	D (LEC)	D (LGDP)
CoIntEq ₁	-0.046	-0.080
	(0.014)	(0.089)
	[-3.113]	[-6. 893]

Note: ‘()’ denotes Standard Errors and ‘[]’ indicates t statistics

The above table 6 reported the error correction result which reveals that the correct negative sign for both energy consumption and economic growth. The value for energy consumption and economic growth are highly significant. This result confirmed that the behaviour of the variables of energy consumption and economic growth implies there is no problem for adjustment in the long run in case of shocks in the short run. That is, considerable high speed adjustment to long run equilibrium every year after the short run shock.

5.6. Granger Causality Test

In order to investigate the causal relationship between energy consumption and economic growth the study used Granger causality method. Granger (1969) causality test regresses a variable y on a lagged value of itself and other variable x. If x is considered to be significant, then explains some of the variance of y which is not described by lagged values of y. This shows that x is causally previous to y and said to dynamically cause y. The study used the following specification model of Granger causality.

$$Y_t = \sum_{i=1}^n \delta_i y_{t-i} + \sum_{i=1}^n \gamma_i x_{t-i} + u_t \dots \dots \dots (6)$$

Table-7. Pair Wise Granger Causality

Null Hypothesis	Obs.	F-Statistics	Prob.	Conclusion
LGDP → LEC	39	4.593*	0.017	Reject
LEC ≈ LGDP		0.958	0.393	Accept

Note: ‘→’ denotes the unidirectional causality ‘≈’ indicates no causality.* indicates rejection of the null hypothesis at the 5% level of significance

The table 7 reports the Granger causality result which reveals that there is unidirectional causality running from economic growth to energy consumption. That means this study support the “Conservation Hypothesis¹” of energy consumption. This result pointed out the emerging country like India needs huge amount of different forms of energy consumption in order to achieve faster economic growth.

5.7. Impulse Response Function

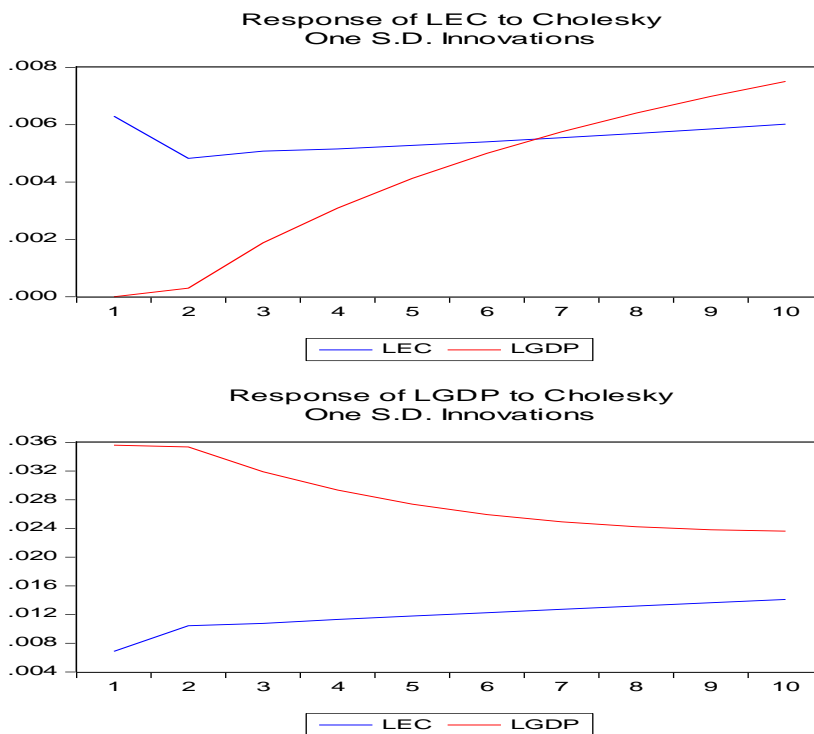


Figure-2. Impulse Response Function

In the above figure-2, LEC to one S. D. innovations of itself, which makes the response initially decreases up to second period and the response level started increasing up to the 10th period and remain positive. This result pointed out that energy consumption accelerated itself in the long run. The response of LEC to one S.D. innovations to LGDP makes an immediate response from the period one and then the response level increases highly up to the 10th period. That means with the increase in the growth rate of the economy the country requires a huge demand for and supply of different energy sources for rapid growth.

In the second part of this figure-2, we observe that, LGDP to one S.D. innovations of LEC make an immediate response up to the 2nd period, then the response level increases highly up to the 10th period and remains positive. That means the consumption of energy has significant positive on

¹ The conservation hypothesis refers to a unidirectional causality running from economic growth to energy consumption. Which holds that economic growth causes energy consumption as the economy grows rapidly energy demand for different sectors of the economy increases.

economic growth in the long run. In the same figure, LGDP to one S.D innovations reduce the response from 2nd period and then the response decreases up to the 10th period and remains positive.

5.8. Variance Decomposition Result

The variance decomposition is defined as to separate to the variations in an endogenous variables into the component shock to the VAR for finding what information about the relative importance of each random innovation in affecting the variables in the VAR. Below in the figure 3, we observe the result of variance decomposition. In the first figure, we observe that the contribution of LEC is mainly from itself. Whereas, the contribution of LGDP increases rapidly from the second period on words up to the tenth period and remains positive. This indicates economic growth comes from the stimulating effect as time increases the stimulating effect is very much significant. Therefore, we can say that the rapid growth of the economy depends on the energy consumption level.

In the second figure, the contribution of LEC to LGDP mainly from itself. The contribution of LEC decreases and remain stable up to the 10th period whereas, the contribution of LGDP increases rapidly up to the 10th period.

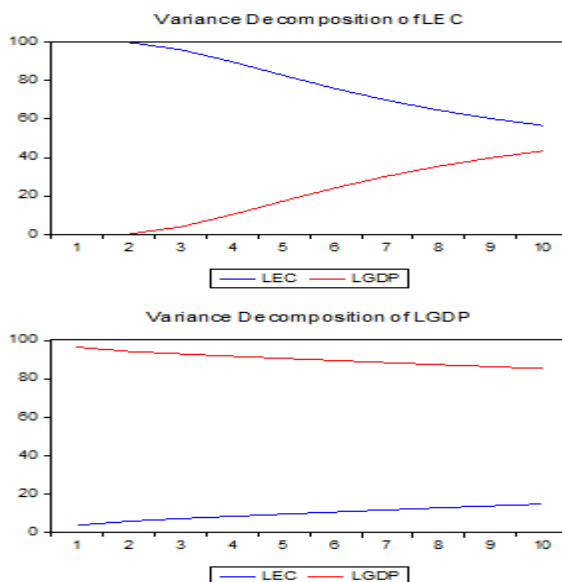


Figure-3. Variance Decomposition

6. CONCLUDING REMARKS

The present study examined the linkage between energy consumption and economic growth in India covers the annual sample period from 1970-71 to 2011-12. The data source of the study cumulated from World Bank, World Development indicators (WDI). The study used two variables such as, Gross Domestic Product as a proxy for economic growth and energy consumption (kg oil equivalent per capita). All the variables are used in the natural logarithm form in the analysis part. In order to check the stationary properties of the variables we used both Augmented Dickey Fuller

(ADF) and Phillip Perron (PP) test. The result of the stationarity test suggests that all the variables become stationary after the first difference. The cointegration result of the study found that there is a one cointegrating vector among the variables which confirms that there is a long run relationship exist between energy consumption and economic growth in India. The error correction result of the study suggests that the variable also have a short run relationship with long run adjustment. The Granger causality test concluded that there is a unidirectional causality running from economic growth to energy consumption. That means the study support the “Conservation Hypothesis” of energy consumption. The result also pointed out that the emerging country like India needs huge amount of different forms of energy consumption in order to achieve faster economic growth. However, the impulse response result found that the country like India requires high demand and more supply of energy for faster economic growth. The decomposition result of the study recommended that the rapid growth of the economy depends on the heavy energy consumption level.

From the policy recommendation point of view, the study propose that the energy policy of India should give more importance to find out the alternative source of energy in order to meet the growing demand for energy in a vast populist country like India. The study also suggests that, in order to achieve sustainable energy conservation and macroeconomic stable, the energy policy in India should follow the energy efficiency and self-sufficiency in energy production for faster economic growth.

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