Global Journal of Management and Business Research
Economics and Commerce
Volume 13 Issue 4 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4588 & Print ISSN: 0975-5853

A Cointegration and Causality Analysis for Assessing Sustainability and Security in Indian Energy Sector

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GJMBR-B Classification : JEL Code: O13, P28

ACOINTEGRATIONANDCAUSALITYANALYSISFORASSESSINGSUSTAINABILITYANDSECURITYININDIANENERGYSECTOR

Strictly as per the compliance and regulations of:

A Cointegration and Causality Analysis for Assessing Sustainability and Security in Indian Energy Sector

Vivek Soni [α], Surya Prakash Singh [σ] & Devinder Kumar Banwet [ρ]

Abstract - The purpose of the paper is to establish the long run relationship between gross domestic product (GDP) and energy consumption in India. This is known that energy plays a vital role for all the economies and the relationship relates to levels and changes in economic development approximated by GDP. Literatures also reveal that the greater is region's GDP, the greater is the energy consumption. The data of three decades (1981-2011) has been taken for analysis and results are analyzed in the software package Stata/SE10.0. The time series analysis is used to develop conceptual framework, which includes testing of stationary using unit root test, Granger causality, cointegration and error correction mechanism (ECM). On applying cointegration, it is found that two variables are co-integrated of order one (*I*~ (1)). The Granger test results confirmed the existence of unidirectional causality running from electricity consumption to economic growth. The same has been verified by ECM approach and a long-run relationship has been developed. This implies that over time higher electricity consumption in India give rise to more economic growth. The proposed framework and results draw a rough road map with much accurate estimations for national policy strengthening in the future to assess the sustainability in Indian energy sector.

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I. Introduction

Energy plays vital role in development of long-range policies to help guide the future of a local, national, regional or even the global energy system. Country like India is the fourth largest consumer of energy in the world after USA, China and Russia. It is not endow with copious energy resources. It must, therefore meet its development needs by using all available domestic resources. This may includes the supplementing domestic production by imports also. The import of energy is costly affairs given the prevailing energy prices, which are not likely to liberal, and thus impinges adversely on nations' energy security. Therefore meeting the energy needs by achieving set and targeted economic growth reflects one side of coin, while meeting energy requirements of the population at affordable prices on another side of the coin, presents a major faces. In this context it is necessary to have glimpse up of linkages that how energy consumption of related to economic growth. Thus lying down the reasons and logical framework for energy security indicator like energy consumption and related issues with the economic growth, is significant research contribution in the mainstream of the energy sector in particular.

It is, therefore important to establish the relationship between consumption and national output and also their direction of causality to get a better understanding of the issues involved and determine the policy strategies. That is why in this study the main purpose is made to examine the causal relationships between electricity consumption, economic growth using three-decade time series data spanning from 1981 to 2011. This paper flows in six parts and has numbered accordingly. The part one of this study is the introductory part. The rest of the study is organized into another five parts. The second part of the study will present contextual information of the study where it discussed regarding current and future situation of Indian power sector. Part three is the literature review section, where it presents relevant literatures that will gives the sound conception of the fact. This section also draws the gaps in the literature review, the nature and sources of data used for this study. The part four provides a path regarding research methodological approach and the relevant key statistics on the time series data sets used, while part five is discussed the empirical results. Finally, part six will provide the conclusion and limitations that will point out the possible policy recommendations of the study.

II. Contextual Information of the Study

a) Recent Issues Related to Energy Security

Energy security involves ensuring uninterrupted supply of energy to support the economic and commercial activities necessary for sustained economic

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growth. Thus, it is obviously more difficult to ensure if there is large dependence on imported energy. This discusses the several areas. First one and most importantly, the domestic production from resources like coal, oil and gas and others, are to used and increased for own use. Recent issues involve E and finds in this regard, have been primarily the availability of land, clearances for environment and forest for compliance of international negotiations. Second issue is that, there has to be a stable and attractive policy regime, which provide and ensure substantial private investment including foreign investment in oil and natural gas blocks and new capacities for renewable energy. Further, to add in this section, the producers must have clarity in the price they will receive and an assurance of a stable tax regime. Since then, oil exploration is a global industry the terms India offers must be comparable with those offered elsewhere. In this context the entire structure of country's New Exploration Licensing Policy (NELP) contracts for oil and gas need to be look again. Third, investments in renewable energies need to be monitor and be strongly emphasised. Referring to the present projections by the international organizations, the share of renewable energy in total energy consumption will only reach 2% by 2021. Fourth, investments in energy assets in foreign countries, especially for coal, oil and gas and uranium should be enhanced. Fifth, to meet any possible disruption in oil supplies, on which country is import-dependent to the extent of more than 80 per cent, storage capacities need to be created. As per, Organisation for Economic Cooperation and Development (OECD), countries has generally created these capacities to the extent of 90 days of their domestic demand. While in India, it has created the capacity for 5 million tonnes. It has, however, not been fully utilised so far. There will be a need to increase this gradually and utilise it fully. Innovation in required to fill up these gaps *(Sources: Twelfth five year Plan 2012-17, Planning Commission, Govt. of India).*

b) Economic Growth: A Human Development Perspective

The world has been noticed the continuous growth in the developing countries including in India, especially when developed economies stopped growing during the 2008–2009 financial crises. As per the United Nations Human Development Report 2013 released recently titled on rise of the southern economics of the world, within the developing world has given as an overdue global rebalancing. This discussion has typically focused narrowly on economic growth and trade growth in a few economies. As this Report also commented and reflected, the rise of the South is both the result of continual human development investments and achievements and an opportunity for still greater human progress for the world as a whole. Making that progress a reality will require informed and enlightened global and national policymaking, drawing on the policy lessons analyzed *(Sources: United Nations Human Development Report, 2013).*

c) Gross Domestic Product as an Indicator of Economic Growth

Gross domestic product (GDP), is defined as the value of all officially recognized final goods and services produced within a country in a given period. GDP per is capita often considered as an indicator of a country's standard of living, GDP per capita is not a measure of personal income. Under economic theory, GDP per capita exactly equals the gross domestic income (GDI) per capita. In general, GDP is related to national accounts, a subject in macroeconomics. The term is different from gross national product (GNP) which allocates production based on ownership. It was first developed by Simon Kuznets for a US Congress report in 1934. In his report, Kuznets warned against its use as a measure of welfare. After the Bretton Woods conference in 1944, it became the main tool for measuring a country's economy.

d) Energy Intensity of GDP and Expanding Access to Energy

Energy intensity, defined as the energy input associated with a unit of GDP, is a measure of the energy efficiency of a nation's economy. As per the United Nation's Human Development Report, 2013, India's energy intensity has been declining over the years and it is expected to decline further. Falling energy intensity implies that the growth in energy used is less than the growth of GDP, which in turn implies that energy elasticity, that is, the ratio of the growth of energy to the growth of GDP is less than unity. In reality, this elasticity has been declining over the years. Total primary energy GDP elasticity was around 0.73 during the period 1980–81 to 2000– 01 and it declined to 0.66 in the period 1981–81 to 2010–11 *(Sources: Twelfth five-year plan 2012-17 document, Planning Commission, Govt. of India).*

Higher levels of GDP will obviously require higher levels of energy as an input but in addition to this requirement India's energy, planning must allow to expand access to clean energy at affordable prices for the bulk of the population. Various government funded schemes supports and found critical ways of its implementation for village electrification and connection of rural households to electric supply. On the same time, the supply of kerosene/liquefied petroleum gas (LPG) at affordable prices is equally important. There is ample evidence of unmet demand in rural areas indicating the need to expand access even as we expand total supply.

e) Framework for Creating Linkages between Energy Consumption and GDP

The assessment of the linkages between use of energy i.e. energy consumption (kWh/capita or kWh/year) and economic growth has been a subject of greater importance as energy is considered to be significant driving force of economic growth in all economies. In recent years, non-oil dependent countries and international associations are facing energy deficiency, as the oil producing economies are unable to meet up the world demand for oil. The reason behind for this is the supply constraint of energy could be attributed to the frequent geo-political tensions between the nations or may be natural physical supply constraints in the oil extracting which is most emerging from and prominent in Gulf region of the world. Further it seen from the various literature and reports of global importance that the increasing world energy demand for oil, leads to abrupt escalation in the oil prices worldwide and subsequently in developing countries like India. Therefore likewise shortage of oil, there is also shortage of electricity and other types of energies viz. importantly energy from natural gas from the aspect of clean environment. The shortage can significantly affect the consumption in household all together and production of goods and export in the economy. This linkage and impact of energy demand, fulfilling national deficit as whole for the economy, on the consumption, production and thus minimization of current account deficit is very much essential to control the inflation and GDP of the economy like India.

f) Framework for Creating Linkages between Energy Consumption and GDP

India's current account deficit was a surplus 2.3% of GDP in 2003–04. Since then it has gone into deficit, reaching 2.7% of GDP in 2010–11 and 4.2% in 2011–12. A large part of the increase in 2011–12 was due to imports of gold, which are not expected to be repeat. Even so, the current account deficit in the first year of the Twelfth Plan will be around 5%, which exceeds what has traditionally regarded as a sustainable level. The macroeconomic analysis in prescribes that policies must be calibrated to ensure that the current account deficit in future planning, averages around 2.9%. On current prospects, it is likely to be somewhat higher. The ability to finance this deficit through stable capital flows is therefore critical *(Sources: Twelfth five-year plan 2012-17, Govt. of India).*

As regard the relative consumption of various sources of energy as percent of the world total, India occupies the third place following China and Japan among the emerging Asian economies. This raises the question whether India's energy consumption levels commensurate with levels of economic growth similar to other high as well as low energy consuming economies of the Asian region. In this context, this paper attempts to explore the possible long-run impact of energy consumption on economic growth, which has not been examined so far using three decades of data at once. The prime motivation of the study relates to addressing the puzzle of the increasing levels of energy consumption to induce economic growth in the event of the increasing cost associated with it as well as apprehensions regarding its sustained supply in future. Therefore, the study undertakes an empirical analysis, towards verifying this nexus of energy consumption and economic growth and suggesting policies that strikes a balance between consumption and conservation of energy in sustaining and speeding up the growth momentum of the economy.

III. Review of Related Study

a) Literature Review

Given the importance of establishments for long run relationship and causality running between time series variables, many studies has been carried out in both developed and developed countries. The Table 1 laid downs the details of authors who have conducted the studies in various part of the world. (Refer Table1 on next page).

b) Gaps Identified in the Literature Reviewed

It is to be noted that the previous studies tried to relate the energy consumption with economic growth in India, but not established the long- run relationship. The cumulative data for long duration has not ever analyzed. In this context, the first issue related to importance of present research work, is the specific changes in the economic growth during the last decade 2001 to 2011. The decade has seen the global recession in the economy and there by up downs in energy sector with variations in national GDP figures. Thus it is important to assessing the long run or short run relationship between the energy consumption in such a circumstances. Which may give warning in futures for policy framework and such type of analysis gives the new imperatives to the sector. This will help to have policy strategies for assessment of energy security with inclusive economic growth. In such a scenario, the application traditional time series cointegration technique is seems to be viable. The next section discusses the data sources, and methodological framework.

c) The Nature and Source of Data for Analysis

The type of data used becomes important specifically the empirical analysis of time series. A time series is set of observations on the values that a variable takes at different times. Such data may be collected at regular time intervals, such as daily, weekly, monthly, quarterly, annually, quinquennially that is for every 5 years or decennially that is, every 10 years. Some data available both quarterly as well as annually as in case of economic development indicator like GDP. The time series data used for heavily in econometric studies and present a social problem. The success of any econometric analysis - ultimately depends on the

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availability of the appropriate data. It is therefore essential to discuss about the nature, sources, and limitations of the data that one may encounter in empirical analysis. This paper considers the annual data of last three decades 1981-2011 for energy consumption and GDP. The source of these data is Ministry of Power, Govt. of India, Planning Commission, National Sample Survey Organization (NSSO), Central Statistical Organization (CSO) India and Ministry of Statistics and Programme Implementation Govt. of India.

Table 1 : Overview of the related literature

Year	Author name	Country	Variables used for identifying relationship	Identifying research issues
1978	Kraft and Kraft	United States	Total energy consumption and income	Unidirectional causality
1985	Yu and Choi			No causal relationship
1989	Abosedra and Baghestani			Unidirectional causality
1995	Cheng	United States	Total energy consumption and income	No causal relationship
1996	Masih and Masih	Asian economies	Total energy consumption and real income	Neutral w. r. t. income for some countries
1998	Yan	Hong Kong	Residential electricity consumption models using climatic variables	Examine the relationship
2002	Ogulata	Turkey	Industrial energy consumption and primary energy demand	Major component is electricity consumption
2003	Soytas and Sari	G7	Energy consumption and GDP	Causality: GDP to energy consumption
2004	Ediger	Turkey	Energy and economy	Close relationship exists between energy and economy
2004	Sari & Soytas	Turkey	GDP and energy consumption	Total energy consumption explained around 21 percentage of forecast error variance of GDP
2005	Ghosh	India	Total petroleum products consumption and economic growth	Long-run equilibrium relationship
2006	Lee	Major industrialized countries	Energy consumption and income	Neutral to each other in countries like UK, Germany, and Sweden
2010	Atanasiu and Bertoldi	EU-27	Electricity consumption for energy efficient equipments	Examine the relationship , the energy efficiency progress and electricity-saving potential

Table 2 : Statistics of time series variables

Statistics description	ECt (Energy Consumption) Billion kWh	*GDPt (Gross Domestic Product) Rs. Cr.
No. of observations	32	32
Mean	2922.588	1981433
Minimum	1012.58	695361
Maximum	7558.47	5202514
Std. Dev.	1655.64	1262409

* From 2008-09 GDPt estimates are with 2004-05 base year, while figure for the year 2011-12 is provisional. Sources: Reserve Bank of India, Ministry of Power and Ministry of Statistics and Programme Implementation Govt. of India.

III. Research Methodology

In order to investigate the relationship between energy consumption and GDP in India, a two-step standard time series econometric model procedure has adopted.

a) Step-1

In Step-I, time series properties of data investigated by use of unit root test and long-run relationship investigated by use of cointegration analysis.

i. *Step 1 (a): Testing Stationarity*

To carry out stationary analysis, unit root test is used. Dickey and Fuller approach was applied using following model. To minimize autocorrelation in the error term, the lagged difference terms are used. The null hypothesis in each case is H_0: $\delta=0$. It means there is a unit root. Failing to reject the null hypothesis implies that the series contain the unit root hence non –stationary at levels. The ADF test is performed on logGDPt and logECt time series.

$$\Delta Y_t = a_0 + a_1 t + \delta Y_{t-1} + \Sigma\, i\alpha\, \Delta Y_{t-1} + u_t \qquad (1)$$

ii. *Step 1(b) : Test for Cointegration*

The test for cointegration is applied using the Engle-Granger two-step procedure (Granger, 1986 and Engle and Granger, 1987). The procedure includes the testing whether the regression residuals of the following long –run regression were stationary:

$$logGDPt = a_0 + a_1\, logECt + u_1 \qquad (2)$$

$$logECt = a_0 + a_1\, logGDPt + u_2 \qquad (3)$$

Where u_1, u_2 are error terms assumed uncorrelated with zero mean and constant variance. The above two equations were estimated using ordinary least square (OLS) method. The term a1 is elasticity of GDP with respect to energy consumption in equation (3). Some time it is called as consumption elasticity. Supposing that ut is subject to unit root analysis and find that it is stationary; that is, it is *I*~ (0). This is an interesting situation, for although logECt and logGDPt, is individually *I*~ *(1)*, that is, they have stochastic trends, their linear combination is *I*~ (0). So to speak, the linear combination cancels out the stochastic trends in the two series. In this case, we say that the two variables are co-integrated. Economically speaking, two variables are cointegrated, if they have a long-term, or equilibrium, relationship between them. In short, provided it can be checked that the residuals from regressions are *I*~ (0) or stationary. The traditional regression methodology is F-test that have considered extensively is applicable to data involving (nonstationary) time series.

b) Step-2

The Step-II follows the investigation of casual relationship between energy consumption and GDP of India. If the variables were non-stationary at levels and linear combination of them is non-stationary, the Granger causality test is used. Further, if the series were non-stationary and there is long-run relationship between the variables, then Error Correction Mechanism (ECM) is used (Yang, 2000).

i. *Step 2 (a) : Granger Causality Test*

The standard Granger causality analysis is done before ECM. This was investigated by using the following two-regression model of Eq. (4) and Eq. (5).

$$logGDP_t = \sum_{i=1}^{n} a_i \log(GDP)_{t-i} + \sum_{j=1}^{n} \beta_j \log(EC)_{t-i} + u_{1t}$$

$$logEC_t = \sum_{i=1}^{m} b_i \log(EC)_{t-i} + \sum_{j=1}^{m} \alpha_j \log(GDP)_{t-i} + u_{2t}$$

Where u_{1t}, u_{2t} are error terms assumed to have zero means and uncorrelated, n and m are lag lengths. The null hypotheses are that $logEC_t$ does not Granger cause $logGDP_t$ in the regression (4) and that is $logGDP_t$ does not Granger cause $logEC_t$ in regression (5). This was done by using F-test for the joint significance of the parameters α_i and β_j.

ii. *Step 2 (b): Error Correction Mechanism*

The error correction mechanism (ECM) first used by Sargan and later popularized by Engle and Granger corrects for disequilibrium. Thus, an ECM is a theoretically driven approach useful for estimating both short term and long-term effects of one time series on another. The approach is employed because many time series appear to be 'first-difference stationary,' with their levels exhibiting unit root or non-stationary behavior. Conventional regression estimators, including Vector Auto regression (VAR), have good properties when applied to covariance-stationary time series, but encounter difficulties when applied to non-stationary or integrated processes. These difficulties were illustrated by Granger and Newbold (J. Econometrics, 1974), when they introduced the concept of spurious regressions. Granger and Engle theoretically developed in their celebrated paper (Econometrica, 1987), raised the possibility that two or more integrated, non-stationary time series might be cointegrated, so that some linear combination of these series could be stationary even though each series is not. If two series are both integrated (of order one, or *I*~ *(1))*, it could model their interrelationship by taking first differences of each series and including the differences in a VAR or a structural model. However, this approach would be suboptimal if it was determined that these series are indeed cointegrated. In that case, the VAR would only express the short-run responses of these series to innovations in each series. This implies that the simple regression in first differences is misspecified. If the series are cointegrated, they move together in the long- run. A VAR in first differences, although properly specified in terms of covariance-stationary series, will not capture those long-run tendencies. Accordingly, the VAR concept maybe extended to the vector error-correction model (VECM), where there is evidence of cointegration among two or more series. The model fits to the first differences of the non-stationary variables, but a lagged error-correction term is added to the relationship. In the current study of two variable i.e. $logGDP_t$ and $logEC_t$, this term is the lagged residual from the cointegrating regression, of one of the series on the other in levels. It expresses the prior disequilibrium from the long-run relationship, in which that residual would be zero. When using the ECM method causality is tested by estimating the following regressions (6) and (7).

$$\Delta logGDP_t = u_0 + \sum_{i=1}^{n} \varphi_i \log(GDP)_{t-i} + \sum_{j=1}^{n} \theta_j \log(EC)_{t-i} + \pi \hat{u}_{t-1} + e_{1t} \tag{6}$$

$$\Delta logEC_t = u_1 + \sum_{i=1}^{m} b_i \log(EC)_{t-i} + \sum_{j=1}^{n} y_j \log(EC)_{t-i} + \rho \hat{u}_{t-2} + e_{2t} \tag{7}$$

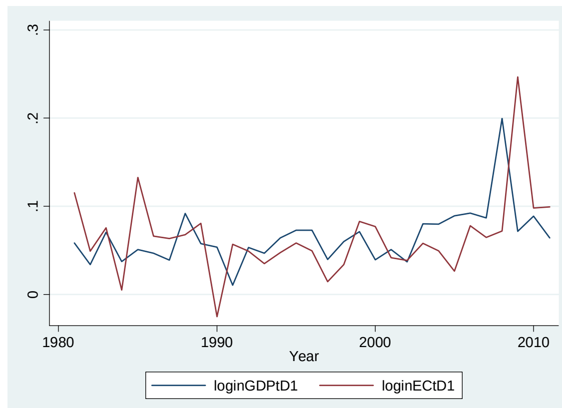
Where Δ, is the first difference operator, while $\hat{u}_{t-1}$ and $\hat{u}_{t-2}$, are estimated residuals from equations (2) and (3), respectively. In this method $logEC_t$ Granger causes $logGDP_t$ if either the coefficients on lagged $logEC_t$ as statistically significance or the coefficient on lagged error term (π) is statistically significant. Similarly, the same is applicable vice-versa for the equations (7). The choice of lag length was determined by testing significance of the parameters used in the equations (6) and (7). All the data were, converted in to natural log before causality analysis.

IV. Empirical Results

The data analyzed in software Stata/SE10.0. The empirical results includes analysis using graphs representations, tables outputs, have been laid down in five sub-sections. Sub-section (a), there is a preliminary analysis using graphs analysis. Sub-section (b), stationary test followed by cointegration results in sub-sections (c). The sub-section (d) presents the causality analysis. In later part of analysis i.e. sub-section (e), the VECM approach is discussed.

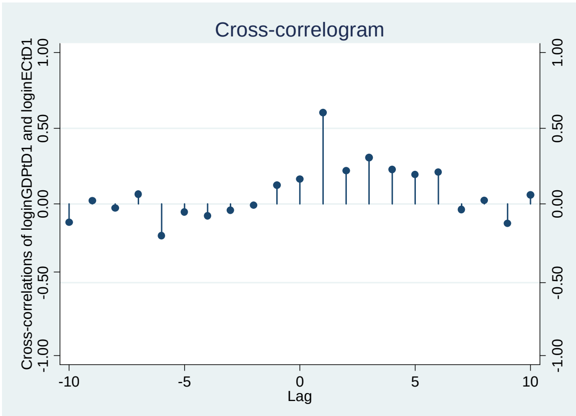
a) Preliminary Analysis and Lag Selection Criteria

Before testing stationarity, the trends of time series variables have been analyzed and drawn in the form of the Graphs. The variables found increasing in levels trends. Therefore, first difference of them has reported here. The first difference trend seems to be cointegrated.



Graph 1(a) : Variables trends at first difference

To explore autocorrelation function (AFC), which is the correlation between a variable and its previous values, use the command corrgram. The time series theory and experience showing, the rule of thumb is to compute autocorrelation function (ACF) up to one-third (1/3) to one-quarter (1/4) the length of the time series. Apart from the best practical advice given by Akaike or Schwarz information criterion (AIC) or (SIC), ACF is analyzed using lag length of 10. Since the auto-correlations at various lags hover around zero, it resembles the correlogram of a white noise time series. This gives a correlogram of a stationary time series. Since the autocorrelation coefficients vanishing or diminishing in nature over the lags (1 to 12), this confirms the stationary of the variables $logGDP_t$ and $logEC_t$



Graph 1(b) : Cross- correlation between the variables at first difference

When running regressions on time-series data, it is often important to include lagged values of the dependent variable as independent variables. In technical terminology, the regression is called a vector autoregression (VAR). When trying to sort out the determinants of $logGDP_t$, it is likely that last year's $logGDP_t$ is correlated with this year's $logGDP_t$, if this is the case, $logGDP_t$ lagged for at least one year should be included on the right-hand side of the regression. If the variable is persistent that is, values in the far past are still affecting today's value's more lags will be necessary. In order to determine how many lags to use, several selection criteria may be used. Three commonly used are the Akaike's information criterion (AIC), the Hannan and Quinn information criterion (HQIC) and the Schwarz's Bayesian information criterion (SBIC). The default number of lags Stata checks is four (4). In order to check a different number, maxlags operator is used. Since data set is yearly for the period 1981 to 2011 and as seen from the many studies the maximum lag length of eight (10) is used for estimating optimal lag length. The maximum lag is (1/4) of the whole range of the data on time series variables.

b) Stationary Test

Alternative to section I (a), one can use the unit room test to carry out stationarity analysis. Dickey and Fuller approach was applied. To minimize auto-correlation in the error term, the lagged difference terms are used. The null hypothesis in each case is H_0: $\delta=0$. It means there is a unit root. Failing to reject the null hypothesis implies that the series contain the unit root hence non-stationary at levels. The ADF test is performed on $logGDP_t$ and $logEC_t$ time series.

Table 3 : Unit root rests for stationary

Variable	Levels	Mackinnon p-values
$logGDP_t$	2.992	1.000
$logEC_t$	1.140	0.995

Variable	First Difference	Mackinnon p-values
$logGDP_t$	-4.117	0.0009
$logEC_t$	-4.846	0.000

If considering constant, trend and drift term in the regression is not included, the null hypothesis of non-stationary of the two of two series at levels not rejected. The $logEC_t$ and $logGDP_t$ were stationary at first difference levels. Thus both time series are therefore, integrated of order one *I~ (1)*.

c) Cointegration Test

It has noticed that the regression of a nonstationary time series on another non-stationary time series may produce a spurious regression. On analysis, of $loginEC_t$ and $loginGDP_t$ time series individually to have stationarity, it has found that they both are containing a unit roots.

A number of methods for testing cointegration have been proposed in the literature. Out of few, the only two are comparatively simple methods. First one is the DF or ADF unit root test on the residuals estimated from the co-integrating regression and second one the co-integrating regression Durbin-Watson (CRDW) test. The first one used for this purpose of this study. Cointegration refers to the fact that two or more series share a stochastic trend (Stock & Watson). Engle and Granger (1987) suggested a two-step process to test for cointegration (an OLS regression and a unit root test), the EG-ADF test. The results for cointegration analysis are presented in the Table 4.

Table 4 : Cointegration Test

Regression	Result (ADF table)	Mackinnon p-values	Optimal lag length as per AIC/HQIC/ SBIC
$logGDP_t$ on $logEC_t$	-1.171	0.686	7
$logEC_t$ on $logGDP_t$	-1.447	0.5597	7

The lag length is determined by AIC was estimated seven (7) for both the regression equation. The results for both equations showed that the residuals of both equations found to be stationary providing evidence that GDP and energy consumption are Co-integrated or order *I~ (1)*.

d) Granger Causality Test

Table 5, presents the outputs from the standard Granger causality test between energy consumption and GDP. On regress, '$logGDP_t$' on lagged values of '$logGDP_t$' and '$logEC_t$' and the coefficients of the lag of

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'$logEC_t$' are statistically significantly different from 0, then it can be said that '$logEC_t$' Granger-cause '$logGDP_t$'. Thus in this way, the time series data on '$logGDP_t$' can be used to predict the '$logGDP_t$' (Stock & Watson, 2007 and Green, 2008). Table 5, noted down the F-values of the regression analysis.

Table 5 : Granger causality test

Regression	F-Value
$logGDP_t$ on $logEC_t$	0.17
$logEC_t$ on $logGDP_t$	4.65

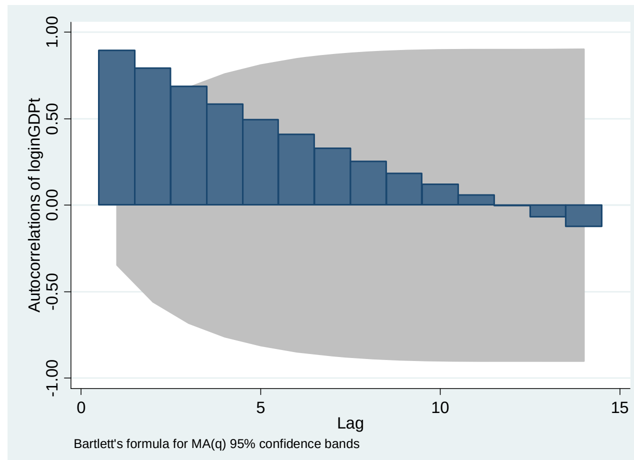
As shown from the table 5, only regression $logEC_t$ on $logGDP_t$ is statistically significant suggesting that there is unidirectional causality running from economic growth to energy consumption. It means, past values of $logGDP_t$ in $logEC_t$ equation, provides the good estimation of current values of $logEC_t$. In other terms, it can be said that economic growth causes energy consumption. The characterization that non-stationary variables may obey a long-run relationship with each other, whose residual is stationary, is the central perception of cointegration. ECM provides the formalization of this intuition.

e) Estimation of Cointegrating Relationship and Vector Error Correction Model

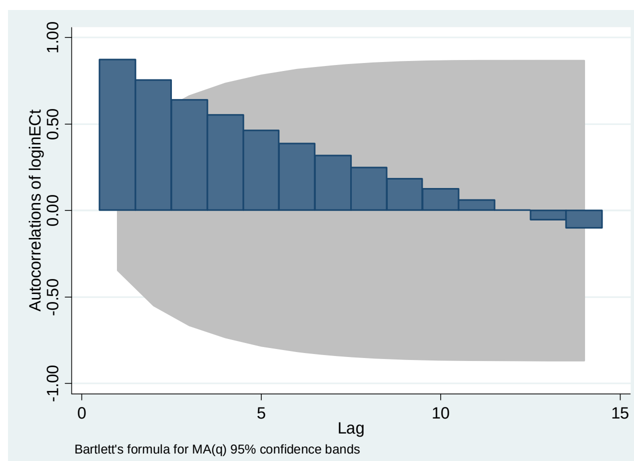
By using the EG or AEG test one can find that two time series are co-integrated, that is, there is a long-term, or equilibrium, relationship between the two. Of course, in the short run there may be disequilibrium. Therefore, one can treat the error term as the "equilibrium error." Further to say, this error term used to tie the short-run behavior to its long-run value. Referring to the ECM equations (6), (7) and results from the causality test, the ECM approach found to be appropriate in testing the causality between energy consumption and GDP. For analyzing the causality, obtained the first difference operator for both the time series variables and estimate residuals the $\hat{u}_{t-1}$ and $\hat{u}_{t-2}$ from equations (2) and (3). In this method, $logEC_t$ Granger causes $logGDP_t$ if either the coefficients on lagged $logEC_t$ as statistically significance or the coefficient on lagged error term (π) is statistically significant. Similarly, this is applicable for the equation (7). ECM modeling in Stata is based on the maximum likelihood framework of Johansen (J. Ec. Dyn. Ctrl., 1988). In that framework, deterministic trends can appear in the means of the differenced series, or in the mean of the Co-integrating relationship. The constant term in the VECM implies a linear trend in the levels of the variables. Thus, a time trend in the equation implies quadratic trends in the level data. Based on Johansen criteria for estimation of the VECM unrestricted constant specifications are used.

i. *Confirm the Unit Root*

The autocorrelations of the two variables displayed here. While these autocorrelations do not provide a formal test for unit root, they appear consistent with that hypothesis. The ACF falls off approximately linearly rather than exhibiting either exponential decay or sudden drop to zero value. The Dickey-Fuller test statistic using a generalized least squares (GLS), also provide more formal support for the hypothesis of a unit root in both the variables. The test statistics is not smaller than any of the critical values at any of the lags, so accept the null hypothesis of a unit root.



Graph 2(a) : ACF of $logGDP_t$



Graph 2(b) : ACF of $logEC_t$

ii. *Identify Number of Lags*

The varsoc command in Stata used to estimate the number of lags. It places an asterisk by the test statistics associated with the recommended lag length. The likelihood-ratio test suggests one lag.

```
varsoc loginGDPt loginECt

  Selection-order criteria
  Sample:  1984 - 2011                        Number of obs      =      28
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	22.1593				.000812	-1.43995	-1.41086	-1.34479
1	116.147	187.98*	4	0.000	1.3e-06*	-7.86764*	-7.78037*	-7.58216*
2	117.564	2.8349	4	0.586	1.6e-06	-7.68317	-7.53771	-7.20738
3	118.486	1.8437	4	0.764	2.0e-06	-7.4633	-7.25967	-6.7972
4	119.083	1.1932	4	0.879	2.6e-06	-7.2202	-6.95838	-6.36378

```
  Endogenous:  loginGDPt loginECt
   Exogenous:  _cons
```

iii. *Identify the Number of Cointegrating Relationship*

The number of linearly independent cointegrating relationships, r, lies between, 0 and K-1. Where, K is the number of dependent variables in a time series. The vecrank command provides three different approaches that can help identify value of r. By default, Stata calculates and displays a trace statistics (Johansen, 1995). The other two approaches provided by vecrank are the maximum eigen value test and assortment information criteria. The later identify the value of r that minimizes the SBIC, HQIC and AIC criteria. The unrestricted constant specification has chosen by default.

With this specification, the null hypothesis that r ≤ 0 is accepted (trace statistics = 14.5876 with a 5% critical value of 15.41). Which seems little unfeasible. While other test statistics on maximum eigenvalue and information –criterion tests reported that maximum value of *r =1.* Thus, it is concluded that there is one cointegrating vector.

iv. *Fitting VECM*

With the specifications of one lags, one cointegrating relationship and constant trend, the model was fitted. From the table of coefficients, in the $logGDP_t$ equation, the L1._ce1 term is the lagged error correction term. It corresponds to the speed of adjustment to nonzero values of cointegrating relationship. The short-run coefficients in this equation are not significantly different from zero. The final table on VEC from Stata output reports the estimated coefficients in the cointegrating equation. The relationship is estimated as:

$$logGDP_t - 1.033 logEC_t - 6.20 \quad (8)$$

The relationship equations suggest that it is in equilibrium, the index of construction $logGDP_t$ is 103% of the index in $logEC_t$.

v. *Test for Stability and White Noise Residuals*

On testing stability of the VECM, it is found that VECM specifications impose a unit root. Aside from the unit root, there is no evidence of instability. Nor is there evidence of auto-correlated errors. The null hypothesis is rejected for the Δ $logGDP_t$ equation by skewness test.

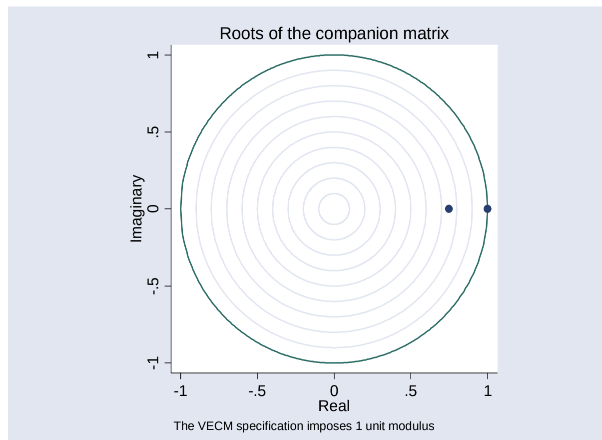
Table 6 : Eigenvalue stability condition

Eigenvalue	Modulus
1	1
0.7474953	0.7474953

Remarks : The VECM specification imposes a unit modulus.

Table 7 : Skweness test

Equation	Skewness	Chi2	df	Prob> Ch2
D_*loginGDPt*	1.8206	16.02	1	0.00006
D_*loginECt*	0.04009	0.008	1	0.92976
ALL		16.028	2	0.00033



Graph 3 : The VECM specifications imposes unit modulus

The VECM specifications impose a unit root and single root is found (modulus<0), thus variables cointegration shows as best long run relationship exits.

V. Conclusion and Further Implications

This paper aimed at investigating causality linkage between economic growth and GDP in India using secondary data over the period 1981-2011. According to Engle – Ganger cointegration methodology, there is a long-run relationship between energy consumption and GDP. The study used the error correction mechanism and compared the results with the standard Granger causality mythology of econometrics. Results show that economic growth causes total energy consumption in India. There was hardly any difference founds between the results from both the techniques. The result agreed with the other studies done in past (Hrushikesh Mallick). One reason for support causality is that India's Agriculture and allied sectors accounted for 15.7% of the GDP till end of 2010, employed roughly half of the total workforce, and despite a steady decline of its share in the GDP, is still the largest economic sector and a significant piece of the overall socio-economic development of the country. Second reason is that power is one of the key sectors driving India's infrastructure growth. Therefore, it is essential for the country's power sector to meet planned capacity additions and reduce power deficits to all time contribute to the country's GDP growth. The power sector in the country currently in the developing stage, and supports the growth of various other important sectors. To this effect, the sector need 100 per cent foreign direct investment through the automatic route, setting up of ultra mega power projects and encouraging joint ventures through the PPP route to step up private sector participation.

India is the fourth largest producer of electricity and oil products and the fourth largest importer of coal and crude oil in the world. Coal and oil together account for 66% of the energy consumption. It is less dependent on energy as an input in it's GDP output as compared to the developed countries and emerging economy like China. The results obtained in this study, has important implications on India's energy and economic growth policy. The country uses many type foreign exchanges to finance energy imports. The other policy implication is that increase economic growth in India, will lead to increase use of energy by keeping other factors constant. Therefore, planning renewable energy sub-sector phase wise and investing in it, seems to be much viable that has more advantages compared to fossil-based energy on environment protection background. In addition, given that there are some factors like coal potential, its import and petroleum potential with in the country, it will save lot of money spent on refining sector.

Therefore, it is concluded that results from this study draws a road map for the country to meet its growing needs of energy faces both energy constraints from the supply side and demand management policies. Hence securing the energy security related issues. The findings implications also suggests for adapting an energy growth policy in order to stimulate economic growth rate in the country.

On the limitations grounds, much of the same post-estimation apparatus as developed for VARs for VECMs may be used. Impulse response functions orthogonalized IRFs, FEVDs etc., maybe constructed for VECMs. The VECM has the capability to compute dynamic forecasts, due to limitations of the scope of work; the present study do not includes the forecasting. These are the relevant issues for the future research, which needs to be addressed for a rational national energy policy in the country.

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