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CO_2 emissions, economic growth and energy consumption nexus: the case of India

Gona Babu RAO
Dr. Abdul Haq Urdu University, Kurnool, India
baburaopcu@gmail.com

Abstract. *In the present global world environmental sustainability has become an important element in achieving a long-term development policy. Nowadays, developing countries like India struggling to deal with these concerns, which all requires a specific treatment. On this basis, this study is to investigate the causal relationship between CO_2 emissions, economic growth and energy consumption for India over the time period of 1990-2019. The study is applied Autoregressive Distributed Lag (ARDL) model to look at the long-run dynamics, while the Vector Error Correction (VECM) model is applied to identify causal direction. The ARDL test confirms that there is a long-run relationship exists between the variables. The VECM results reveal that there is a long-run causality in CO_2 emissions, GDP and EC. A range of diagnostic tests were also used to confirm the validity and reliability of the results. The results also point out to a unidirectional causality running from CO_2 emissions to economic growth to energy consumption, from energy consumption to CO_2 emissions. This study reveals new findings that contribute the existing literature and may be of particular interest to the country's policymakers in light of the economic system and role of in environmental issues.*

Keywords: energy consumption, economic growth, CO_2 emissions, ARDL, VECM.

JEL Classification: L95, O4, Q5.

1. Introduction

Presently every country is more focused on the saving of its natural resources and renewable energies. In that point of view Energy is an important variable to an economy to adopt a long term progress. It is also noticed that, economy and environment both have interdependency, there is a huge demand for energy it is because of affecting factors like; increase of world population, quality of life styles, advancements in manufacturing, and economic competitiveness among the nations. Qayyum M et al. (2021) noticed that the global energy consumption surged by 44 percent between 1971 and 2014. In our context, Energy is a necessary component for an economy to adopt long term progress. Its ever-increasing need has intensified in recent times and is still increasing currently. As India's globalized economic activities, there is a strong interactive connections between economic and energy supply and demand. India's energy sector is still heavily dependent on the fuel such as crude oil, natural gas and coal as source of energy. Today, prior to the global pandemic, India's energy demand was projected to increase by almost 50% between 2019 and 2030, but growth over this period is now closer to 35% in the STEPS and 25% in the Delayed Recovery Scenario. However, at the same time, the consumption of these non-renewable fuels is gradually depleting and can contribute to huge amount of greenhouse gas emission (GHG). Coal is cheaper than petroleum. For industrial progress cheap energy is necessity for this coal come into picture. Due to huge presence of coal reserve it remains as the most important source of energy usage in India.

The reports of 2015, 2016 and 2017 have been confirmed as the three warmest years on record. European Commission Directorate 2015 (ECD) highlights that CO_2 emission has become a worldwide problem it's due to heavy environmental pollution. The government of EU commission has given funds for research initiatives aiming to reduce the fossil usage, improving energy efficiency and developing new technological advances for renewable energy. WMO Greenhouse Gas Bulletin (2017) revels that in the year 2016 the atmospheric CO_2 emission content has reached the highest level in the last years. BP Statistical Review of World Energy (2017) another issue facing by many countries is that, uncertainty in energy. It is happening due to their reliance on fossil usage on a large scale and oil has become as the largest utilised resource in the world, presently it is one-third of global energy usage. Major oil producing countries like OPEC itself controls 71.5 percent of overall oil reserves, remaining countries depends on the producing countries. Alshehry, A.S. et al. (2015) and Tang C.F et al. (2016) found there are unstable of fossil fuel markets puts importing countries into danger of their economic instability. It is happened because of disturbance in the energy supply-demand equilibrium is expected to have a serious impact on economic activities. As results, it is necessary that energy-based countries are subjected to conversation regulations that restrict energy usage. Fostering Effective Energy Transition (2018) to address the climate change problem in developed and developing countries, the fossil energy consumption has appeared as the major reason for the sever CO_2 emissions problem, and reducing energy consumption becomes a necessary step for both the countries. It concludes that energy consumption is one of the most important drivers of economic growth.

Therefore, by observing the above scenario, there is an interesting question needs to be considered. Will India be able to sustain economic growth without running into resource constraints or despoiling the environment? In order to overcome the phenomena, the government of India is aware of its role in formulating its national energy development policies, which is sensitive towards the environment and the sustainability of energy resources. However, to curb the greenhouse gas emissions and to ensure the sustainability the economic development, it is important to better understand the link between greenhouse gas emission, energy consumption and economic growth.

The main goal of this study is to examine the dynamic association between CO_2 emissions, Economic Growth (GDP), and Energy Consumption (EC). It also studies the causality between CO2 emissions, and GDP, and EC by using the multivariate models which are closer to the economic theory. The main framework for the analysis is the economic interaction between energy demand, economic growth and pollutant emissions.

The overview of the paper consists like this; section 2 explains the review of literature which consists of theoretical and empirical reviews. Section 3 covers the econometric methodology and data source. The empirical analysis and results presented in section 4. Section 5 shows the conclusion and policy implications of the study.

2. Review of literature

The study examines the dynamic association between CO_2 emissions, economic growth and energy consumption in Indian context. The present study had done on two ways of literature reviews namely; theoretical basis and empirical basis. In the literature of energy economics, other researchers have expressed the linkage between energy and economy in different ways, which is largely reflected on the theoretical background of each issue.

2.1. Theoretical basis literature reviews

By taking into the account of neoclassical theory of economic growth, Berndt et al. (1975) focused on the interaction between energy, technical progress, productivity as well as examining the substitutability or complementarily between energy and other factors of production. Other studies like Andrew Andewale Alola et al. (2019) showed energy consumption has an improvement variable in the environmental sustainability. Qayyum M et al. (2021) found financial development has a negative relationship with energy consumption in the short and long-run. El-Sakka (2004), Soytas et al. (2006) highlighted energy as an important input in the process of production. Toman et al. (2003) studied on relationship of energy development with economic development; they found energy development is an important component of economic development. In the other side, Stern et al. (2004) looked differently on ecological economic point of view and they highlight energy, capital, labour etc main inputs of production process. They all suggest that, all economic process requires energy as an essential factor of production and conclude that energy is necessary for growth of any country. Gudarzi et al. (2012) forecasted the Iran's energy consumption and to discuss potential implications by applying the Bayesian Vector Autoregressive method. They found that, slower growth reflects an expected slower economic growth and decline in energy consumption due to structural changes in the Iran economy. A.A Azlina (2012) examined on the causality between energy consumption and economic development in Malaysia. It found that there is a direct causality running from economic development to energy consumption and the study highlights that energy saving would not harm economic development in Malaysia.

2.2. Empirical literature reviews

Gessesse A.T., He G (2020) examined on the nexus of CO_2 emissions, energy consumption and economic growth by using ARDL bounds test, error-correction model (ECM). The study found there is a long-run and short-run co-integration relationship between the variables. CO_2 emissions and GDP is "relatively decoupling" and its CO_2 emissions are more explained by economic consumption and contribute twofold of GDP. In the long-run, there was significant negative causality from CO_2 emission to GDP to Economic Consumption. Rabindra et al. (2018) found energy consumption does not lead to economic growth while income leads to energy consumption. It rises due to energy supply-demand gap. Zhang et al. (2009) applied causality test and found a unidirectional Granger causality running from GDP to energy consumption, and energy consumption to carbon emissions. In the case of Turkey, Soytas et al. (2009) raised same conclusion as there is a unidirectional Granger causality from carbon emission to energy consumption in the long-run based on the Toda and Yamamoto procedures in the case of Turkey. Ilhan Ozturk et al. (2010) analysed on consumption and economic growth relationship on low and middle income countries. It was found there is no strong relation between energy consumption and economic growth for all income groups. Menyah et al. (2010) by applying the bound test approach; they found a unidirectional causality running from pollutant emissions to economic growth; from energy consumption to economic growth and from energy consumption to CO_2 emissions all without a feedback in South Africa. Soyatas et al. (2007) investigated on energy consumption, output and CO_2 emissions for USA by using the VAR approach. They found non-causality between CO_2 emission and energy consumption. Bastola et al. (2015) examined on relationship between economic growth, energy consumption and CO_2 by applying cointegration and ARDL bound tests. They found a bi-directional causality running from energy consumption to carbon emission and vice-versa and a unidirectional causality running from economic growth to both carbon emissions and energy consumption in the case of Nepal. Siok et al. (2017) empirical test on relationship between energy consumption with economic growth and environmental degradation, their results indicates that bi-directional relation between energy consumption and greenhouse gases emissions and uni-directional causal effect from GDP to energy consumption in the short-run. Huajun Liu et al. (2019) says by leveraging a variety of samples and a new approach and it provides a new evidence for policy authorities to formulate country-specific policies to obtain better environmental quality while achieving sustainable economic growth.

There are few studies includes carbon dioxide emissions in the energy consumption-economic growth nexus and majority studies found causal relationship on these three variables. Among these studies include Soyatas et al. (2009), Wolde (2016), Alege et al. (2016) and Chindo et al. (2015). However, the results are questionable due to the concerns relating to the problems of omitted variables bias in the absence of a multivariate framework. Besides, with the increases in clean energy and renewable energy consumption it is noticed that the relationship between energy consumption and carbon emission also has gradually attracted more attention. Many studies Baek J (2015) and Shabhaz M et al. (2013) found that energy consumption has no significant positive effect on carbon emissions, which makes the linkages between energy consumption, carbon emissions and economic growth more complex and confusing. The existing literature shows that the relationship between energy consumption, economic growth and CO_2 emission has different relationship with one another. Energy consumption has a significant influence on carbon emission but not on economic growth. Some studies found carbon emission can be effected by economic growth. Energy consumption has no significant impact on CO_2 emissions but CO_2 emissions are a cause of economic growth, another side it has a reverse relationship between CO_2 emission and economic growth.

From the above discussion, it comes to know that energy plays as an important role in the economic development of any country. It also shows that there is inter relationship among these variables like energy consumption, economic growth and CO_2 emission. As we observe that there are four major views we can notice here. They are firstly; there is a causal relationship between energy consumption and economic growth. Secondly, importance of energy as essential factor of production and it is suggested that energy is necessary for economic growth. Thirdly, energy consumption and economic growth cause each other; it means there is bidirectional causality between energy consumption and economic growth. Fourthly, it argues that there is no causal relationship between energy consumption and economic growth.

The main goal of this study is to examine the dynamic association between CO_2 emissions, Economic Growth (GDP), and Energy Consumption (EC). It also studies the causality between CO2 emissions, and GDP, and EC by using the multivariate models which are closer to the economic theory. The main framework for the analysis is the economic interaction between energy demand, economic growth and pollutant emissions.

3. Data and methodology

In order to examine the above objective the study has been taken data on CO_2emissions, GDP growth and EC. The study sought to examine the dynamic association between CO_2emissions, GDP and EC in India by utilizing the ARDL cointegration method and it also studies the linkages between CO_2 emissions, GDP and EC by considering the vital role of India's GDP and EC. The data has covered from 1990 to 2019 and chosen country is India and data has collected from World Development Indicators (WDI).

3.1. Theoretical relationship and model specification

The paper studies the relationship between CO_2 emissions, Economic growth (GDP) and Energy Consumption (EC). Bhattacharya et al. (2017) it is noticed that by adding the EC method for expansion and energy-efficient technology, EC could have an influence on environmental performance. Advancement technology in energy could bring changes in the environmental performance. Yang et al. (2020) highlights that, economic progress is a main cause of high CO_2 emissions because the development of any economy relies on the high energy consumption, which ultimately affects the performance of the environment. In case of the relationship between CO_2 emission and GDP, Wang et al. (2015) identifies that CO_2 emissions can represent the redundancy in energy inputs which in turn can be a major source of inefficiency in production. The hypothesis says that a decrease in emissions has a certain cost, means that it is accompanied with a decrease in economic output, whether in the form of policies reducing CO_2 emissions directly and it affect economic growth negatively.

To examine the relationship between CO_2 Emissions, Economic Growth, and Energy Consumption, the study framed a simple regression framework where the relationship can be specified as follows:

$$CO_{2t} = f(GDP_t,\ EC_t) \tag{1}$$

Where, CO_2, GDP and EC represent the CO_2 emissions, real output or GDP and energy consumption, respectively. For empirical investigation, we converted all parameters to natural log to use a log-linear configuration instead of a linear configuration. The study also used the log-linear method for the empirical analysis. The log-linear function of CO_2 is as follows.

$$InCO_{2t} = \alpha_0 + \alpha_1 InGDP_t + \alpha_2 InEC_t + u_t \tag{2}$$

Where In is the natural-log, and $u_t$indicates the error term, presumed to have a normal distribution. Energy consumption enhances environmental performance if $\alpha_1 < 0$; otherwise; the environmental quality is hindered with a rise in energy consumption. We expect $\alpha_2 > 0$ if growth rate is not ecofriendly, otherwise, $\alpha_2 < 0$.

The previous studies have used different methodological approaches to measure time series and panel data but this study used ADRL model. The ARDL test method, established by

Pesaran et al. (2001) is used in the present analysis. Due to its unique characteristics in connection with Engle and Granger (1987) and Johansen S (1988) cointegration approaches, the ARDL approach to cointegration in time series data is preferred. In that point of view, firstly, the ARDL method works best in the case of limited sample data size compared to other cointegration strategies. Secondly, it is free of the fact that the series integrated in or not in certain order and excuses both I (0) and I (1) but is then not compatible with the series built into I (2). Thirdly, the ARDL method provides an ample number of lags to capture the data generation method in a particular modelling system. Fourthly, it also supports us in extracting the Error-Correction Model (ECM) by a simple linear conversion methodology. Finally, it shows that utilizing the ARDL method prevent complications caused by non-time series data. The present study examines the dynamic association between the CO_2, GDP and EC, by using ARDL cointegration technique.

By following the unrestricted error correction model and the empirical equation for equation (2) is as follows:

$$InCO_{2t} = \varphi_0 + \theta_1 InGDP_{t-1} + \theta_2 InEC_{t-1} + \sum_{i=1}^{p} \pi_1 \Delta\, InCO_{2t-i} + \sum_{j=0}^{p} \pi_2 \Delta\, InGDP_{t-i}$$

$$+ \sum_{j=0}^{p} \pi_3 \Delta\, InEC_{t-i} + \mu_t \qquad (3)$$

The Δ is the first difference operator. In the case of equation (3), the null hypothesis of cointegration ($H0\colon \pi_1 \neq \pi_2 \neq \pi_3 \neq 0$) is to be verified alongside the alternate hypothesis ($H0\colon \pi_1 = \pi_2 = \pi_3 = 0$). We depend on the evaluation of the F-value using the binding test procedure to analyze cointegration. If the F-statistic value surpasses the upper limit, the cointegration between the variables is supported. However, if the F-statistic exists below the lower limit, there is no cointegration, showing that no cointegration hypothesis accepted. The F-statistics indicates inconclusive results within the upper and lower limits. Cointegration validation allows the long-term and short-term dynamics to be evaluated on the basis of ARDL model. We also take various diagnostic tests such as the Ramsey Reset, ARCH, LM, CUMSUM, and CUMSUMSQ into account for robust control and model reliability.

The last stage is to investigate the causality among the described data. We utilize the vector error correction model (VECM) suggested by Engle and Granger (1987) to asses causality. If the data in the model are all cointegrated, an appropriate methodology of the VECM Granger causal mechanism can be represented as follows:

$$\begin{pmatrix} \Delta InCO_{2t} \\ \Delta InGDP_t \\ \Delta InEC_t \end{pmatrix} = \begin{pmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \end{pmatrix} + \begin{pmatrix} \partial_{11}\partial_{12}\partial_{13} \\ \partial_{21}\partial_{22}\partial_{23} \\ \partial_{31}\partial_{32}\partial_{33} \end{pmatrix} \begin{pmatrix} \Delta InEC_{t-j} \\ \Delta InGDP_{t-j} \\ \Delta InCO2_{t-j} \end{pmatrix} + \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \end{pmatrix} ECT_{t-1} + \begin{pmatrix} \omega_{1t} \\ \omega_{2t} \\ \omega_{3t} \end{pmatrix} \quad (4)$$

Where,Δ represents the difference operator and ECT_{t-1} is the lagged error correction term. ECT_{t-1} for correlation analysis should be significant for both long-run and short-run associations.μexpress the speed of variations, and its value indicates the degree to which inconsistency can be within one duration. $\omega_{1t} - \omega_{3t}$corresponds to the error term, which is possible as must be serially uncorrelated around zero means.

4. Analysis and empirical results

Descriptive statistics related to India for the variables of the study are presented in Table 1. The results of minimum mean and maximum values of all variables are stated i.e CO_2 (4.184 4.245 4.296), GDP (0.055 1.762 2.179), and EC (3.450 3.817 4.071).

Table 1. *Descriptive Statistics*

Variable	Observations	Mean	Std. Dev.	Min	Max
CO_2	30	4.245	0.026	4.184	4.296
EC	30	3.817	0.198	3.450	4.071
GDP	30	1.762	0.430	0.055	2.179

Note: CO_2 is carbon dioxide emission, GDP is a gross domestic product, EC is energy consumption.

To go further analysis it is necessary to test the stationarity of the data and it is one of the most crucial assumptions to be checked for time series analysis. The present study has applied Augmented Dickey Fuller (ADF) test and Philips-Perron (PP) tests and the results of the unit root tests are summarized in Table 2, it shows that whose null hypothesis is the existence of a unit root test. The results show that the null of a unit root in both tests cannot be rejected in any of the relevant variables in their level. However, upon taking first differences, the null of unit roots is rejected at the 1% significance level. Therefore, it is concluded that all the series are non-stationary and integrated of order one i.e *I (1).*

Table 2. *Unit Root Test (ADF&PP)*

Variable	ADF-I(0)		ADF-I(1)		PP-I(0)		PP-I(1)		Decisions
	t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.	
CO_2	-2.805	0.069	-5.963	0.000***	-2.743	0.079	-7.378	0.000***	I(1)
GDP	-4.409	0.001	-5.208	0.000***	-4.289	0.002	-10.613	0.000***	I(1)
EC	0.987	0.995	-7.841	0.000***	0.803	0.992	-3.278	0.0258***	I(1)

Note: Figure in the parentheses are p-value. (***), (**) and (*) indicates 1%, 5% and 10% level of significance, respectively.

Moreover, to check the long-run connection with the bound testing, it is important to have a correct lag length. We use the Akaike Information Criteria (AIC) to determine the acceptable lag length because it produces more accurate and consistent results than the Schwartz Bayesian Criterion (SBC). Hence, we pick AIC to select the lag length, the selection of lag length calculates the F-value to determine whether or not co-integration among variables exists. Table 3 shows the results of the ARDL bounds test method for co-integration and shows that the hypothesis of co-integration can be accepted at a 5% level of significance. Table 4 shows that the projected F-statistic is greater than the upper bound at a 5% level. The critical bounds computed by Pesaran et al. (2001). The empirical analysis confirms that co-integration is reported, confirming the long-run link between the variables studied in the case of India from 1990 to 2019. In addition, the Johansen cointegration technique is used to improve the accuracy of the bound testing method. The findings of the Johansen cointegration also support the cointegration for variables of concern as shown in the Table 4.

Table 3. *Bound Testing Approach*

Estimated Model	Lag Selection	F-Value	Remarks
CO_2=f(GDP,EC)	1,0,0	1.549379**	Conclusive
Critical Value Bounds			
Significance	I0 Bound	I1Bound	
10%	2.63	3.35	
5%	3.1	3.87	
2.5%	3.55	4.38	
1%	4.13	5	

Note: **shows acceptance of the alternative hypothesis at a 5% level of significance.

Further the study carry out the cointegration test and the results of the cointegration test has shown in Table 4. The empirical results of Johansen trace statistics and Johansen maximum Eigenvalues statistics suggest evidence in favour of a long-run relationship between CO_2 emissions, economic growth and energy consumption at the 1% level of significance. Therefore, it appears to be clear evidence that there is one cointegrating relationship between the variables.

Table 4. *Johansen Cointegration Tests*

Hypothesized no. of CE(s)	Trace Statistic	Prob.*	Max-Eigen Statistic	Prob.*
None*	34.681	0.012	30.197	0.002
At most 1	4.484	0.860	14.264	0.828
At most 2	0.199	0.655	3.841	0.655

Note: * shows the rejection of the hypothesis at the 0.05 level.

The empirical analysis confirms that co-integration is reported, confirming the long-run link between the variables in the case of India from 1990 to 2019. In addition, the Johansen cointegration technique is used to improve the accuracy of the bound testing method. The findings of the Johansen cointegration also support the co-integration for variables of concern, as shown in Table-5.

Table 5. *Estimation of ARDL Long-run and Short-run Estimation*

Regressor	Coefficient	Standard Error	*P* Value
Long run estimate			
C	28.79300***	12.6119	0.0348
GDP	-0.165500***	0.2009	0.4208
EC	-0.645658***	0.4906	0.2047
Short run estimate			
GDP	0.3727**	0.1194	0.0059

Regressor	Coefficient	Standard Error	*P* Value
EC	0.5458*	0.3532	0.0842
CointEq (-1)	-0.3725***	0.1385	0.0150
R^2	0.5509		
F-Statistics	2.7601		0.0350
DW Stat.	2.0763		
Breusch-Godfrey Serial Correlation LM Test	2.5998		0.1053
ARCH Test	0.0041		0.9491
Ramsey RESET Test	1.6359		0.1202

Note: *, **, and *** shows acceptance of the alternative hypothesis at 10%, 5%, and 1% level of significance, respectively.

The above Table 5 shows the long-run and short run association between estimated variables. The empirical findings provide some exciting evidence about the connection between India's GDP and CO_2emission. In the long-run and short-run, the relationship between and GDP and CO_2emission is negative and not significant in the long-run but in case of short-run it was negative and significant. This means that CO_2emission significantly decreases GDP. The coefficient of CO_2emission concludes that considering other things constant, a 1% decrease of CO_2emission damages the GDP by decreasing 0.1655% and 0.3727% CO_2emission respectively. When it comes to the relationship between EC and CO_2emission, we see that the coefficient of EC has a negative coefficient and statistically insignificant effect in the long-run and in the short-run it has positive and significant. A 1% rise in EC cuts CO_2 emission by 0.6456% and 0.5458%, respectively. It posits that renewable energy is consistent and crucial element in improving the performance of the atmosphere. Our results suggest that augmenting renewable energy exploitation could be a valuable policy tool for reining environmental performance in India.

Other than these variables, population is rise in the India and is also rising in urbanization; this has also boosted the need for transport, such as private cars. The increasing use of cars required higher fossil fuel consumption, which ultimately worsened the quality of the environment. The low standard of India's transportation has boosted private car ownership. The surge in urban density has accelerated the development of residential and industrial facilities. The usage of high energy consumption products has also increased in commercial and residential areas. It is notable that the household sector has been the main energy user due to rapid urbanization. Moreover, the urbanization trend has increased the generation of waste, deforestation and land-use changes in the region. All such problems have greatly increased traffic problems, electricity consumption and pollution in the urban regions. India has also seen a rapid rise in industrial growth, thus, urbanization implicitly deteriorates atmosphere quality by the industrial revolution.

At a 1% level, the error correction term has a negative coefficient and is statistically significant. As a result of the error correction term (ECT) finding, CO_2 emissions in India effectively correspond to the direction of long-term equilibrium with 100 percent adjustment speed. Finally, we have used a variety of diagnostic tests to confirm that there are no issues of Serial Correlation, Heteroscadasticity, and Multicollinearity in the model.

The results of these diagnostic tests are also shown in the Table 5. Diagnostic check outcomes eliminate all complications that could have occurred in the model. This specifies that the analysis model is correct and that policy recommendations can be based on it. The reliability of long-run parameters is tested by adding the recursive residuals, cumulative sum (CUSUM) and cumulative sum of square (CUSUMSQ) graphs. These figures like Figure-1 and Figure-2 show that the plotlines for both tests are within the critical limits, endorsing the accuracy of the long-run estimates.

Figure 1. *The plot of the cumulative sum of recursive residuals*

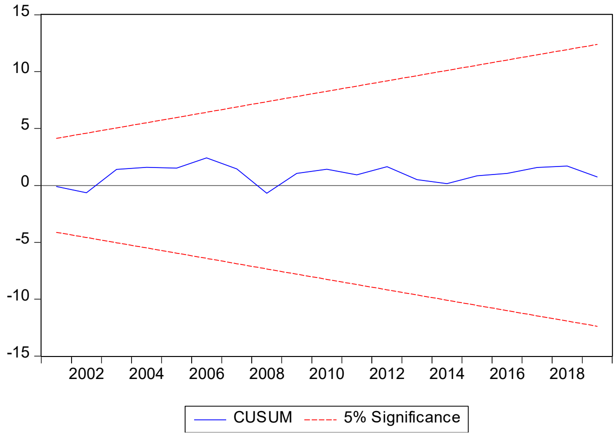
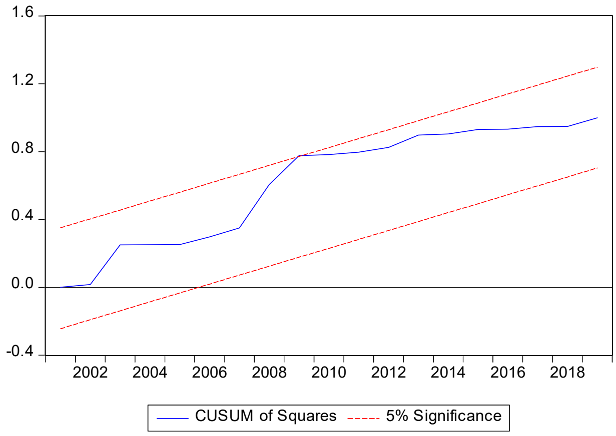


Figure 2. *The plot of the cumulative sum of squares of recursive residuals*



5. Conclusion and policy implications

This paper studies the effects of the gross domestic product and energy consumption on CO_2emission in India during 1990-2019. Only few studies were performed to examine the relationship between CO_2 and energy consumption in the context of India. As per the author's knowledge, it is the first attempt to explore the relationship between gross domestic product, CO_2 emission and Energy consumption. To measure the long-run connections between parameters, we used the ARDL cointegration approach. The VECM Granger Causality test was used to determine whether or not there was a causal link between the variables under consideration. The unit root test was used to conclude the variables' stationarity. Finally, the model's reliability was tested by using CUSUM and CUSUMSQ checks.

The study's results reveal some important findings of the variables used in this study. In the short and long-run, the empirical investigation outcomes indicate that the link between gross domestic product and CO_2emission in India is significantly negative. This means that India's gross domestic product needs to be increased and CO_2 emission needs to be controlled and save the energy. The coefficient of CO_2emission and energy consumption is significantly negative in both short and long-run, specifying that an increase in both indicators will decrease CO_2emission. It means that, India's energy consumption to be controlled and save the energy.

The overall assessment of the analysis shows that energy saving policy option is independent of the relationship between energy consumption and economic growth. More precisely, energy saving policy may have a positive effect on economic growth rather than negative effect. That is, energy saving policy should be followed in every scenario to reduce the cost of energy and environmental pollution. The empirical conclusions of this study have significant implications for India's economic policy development. Our research results found that India's current policies for strengthening financial institutions are detrimental to the climate, so this strategy must be revisited. Moreover, India must develop a secure financial system which can help and enable business to implement advanced and effective technologies, reduce energy use, and contribute to environmental improvement. India's policymakers must implement financial reforms that promote and reward companies that use effective and environmentally sustainable technologies to enhance environmental performance through by saving energy consumption. It will encourage businesses to embrace environmentally sustainable technologies to attain financial rewards, lower energy use, and lower greenhouse gas emissions.

While the study has important policy implications, it is not without limitations, which leaves space for further analysis in the future. Future work could be enrichingthe literature by scrutinizing the relationship between financial development, urban population and technological innovations.

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*** The datasets during and/or analysed during the current study are available from the corresponding author on reasonable request.