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A Study of the Causal Relationship between Energy and Economic Growth in India

Dr. Aleykutty Robert

Assistant Professor, Department of Economics, Loyola College, Chennai-34

Abstract: **Energy sector is one of the basic infrastructural sectors. Depleting resources and growing pollution of environment due to energy use has necessitated optimum use of its resources. In a growing economy like India, the need and demand for Energy sectoral growth is imperative. As the economy is showing growth prospects, whether this growth helps in corresponding sectoral improvement in the energy sector is the main focus of this paper. The objective of this study is to find the causal relationship (if it exists) between GDP growth and energy production / consumption. This study uses the formal tests of causality developed by C. J. Granger, taking secondary data of energy production, consumption and GDP growth of India from 1990 to 2014. The results of granger casualty test show that there exists a feed – back causality between energy production / consumption and GDP growth.**

Keywords: **Economic growth, Energy Production / Consumption, GDP, Stationarity, Granger causality.**

1. INTRODUCTION

Energy sector is one of the basic infrastructural sectors. Depleting resources and growing pollution of environment due to energy use has necessitated optimum use of its resources; which in turn requires proper energy planning to achieve energy security.[1] To optimise the use of resources, a proper database of the production and the consumption of energy is required. Energy plays a vital role in our day to day lives. Some energy that we use are renewable in nature which includes hydro, wind, solar, geothermal etc. while, the other form is non-renewable which cannot be replenished once it gets exhausted. These non-renewable forms of energies are produced through fossil fuels which took millions of years to form. By reducing the demand for fossil fuels, the utilization of renewable energy sources can result in important benefits of environment, developing security and employment.[2]

Indian Scenario:

India's significant and sustained growth is exerting more pressure on the demand for energy resources. A shift from less efficient energy sources to more efficient and less polluting options may establish a stimulus rather than an obstacle to economic growth (Costantini and Martini, 2010)[4]. The rise in the demand for energy is not only because of the growing population, but also of the state of having more money or increased income leading to availability of more technological goods, to reach out to most people. This leads to an increase in production of energy that in turn adds to an increase in GDP (Gross Domestic Product) which is the leading macro-economic indicator of growth. This gap between the supply and demand in the energy sector suggests the magnitude of the energy crisis the economy faces due to over consumption of energy that are produced using fossil fuels resulting in the depletion of the resources. Therefore, attempts to reduce emissions and decrease the consumption of energy has been an issue focussed by policy makers and studied by environmental economists heavily in recent times[6].

2. THEORETICAL BACK GROUND

Production and consumption activities involve energy as the basic input. Since the time of Adam Smith only land, labour and capital were the only inputs. Later during the 19th century, due to the growth of industrial nations, energy was regarded as the fourth input. Energy consumption leads to economic growth and higher GDP. The fact that energy consumption leads to economic growth can be backed up by the 1970's energy crisis where OPEC restrained delivery of oil to US. Thus, there was an increased demand due to scarcity of oil and increased cost. In the US alone in 1974, GDP turned down after 20 years of steady growth. Therefore, the 1970s-energy crisis lead to the investigation of relationship between energy production / consumption and economic growth where it was emphasised that energy consumption leads to growth in GDP. The availability of energy is essential in initiating and sustaining economic growth. The availability of energy is a necessity for economic growth.

With increasing agricultural and industrial activities in the country, the demand for energy is also increasing thus more fossil fuels are used to meet the demands ending up in harmful emissions due to combustion of the fossil fuels. In India agriculture and domestic consumption combined accounts for one third of Indian electricity usage. Formulation of a renewable energy production will help in the proper allocation of widely available renewable energy resources in meeting the future energy demand in India. Also, majority of the power produced are lost through transmission itself. As per International Energy Data, 250074 GWh was lost from a total production of 1287398 GWh where, only 947126 GWH was consumed in the year 2014.

Review of earlier studies:

The relationship between energy consumption / production and economic growth has been studied extensively by earlier researchers. According to Farret A Felix, Simoes M Godoy (2006), since humankind's beginning, the ability to harvest and convert energy has been a means of survival[11].Shuyuna Yang & Donghuab Yu (2011) state, for designing effective energy and development policies, policymakers need to identify the relationship between energy consumption and economic growth[12]. According to Costantini and Martini (2010), economic growth should be decoupled from energy consumption to avoid a negative impact on economic development resulting from a reduction of energy use[13].

Apergis, N. and J. E. Payne (2010), highlight the growth hypothesis suggesting that a decrease in energy consumption causes a decrease in real GDP. The conservation hypothesis claims that policies directed towards lower energy consumption may have little or no adverse impact on real GDP. This hypothesis is based on a uni-directional causal relationship running from real GDP to energy consumption. Bi-directional causality corresponds with the feedback hypothesis, which argues that energy consumption and real GDP affect each other simultaneously. Finally, the neutrality hypothesis indicates that reducing energy consumption does not affect economic growth or vice versa. Hence, energy conservation policies would not have any impact on real GDP[14].

According to Per BelkeAnsgar, Dreger Christian, and Haan De Frauke (2010), there is long-run relationship between energy consumption and real GDP[15]. Stern (1993) used multivariate framework including capital and labour force into the model of energy consumption and GDP[16]. Asafu-Adjaye (2000) estimated the causal relationship between energy consumption and income for India, Indonesia, Philippines, and Thailand which indicates the presence of causality between energy consumption and economic growth[17].

Shahbaz Muhammad &Feridun Mete (2011), reveal that increased use of energy may lead to more efficient production and, hence lead to faster economic growth[18]. In the words of Chontannwat, J., Hunt, L. C., &Pierse R, (2008), whether there is causality between energy consumption and GDP is important in deciding energy policies[19]. Stern and Cleveland (2004) argue that energy consumption and output are positively correlated as energy availability is crucial in permitting growth[20].

Mallick (2007) using the Granger causality test found that the growth rate of GDP leads to higher demands for natural gas and electricity and increased levels of total energy consumption and found a possible two-way causality between electricity energy consumption growth and economic growth[21].

Need for the study:

According to Pokharel (2006), the relationship between the use of energy and economic growth has been a subject of greater inquiry as energy is one of the important driving forces of economic growth in all economies[8]. A renewables-intensive energy future would introduce new choices and competition in energy markets. Growing trade in renewable fuels and natural gas would diversify the mix of suppliers and the products traded, which would increase competition and reduce the likelihood of rapid price fluctuations and supply disruptions. It could also lead eventually to a stabilization of world energy prices. In addition, new opportunities for energy suppliers would be created[10]. As per the International Energy Agency report, in India during 2014, out of 1287398 GWH total production, of which 989216 GWH was produced only from coal and oil, while only211345 GWH through renewable sources of energy like solar, wind, hydro, nuclear and waste.

The main focus of this paper is to examine whether the energy produced / consumed in our economy will in any way lead to an improvement to the GDP growth track. In the same way, an increase in economic growth in terms of GDP, would in any way help in improving the production / consumption standards in the energy sector based upon its rising demand. The issue of causal relationship between electricity production / consumption and economic growth (GDP) has been a topic concerning energy economists for several years given that the results have important implications for policy makers. With this back ground, the question arises 'Does development of energy sector promote economic growth and / or economic development foster energy sector development?

Objectives of the study:

1. To study whether there is a relationship between development in energy sector and economic growth.

2. To examine the nature and direction of the causal relationship (if it exists) between GDP and Energy Production / Consumption.

Scope of the Study:

The study is essentially carried out in a very modest scale when compared to regular granger causality tests, but the researcher has taken care in including all the relevant data available for analysis. Findings and conclusions of this study may help future scholars to take reference, but surely it will help common man to understand the relation between energy standards and economic growth in the country.

3. METHODOLOGY OF THE STUDY

To study the causal relationship between the selected variables such as GDP, Energy Consumption and Energy Production, data pertaining to these variables were collected for 25 years from 1990 to 2014 from various secondary sources.

Stationarity of the given data set was examined using Augmented Dickey Fuller test.

$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha_1 \Sigma \Delta Y_{t-1} + \varepsilon_\tau$

Granger Causality test:

The following model tests Granger causality:

$GDP_t = \Sigma\alpha_i ENERGY_{t-i} + \Sigma\beta_j GDP_{t-j} + u_{1t}$

$ENERGY_t = \Sigma\Phi_i ENERGY_{t-i} + \Sigma\delta_j GDP_{t-j} + u_{2t}$

Then, the F-statistic is calculated using the formula

$$F = \frac{(RSS_R - RSS_{UR})/m}{RSS_{UR}/(n-k)}$$

Which follows the F distribution with m and (n-k) degrees of freedom. In the present case 'm' is equal to number of lagged GDP and ENERGY PRODUCTION /CONSUMPTION and k is the number of parameters to be estimated in the unrestricted regression.

Pre Diagnostic test for selection of appropriate lags to be included in the regression was conducted prior to the causality analysis. **Lagrangian Multiplier method** was used to test the degree of residual correlation.

Limitations of the Study: 1. The research tools used in the study have their own limitations .

2. The study is primarily carried out on the data collected from the official websites and other secondary sources. The reliability of the results depends on the accuracy of data set.

Therefore, any conclusions drawn from the study and the findings should necessarily be interpreted with utmost care and caution on part of the reader.

Empirical Analysis: The selected time series data for a period of 25 years (1990-2014) on the variables GDP, Energy Production/Consumption were used for testing the causality between these time series variables. The results of the analysis are as follows:

STATIONARITY TEST Selected time series data was first examined for stationarity using Augmented Dickey Fuller unit root test. The results are given below:

4. GDP

Null Hypothesis: GDP has a unit root

Exogenous: Constant

```
. dfullerGDPmp, trend regress lags(1)

Augmented Dickey-Fuller test for unit root                Number of obs   =
23


                    ---------- Interpolated Dickey-Fuller ---------
              Test        1% Critical      5% Critical     10% Critical
            Statistic        Value          ValueValue
------------------------------------------------------------------------------
 Z(t)         0.415          -4.380          -3.600          -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9967


------------------------------------------------------------------------------
D.GDPmp|     Coef.   Std. Err.      t   P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
GDPmp |
 L1. |  .0655242   .1577002     0.42   0.682    -.2645461    .3955945
  LD. | -.2197302    .28702    -0.77   0.453     -.82047     .3810096
 _trend |  363.9161   407.5505    0.89   0.383   -489.0969    1216.929
  _cons | -2685.164  2709.738   -0.99   0.334    -8356.71    2986.382
```

```
. pperronGDPmp, lags(1) trend regress

Phillips-Perron test for unit root              Number of obs  =       24
Newey-West lags =        1


                    ---------- Interpolated Dickey-Fuller ---------
 Test       1% Critical      5% Critical     10% Critical
 Statistic        Value          ValueValue
------------------------------------------------------------------------------
 Z(rho)       0.513          -22.500          -17.900          -15.600
 Z(t)         0.211           -4.380           -3.600           -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9958
------------------------------------------------------------------------------
GDPmp |     Coef.   Std. Err.      t   P>|t|    [95% Conf. Interval]
-------------+----------------------------------------------------------------
GDPmp |
 L1. |  1.000502   .1169603     8.55   0.000      .75727     1.243734
 _trend |  423.8646   346.0152    1.22   0.234   -295.7134    1143.443
 _cons | -1835.719   2336.798   -0.79   0.441   -6695.357    3023.919
------------------------------------------------------------------------------
```

5. ENERGY CONSUMPTION

Null Hypothesis: Energy Consumption has a unit root

Exogenous: Constant

```
.dfullerEnergyConsumption, trend regress lags(1)

Augmented Dickey-Fuller test for unit root        Number of obs   =       23

---------- Interpolated Dickey-Fuller ---------
Test        1% Critical       5% Critical      10% Critical
Statistic          Value           ValueValue

Z(t)            0.593           -4.380           -3.600           -3.240

MacKinnon approximate p-value for Z(t) = 0.9970

D.EnergyCo~nCoef.   Std. Err.      t    P>t     [95% Conf. Interval]

EnergyCons~n
L1.   .0302133  .0509739    0.59   0.560    -.0764762    .1369028
LD.    .2502871    .242568    1.03   0.315    -.2574135    .7579877
_trend    912.2953   1261.622     0.72   0.478    -1728.311    3552.901
_cons   -2662.877    7603.73    -0.35   0.730    -18577.67    13251.91
```

```
. pperronEnergyConsumption, lags(1) trend regress
Phillips-Perron test for unit root              Number of obs   =       24
Newey-West lags =         1
                              ---------- Interpolated Dickey-Fuller ---------
               Test        1% Critical       5% Critical      10% Critical
            Statistic         Value            ValueValue
--
 ------------------------------------------------------------------------------
 EnergyCons~n |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
 -------------+----------------------------------------------------------------
 EnergyCons~n |
          L1. |   1.069234   .0418916    25.52   0.000     .9821152    1.156352
       _trend |   233.1494   1171.859     0.20   0.844    -2203.865    2670.164
        _cons |  -4636.628   7131.793    -0.65   0.523       -19468    10194.75
 ------------------------------------------------------------------------------
------------------------------------------------------------------------------
 Z(rho)          1.572          -22.500          -17.900          -15.600
 Z(t)            1.420           -4.380           -3.600           -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 1.0000

------------------------------------------------------------------------------
EnergyCons~n |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
EnergyCons~n |
  L1. |   1.069234   .0418916    25.52   0.000     .9821152    1.156352
     _trend |   233.1494   1171.859     0.20   0.844    -2203.865    2670.164
      _cons |  -4636.628   7131.793    -0.65   0.523       -19468    10194.75
------------------------------------------------------------------------------
```

6. ENERGY PRODUCTION

Null Hypothesis: Energy Production has a unit root

Exogenous: Constant

```
. dfullerEnergyProdn, trend regress lags(1)

Augmented Dickey-Fuller test for unit root      Number of obs  =      23

                    ---------- Interpolated Dickey-Fuller ---------
             Test       1% Critical      5% Critical     10% Critical
           Statistic       Value           ValueValue

------------------------------------------------------------------------------
 Z(t)           1.565          -4.380          -3.600          -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 1.0000

------------------------------------------------------------------------------
D.EnergyPr~n |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
EnergyProdn |
 L1. |   .1496794    .095662     1.56   0.134    -.0505435    .3499022
   LD. |  -.4015441   .2462191    -1.63   0.119    -.9168866    .1137983
     _trend |   -2171.86   3422.286    -0.63   0.533    -9334.787    4991.066
  _cons |  -14097.58   18774.74    -0.75   0.462    -53393.57    25198.41
------------------------------------------------------------------------------
```

```
. pperronEnergyProdn, lags(1) trend regress

Phillips-Perron test for unit root              Number of obs  =      24
Newey-West lags =        1

                    ---------- Interpolated Dickey-Fuller ---------
             Test       1% Critical      5% Critical     10% Critical
           Statistic       Value           ValueValue
------------------------------------------------------------------------------
 Z(rho)         2.651         -22.500         -17.900         -15.600
 Z(t)           1.661          -4.380          -3.600          -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 1.0000

------------------------------------------------------------------------------
EnergyProdn  |Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
EnergyProdn |
         L1. |   1.086066   .0829233    13.10   0.000     .9136174    1.258514
      _trend |  -737.3353   3100.859    -0.24   0.814    -7185.924    5711.254
       _cons |   -5575.92   18329.41    -0.30   0.764    -43694.01    32542.17
------------------------------------------------------------------------------
```

The results above show that both GDP and Energy Production/Consumption are stationary in their first difference.

The results of granger causality tests are given below:

GRANGER CAUSALITY TEST: GDPmp at Constant prices, Energy Consumption

The Null Hypothesis framed are:

Ho: GDP does not granger cause Energy Consumption

Ho: Energy Consumption does not granger cause DP

The results are as follows:

1. Pre diagnostic test for selection of lags

varsocGDPmpEnergyConsumption, maxlag(8) noconstant

Selection-order criteria
Sample: 1998 - 2014 Number of obs = 17

lag	LL	LRdf	p	FPE	AIC	HQICSBIC	
3	-348.273	9.0136 4	0.061	9.3e+15	42.3851	42.4436	42.9733
4	-346.404	3.7384 4	0.443	1.3e+16	42.6358	42.7137	43.42
5	-339.041	14.726 4	0.005	1.1e+16	42.2402	42.3376	43.2204
6	-322.508	33.068 4	0.000	3.5e+15	40.7656	40.8825	41.9419
7	-293.18	58.655 4	0.000	3.5e+14	37.7859	37.9223	39.1582
8	45.9018	678.16* 4	0.000	.016858*	-1.6355*	-1.4796*	-.0671*

Endogenous: GDPmpEnergyConsumption
Exogenous:

The result above shows that the most favourable lag is 8 which is recommended by all the criteria.

2. VAR Vector autoregression (2 lags)

Sample: 1992 – 2014 No. of Obs = 23
Log likelihood = -468.997 AIC = 41.65191
FPE = 4.27e+15 HQIC = 41.77607
Det(Sigma_ml) = 1.76e+15 SBIC = 42.1456

Equation	Parms	RMSE	R-sq	chi2	P>chi2
GDPmp	5	5084.9	0.964	615.3631	0
EnergyConsumpt~n	5	11354.2	0.9976	9651.67	0

VAR GRANGER
Granger causality Wald tests (2 lags)

Equation	Excluded	chi2	df	Prob> chi2
GDPmp	EnergyConsumption	8.822	2	0.012
GDPmp	ALL	8.822	2	0.012
EnergyConsumption	GDPmp	.23323	2	0.890
EnergyConsumptin	ALL	.23323	2	0.890

Result; Energy Consumption granger cause GDP, but GDP does not granger cause EnergyConsumption

```
. varGDPmpEnergyConsumption, lags(1/4)

Vector autoregression

Sample:  1994 - 2014                       No. of obs=       21
Log likelihood = -423.2265                 AIC          =  42.02158
FPE     =  6.86e+15             HQIC=  42.21588
Det(Sigmaml)  =  1.10e+15                 SBIC          =  42.91688

Equation          ParmsRMSE     R-sq      chi2     P>chi2

GDPmp  9     5695.62   0.9670   614.5784   0.0000
EnergyConsumpt~n      9     10753.4   0.9984   12740.62   0.0000
```

```
Vargranger

  Granger causality Wald tests (4+A56 lags)
 +------------------------------------------------------------------+
 | Equation          Excluded |       chi2     dfProb> chi2 |
 |--------------------------------------+---------------------------|
 | GDPmpEnergyConsumption |  6.4875     4    0.166    |
 |  GDPmp ALL |        6.4875     4   0.166    |
 |--------------------------------------+---------------------------|
 | EnergyConsumptionGDPmp |  12.838     4    0.012    |
 | EnergyConsumption           ALL |  12.838     4    0.012    |
 +------------------------------------------------------------------+
```

Result: Energy Consumption does not granger cause GDP, but GDP granger causes Energy Consumption. Thus when2 and 4 lags are considered, unidirectional causality exists between GDP and Energy Consumption.

```
. varGDPmpEnergyConsumption, noconstant lags(1/5)

Vector autoregression

Sample:  1995 - 2014                       No. of obs    =       20
Log likelihood = -397.7958   AIC           =  41.77958
FPE=  5.83e+15                HQIC         =  41.97396
Det(Sigma_ml)  =  6.47e+14                 SBIC          =  42.77531

Equation          ParmsRMSE     R-sq      chi2     P>chi2
---------------------------------------------------------------
GDPmp  10      5200.3   0.9943   3460.425   0.0000
EnergyConsumpt~n     10     10952.6   0.9998   111212.6   0.0000
---------------------------------------------------------------
```

```
. vargranger

Granger causality Wald tests
 +------------------------------------------------------------------+
 | Equation           Excluded |   chi2     dfProb> chi2 |
```

```
|------------------------------------+---------------------------|
|GDPmpEnergyConsumption |  11.739     5    0.039 |
|GDPmp  ALL |  11.739     5   0.039 |
|------------------------------------+---------------------------|
| EnergyConsumptionGDPmp |  15.987     5    0.007     |
| EnergyConsumption            ALL |  15.987     5    0.007   |
+-----------------------------------------------------------------+
```

Result: Feed-Back Causality exists as both the Hoare rejected. Thus Energy Consumption and GDP granger causes each other.

Checking for Residual Correlation:

```
Varlmar

Lagrange-multiplier test
+--------------------------------------+
lag       chi2  dfProb> chi2

------+-------------------------------
1     9.3043     4        0.05393

2    15.6092    4   0.00359

+--------------------------------------+
H0: no autocorrelation at lag order
```

Conclusion:

In order to test whether there exists a causal relationship between GDP and Energy Consumption, Granger Causality tests were conducted and the results reveal that with 2 and 4 lags, uni-directional causality exists and with 5 lags, feed – back causality exists. It is also established that the residual terms are uncorrelated.

GRANGER CAUSALITY TEST: GDPmp at Constant prices, Energy Production

The Null Hypotheses are:

Ho: GDP does not granger cause Energy Production.

Ho: Energy production does not granger cause GDP.

The results are as follows:

```
varsocGDPmpEnergyProdn, maxlag(8) noconstant

  Selection-order criteria
  Sample:  1998 - 2014                      Number of obs     =       17
 +-------------------------------------------------------------------------+
 |lag |    LL     LRdf p     FPE    AIC      HQICSBIC    |
 |----+--------------------------------------------------------------------|
 1 | -358.977       .     4       .  1.2e+16   42.7032   42.7226   42.8992  |
2 | -354.139  9.6756    4  0.046  1.1e+16   42.6046   42.6436   42.9967  |
3 | -351.014  6.2497    4  0.181  1.3e+16   42.7075    42.766   43.2957  |
4 | -345.059  11.911    4  0.018  1.1e+16   42.4775   42.5554   43.2617  |
5 | -336.712  16.694    4  0.002  8.2e+15   41.9661   42.0635   42.9463  |
6 | -332.717  7.9895    4  0.092  1.2e+16   41.9667   42.0836    43.143  |
 7 | -322.302  20.83*   4  0.000  1.1e+16    41.212*  41.3484*  42.5843* |
 8 |        .       .     4      . -7.06434*        .          .          .  |
 +-------------------------------------------------------------------------+
```

Endogeous: GDPmp Energy Production

Exogenous:

The pre-diagnostic test for selection of lags result shows that all the criteria recommend up to 7 lags for testing causality between GDP and Energy Production.

```
varGDPmpEnergyProduction, noconstant lags(1/3)

Vector autoregression

Sample:  1993 - 2014                    No. of obs   =       22
Log likelihood = -461.1746              AIC          =  43.01588
FPE=  1.69e+16            HQIC          =  43.15607
Det(Sigma_ml)  =  5.53e+15              SBIC         =  43.61099

Equation       ParmsRMSE    R-sq     chi2     P>chi2
----------------------------------------------------------------
GDPmp 6    5284.58   0.9906   2324.121   0.0000
EnergyProdn         6    19747.4   0.9995   46560.44   0.0000
----------------------------------------------------------------
```

```
Vargranger

  Granger causality Wald tests (3 lags)
 +------------------------------------------------------------------+
 Equation          Excluded |   chi2     dfProb> chi2 |
 |-------------------------------------+---------------------------|
GDPmpEnergyProduction |  9.4175     3    0.024     |
GDPmp      ALL |  9.4175     3    0.024    |
 |-------------------------------------+---------------------------|
EnergyProductionGDPmp |  4.7294     3    0.193     |
EnergyProduction              ALL |  4.7294     3    0.193    |
 +------------------------------------------------------------------+
```

The above result states that Energy Production granger causes GDP, on the other hand, GDP does not granger cause Energy Production.

```
. varGDPmpEnergyProdn, noconstant lags(1/4)

Vector autoregression

Sample:  1994 - 2014                      No. of obs     =       21
Log likelihood = -437.1119              AIC          =  43.15351
FPE =  2.05e+16               HQIC          =  43.32623
Det(Sigma_ml)  =  4.12e+15              SBIC          =  43.94934

Equation          ParmsRMSE R-sqchi2     P>chi2
----------------------------------------------------------------
GDPmp              8     5336.47   0.9922    2666.28   0.0000
EnergyProdn        8     19462.8   0.9996   55762.37   0.0000
----------------------------------------------------------------
```

```
Vargranger
  Granger causality Wald tests (4 lags)
 +------------------------------------------------------------------+
```

```
Equation          Excluded |  chi2      doff     Prob> chi2 |
 |-------------------------------------+---------------------------|
GDPmpEnergyProduction |  12.504     4    0.014    |
GDPmp   ALL |  12.504     4    0.014    |
 |-------------------------------------+---------------------------|
EnergyProductionGDPmp |  10.307     4    0.036    |
EnergyProduction             ALL |  10.307     4    0.036    |
 +-----------------------------------------------------------------+
```

Results: There exists Feed – back causality between the two variables when 4 lags are considered. The null hypothesis is rejected and so GDP and Energy Production granger causes each other.

Checking for Residual Correlation:

```
. varlmar

  Lagrange-multiplier test

 +--------------------------------------+

 | lag  |      chi2   dfProb> chi2 |

 |------+-------------------------------|

 |   1  |   10.0079     4     0.04030   |

 |   2  |    7.1331     4     0.12902   |

 +--------------------------------------+

  H0: no autocorrelation at lag order
```

Conclusion: In order to test whether there exists a causal relationship between GDP and Energy Production, Granger Causality tests were conducted and the results reveal that at 3 lags, uni-directional causality exists and with 4 lags, feed – back causality exists between the two variables. It is also proved that there is no correlation between the residual terms in the model.

Testing for Granger Causality:

The procedure used in the study for testing causality between the Energy production / consumption and the economy's growth is the Granger-causality test (Granger, 1969). The Granger causality tests determine the predictive content of one variable beyond that inherent in the explanatory variable itself. The variables to be used in the Granger Causality test are assumed to be stationary. In the case of the study's data set, unit root has already been tested with the conclusion that the time series are I(1) or stationary. Based on the results of the lag length, we proceed with testing for Granger causality. The results are: there exists Feed – back causality for equations (1) and (2) stated above. This implies that the null hypothesis that ENERGY does not Granger cause GDP and GDP does not granger cause Energy is rejected at different lag selections. Thus, there exists the Feed-back Granger causality from GDP to ENERGY and vice versa.

7. CONCLUSION

It is found out from the study that there is a two-way or feed-back causality between economic growth and energy. Thus the causal relationships have important implications to policy makers for economic forecasting. The availability of energy is essential for initiating and sustaining economic growth and vice versa.

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