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Study of EKC Hypothesis and Long Run and Short Run Linkages between CO_2 Emission, GDP, Coal Consumption, power Consumption and Renewable Energy in India

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Abstract-In this paper we used most recent and robust econometric technique for estimation of cointegration to provide decisive proof on the linkage between CO_2 emission, electric power consumption, electricity production from coal source, renewable energy consumption and economic growth in India from 1971-2014. Furthermore, the study also explored the Granger causality among the variables. The empirical result suggest that the variables are cointegrated and hence suggest the existence of long term relationship between the variables. Granger Causality test reveals strong evidence of bi-directional causality from CO_2 emission and renewable energy consumption as well as unidirectional causality from GDP, electricity production from coal source, electric power consumption to carbon emission. The implication of the results is further discussed.

Keywords- ARDL Error Correction Model, Environment Pollution, Johansen Cointegration, Granger Causality, EKC hypothesis.

I. INTRODUCTION

Coping with the development goals, countries generally face dilemma in choosing between policies favouring economic growth over environmental sustainability. It is prominent in developing economies like China and India, where energy usage has increased over the years as does the economic growth. This study focusses on India which is the fast growing economy in the world and tries to find the conclusive evidence how the policies can be amended to go with the sustainable development. Energy is an important factor contributing towards economic development. In India coal is the prominent source for energy and in terms of total energy it is nearly 75% in 2015. Any effort made to lessen it may have unswerving effect on the economic growth. However, renewable energy percentage to total energy usage is merely 5.3% , though we have observed its increasing trends in the past years. Figure 1 shows the increasing trend of these variables in the past forty four years. This study comes up at specific time when India has recorded 7.4% annual growth in GDP and the consumption of coal is ever increasing and making it one of the third largest consumer of energy in the world. In contrary, the pressure on countries to reduce CO_2 is ever increasing after signing of the Kyoto protocol by United Nations Climate Change, (United Nation Climate Change : Kyoto Protocol - Targets for the first commitment period) and Paris Climate Agreement signed in

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2015 (United Nation Climate Change: Paris Agreement).
So, the biggest challenge is to maintain the economic growth while keeping CO_2 emission, electricity production from coal, electric power consumption at the acceptable level so that any policy change made for reducing the power consumption or replacing the coal usage should not disturb the growing trend of economic growth especially if there is long run causal relationship between economic growth, electricity production from coal, electric power consumption and CO_2 emission.

Therefore, the question arises. Will the economic growth suffer if the coal consumption is controlled? Whether policy makers move towards alternative sources of energy? Whether increase use of technology leads to smart use of energy? Whether we will witness renewable energy as an alternative? These questions are important for the policymakers, and it will allow better formulation of policy and investment in building infrastructure for renewable energy sources.

There are many researchers who have focussed in finding the nexus between CO_2 emission, GDP and energy. Some of them have used coal, trade, population as the variable to find the relationship. There are few research gaps that exists. First, from Indian perspective we find very less research has been done to explore the effect of coal and renewable energy on the GDP and CO_2. Second, the electric power consumption as factor contributing to economic growth and CO_2 emission can't be ignored. Third, effect of electricity production from coal sources has direct effect on GDP and CO_2 emission which needs to be ascertain. Fourthly, we found that ARDL was the most prominently used method for exploring long term relationship and finding cointegration in Indian research. So, the study used Johansen cointegration to validate the results of ARDL. Some of the studies have not performed EKC curve analysis on the due to high multi collinearity among the exploratory variables. We overcame this problem by conducting EKC analysis between carbon emission, electricity production from coal sources, electric power consumption and GDP in each model.

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.

II. LITERATURE REVIEW

A great volume of work done on the existence of EKC hypothesis between economic growth and environmental variable in various countries. The concept of EKC hypothesis, showing linkage between GDP and environment variable was formulated by Grossman and Kreuger (1991) while analysing impact of economic growth and environment quality. The EKC hypothesis has been tested by several researchers a) for different countries b) for different explanatory variables c) different econometric methods and techniques.
As focus of our study is to analyse the EKC existence of CO_2 emission as environment parameter along with economic growth and renewable energy source. The seminal work of Richmond and Kaufmann (2006) is considered to be the earliest studies which used renewable energy source as explanatory variable along with economic growth to study the effect on CO_2 emission. Their study was conducted on numerous countries and found the existence of inverted U shaped curve in few countries. We found number of studies have used renewable energy as exogenous variable in finding existence of EKC.

The estimation of EKC hypothesis for Korea was conducted by Baek and Kim (2013) for the period of 1975 to 2006. Their tests revealed the existence of inverted U shaped curve in Korean economy bu the turnaound point was found to be beyond the sample size.

Sulaiman et al. (2013) tests also revealed the existence of EKC hypothesis in Malaysian economy

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during the period of 1980 to 2009 and the turnaround point was found to be at $8.77K which was also beyond the sample space. Similarly B€olük et.al (2015) also analysed EKC for Turkey economy and similar results were found having turnaround point beyond the sample space.

Jebli et al. (2015) also analysed the existence of EKC in Tunisia economy, they have used ARDL approach in their study and revealed the existence of the U shaped curve and turnaround point was between $2878.6 and $3259.37.

In India, Boutabba (2014); Ghosh (2010) has witnessed the existence of the Environmental Kuznets Curve (EKC) curve both used ARDL bound Cointegration approach in their study.

However, the validity of EKC hypothesis was not confirmed by Mukhopadhyay et al. (2005); Dietzenbacher et al. (2007) in Indian scenario. Govindaraju et. al. (2013) 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. (2013), they also checked the existence of EKC hypothesis in Indian scenario. The effect of Industrialization and coal usage on CO2 emissions in India and China was studied by Shahbaz et al. (2015), 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 CO_2 emissions in both the countries.

In this study we have used renewable energy consumption, electricity production from coal sources, electric power consumption and as exogenous variable to study the EKC hypothesis in India. Most of the studies of existence of EKC in developing countries have used renewable energy source as exogenous variable. India is the growing economy, and its energy demand is third highest in the world. It is important to incorporate the renewable energy source while analysing the EKC hypothesis and its existence. This study has also realised long run and short run association between CO_2 emission, energy consumption and economic growth in Indian scenario.

The long-run and short-run causal relationships among energy consumption, real gross domestic product (GDP) and CO_2emissions 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. (2015) and Ahmad et al. (2016) used different time period but their results were similar. Alam et al. (2011) 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 as well as long run effect of energy consumption on environment variable CO_2 emissions is observed. But both these variables do not cause any effect on GDP. Another finding is that there exists no causality amongst energy consumption and income in any direction.

III. DATA MODEL AND ECONOMETRIC METHODS

Data and Empirical Model

The model used the annual data of CO2 emission (kt), per capita GDP, Electric power consumption (kWh per capita), Renewable energy consumption (kWh per capita), electricity production from coal. The study data is downloaded from the World Bank Data repository for India (https://data.worldbank.org/country/india?view=chart) from 1971-2014. All variables are converted to natural logarithms for empirical analysis of growth. Existing literature on carbon emission, economic growth, energy production from coal and energy consumption are considered as major determinants of pollution. The EKC hypothesis from the previous studies suggests the existence of non linear relationship between these determinants. According the EKC hypothesis the economic growth should show inverted U shape relationship to CO_2 emission.

This study has used the renewable energy consumption as exogenous variable to find its effect on environmental pollution levels in India. The share of renewable energy consumption out of total energy consumption has shown a raise in the past few years. Therefore, its impact on the environment pollution needs to be explored. Based on the above conclusion, we proposed two econometric model are considered in the study are

$$\ln CO_{2t} = \alpha_0 + \beta_1 \ln GDP_t + \beta_2 \ln Ren_t + \varepsilon_t \quad (1)$$

$$\ln CO_{2t} = \alpha_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP^2{}_t + \beta_3 \ln Ren_t + \varepsilon_t \quad (2)$$

The first model represented as Equation 2 is based on the EKC framework that was suggested by Panayotou (1993) in their work and Equation 1 shows the basic model used in this study.

The equation can predict different outcomes based on the coefficients of the explanatory variables.

- $\beta_1 = \beta_2 = 0$ it implies that the economic growth has no impact on CO_2 emissions.
- $\beta 1 > 0$ and $\beta_2 = 0$ implies that the economic growth has gradually increasing and positive effect on CO_2 emissions.
- $\beta_1 < 0$ and $\beta_2 = 0$ implies that the economic growth has gradually decreasing and negative effect on CO_2 emissions.
- $\beta 2 < 0$ implies that the economic growth and CO_2 emission takes the inverted U shaped form.
- $\beta 2 > 0$ implies that the economic growth and CO_2 emissions takes the U shaped form.

In this case the fourth scenario purely depicts the EKC existence in the country and it achieves a turnaround point when alternative source of energy is identified or any other reason leading to improvement in the environment conditions is met.

In order to elucidate the economic growth elasticity to pollution. The model given by Narayan (2009) and Jalil et al. (2009) is used and it is shown Equation 1. The expected positive effect of renewable energy on CO_2 emission can be see with negative sign of $\beta 2$.

There exist several issues in EKC estimation, the major one being omitted variable bias as suggested by Stern (2004), alongwith scale effect, constitution effect, technique effect, which was suggested in literature by Grossman and Kruegar (1991). In order to address the above issues, we have incorporated energy consumption (kWh per capita), electricity production from coal sources in our model.

Energy consumption effects the GDP by rise in the production and manufacturing process and its cumulative effect is observed in the rise of environment pollution. In this way energy consumption shows a negative effect of the CO_2 emissions. Coal being the major share of energy generation in India, its effect on CO_2 emission is prominent and negative.

In order to analyse their effect on environment degradation, we have considered four case models in our study.

Model 1: Linear EKC without Coal and Energy

Model 2: Quadratic EKC without Coal and Energy

Model 3: Linear EKC with Coal and Energy

Model 4: Quadratic EKC with Coal and Energy

The equation for Model 3 and 4, are represented as:

$$\ln CO_{2t} = \alpha_0 + \beta_1 \ln GDP_t + \beta_2 \ln Ren_t + \beta_3 \ln EPC_t + \beta_4 \ln Coal_t + \varepsilon_t \quad (3)$$

$$\ln CO_{2t} = \alpha_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP^2{}_t + \beta_3 \ln Ren_t + \beta_4 \ln EPC_t + \beta_5 \ln Coal_t + \varepsilon_t \quad (4)$$

In this study all four models were analyzed to show the effect of these variables on the environment degradation.

Cointegration Test

The Cointegration test is generally used to find the relationship between study variables, in this study we used it for finding relationship between economic growth and other parameter on the environment quality. We have employed two cointegration test to confirm the validity of the result, Johansen Cointegration and ARDL bound cointegration approach suggested by Pearson (1999,2001) . These methods are proficient in handling small sized sample, which is true in our case of sample size equals 44. In the process of assessing the linkage between economic growth, carbon emission and other variables, we needed to assess the long run and short run elasticities. We used ARDL model for study. The equation for ARDL Model (Case 4) for testing cointegration and long and short run estimation is specified as

$$\Delta lnCO_2 = a_0 + \sum_{i=1}^{p} a_{1j}\, \Delta lnCO_{2\,t-i} + \sum_{i=1}^{q1} a_{2j}\, \Delta lnGDP_{t-i} + \sum_{i=1}^{q2} a_{3j}\, \Delta ln\ GDP^2{}_{t-i} + \sum_{i=1}^{q3} a_{4j}\, \Delta lnRen_{t-i} + \sum_{i=1}^{q4} a_{5j}\, \Delta lnEPC_{t-i} + \sum_{i=1}^{q5} a_{6j}\, \Delta lnCoal_{t-i} + a_7\, lnGDP_{t-1} + a_8\, lnGDP^2{}_{t-1} + a_9\, lnRen_{t-1} + a_{10}\, lnEPC_{t-1} + a_{11}\, lnCoal_{t-1} + e_t \quad (5)$$

Where, Δ denotes the difference operator.
Where, a1 to a6 are short run estimates and a7 to a11 are long run coefficients. The study conducted two tests for finding the existence of cointegration among study variables using Johansen Cointegration as well as ARDL bound Cointegration, the critical value of F-statistics is used in both the tests for confirmation of cointegration. The values are segregated by integration between the variables i.e., the critical values are computed for I(0) and I(1). In these models we reject the null hypothesis of no cointegration if the critical value of F-statistics is outside the lower and upper bound. Otherwise, we accept the null hypothesis that there exists no cointegration among variables.

Further, we need to find the appropriate lag length for each variable used in the study. We have used the Akaike Information Criterion(AIC) for finding the suitable lag length for our models. Once we found the cointegration among the variables , the model is tested for long run estimation.

$$\Delta lnCO_2 = a_0 + \sum_{i=1}^{p} a_{1j}\, \Delta lnCO_{2\,t-i} + \sum_{i=1}^{q1} a_{2j}\, \Delta lnGDP_{t-i} + \sum_{i=1}^{q2} a_{3j}\, \Delta ln\ GDP^2{}_{t-i} + \sum_{i=1}^{q3} a_{4j}\, \Delta lnRen_{t-i} + \sum_{i=1}^{q4} a_{5j}\, \Delta lnEPC_{t-i} + \sum_{i=1}^{q5} a_{6j}\, \Delta lnCoal_{t-i} + e_t \quad (6)$$

After estimating Eq (6) , the model is tested for short run estimation with equation

$$\Delta lnCO_2 = a_0 + \sum_{i=1}^{p} a_{1j}\, \Delta lnCO_{2\,t-i} + \sum_{i=1}^{q1} a_{2j}\, \Delta lnGDP_{t-i} + \sum_{i=1}^{q2} a_{3j}\, \Delta ln\ GDP^2{}_{t-i} + \sum_{i=1}^{q3} a_{4j}\, \Delta lnRen_{t-i} + \sum_{i=1}^{q4} a_{5j}\, \Delta lnEPC_{t-i} + \sum_{i=1}^{q5} a_{6j}\, \Delta lnCoal_{t-i} + \phi ECT_{t-1} + e_t \quad (7)$$

In Equation 7, ϕ is the parameter that represents the speed of adjustment in long run and ECT_{t-1} represents the error correction term. The expected value for error correction term must be significant and negative.

The model has been tested for number of diagnostics tests to confirm the validity of the model i.e, serial correlation among the independent variables, normal distribution of variables, testing the heteroscedasticity, and goodness of fit of the model. To the check the stability of model, the cumulative sum (CUMSUM) and cumulative sum of squares (CUMSUMSQ) have been performed on each model and the values of each model falls in the range.

Analysing the Results

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 I.

Table I. Variables used in the study

Variable	Explanation
CO_2	CO_2 emissions(kt)
GDP	GDP per capita growth
Ren	Renewable energy consumption (kWh per capita)
EPC	Electric power consumption(kWh per capita)
Coal	Electricity production from coal sources(% of total)

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

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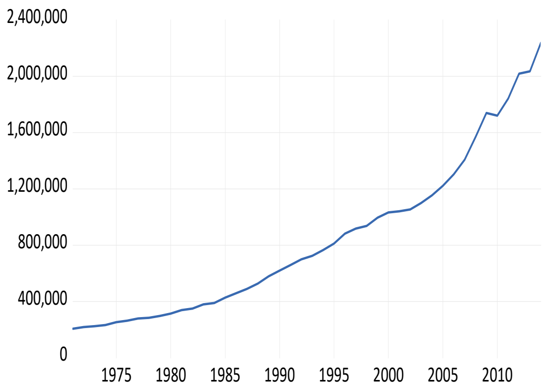
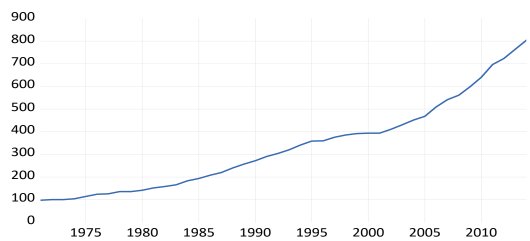
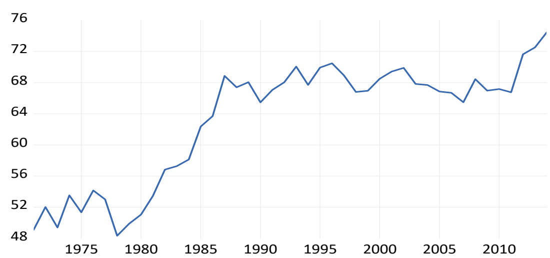
emission is showing an exponential curve, it has increased ten folds from 1971 to 2014. A positive growing curve for electric power consumption and GDP per capita was also noted.



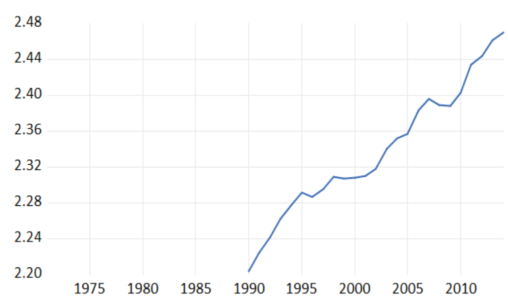
CO_2 emission



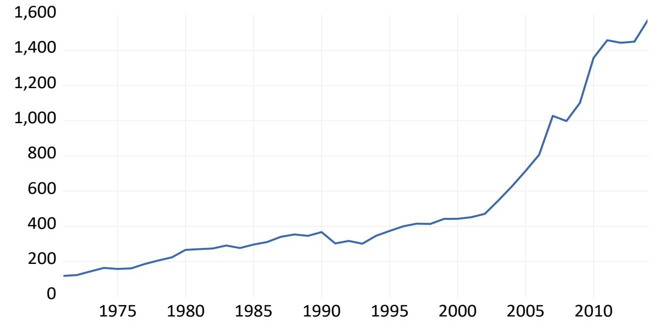
Electric Power Consumption



Electricity Production from coal sources(% of Total)



Renewable energy consumption (kWh per capita)



GDP per capita

Fig 1: Trends of all study variables on time series

The Exploratory tests were performed on the model, the Descriptive statistics and correlation analysis of the study variables is shown in Table II. The Descriptive statistics indicates that CO_2 emission, GDP per capita growth, Renewable energy consumption (kWh per capita), Electric power consumption(kWh per capita), Electricity production from coal sources(% of total) as per Jarque–Bera statistics are normally distributed.

The correlations analysis describes that CO_2 emission is positively correlated with most of the variables viz. GDP per capita growth, Renewable energy consumption (kWh per capita), Electric power consumption(kWh per capita), Electricity production from coal sources(% of total).

Table II: Descriptive Statistics

	CO_2	GDP	Ren	EPC	Coal
Mean	6.055	2.790	2.337	2.652	2.487
Median	6.022	2.673	2.317	2.613	2.457
Maximum	6.349	3.196	2.469	2.905	2.777
Minimum	5.791	2.478	2.202	2.434	2.250
Std. Dev.	0.164	0.248	0.073	0.135	0.141
Skewness	0.209	0.416	.126	0.362	0.466
Kurtosis	1.953	1.660	2.174	2.071	2.400
Jarque-Bera	1.324	2.589	0.776	1.445	1.279
Probability	0.515	0.273	.678	0.485	0.527
Sum	151.393	69.759	58.443	66.313	62.196
SumSq.	0.651	1.479	0.128	0.443	0.479

Dev.					
	CO_2	GDP	Ren	EPC	Coal
CO	1	0.974	0.984	0.994	0.988
GDP	0.974	1	0.959	0.978	0.962
Ren	0.984	0.959	1	0.991	0.987
EPC	0.994	0.978	0.991	1	0.995
Coal	0.988	0.962	0.987	0.995	1
Observations	44	44	44	44	44

After diagnosing the variables, we begin by testing the model for their unit roots, the stationarity of the variables is checked before applying any model. The ARDL bound test needs the variables integrated in order of zero I(0) or I(1). To check the order of stationarity of the test variables, we used the most popular Augmented Dickey Fuller(1994) and Phillip Pheron (1988) unit root tests and its results are shown in Table III. The result infers that there exist no unit root after the first difference. Hence variables are said to be integrated to the order of 1 i.e., I(1) in nature.

Table III Unit Root Test results with log transformed variable

	Augmented Dickey Fuller test				Phillip-Perron test			
	At level		At First Difference		At level		At First Difference	
Variables	ADF t-statistics	p-Value	ADF t-statistics	p-Value	Adjusted t- statics	p-value	Adjusted t-statics	p-value
CO2	0.493*	0.985	-7.839**	0.0000	0.506	0.985	-7.822	0.000
GDP	0.656*	0.990	-6.995**	0.0000	0.625	0.989	-6.995	0.000
Ren	-0.453*	0.884	-3.756**	0.009	-0.480	0.878	-3.698	0.011
EPC	-0.317*	0.913	-5.064**	0.000	-.074	0.945	-5.087	0.000
Coal	-1.116*	0.680	-2.908**	0.053	-0.543	0.873	-5.441	0.000

* 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.

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

Table IV : Results of ARDL Bound test for Cointegration

	Linear Model		Quadratic		Linear with Coal and EPC		Quadratic with Coal and EPC	
	Case I		Case II		Case III		Case IV	
	Value	K	Value	K	Value	K	Value	K
F-statistics	24.55	2	28.01	3	7.46	4	14.58	5
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
10%	2.63	3.35	2.37	3.2	2.2	3.09	2.08	3
5%	3.1	3.87	2.79	3.67	2.56	3.49	2.39	3.38
1%	4.13	5	3.65	4.66	3.29	3.87	3.06	4.15

Once the order of integration is found to be one, the models were tested for existence of cointegration using the ARDL bound test and Johansen Cointegration using equation 5. We have designed four case models, first two have economic growth and renewable energy per capita as control variables and another two have economic growth, renewable energy per capita, energy consumption and coal consumption are used as the control variables. In order to proceed with ARDL bound test, the optimum lag length is estimated, the minimum values of AIC and SBC are chosen to find the optimal lag length for the models. The results of ARDL bound test for cointegration is depicted in Table IV.

The results shows the existence of cointegration, hence we can proceed for estimating the long run and short run coefficient using equations 6 and 7. The results are shown in Table V and VI. In the Linear Models, the coefficients of GDP and D(GDP) are positive and significant, and it implies that rise in the economic growth leads to rise in CO_2 emission. The elasticity has shown decline in long run for both the models, for Model 1 elasticity is 0.126 in long run and 0.366 in short run, which implies that the impact of economic growth in long run on Carbon emission is diminishing. Our results contradict the finding by Ghosh (2010) which denies the existence of long run relationship to CO_2 emission, while Ahmad et al. (2016) mentioned the similar context. However, Govindraju (2013), Sinha (2018) mentioned the existence of long run elasticity. The reason would be inclusion of renewable energy and coal consumption as exogenous variables in this economic growth – carbon emission framework. This is indicating the shift towards sustaining environment stability. The long term effect of economic growth towards carbon emission is though prominent.

Another important finding of this research is the impact of renewable energy on the carbon emission. The renewable energy consumption in long run as well as short run elasticity is negative and significant. The results are similar in line with findings of A.Sinha (2018) and Tiwari (2013). This finding portrays a significant shift in the energy consumption towards renewable energy source and the effect of renewable energy will be achieved in long run. We have seen in Figure 1 that there exists a gradual rise in the usage of renewable energy in India and the percent share of renewable energy is increasing in the complete energy mix. This suggests the right move towards attaining environmental sustainability.

Table V : Long run estimates of ARDL

	Case I		Case II		Case III		Case IV	
	Linear		Quadratic		Linear		Quadratic	
	Coeff.	p-value	Coeff	p-value	Coeff	p-value	Coeff.	p-value
GDP	0.126	0.000	0.238	0.002	0.129	0.002	0.247	0.005
GDP2			-0.015	0.003			-0.016	0.009
Ren	-0.0271	0.0001	-0.0270	0.006	-0.016	0.001	-0.02907	0.005
Coal	0.791	0.005	0.783	0.000	0.835	0.000	0.824	0.000
EPC	0.582	0.001	0.587	0.001	0.573	0.000	0.562	0.000
C	2.888	0.000	2.159	0.028	2.833	0.000	0.945	0.215
Serial Correlation	0.57(0.58)		0.519(0.700)		4.56(0.39)		6.54(0.015)	
Heteroske dastcity	0.25(0.98)		1.37(0.45)		1.191(0.38)		1.038(0.47)	
Normality	3.519(0.172)		1.634(0.44)		1.190(0.55)		0.370(0.830)	

Our estimates of both the Quadratic models are almost similar to the linear models. The Coefficients of GDP, D(GDP), GDP2 and D(GDP2) are significant and sign of coefficients of GDP2 are negative which proves the existence of EKC curve in Indian scenario. The long run coefficient of Quadratic Model II and IV provided inverted U shaped association between GDP and CO_2 emission, and it is the accepted form of EKC. The turnaround point in Model II is estimated to be 2121.757. This value of turnaround point is outside the sample space of GDP in India. The highest GDP in India is 1573.88 USD. Since India is a developing country, where full potential of renewable energy has yet not been utilised and energy efficient technology growth is still in its inception stage. Therefore, the turnaround point outside the sample space can be accepted.

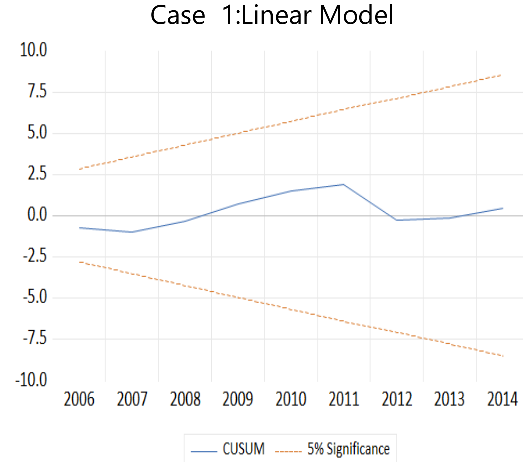
Another important observation from short run estimates shows that error correction term is significant and negative. It proves the existence of cointegration among variables. The absolute value of error correction term indicates the speed of adjustment during long run.

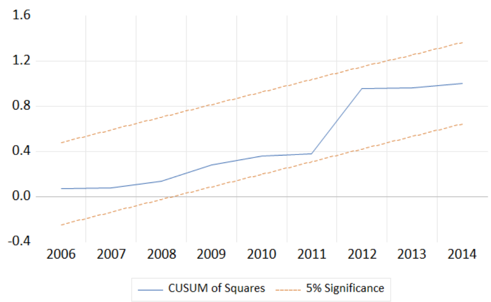
Table VI : Short run estimates of ARDL Model

	Linear							
	Case I		Case II		Case III		Case IV	
	ARDL (3,4,3)		ARDL(4,4,4,3)		ARDL (2,2,2,0,0,0)			
D(co2(-1)	0.366	0.016	0.362	0.293	0.364	0.010	0.329	0.009
D(co2(-2)	-0.662	.0001	-0.473	0.002				
D(GDP)	0.244	.0032	0.239	.003	0.262	0.001	0.261	0.0037
D(GDP(-1))	-0.246	0.000		0.0085	-0.096	0.04		
D(GDP2)			-0.039	0.003			-0.028	0.004
D(GDP2)(-1)			-0.034	.003			-0.029	0.001
D(REN)	-0.250	.0006	-0.249	0.001	-0.244	0.001	-0.251	0.000
D(ren(-1)	-0.258	.0001	-0.257	0.001	-0.252	0.067	-0.258	0.000
D(COAL)	0.541	0.005	0.541	0.006				
D(EPC)	0.509	0.002	0.507	0.001				
D(EPC(-1)	0.489	0.002	0.488	0.000				
ECT(-1)	-1.148	0.000	-1.168	0.0004	-0.666	0.000	-0.734	0.000

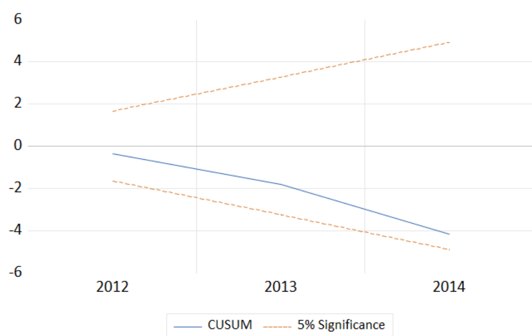
Finally, series of diagnostic tests are performed on models and the results are shown in Table V. It clearly depicts that the models are free from serial correlation, data is normally distributed and data shows heteroskedasticity. Therefore, we conclude that all our models are stable. The models are also tested for CUMSUM and CUMSUMSQ tests and results are shown in Figure 2. The graph shows that models are within 5% critical bounds, and hence all the models are stable in the given time period.

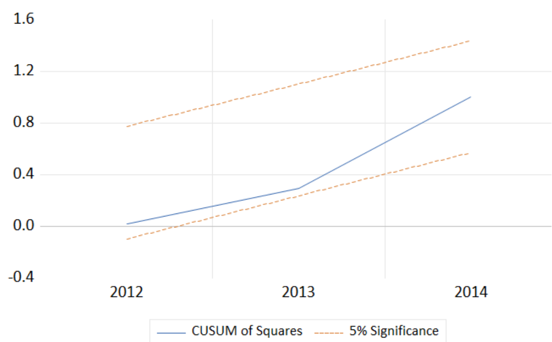
Case 1:Linear Model



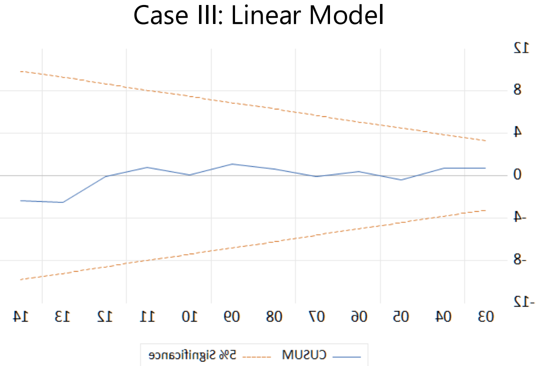


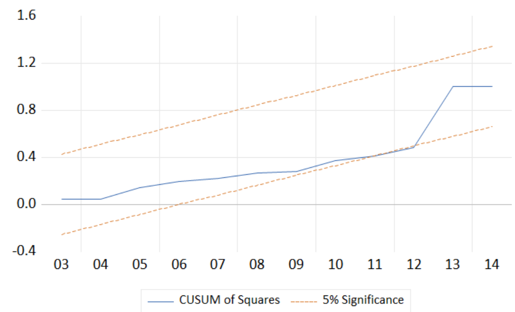
Case 2: Quadratic Model



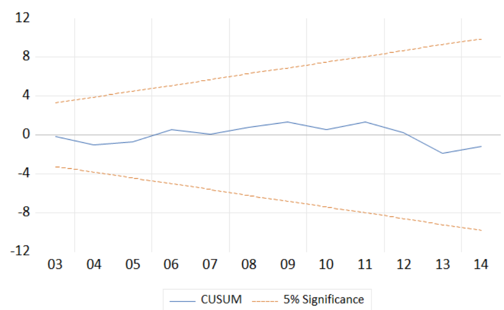


Case III: Linear Model





Case IV: Quadratic Model



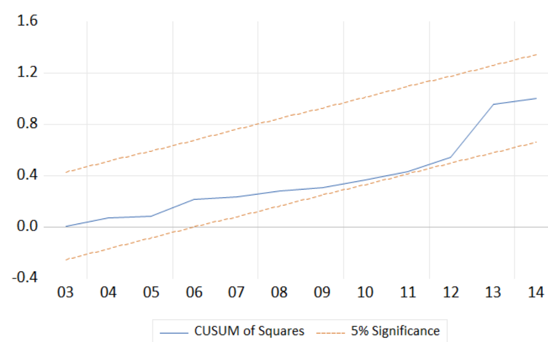


Figure 2: Graph of Cumsum and CumsumSQ test result of all four Cases

The study also performed the Granger Causality test, to see the causality among the study variables. The results of the pairwise granger causality is shown in Table VII. The following observations were made there exits bi directional causality between GDP and Coal, Renewable energy consumption and carbon emissions and there exists one direction causality from GDP to Carbon emissions, GDP to Coal, GDP to Energy power consumption and Energy power consumption to electric production from coal.

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Table VII: The result of Pairwise Granger Causality tests

Null Hypothesis	F-statistics	p-value
Coal → CO_2	4.270**	0.0214
CO_2 → Coal	0.782	0.4645
GDP → CO_2	3.183**	0.0530
CO_2→ GDP	0.58343	0.5620
EPC → CO_2	6.6880*	.00029
CO_2→ EPC	1.19151	0.1610
REN → CO_2	7.4665*	0.0044
CO_2→ REN	4.2697**	0.0304
GDP → Coal	4.4087*	0.0192
Coal →GDP	0.0267*	0.0073
EPC →Coal	3.7959**	0.0335
Coal →EPC	0.80289	0.4557
Ren →Coal	1.3856	0.2756
Coal → Ren	2.4998	0.1101
GDP →EPC	3.2498**	0.0501
EPC → GDP	0.09422	0.9103
Ren → EPC	0.5881	0.5657
EPC → Ren	2.94412	0.0783
Ren → GDP	0.47767	0.6279
GDP → Ren	2.18657	0.1412

Note: shows null hypothesis does not cause Granger causality.
* shows level of significance at 1%
** shows level of significance at 5%

Now, if we summarize the results of all four models, we conclude that India is showing a positive trend towards using renewable energy resources and this has positive impact on economy, and it proves beneficial for environment. This positive shift can be strengthened by use of green technology and gradually reduce the use of fossil fuel in energy consumption.

IV. CONCLUSION AND POLICY IMPLICATIONS

The objective of this study was to estimate the existence of EKC for CO_2 and GDP in India during the period 1971 to 2014 and also to understand the long term and short term effect of renewable energy consumption on Carbon emission. The models also included the electricity production from coal and electric power consumption. These variables are used to eliminate the omitted variable bias and introducing the scale and composition effect.

The result shows the evidence of EKC in India. All four models show positive effect of GDP on CO_2 emission. However, the linear model shows decreasing long run elasticity of GDP towards CO_2. Both the quadratic models show the existence of inverted curve and hence proves the hypothesis to be correct that EKC curve exits in India and however, the turnaround point was found to be 2121.757 USD, which is outside the sample space of GDP, which is acceptable. For both the linear and quadratic models renewable energy resource are significant and negative.

The results shows that India need to work towards make a gradual shift in use of renewable energy resource and green technology. However, the sudden change from coal usage to renewable can't be achieved, it needs proper implementation plan.
The result of this study further strengthens the statement by Niti Aayog[29] 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.

If we want to observe the decoupling of GDP with Carbon emissions and energy demands. Firstly, we need to lay emphasis on shifting from Industrial to Service sector economy. Secondly, more focus should be on the improvement in technology and implementation of green environment in the work culture. Thirdly, shift towards use of solar energy efficient technology in work and household usage.

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Fourth, shift from coal to renewable energy usage in Industries and households.

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