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Renewable and Non-renewable Energy Consumption and Economic Growth in India

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Abstract

The aim of this study is to examine the nexus among the renewable energy, non-renewable energy consumption and economic growth in India by considering gross fixed capital formation and labour force during 1990-2011. Using Johanson cointegration technique, we find long-relationship among the variables. The long-run estimates reveal that renewable energy consumption has a negative impact on economic growth whereas non-renewable energy consumption has a positive impact. The short-run Granger causality results display that there is an evidence of a feedback relationship between GDP growth-renewable energy consumption, GDP growth-non-renewable energy consumption. The results on long-run (error correction term) causality shows that GDP growth, renewable energy consumption, non-renewable energy consumption, gross fixed capital formation and labour force have bidirectional causality. Our study findings are suggested that India may continue in using non-renewable energy sources for growth process. This study also suggests that government and policy makers should take attention to investment in renewable energy for low carbon growth in India.

Keywords: Renewable Energy Consumption, Non-renewable Energy Consumption, Gross Fixed Capital Formation, Labour Force and Economic Growth, Cointegration FMOLS India.

1. Introduction

The most serious environmental problem facing human society is the potential for significant changes in the global climate. The main source of CO2 emissions is the burning of fossil fuel, which accounted for 87% global energy supply in 2012. The United Nations designed the decade 2014-2024 as the Decade of Sustainable Energy for all. In the global context, there is an increasing development of renewable energy that helps in addressing climate change.

India was the fourth-largest energy consumer in the world after China, U.S. and European Union in 2013. Indian energy sector is predominantly coal-based (69%), with 5% non-hydro renewable and hydro power. The increase in carbon dioxide (CO_2) emissions in the atmosphere considered as a Green House Gas (GHG) effect leads to environmental degradation. The energy consumption-economic growth nexus is set around four different hypotheses (Apergis and Payne, 2009, 2011 Paramati et al., 2016; Ewing et al., 2007; lee 2006):

Growth hypothesis refers to a situation in which energy consumption plays a vital role in the economic growth process, if unidirectional causality found from energy consumption to economic growth. In this scenario, energy conservation policies will have a negative impact on economic growth. The conservation hypothesis implies that economic growth causes consumption of energy. Under situation, conservation policy will not affect economic growth. The feedback hypothesis states a mutual relationship among energy consumption and economic growth. The feedback hypothesis supported if there exists bi-directional causality between energy consumption and economic growth. In this case, energy conservation policies designed to reduce energy consumption may decrease economic growth performance, changes in economic growth are reflected back to energy consumption. The neutrality hypothesis indicates that energy consumption does not affect economic growth. The absence of causality between energy consumption and economic growth provide evidence for the presence of neutrality hypothesis. In this case, energy conservation policies devoted to reducing energy consumption will not have any impact on economic growth.

2. Literature review

The idea that energy consumption is one of the basic indicators of economic development (Halicioglu, 2009) has attracted economists to deal with studies which try to explain the interrelations between energy and economic growth. Payne (2009) examined the causal relationship between renewable and non-renewable energy consumption and real GDP in the US over the period 1949-2006. Findings showed that there exists no casual relationship between renewable and non-renewable energy consumption and economic growth, which indicating the presence of the neutrality hypothesis. Huang et al. (2008) provide evidence in favour of the neutrality hypothesis for low income panel.

Apergis and Payne (2012) examined the relationship between renewable and non-renewable energy consumption and economic growth for 80 countries within a multivariate panel framework over the period 1990-2007. Results supported the existence of bi-directional causality between renewable and non-renewable energy consumption and economic growth both short-run and long-run, indicating the validity of the feedback hypothesis. Sebri and Salha (2014) investigated the casual relationship between economic growth and renewable energy consumption in the BRICS countries over the period 1971-2010. The empirical findings conformed feedback hypothesis between economic growth and renewable energy consumption.

Tugcu et al. (2012) analysed the long-run and causal relationships between renewable and non-renewable energy consumption and economic growth by using classical and augmented production functions in G7 countries for 1980-2009, results confirmed that there is no causal relationship between renewable energy consumption and economic growth in France, Italy, Canada and the USA; the feedback hypothesis present for England and Japan, that is there exists bi-directional causality between renewable energy consumption and economic growth, and the conservation hypothesis supported for Germany.

A recent study by Mallaiah and Santhosha (2016) examined the relationship between energy consumption and economic growth in India during the period from 1971Q4 to 2011Q4. The empirical results confirmed that there is a unidirectional causality running from per capita GDP and CO_2 emissions to energy consumption in the long-run.

3. Data and methodology

Annual data covering the period from 1990 to 2011 were used in this study. The data on all series are extracted from the World Development Indicators (WDI) database. We use real GDP or output (Y) in constant 2010 US Dollars as measure of economic output, we use renewable energy consumption as electricity consumption generated from renewable energy sources and measured in billion kilowatt-hours. On the other hand, non-renewable energy sources include coal and coal products, oil and natural gas, real gross fixed capital formation (GFCF) in constant 2010 US Dollar is used as a proxy for the growth of capital stock, and total labour force (LF) is used as measure of available labour in the market. The output and GFCF are measured in monetary units while labour is measured in numbers.

$$\ln Y_t = \beta_1 \ln REC_t + \beta_2 \ln NREC_t + \beta_3 \ln GFCF_t + \beta_4 \ln LF_t + \varphi_{t_t} \quad (1)$$

Where β_1, β_2, β_3 and β_4 are elasticities of output with respect to renewable, non-renewable, gross fixed capital formation and labour respectively. φ is the error term.

3.1 ADF and PP test

Before going to estimate any econometric model, we have to apply unit root tests on time series data because it is important in examining the stationary of a time series. There are several tests are identified in literature for testing unit root tests, some of them are augmented Dickey and Fuller (ADF) (1979) and the Phillips and Perron (PP) (1988). In order to check the stationary properties of variables the ADF and PP tests are applied.

3.2. Cointegration test

We applied Johansen and Juselius (1990) cointegration technique to analyze the long run relationship between economic growth, renewable energy, non-renewable energy, gross fixed capital formation and labour force in India.

The Johansen methodology involves two tests for cointegration: the trace and maximum-eigenvalue cointegration rank (r) tests. The trace statistic (λ_{trace}) evaluates the null hypothesis that there are at most r cointegrating vectors against alternative that they number more than r. The null hypothesis under the maximum-eigenvalue test is that there are r cointegrating vectors and the alternative is that there are r +1 cointegrating vectors.

The trace test and maximum eigenvalue which follow:

$$\lambda_{trace} = -T \sum_{i=r+1}^{N} \ln(1 - \hat{\lambda}_i) \quad (2)$$

$$\lambda_{\max}(r, r+1) = -T \ln(1 - \lambda_{r+1}) \quad (3)$$

Where λ_i is the estimated ordered eigenvalue obtained from the estimated matrix and T is the number of usable observations after lag adjustment. The trace statistics tests the null hypothesis that the number of distinct cointegrating vector (r) is less than or equal to r against alternative. The maximal eigenvalue tests the null that the number of cointegrating vector is against the alternative of r+1 cointegrating vector.

3.3. Granger causality Test

In this section, we describe the methodology that aims to explore the dynamic causal relationship between economic growth, renewable energy consumption, non-renewable energy consumption, gross fixed capital formation and labour force. Engle and Granger (1987) argue that if non-stationary variables are cointegrated in the long-run, then the vector error correction model (VECM) can be applied for exploring the direction of causality among the variables in the short-run as well as in the long-run. The short-run Granger causality can be established by conducting a joint test of the coefficients based on the F-test and the x^2 test. Likewise, the long-run Granger causality between the variables can be understood through the statistical significance of the lagged error term in the VECM framework based on the t-statistics.

Ganger causality test for short-run and long-run can be described based on the following equations:

$$\Delta \ln Y_t = \beta_1 + \sum_{j=1}^{p} \beta_{1j} \Delta \ln Y_{t-j} + \sum_{j=1}^{p} \beta_{2j} \Delta \ln RE_{t-j} + \sum_{j=1}^{p} \beta_{3j} \Delta \ln NRE_{t-j} + \sum_{j=1}^{p} \beta_{4j} \Delta \ln GFCF_{t-j} + \sum_{j=1}^{p} \beta_{5j} \Delta \ln LF_{t-j} + \lambda_6 ECM_{t-1} + \varepsilon_{1t} \quad (4)$$

$$\Delta \ln RE_t = \beta_1 + \sum_{j=1}^{p} \beta_{1j} \Delta \ln RE_{t-j} + \sum_{j=1}^{p} \beta_{2j} \Delta \ln Y_{t-j} + \sum_{j=1}^{p} \beta_{3j} \Delta \ln NRE_{t-j} + \sum_{j=1}^{p} \beta_{4j} \Delta \ln GFCF_{t-j} + \sum_{j=1}^{p} \beta_{5j} \Delta \ln LF_{t-j} + \lambda_6 ECM_{t-1} + \varepsilon_{2t} \quad (5)$$

$$\Delta \ln NRE_t = \beta_1 + \sum_{j=1}^{p} \beta_{1j} \Delta \ln NRE_{t-j} + \sum_{j=1}^{p} \beta_{2j} \Delta \ln Y_{t-j} + \sum_{j=1}^{p} \beta_{3j} \Delta \ln RE_{t-j} + \sum_{j=1}^{p} \beta_{4j} \Delta \ln GFCF_{t-j} + \sum_{j=1}^{p} \beta_{5j} \Delta \ln LF_{t-j} + \lambda_6 ECM_{t-1} + \varepsilon_{3t} \quad (6)$$

$$\Delta \ln GFCF_t = \beta_1 + \sum_{j=1}^{p} \beta_{1j} \Delta \ln GFCF_{t-j} + \sum_{j=1}^{p} \beta_{2j} \Delta \ln Y_{t-j} + \sum_{j=1}^{p} \beta_{3j} \Delta \ln RE_{t-j} + \sum_{j=1}^{p} \beta_{4j} \Delta \ln NRE_{t-j} + \sum_{j=1}^{p} \beta_{5j} \Delta \ln LF_{t-j} \lambda_6 ECM_{t-1} + \varepsilon_{4t} \quad (7)$$

$$\Delta \ln LF_t = \beta_1 + \sum_{j=1}^{p} \beta_{1j} \Delta \ln LF_{t-j} + \sum_{j=1}^{p} \beta_{2j} \Delta \ln Y_{t-j} + \sum_{j=1}^{p} \beta_{3j} \Delta \ln RE_{t-j} + \sum_{j=1}^{p} \beta_{4j} \Delta \ln NRE_{t-j} + \sum_{j=1}^{p} \beta_{5j} \Delta \ln GFCF_{t-j} + \lambda_6 ECM_{t-1} + \varepsilon_{5t} \quad (8)$$

Where Δ is the first difference operator; lnY_t is the natural logarithm of GDP growth at time t; $lnRE_t$ is the natural logarithm renewable energy at time t; $ln\text{NRE}_t$ is the natural logarithm of non-renewable energy at time t; $ln\text{GFCF}_t$ is the natural logarithm of gross fixed capital formation at time t; $ln\text{LF}_t$ is the natural logarithm of labour force at time t; β, δ *and* γ are short-term coefficients and p , $q\ and\ r$ are the log orders, ε_{it} ($i = 1,2,3,4,5$) are serially uncorrelated error terms, ECM_{t-1} is the lagged error correction term, and λs are the speed of adjustment parameters.

3.4. FMOLS

The FMOLS technique was at first introduced and developed by Phillips and Hamsen (1990) for estimating the single cointegrating relationship. In order to achieve asymptotic efficiency, this technique modifies least squares to account for serial correlation effects and test for the endogeneity in the regressors that result from the existence of cointegration relationships (Rukhsana and M. Shahbaz, 2008).

4. Empirical findings

Table 1 Summary Statistics

Variables	Mean	Median	Max.	Min.	Std. Dev.	Skew.	Kurt.	J.-B
Y	9.61	8.57	1.82	4.86	4.09	0.67	2.30	2.13
RE	51.06	52.40	58.40	39.85	5.40	-0.73	2.61	2.12
NRE	80.64	81.24	85.26	73.11	2.98	-0.86	3.35	2.84
GFCF	2.51	1.89	5.93	9.72	1.54	0.88	2.44	3.12
LF	4.13	4.12	4.75	3.29	5.10	-0.66	1.55	2.00

Summary statistics of this study are presented in above the table 1. This indicates that all the series are having positive mean. The series of real GDP growth and real gross fixed capital formation are having positive skewness and renewable energy consumption, non-renewable energy consumption and labour force are shows negative skewness. This implies that the positively skewed series are flatter to the right as compared to the normal distribution and while negative skewed series is flatter to the left. While the kurtosis value of non-renewable energy consumption are higher than the normal value of it and this suggests that the kurtosis curve is leptokurtic. While the kurtosis value of all other series are less than the normal values of it, and this suggest that the kurtosis curve is platykurtic. In general, value for skewness is 'zero' and kurtosis is 'three' when the observed series is perfectly normally distributed. Since, the results of this study indicate that none of these series are normally distributed. This view also supported by Jaque-Bera (JB) test, the JB test is used to assess whether the given series is normally distributed or not. Here, the null hypothesis is that the series is normally distributed. Results of JB test find that the null hypothesis is rejected for all the variables and suggest that all the observed series are not normally distributed.

Table 2 Correlation Matrix

	Y	RE	NRE	GFCF	LF
Y	1	-0.98***	0.36***	0.99***	0.92***
RE		1	-0.39***	-0.97***	-0.89***
NRE			1	0.26***	0.60***
GFCF				1	0.88***
LF					1

Note: Variables are in natural logarithms. *** Indicates statistical significance at 1% level.

The above table provides information on correlation between observed variables. The renewable energy consumption is negatively correlated with real GDP growth. This is suggesting that there is an inverse relationship from real GDP growth to renewable energy consumption. In contrary, output had higher correlation with capital and labour, and lowest correlation with non-renewable energy consumption. These finding indicates that capital and labour non-renewable energy consumption played a significant role in promoting economic growth.

Table 3 Unit Root Test Results

	ADF Test		**PP Test**	
Variable	**Level**	**1st Difference**	**Level**	**1st Difference**
Y	2.306 (0.999)	-4.184 (0.004) ***	2.671 (1.000)	-4.276 (0.003) ***
RE	2.401 (0.999)	-2.976 (0.054) **	2.401 (0.999)	-2.931 (0.059) **
NRE	-3.081 (0.056) **	-3.821 (0.043) ***	-3.114 (0.040) **	-3.787 (0.010) ***
GFCF	1.469 (0.998)	-4.872 (0.001) ***	1.469 (0.998)	-4.877 (0.001) ***
LF	-1.578 (0.474)	-4.334 (0.003) ***	-2.149 (0.228)	-4.334 (0.003) ***

Note: The ADF and PP tests examine the null hypotheses of a unit root against the alternative of stationarity and P values are parentheses. (***) and (**) denotes that 1% level and 5% level of significance, which are estimated in EVIEWS 8 version.

The table 3 display unit root tests results, by encompassing the ADF (Augmented Dickey and Fuller, 1979), PP (Phillips and Perron, 1988) t-statistics. The unit root tests are performed on the natural logarithm data series. The ADF and PP tests are carried out on the assumption that the null hypothesis of a unit root (non-stationary) is tested against the alternative hypothesis of no unit root (stationary). These tests models are estimated at the levels and first-difference for each case. Our estimated results reveal that all variables are non-stationary (except non-renewable energy consumption) in their level form. However, all the series are stationary at first difference. Thus, we reject the null hypothesis of non-stationary at 1% level, 5% level of significance. Since the results indicate that all of the variables are integrated of same order. Therefore, there may be a cointegration relationship among these variables which can be explored using the Johansen cointegration approach in the following section.

Table 4 Johansen cointegration test results

Hypothesized	Trace test		Max-Eigen test	
No. Of CE(s)	Statistic	Prob. **	Statistic	Prob. **
None*	111.58	0.000**	50.89	0.00**
At most 1*	60.87	0.00**	31.25	0.01**
At most 2	29.42	0.05	17.73	0.14
At most 3	11.04	0.30	10.64	0.17

Note: ** indicates the rejection of the null hypothesis of no cointegration 1 % level of significance levels respectively.

The above Table 4 presents the following the unit root properties, we have estimated the Johansen cointegration test to examine the long run relationship between the renewable consumption, non-renewable energy consumption, economic growth, gross fixed capital formation and labour force in India. Based on the trace statistics and maximum eigenvalue statistics, we have rejected the null hypothesis of no cointegration between the variables at 5 per cent level of significant. We have identified two cointegrating equation among the variables. The results indicate that existence of long run relationship between the economic growth, renewable energy consumption, non-renewable energy consumption, gross fixed capital formation and labour force.

We aim to empirically investigate the short-run and long-run causal relationship between GDP growth, renewable energy consumption, non-renewable energy consumption, gross fixed capital formation and labour force. The dynamic Granger causality tests results on short-run and long-run are presented in Table 5. The short-run Granger causality results display that there is an evidence of a feedback relationship between GDP growth-renewable energy consumption, GDP growth-non-renewable energy consumption.

The short-run causality test results show the unidirectional causality that runs from labor force to GDP growth. We also found one-way causality that runs from GDP growth, non-renewable energy consumption and gross fixed capital formation to the renewable energy while non-renewable energy is also caused by Y, gross fixed capital formation and labour force in the short-run.

The results on long-run (error correction term) causality shows that GDP growth, renewable energy consumption, non-renewable energy consumption, gross fixed capital formation and labour force have bidirectional causality.

Table 5 Granger Causality VECM test results

		ΔY	ΔRE	ΔNRE	$\Delta GFCF$	ΔLF
Short-run Granger causality						
ΔY	F- Statistic		9.464***	2.150*	0.820	5.597***
	Prob.		0.008	0.341	0.663	0.060
ΔRE	F- Statistic	1.857		1.122	4.311***	4.642***
	Prob.	0.395		0.570	0.115	0.098
ΔNRE	F- Statistic	0.640	2.991*		0.418	2.939**
	Prob.	0.725	0.224		0.811	0.230
$\Delta GFCF$	F- Statistic	1.740	3.434***	4.336***		7.265***
	Prob.	0.418	0.179	0.114		0.026
ΔLF	F- Statistic	2.848**	1.168	2.265*	5.751***	
	Prob.	0.240	0.557	0.322	0.056	
Long-run Granger causality						
Ect (-1)	t- Statistic	2.358***	2.296**	2.557***	9.213***	3.714***
	Prob.	0.000	0.000	0.000	0.000	0.001

Note: $Ect(-1)$ represents the error correction term with one lagged period;
Δ represents the first difference;
The optimal lag length is selected based on the AIC;
***, ** & * denote rejection of null hypothesis of no Granger causality at the 1%, 5% and 10% significance levels, respectively.

Table 6 Long-run output elasticities using FMOLS model (dependent variable: Output).

Variables	Coefficient	t- Statistic	Prob.
RE	-1.03	-4.41	0.00
NRE	0.45	1.60	0.12
GFCF	0.32	3.26	0.00
LF	0.92	2.76	0.27
R-squared	0.99		

Notes: FMOLS is fully modified ordinary least square method respectively.

The long-run output elasticities are estimated using fully modified OLS (FMOLS) model. The empirical findings are presented in Table 5. For empirical interpretation, the long-run output elasticities were statistically significant but had negative coefficient (-1.03), it implying that the increase in renewable energy consumption led to decrease in output growth. A 1% increase in non-renewable energy consumption increased output by 0.45. Each of the variables from FMOLS estimations is statistically significant at 1% level. Our findings suggest that India may continue to use non-renewable energy sources for future growth process. The findings on long-run output elasticities suggest that along with traditional inputs such as capital and labour played a significant role in the process of economic development.

5. Conclusion and policy implications

The aim of this study is to examine the nexus among the renewable energy, non-renewable energy consumption and economic growth in India by considering gross fixed capital formation and labour force during 1990-2011. Using Johanson cointegration technique, we find long-relationship among the variables.

The empirical result of cointegration test suggest that a significant long-run equilibrium relationship exists between GDP growth, renewable energy consumption, non-renewable energy consumption, gross fixed capital formation and labour force. This evidence indicates that all of these variables share a common trend in the long-run. The short-run Granger causality results display that there is an evidence of a feedback relationship between GDP growth-renewable energy consumption, GDP growth-non-renewable energy consumption.

The long-run output elasticities were statistically significant but had negative, it implying that the increase in renewable energy consumption led to decrease in output growth, which may cause slow development process with an adverse effect on economic growth. India, energy depending more on coal-based, our findings suggest that India may continue to use non-renewable energy sources for future growth process. The findings on long-run output elasticities suggest that along with traditional inputs such as capital and labour played a significant role in the process of economic development. This study also suggests that government and policy makers should take attention to investment in renewable energy and clean energy for low carbon growth in India.

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