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Identification of Long Run and Short Run Linkage between Energy and GDP towards Carbon Emissions- An Indian Perspective

Dr. Neetu Narwal
Department of Computer Applications
Maharaja Surajmal Institute
New Delhi

Abstract-Energy is the driving force behind the economic growth of any country, and it is said to be coupled with environment degradation. In India, CO2 emission is continuously increasing, and the major contribution lies in coal burning to meet electricity demands. This study is an attempt to analyse the World Bank data pertaining to India in order to find the aggregate effect of different energy sources on economic growth. The results show that energy variables and GDP are cointegrated and hence there exist long term relationship between these variables. The outcomes are evident for existence of both short-term and long-term association of all energy variables and GDP with the carbon emission. This study further analyses the current energy scenario of India and suggests that there is urgent need to Transend towards alternative resources of energy like hydroelectric or nuclear energy.

Keywords-Cointegration, ARDL Error Correction Model, GDP, Electric Power Consumption, Carbon emission, Granger Causality, Electric power consumption, Coal Sources, Hydroelectric Sources, Natural gas sources, Nuclear sources, Oil sources, GDP per capita growth.

I. INTRODUCTION

Climate is the lifeline of our existence as it has a significant effect on sustainability of living beings. India's stake in carbon emission is increasing rapidly which is a matter of great concern. As one of the fastest growing economies, there is an urgent need to change India's environmental policies so that decoupling of economic growth with environmental degradation is realized.

Arto I. et al.[1] in their work stated that developed nations is showing a trend towards decoupling between economic growth and environment degradation. The prominent reason being when the per capita income of a country reaches a threshold level, their focus shifts towards stabilising the environment and hence they use better technology to reduce the effect of greenhouse gas emissions, which results in decoupling.

In this era of industrialization, the primary focus of developing nations is majorly on economic growth but the negative effects of industrialization on environment have been ignored since ages. Particularly in India, with increase in economic growth, there is increase in greenhouse gas emissions that hugely deteriorates the climate in the long run. It is known that the economic growth of any country is influenced by many factors primarily the Foreign Policies, Manufacturing, Trade, Electricity usage etc. It is also historically evident that the usage of electricity by any country is coupled with its economic growth. The developing countries like India, China, Brazil and Egypt are the highest growing economies, and hence have higher energy demands.

These countries have large and growing manufacturing sector, which is less technology efficient as compared to developed economies and are more labour intensive.

This results in more energy requirement and more electricity usage to manufacture goods and services to cater the demands from developed nations and to cater their own needs. Particularly India, in the last few decades has witnessed a prolific economic growth and has gradually increased its energy consumption and electricity production capacity and hence it holds a prominent stake in the global energy market.

When we see the overall picture of India in comparison to the World, in the past few decades India demonstrated major changes in terms of its energy usage, electricity power consumption, manufacturing % of GDP, CO_2 per capita and CO_2 emission % of World. The graph as seen in Figure 1 depicts the overall scenario and portrays that globally India's share of energy usage has increased from 23% in 1990 to 33% in 2014. Manufacturing share of % share in GDP has been gradual but last decade has shown steep incremental trend. In India, the share of agriculture in its economic growth declined from 27% in 1990 to 14% in 2018, and at the same time there was gradual increase in the share of Service Sector from 39% 1990 to 49% 2018.

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The effect of growth in service sector has resulted in increase in average GDP growth rate to 6% and average energy usage growth to 4.75%. In summary, the decline in agriculture and increase in service sector share coupled with economic growth and energy usage has cumulatively affected the CO2 emissions which have increased from 2.63% in 1990 to 6.19% in 2015 as % share in the World.

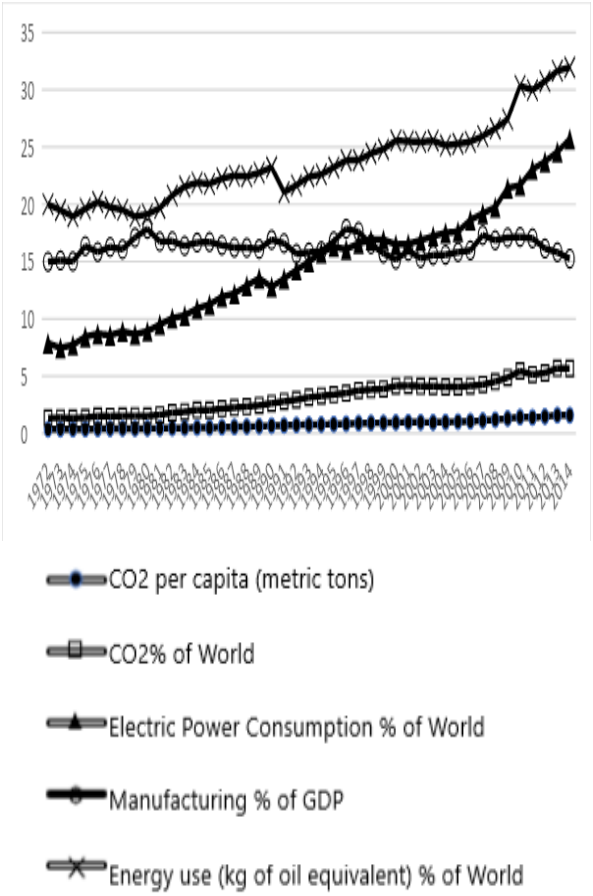

Fig 1. Energy use, manufacturing % of GDP and CO2 Emission in India.
Source: compiled from World Bank data.

India's energy sector is well-endowed with both exhaustible and renewable energy resources. Coal, oil, and natural gas are the three primary commercial energy sources. India's energy policy, till the end of the 1980s, was mainly based on availability of indigenous resources. Coal was by far the largest source of energy and electricity production since past five decades is mostly through coal power plants. Figure 2 shows the share of Total electricity production from various energy sources *viz.*

Oil source, Nuclear sources, Natural Gas, Hydroelectric sources and Coal sources in India from 1971 to 2014 on the basis of World Bank data mentioned in Table 1. It is evident from Figure 2 that the emission of carbon dioxide from combustion of natural gas is 50 to 60% less than coal and oil plants.

Table 1 Total electricity production from different energy sources in India from 1971 to 2014

Energy source under study	Electricity production in 1971	Electricity production in 2014	Trend
Oil source	6.32%	1.76%	↓
Nuclear sources	1.8%	2.8%	↑
Natural Gas	0.56%	4.6%.	↑
Hydroelectric sources	42%	11%	↓
Coal sources	49%	74.5%	↑

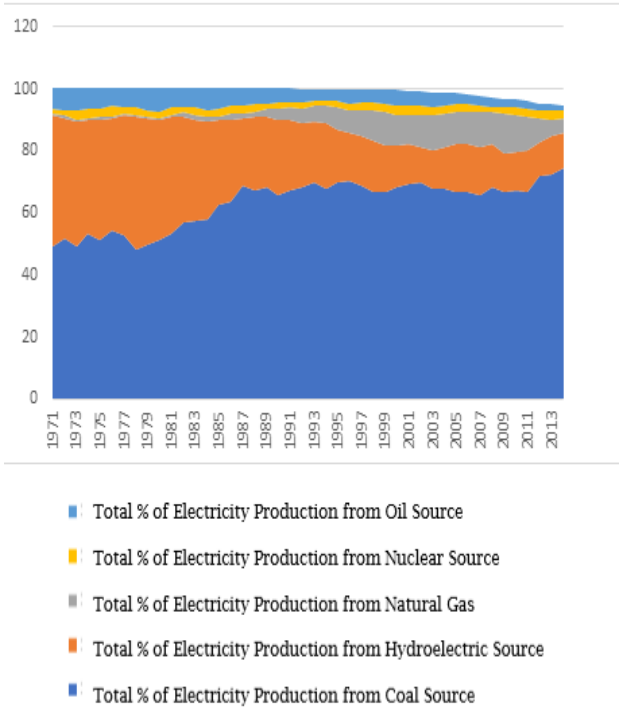

Fig 2. Total electricity production from different energy sources in India from 1971 to 2014.
Source: compiled from World Bank data.

This study tries to analyse the aggregate effect of net electric power consumption in India and disaggregate effect of individual source of electricity production on Carbon emission. The finding from long term effect of different energy sources on pollution will give insight into India's current energy scenario. The objective is to analyse the overall effect of different energy sources and validate the hypothesis that making a shift towards non-renewable energy sources would result in decline in degradation of environment.

The rest of the paper is organised as follows. Section 2 reviews some of the literature work conducted on the similar lines to explore the effectiveness of this research. Section 3 explains the study variables, empirical analysis on ARDL methods and discusses the results. Section 4 presents the conclusion of the research, with certain policy implications.

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II. LITERATURE REVIEW

There are numerous studies conducted on data of different countries to find relation between GDP, energy consumption and CO2 emission. The focus of the studies is different based on the country under consideration i.e., Ang et al. [4] analysed the data of Malaysia, Zhang et al. [5] and Jalil et al. [6] conducted study on the data and found both short run and long run association exist in the study variables in China.

Soytas et al. [7] conducted similar study on the data of USA, Kuo et al. [8] for Hong Kong and Albiman et al. [9] conducted study on data of Tanzania. Ocal et al. [10] studied Turkey; Chindo et al. [11] studied the data of Nigeria. Each result explores different countries with varying economic background, energy usage, environmental policies and their effect on CO_2 emission.

Most of the researchers have emphasised on using single energy source as regressor for CO_2 emission, thereby doesn't provide the disaggregate analysis for energy sources which can help policy makers. Some empirical studies have focussed on Indian Economy. Some of them studied the existence of the Environment Curve and found the relationship among CO_2 emissions, energy consumption and economic growth. Like, Boutabba [12]; Ghosh [13] has witnessed the existence of the Environmental Kuznets Curve (EKC) curve. However, the validity of EKC hypothesis was not confirmed by Mukhopadhyay et al. [14]; Dietzenbacher et al. [15] in Indian scenario.

Similarly, Ghosh [13] also studied the relationships between GDP and CO_2 emissions and found that there exists a long run effect in the study variables. However, their study was on aggregated level hence it could not provide a clear picture on the existence of relationship between CO_2 emissions, energy consumption and economic growth in India because causalities of energy source with CO_2 emissions and economic growth varies with different energy sources.

Some researchers have used non aggregate methods to study the association between CO_2 emissions, energy consumption and GDP. Govindaraju et. al. [16] in their study used coal consumption to explore the association between CO_2 emissions and economic growth for India and China. Their results clearly indicate the existence of feedback effect among CO_2 emissions and GDP and also among coal consumption and CO_2 emissions in India.

Similar study was conducted by Tiwari et al. [17], they also checked the existence of EKC hypothesis in Indian scenario. The effect of Industrialization and coal usage on CO_2 emissions in India and China was studied by Shahbaz et al. [18], their findings show the existence of the EKC curve in China, but it does not exist in India. And also found a unidirectional causality from industrial growth and coal consumption towards CO2 emissions in both the countries.

The long-run and short-run causal relationships among energy consumption, real gross domestic product (GDP) and CO2 emissions was studied by many researchers in Indian scenario. The outcome clearly shows the existence of EKC curve and also proves that there exists long term cointegration among the studied variables. Nain M. Z. et al. [19] and Ahmad et al.[20] used different time period but their results were similar.

Alam et al.[21] have applied a dynamic modeling approach in order to investigate the causality relationships among energy consumption, carbon dioxide emissions and income for India. They have found that there exists bi-directional Granger causality between energy consumption and CO2 emissions in the long-run but neither CO2 emissions nor energy consumption causes movements in real income. Another finding is that there is no causality relationship between energy consumption and income in any direction in the long-run.

In order to discover more on the findings of various authors, we have considered energy variable in disaggregate level *viz.* Electricity production from coal sources, hydroelectric sources, natural gas sources, nuclear sources and oil sources so as to find the effect of each on CO2 emissions in long run as well short run. Also, we have analysed the effect of economic growth and energy consumption at aggregate level as independent variables on CO2 emissions in India.

The outcome of the research states that there exists long term cointegration relation in India with different energy sources, GDP and carbon emission. Furthermore, there exists a bi-directional causal relationship of energy sources with carbon emission. The energy requirement of India is enormous and can't be met with single energy source, so the economy is dependent on crude oil, petroleum, nuclear, natural gas, fossil fuel, renewable energy sources and others. In India, there is prominent use of coal as energy resource since decades, whereas other energy resources are being utilised in negligible proportion as compared to coal. There must be change in the policies adopted by Indian Government to counter the effect of energy usage on environment along with sustainable economic growth.

III. RESEARCH METHODOLOGY

1. Data Collection:

To conduct the empirical analysis, datasets have been collected from the World Bank site for 44 years, from 1971-2014 pertaining to Indian region. The variables are continuous in nature and their description is shown in Table II.

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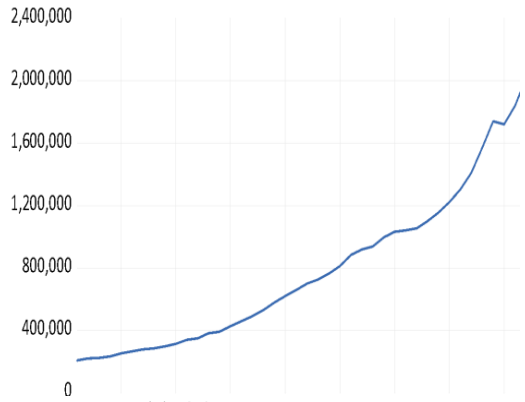
Table 2. Variables used in the study.

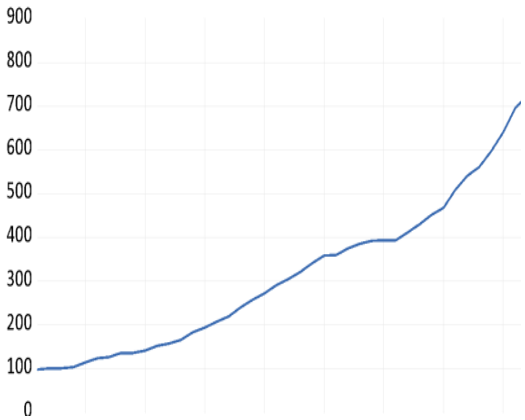
Variable	Explanation
CO	CO2 emissions(kt)
EPC	Electric power consumption(kWh per capita)
EPCO	Electricity production from coal sources(% of total)
EPHY	Electricity production from hydroelectric sources(% of total)
EPNG	Electricity production from natural gas sources(% of total)
EPNS	Electricity production from nuclear sources(% of total)
EPOS	Electricity production from oil sources(% of total)
GDP	GDP per capita growth (annual%)

2. Exploratory data analysis:

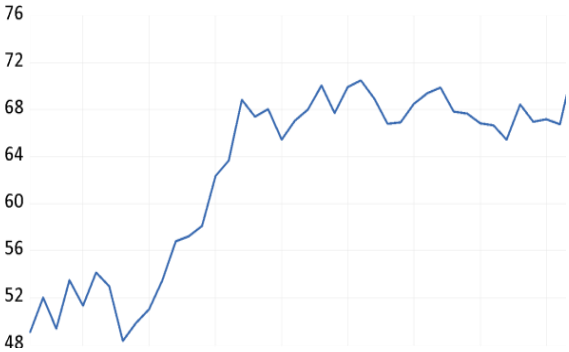
The visualization of trend of the variables under study was plotted, as shown in Figure 3, it was observed that the data has no pattern and are nonstationary in nature. We observed that carbon emission is showing an exponential curve, it has increased ten folds from 1971 to 2014. A positive growing curve for electric power consumption and GDP per capita was also noted.



(a) CO_2 emission .

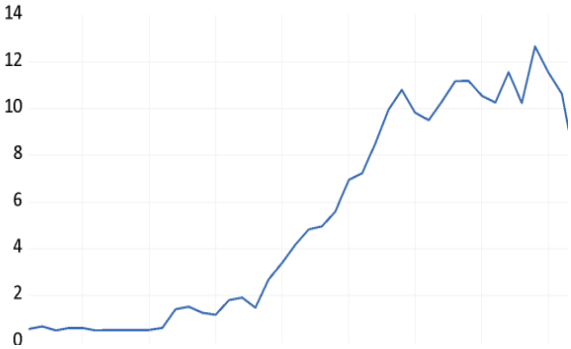


(b) Electric Power Consumption.

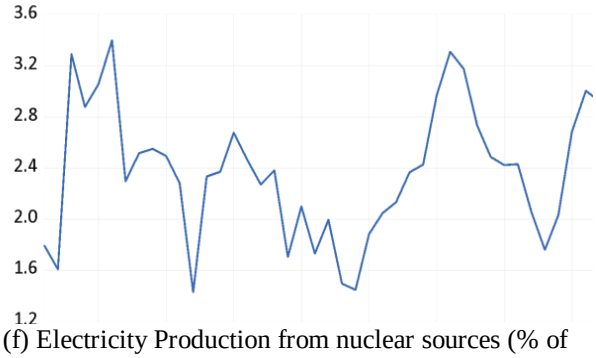


(c) Electricity Production from coal sources(% of Total).

(d) Electricity Production from hydroelectric sources (% of Total).



(e) Electricity Production from natural gas sources(% of Total).



(f) Electricity Production from nuclear sources (% of Total).

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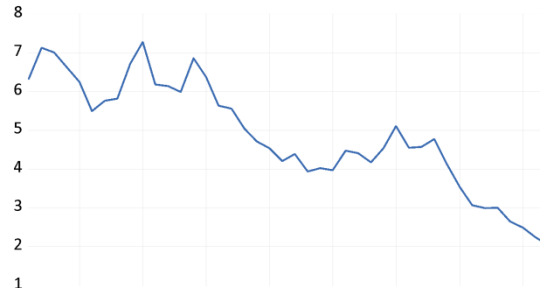

(g) Electricity Production from oil sources (% of Total).

(h) GDP per capita

Fig 3. Trends of all study variables on time series

3. Descriptive Analysis of Variables:

The Descriptive statistics and correlation analysis of the study variables is shown in Table III. It indicates that CO_2 emission, Electric Power Consumption, Electricity Production from hydroelectricity, natural gas and nuclear source, oil source and GDP per capita as per Jarque–Bera statistics are normally distributed.

Table 3. Descriptive Statistics.

	CO	EPC	EPCO	EPHY	EPNG	EPNS	EPOS	GDP
Mean	5.821746	2.445387	1.797122	1.326067	0.485929	0.367390	0.649529	2.600466
Median	5.852044	2.494693	1.825483	1.321103	0.674699	0.380342	0.659427	2.544202
Maximum	6.349933	2.905534	1.872111	1.631783	1.102365	0.531625	0.862093	3.196972
Minimum	5.313591	1.990218	1.684132	1.044546	-0.308224	0.135080	0.247344	2.074097
Std. Dev.	0.310822	0.274709	0.055981	0.199980	0.525197	0.098773	0.161621	0.305116
Skewness	-0.040047	-0.130138	-0.801909	0.162518	-0.363268	-0.433982	-0.856459	0.425498
Kurtosis	1.785407	1.836380	2.106198	1.529958	1.522501	2.494187	2.958188	2.454108
Jarque-Bera	2.716361	2.606552	6.180378	4.155563	4.969908	1.850216	5.382361	1.874021
Probability	0.257128	0.271640	0.045493	0.125208	0.083329	0.396489	0.067801	0.391797
Sum	256.1568	107.5970	79.07339	58.34694	21.38086	16.16516	28.57926	114.4205
Sum Sq. Dev.	4.154254	3.245006	0.134758	1.719655	11.86075	0.419516	1.123215	4.003110

	CO	EPC	EPCO	EPHY	EPNG	EPNS	EPOS	GDP
CO	1							
EPC	0.998138	1						
EPCO	0.865056	0.880289	1					
EPHY	-0.963109	-0.958670	-0.901355	1				
EPNG	0.919616	0.920698	0.877464	-0.946360	1			
EPNS	0.091329	0.067517	-0.075082	-0.144310	-0.045970	1		
EPOS	-0.905905	-0.905146	-0.713929	0.804876	-0.724471	-0.068738	1	
GDP	0.954314	0.949212	0.746335	-0.866446	0.791040	0.154564	-0.920244	1
Observations	44	44	44	44	44	44	44	44

The correlations analysis describes that CO_2 emission is positively correlated with most of the variables viz. Electric Power Consumption, Electricity Production from coal source, natural gas, nuclear source and GDP per capita. However, Electricity Production from hydroelectricity and oil source are negatively correlated to CO_2 emission.

4. Objective Function:

This study tries to analyse the aggregate effect of net electric power consumption in India and disaggregate effect of individual source of electricity production on Carbon emission. The objective of the study is two fold, first, to find relation between energy production sources in India like oil, natural gas, hydro, nuclear, power consumption, economic growth and their impact on CO2 emission. Second, to validate the hypothesis that making a shift towards non-renewable energy sources would result in decline in degradation of environment.

The objective function of the research has been formulated as given below:

$$CO_2 = f(EPC, EPCO, EPHY, EPNG, EPNS, EPOS\ GDP) \quad (1)$$

The description of all these variables has already been shown in Table II.

The objective function can be written in the given mathematical equation and is used to examine the relation between independent variable and dependent variables in India:

$$CO_{2t} = \alpha_0 + \beta_1 EPC_t + \beta_2 EPCO_t + \beta_3 EPHY_t + \beta_4 EPNG_t + \beta_5 EPNS_t + \beta_6 FEPOS_t + \beta_7 GDP_t + \varepsilon_t \quad (2)$$

For the model the equation is transformed into their natural logarithm form to produce the log-linear model which is represented in Equation 3. The logarithmic form is used to address the problem of heteroskedasticity.

$$\ln CO_{2t} = \alpha_0 + \beta_1 \ln EPC_t + \beta_2 \ln EPCO_t + \beta_3 \ln EPHY_t + \beta_4 \ln EPNG_t + \beta_5 \ln EPNS_t + \beta_6 \ln EPOS_t + \beta_7 \ln GDP_t + \varepsilon_t \quad (3)$$

Where*t* is the time dimension; α_0 is the constant intercept; and β_1 to β_7 is the coefficient of all the variables used in the model that are described in Table II.

IV. RESULTS AND DISCUSSION

We have used ARDL for testing the cointegration between the study variables. Since cointegration has been found, we have further applied Error Correction Model in order to gauge the existence of long term and short-term association between the dependent variable Carbon emission and the independent variables used in this study.

To begin with, the stationarity test has been applied on the study variables. The stationarity can be visualised by time series chart and also it can be analysed empirically with unit root tests.

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1. Stationarity of the time series data:
To formally check the stationarity of the study variables in time series, the visual representation of these variables is done as shown in Figure 3, and it clearly shows that all the study variables are non-stationary in nature. The time series plot of CO_2 emission, Electric Power Consumption, Electricity Production from coal and GDP per capita shows upwards trend, whereas Electricity Production from hydroelectricity and oil source show negative trend. However, Electricity Production from natural gas and nuclear source shows mixed trend.

To empirically analyse the stationarity of the study variables, a Unit root test is performed on all the study variables at level. Unit root indicates that a given series is not constant with time, which is the condition for stationarity of time series.

The mathematical representation of time series is as follows:

$$y_t = a_n * y_{t-n} + \Sigma\, \varepsilon_{t-i} * a_i \qquad (4)$$

If the value of a is 1 in the equation (4), then the y at time t will be equal summation of y_{t-n} and sum of all errors from t-n to t.

ADF (Augmented Dickey Fuller) Test is most popular unit root test which determines the presence of unit root in the series. The test statistics value returned by the ADF test determines whether it fails to reject the null hypothesis or not.

The null and alternate hypothesis of ADF tests is stated as follows:

- Null Hypothesis: The series has a unit root (value of a=1)
- Alternate Hypothesis: The series has no unit root.

According to test statistics value if we fail to reject the null hypothesis, it means the series is non-stationary and has a unit root. If the value of the test statistic is found to be less than the critical value at 1% or 5% level, the null hypothesis is rejected, and the series is said to be stationary. Contrary, test fails to reject the null hypothesis and the series is said to be non-stationary.

The empirical evaluation of ADF unit root test at level and first difference and comparison with Critical Value at 1%, 5% and 10% significance are shown in Table IV. It has been observed that all the study variables at level have test-statistics value greater than critical value at 1% level, and hence the null hypothesis is accepted and it is concluded that at level all the study variables are non-stationary. Further, First Differencing which is one of the most common methods of dealing with both trend and seasonality is applied on these variables and they are tested for stationarity again.

The results showed that all variables are found to be stationary at their first difference.

Table 4. ADF Unit Root Test results with level and first difference.

	At level		At First Difference	
Variables	ADF t-statistics	p-Value	ADF t-statistics	p-Value
CO	0.310177*	0.9762	-6.332293**	0.0000
EPC	-0.317644*	0.9135	-5.064004**	0.0001
EPCO	-1.464897*	0.5416	-3.849350**	0.0052
EPHY	-0.744848*	0.8242	-7.371536**	0.0000
EPNG	-1.376424*	0.5849	-5.626048**	0.0000
EPNS	-0.963976*	0.7548	-4.230797**	0.0022
EPOS	1.176557*	0.9975	-5.933463**	0.0000
GDP	0.235257*	0.9718	-5.877105**	0.0000

* ADF t-statistics value is greater than 1%,5%, 10% critical value. Hence accepts the Null hypothesis and conclude series is non-stationary.
** ADF t-statistics value is less than 1%,5%, 10% critical value. Hence accepts the reject Null hypothesis and conclude series is stationary.

2.Test of Cointegration and Error Correction Model:
The outcome of ADF unit root test, clearly states that all the study variables become stationary at their first difference I(1) and hence the series is stable at first lag. Therefore, the ARDL approach can be employed for examination. The next step is to find whether there exist any cointegration among the dependent and the independent variables.

The mathematical equation of an ARDL model is specified as:

$\Delta lnCO2 = a0 + i=1 pa1j\ \Delta lnCO2\ t-i + i=1q1a2j\ \Delta lnEPC\ t-i + i=1q2a3j\ \Delta lnEPCO\ t-i + i=1q3a4j\ \Delta lnEPHY\ t-i + i=1q4a5j\ \Delta lnEPNG\ t-i + i=1q5a6j\ \Delta lnEPNS\ t-i + i=1q6a7j\ \Delta lnEPOS\ t-i + i=1q7a8j\ \Delta lnGDP\ t-i + a9\Delta lnCO2\ t-1 + a10\ lnEPC\ t-1 + a11\ lnEPCO\ t-1 + a12\ lnEPHY\ t-1\ a13\ lnEPNG\ t-1 + a14\ lnEPNS\ t-1 + a15\ lnEPOS\ t-1 + a16\ lnGDP\ t-1 + et$ (5)

Where, Δ denotes the difference operator.

The ARDL methodology [22] was designed by Pesaran et al. to estimate the long-run and short-run elasticities among the given time series data. The ARDL model provides better results when the size of observation is small, and the variables are integrated at I (0) or at I (1). In order to determine whether there exists cointegration among the data series, we applied the ARDL bound cointegration test [23].We used F-statistics to determine whether there exists cointegration among the study variables.

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The Null Hypothesis for testing cointegration among the variables is given below:

H0: $a_9=a_{10}=a_{11}=a_{12}=a_{13}=a_{14}=a_{15}=a_{16}=0$
Against H1: $a_9\neq a_{10}\neq a_{11}\neq a_{12}\neq a_{13}\neq a_{14}\neq a_{15}\neq a_{16}\neq 0$

Which is denoted by f(CO_2(CO_2 | EPC,EPCO, EPHY, EPNG, EPNS, EPOS, GDP))

If the F-statistics value falls within the limit of I(0) and I(1), inference of cointegration existence in study variable remains inconclusive. If F-statistics is above the I(0) and I(1) values then there exists a cointegration and if F-statistics is below I(0) and I(1), there is no cointegration among the variables.

The outcomes of the ARDL bound cointegration test is shown in Table V. The F-statistics value is 4.38 which is greater than Upper Bound I(1) at both 1 and 5 percent level of significance i.e. 4.26 and 3.5 respectively. The outcome of bound test concludes that there is presence of long-run association among the study variables. The optimal lag of variables is ARDL (1, 1, 3, 2, 3, 0, 0, 2), which used the Akaike Information Criterion (AIC) lag specification for lnCO_2 as dependent variable.

Table 5. Results of ARDL bound cointegration test.

Variable	lnCO_2		
Optimal lag structure	(1,1,3,2,3,0,0,2)		
F-statistics	4.382906***		
Critical value (%)	1	5	10
Lower bounds I(0)	2.96	2.32	2.03
Upper bounds I(1)	4.26	3.5	3.13
Diagnostic tests	Statistics		
R^2	0.999644		
Adj R^2	0.999323		
F^2 statistics	4.382906***		
χ^2 NORMAL	0.858619(0.650959)		
χ^2 SERIAL	1.366690(0.2848)		
χ^2 HETEROSKEDASTICITY	1.168456(0.3627)		

Notes: **,*** denotes the probability and the significant levels at 5 and 1 percent, respectively.

Further, since there exist long term cointegration, we must analyse the Error Correction model (ECM) to find how long-term equilibrium is achieved by normalising the dependent variable.

The mathematical equation for ARDL Error Correction Model is as mentioned:

$$\Delta lnCO2 = a0+\sum_{i=1}^{p} a1j\ \Delta lnCO2\ t\text{-}i+\sum_{i=1}^{q} a2j\ \Delta lnEPC\ t\text{-}i+\sum_{i=1}^{q} a3j\ \Delta lnEPCO\ t\text{-}i+\sum_{i=1}^{q} a4j\ \Delta lnEPHY\ t\text{-}i+\sum_{i=1}^{q} a5j\ \Delta lnEPNG\ t\text{-}i+\sum_{i=1}^{q} a6j\ \Delta lnEPNS\ t\text{-}i+\sum_{i=1}^{q} a7j\ \Delta lnEPOS\ t\text{-}i+\sum_{i=1}^{q} a8j\ \Delta lnGDP\ t\text{-}i+\alpha\ ECMt\text{-}1+et \quad (6)$$

Here the coefficients a1j, a2j, a3j, a4j, a5j, a6j, a7j, a8j are the short run coefficients. In the outcome, if the value of ECM_{t-1} is negative and significant at 1% or 5% level, it means that any long-term disequilibrium between the regressors and the dependent variable will congregate at the rate of coefficient α to achieve the long-term equilibrium.

The result of ARDL Error Correction Model is shown in Table VI (Panel A and Panel B). It shows the long term and short-term association between the dependent variable Carbon emission and the independent variables used in the study.

Panel A shows the long-term association results. It is found that four of the seven variables are statistically significant and affect the CO_2 emission in long run. The following information can be inferred from the long run coefficients.

- One percent increase in Electric power consumption leads to 0.59 percent increase in CO_2 emission.
- GDP is positively and significantly associated with CO_2 emission, as one percent increase in GDP per capita result in 0.19 percent increase in CO_2 emission.
- Electricity production from natural gas is significant and has positive effect on CO_2 emission. A one percent increase in electricity production from natural gas results in 0.06 percent of CO_2 emission.
- A one percent increase in electricity production from hydroelectric sources (% of total) has negative influence on CO_2 emission hence result in decrease in 0.23 percent of CO_2 emission.

Panel B in Table VI shows the outcome of Error Correction Model. The nine out of fourteen lagged variables have high short run significance for CO_2 emission. The observations are as follows..

- It is noted that a one percent increase in GDP per capita raises 0.067 percent CO2 emission.
- In short-run estimation, the effect of electric power consumption, electricity production from hydroelectric sources (% of total), coal source(% of coal), natural gas(% of total), oil source (% of total) as highly significant impact on CO_2 emission.
- Electricity production from nuclear source doesn't have short run significance on CO_2 emission.

According to the ARDL result as shown in Table VI, the error correction term (ECT_{t-1}) is negative and is statistically significant at 1 percent level. The coefficient of ECT_{t-1} is -0.8398, which shows that there exist a long term relationship amongst variable and the how long run equilibrium can be achieved at the speed of 83.9%, which is highly significant.

In order to check the validity of model, the residual diagnostics test was performed whose results are shown in

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Panel C of Table VI. The results clearly support the ECM model and its creditability. The R^2 value and adjusted R^2 value is 85.03% and 75.05% respectively, which confirms that the model is good fitted and can be relied upon. The model gives calculated F-statistic as 8.5213 which is significant at 1% level and proves the reliability of the model.

In addition to all tests done and discussed, various diagnostics tests have also been performed to testify the stability of the Model. The Serial Correlation is testified by performing Breuch Godfrey LM test and the value obtained for the model is 1.3667 (0.2848) which shows that there exists no serial correlation among the study variables. The Jarque–Bera normality test is performed on the Model, the value obtained is 0.8659(0.6509) which is positive and shows that data in model is normally distributed.

The study also performed Breusch-Pagan Godfrey heteroskedasticity and the value obtained is 1.1685 (0.3627) which states that there is no heteroskedasticity observed in the model.Hence the entire diagnostics test proves that model is highly significant, and highly reliable.

Table 6. The outcomes of ARDL method : long-run and short-run coefficients.

Dependent variable is lnCO2: ARDL(1, 3, 2, 2, 3, 2, 0, 2) selected based on AIC				
Variable	Coefficient	SE	T-ratio	p-value
Panel A: long run estimation				
lnEPC	0.595354***	0.140813	4.227976	0.0006
lnGDP	0.191469**	0.056170	3.408743	0.0033
lnEPCO	0.017966	0.235461	0.076302	0.9401
lnEPHY	-0.229903**	0.082241	-2.795481	0.0124
lnEPNG	0.057937**	0.023614	2.453542	0.0252
lnEPNS	-0.049819	0.032922	-1.513237	0.1486
lnEPOS	-0.073969	0.064007	-1.155642	0.2638
Panel B : short run estimation-				
Constant	3.539802***	0.550387	6.431473	0.0000
ΔlnEPC	0.019478	0.117600	0.165627	0.8704
ΔlnEPC t-1	-0.132041	0.149722	-0.881911	0.3901
ΔlnEPC t-2	-0.294858**	0.109440	-2.694248	0.0154
ΔlnGDP	0.067870**	0.032677	2.076974	0.0533
ΔlnGDP t-1	-0.062486	0.039300	-1.589997	0.1303
ΔlnEPCO	-0.303322**	0.108542	-2.794517	0.0124
ΔlnEPCO t-1	0.228031	0.120082	1.898958	0.0747
ΔlnEPHY	-0.217538***	0.045711	-4.759030	0.0002
ΔlnEPHY t-1	0.149646**	0.046268	3.234315	0.0049
ΔlnEPHY t-2	0.151598***	0.033367	4.543298	0.0003
ΔlnEPNG	0.016193	0.012451	1.300561	0.2108
ΔlnEPNG t-1	-0.027518**	0.012141	-2.266636	0.0367
ΔlnEPOS	-0.116012**	0.037224	-3.116601	0.0063
ΔlnEPOS t-1	0.104311**	0.034934	2.985979	0.0083
Dummy08	0.022431***	0.004557	4.922513	0.0001
ECT t-1	-0.839822***	0.130988	-6.411448	0.0000
Panel C : Residual diagnostic tests				
R^2	0. 850319			
Adj R^2	0. 750532			
Durbin-Watson stat	2.483320			
F- statistic	8.521342***			
χ^2 NORMAL (Jarque-Bera)	0.859619(0.650959)			
χ^2 SERIAL Correlation (Breuch-Godfrey LM Test)	1.366690 (0.2848)			
χ^2 Heteroskedasticity (Breusch-Pagan Godfrey)	1.168456 (0.3627)			
Note: *** Significant at 1%, ** Significant at 5%				

Above all test prove that model is highly significant and can be used for forecasting. The model is finally tested for its stability using the cumulative sum recursive residuals (CUMSUM) and the cumulative of square of recursive residuals (CUMSUMSQ) to investigate the stability of long- and short-run parameters.

The plots of CUMSUM and CUMSUMSQ values are shown in the Figure 4 and Figure 5 and clearly indicate critical boundaries of 5% significance. Hence the model is stable and is good fit.

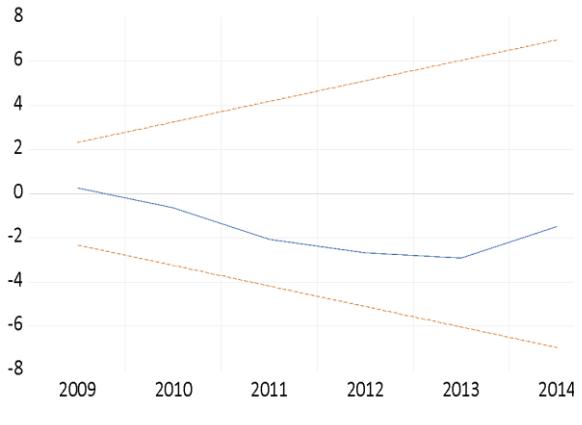

Fig 4. Plot of cumulative sum of recursive residuals.

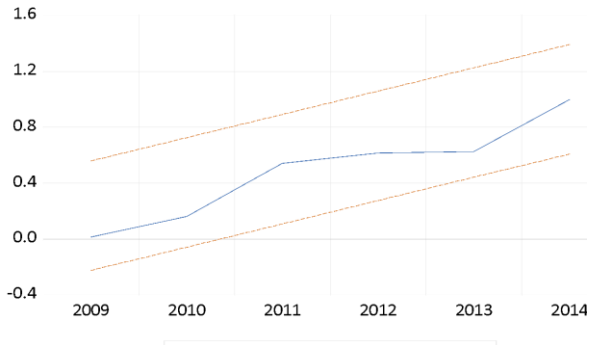

Fig 5. Plot of cumulative sum of squares of recursive residuals.

We also performed pairwise Granger Causality Test, which is a statistical hypothesis test to determine whether the time series is useful for forecasting another. The high probability value rejects the Null Hypothesis: that there doesn't exist causal relationship.

The results of Granger Causality Test and their probability values are shown in Table VII, and the findings are explained below: -

- There exists uni-directional causality between Electric power consumption towards Carbon emission.
- There exists uni-directional causality between GDP towards Carbon emission.
- There exists no causality between Carbon emission and rest of the six independent energy variables

Table 7. Pairwise Granger Causality.

Pairwise Granger Causality	Probability	Casuality
EPC -> CO CO<- EPC	0.0044* 0.3947	Uni-directional
EPCO ->CO CO-<EPCO	0.4398 0.8770	-
EPHY -> CO CO <- EPHY	0.2219 0.7573	-
EPNG -> CO CO <- EPNG	0.8164 0.6591	-
EPNS -> CO CO <- EPNS	0.2621 0.8377	-
EPOS -> CO CO<-EPOS	0.1842 0.5175	-
GDP->CO CO<-GDP	0.0589* 0.5852	Uni-directional

* Null Hypothesis is rejected and we say there don't exist causal relationship

V. CONCLUSION AND POLICY IMPLICATIONS

The empirical study conducted using ARDL Econometric Model on various parameters viz. Electricity Sources, Economic growth and CO_2 emission on the time series data of India from 1971 to 2014. The results revealed that there exist both long term and short-term association between these study variables. There is evidence that Electricity from Hydroelectric sources has long term negative effect on CO_2 emission. However, the Electricity from Nuclear Sources doesn't seem to have long and short-term relation to CO_2 emission.

This result may be due to its minimal share in total energy usage. The result of this study further strengthens the statement by Niti Aayog that government polices need to focus on increasing non-renewable energy share in the total energy consumption to decrease the effect on CO_2 emission.

Following policy implications have been suggested based on the outcome of the study:

- We need to look for alternate resource of energy other than coal as the presence of cointegration among the variables has been observed. India's fast-growing economy and its economic activities validate the fact that we are moving towards more energy consumption.
- Indian government must pay attention towards making a shift from coal to PNG or LPG usage in rural household. Coal is still a major source of energy in rural segment of India which accounts for 70% of total population. Since the share of coal usage is increasing at a rapid rate which was 49% of the total share of energy production in 1971 and has increased to 74.5% in 2014.
- India must plan to shift towards nuclear energy sources, which is one of the non-renewable as well as environment friendly resources. In long run, it will have a negative relation with carbon emissions though we could not establish a clear relation at present. The valid reason being its negligible share in total electricity production.
- Government needs to invest more on hydroelectricity projects, as the result clearly validates the fact that hydroelectricity source cause negative effect on carbon emissions which is need of the hour.

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