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REVIEW ARTICLE

Impact of FDI, crude oil price and economic growth on CO2 emission in India: - symmetric and asymmetric analysis through ARDL and non -linear ARDL approach

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Abstract
The paper examines the impact of macroeconomic variables on CO2 emissions, very few research studies are available to estimate the asymmetric impact and causality. Because of the significance of asymmetries, this paper examines the asymmetric impact of economic growth, crude oil use, and FDI inflows on CO2 emissions in the India wherein COP (Crude oil price) is comprised as the extra variable. The implicate aggressive growth of selected variables over the period 1990–2020 is also assessed. This study uses the methodology ARDL and NARDL model to determine the macroeconomics variable's effects on CO2 emission over the period 1990-2020. Additionally, also applied the EKC (Environmental Kuznets Curve) hypothesis with an application of ARDL and NARDL model. With help of the ARDL and NARDL model, the study shows the results that a rise in economic growth would reduce CO2 (carbon dioxide) emissions while a decrease in economic growth would raise CO2 emissions which indicates an inverted U-shaped Curved relationship between economic growth and CO2 emissions. The positive and negative shockwaves in COP (crude oil prices) have a satisfactory and substantial impact on CO2 emissions as well. Besides, the crude oil consumption with positive shockwave confirmations has a positive and substantial impact on CO2 emission. In addition, the results of FDI inflows support the pollution heaven hypothesis. In light of these outcomes, this paper also recommended policy implications and future research, the policy implications are where the descending flow of FDI allows limited space to India in FDI selection; however, the existence of emission merging and implementation of carbon pricing may facilitate India in achieving its environmental targets.

Keywords Crude oil price · CO_2 Emission · FDI · Economic development and EKC

JEL classification F21 · Q43 · Q56 · C15

Introduction

Climate change is an international issue, where CO_2 emission is the major serious cause of the rise in the earth's temperature. The significance of the environmental change was globally recognized in 1992 is organized by the UN in brazil theme the conference is the earth Summit, Environment change is among the utmost challenges facing people. It affects all nations and can have disturbing effects on societies and individuals. Hence, the attainment of sustainable growth and the reduction of global warming have confronted researchers and decision-makers to emphasise the 'drivers of CO2 emissions, in the direction to develop the measures and policies required to expand environmental quality. The condition becomes even inferior when it arises to encouraging economic growth, in the meantime energy is a significant determining factor in achieving such a goal, Baek (2016). The environmental impact of economic development is based on a divisive assumption, as long as by Grossman and Krueger (1995) which so-called Environmental Kuznets Curve (EKC). It specifies an inverted U-shaped connection between the level of growth and emissions (Economic and CO2) whereby a countrywide pollution congregation rises as the economy grows to a certain level where its reductions again as the nation uses its increased prosperity

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to further decrease pollution congregation. In the same way, certain its role as operators of economic growth, crude oil, FDI inflows could be unfavourable to the environment, usually emerging nations, where overseas companies producing polluting goods would seek to locate in those nations with relatively poor environmental guidelines equated to their nations of origin with environmental needs, Sreenu (2019a, b). According to Abdullah (2015) Explored the association between economic growth and CO_2 emission, and in his article, the outcome has suggested to the policy decision-makers and investigators, that the decrease CO_2 emission without disturbing the economic growth while adopting the EKC approaches. Further, also the paper focused on the CO2 emission how much released in India and global after the industrial revolution, the reviewed articles show data that there are continuous rises in emissions of greenhouses gases and carbon emissions, which is constitute a significant part of CO2 emissions and the emissions of greenhouses gases account for about 75%. However, it is meaningful to note that established on PCCE (per capita carbon emissions) from the industry, energy, land use, agriculture, and forestry, India ranks in the bottom 100 of 196 countries in terms of greenhouse gases emissions, Sreenu et al. (2021).

India has enough managerial skills trainers and practical knowledge specialists, as well as less labour cost and a massive market approachability, all these factors may indicate the positive impact to control the FDI, oil price and improve economic growth. Strategy issues and government policy issues with concern to FDI inflow was stopped till the year 1985s. After the 1990s industrial reforms, the government of India has reframed policy issues that the deregulating of the economic strategy from period to period paying attention towards FDI consideration in India, and FDI as a proportion of gross domestic product improved from 0.092 to 1.85 between 1995 and 2010. Foreign direct investment policy was made very easy to invite and invest the investment in emerging industries during 2014, and after 2019 the FDI is even permitted in the defence industry also. The Indian economic growth size is huge in the world economy size so the CO2 emission internationally makes the nation a good position towards development to research the determining factor of climate degradation with regards to the EKC hypothesis. Crude oil is preserved as an identical key factor of climate filth in the outline of EKC testing in the context of developing nations. Further, the paper also considers the exports and imports impact on climate degradation and this one has been considered as the identical key factor for policy implications and additionally few reviewed articles have indicated the results of the effect of exports shown the negative impact on environmental quality changes. This paper very preciously illustrates, this study is different from others articles, and the originality of the paper is contributing to the standing literature. Primary information is that the FDI is used as a likely it shows negative impact initially on the climate degradation with the help of the methodology ARDL and non-linear ARDL, Iwata et al. (2012).

From the above conversation, the current paper hypothesizes the ensuing research questions from the Indian perspective: (1) Whether the EKC hypothesis influence in India? (2) If does a transformation of global crude oil price have negative effects on its consumption? (3) Does India can act as pollution heaven for the foreign direct investment inflow? Additionally, the paper determines is there any unequal impact of economic expansion, in the same order the study examines the impact of FDI inflow, and crude oil prices on CO2 emission also. In this connection, the present study attempts to answer the raised-up query while provided that further knowledge in the standing secondary data. Initially, the paper used crude oil price along with FDI, which is an innovative influence, to evaluate the equal and unequal impact on CO2 emission along with the control variables. Next step, the paper expanded the energy consumption, the adopted methodology model as not to prejudice in findings results, thus provided that a more convincing outcome of the EKC and other contributions of CO2 emission, Mazzanti and Roberto (2007). Furthermore, the non-linear ARDL studies the asymmetric relationship among the variable during the short and long-run periods, to evaluate how a rise and decline in crude oil price and FDI impact CO2 emission in India. While the linear ARDL model explores the symmetric short-run and the long-run association between the variables. Finally, the paper has studied the collective as a long and short-run way of causality between CO2 emission and its determining factor by using the block homogeneity Wald test. Moreover, ARDL outcomes recommend that the crude oil uses has an encouraging impact on CO2 emission in a short period, but an adverse impact in the long -period, while economic development and FDI has an optimistic effect on CO2 emission in both the long and short -run. Despite the fact, the non-linear ARDL outcomes specify that arise in COP decrease CO2 emission, while a reduction in crude oil price boosts CO2 emission in the long -run.

By proposing the overhead motivation, this research paper furnishes to the literature by backpacking the impact of gangrenous FDI inflow, Crude oil price and economic growth with their negative and positive shockwaves on CO2 emissions, by applying ARDL and NARDL. The present analysis goes outside the reachable literature in various stages; the first stage is that there is no available information that analyses the asymmetric outcome of selected variables on CO2 emissions. Next stage, this paper uses the asymmetric causality test for asymmetrical causality investigation, and the implicate exponential growth method, to observe the growth rate of the selected variables, which is an original contribution to the literature. The remaining of the paper is

planned as follows: section -1, introduction and literature review, literature review contains consist the relationship between CO2 emission and Economic growth, CO2 emission and FDI and CO2 emission and Crude oil price. Section-2 discuss the model and research methodology. Section -3 estimated results and discussion. Section-4 the Conclusions and policy implications.

Literature review

The present literature review explored the connection between FDI inflow, COP (crude oil Price) and economic development, and these variables impact on CO_2 emission. The literature review has been classified into three parts for better understanding, the first part of the literature has discussed the economic development and CO2 emission, the second part illustrates the FDI inflow and CO_2 emission, and the last part of the literature review crude oil price and CO_2 emission along with the control variables also.

Relationship between economic growth and CO_2 emission

Constant economic progress holds import among policymakers, as it is one of the significant macroeconomic pointers. Many researchers have considered the relationship between economic development and environmental quality degradation in the form of the EKC hypothesis. Some researchers favour the EKC hypothesis, such as Mazzanti and Roberto (2007). In contrast, Kacar and Kayalica (2014), do not agree. Numerous works of literature review have also recommended that in the long -run, the association between economic growth and quality protection of the environment is not an upturned U-shape curve, but moderately it is N -shape considered. After accomplishing an upturned U-shape, the researchers emphasized how those nations must begin degrading the environment to achieve more economic growth. Sreenu (2020) considered the EKC hypothesis for different nations applying panel data of cointegration by applying data from 1980 – 2015 and found mixed outcomes. Based on the results, it is suggested that the EKC hypothesis is dependent on the level of nations' growth. Their studies of developed and emerging economies have initiated support for the Environmental Kuznets Curve hypothesis, whereas Lee (2013a, b, c) have originated the association to be N -shaped.

In the same sequence to accomplish economic development without hampering environmental safety is a substantial challenge for any nation, but the environmental challenge becomes utmost intricate for an emerging nation like India. In consideration of India, the provision for Environmental Kuznets Curve hypothesis is also doubtful, Kahouli (2018), shows the evidence for the backing of the EKC hypothesis, Karasoy and Akcay (2019), indicates the evidence, the Environmental Kuznets Curve hypothesis is not supported at the initial level in the context of India, the beginning level all selected variables its showing that the negative impact on the overall economic growth during the short run. As crude oil consumption is a dynamic factor for economic development, thus, there is no doubt at all about the consumption of crude oil and economic growth found that the positive relationship between each other's related factors and the real function of crude oil price mix of the nation. Developing nations if having a high percentage of mixed renewable energy it would have an adverse relationship with CO_2 emission, so in the view of Liu and Bae (2018), and contrarywise. In 2013, the consumption of India's renewable energy was 18.3% of the total energy in India, these results have shown the negative connection between the use of renewable energy and CO_2 emission, Chen et al. (2016). After these issues, the government of India has invited more projects on energy infrastructure, with an anticipated achievement date of 2030. After considering the above parameter and review the paper decided to frame the hypothesis related to CO2 emission and economic growth in India. Thus, the hypothesis has developed based on the literature review related to economic evolution and CO2 emission.

> Hypothesis: Is there any positive or negative relationship between economic growth and CO2 Emission?

Relationship between FDI and CO_2 emission

The equivalent FDI and environment conversation led to the escalation of various research hypotheses like “Porter’s hypothesis,” “Pollution Havens hypothesis,” “Pollution Haloes hypothesis.” Additionally, the FDI and environment debate can be considered into two broad aspects, first one is recognized in the classical trade perspective of proportional benefit and the second one is recognized neo-technology trade viewpoint. According to Nkengfack and Kaffo (2019), the classical trade explains that the relative gain treats the environment as an influence of production, in which stringent environment rules can increase the production cost, and in the point of neo-technology trade illustrates the rigorous environment rules are synchronized to the merging of disordered ventures in countries with slack environment guidelines, Wang et al. (2011). In this connection, the paper initiates from the technological research gap method which primes to accomplish that FDI may have a better influence on the environmental quality protection through the transmission of environmentally approachable technology in the view of developed and developing nations. The neo-technology viewpoint is carried to the FDI and environment

construction through Porter's hypothesis and Porter's theory, which was formerly articulated by Lee (2013a, b, c), and later altered by Pata (2018). Additional, Ozturk and Al-Mulali (2015) coped with three forms of Porter's hypothesis, i.e., Weak, semi-weak and Strong, these forms were created based on the degree of innovations associated with environmental guidelines. The hypothesis of pollution havens circumstances that with permitted trade and drive of capital, further is the conveyance of pollution-intensive trades from nations with stringent environmental guidelines and procedures to nations with unsecure environment guidelines. More, Acharyya (2015) describes that this framed hypothesis of pollution havens has three proportions, the first form is stated that the relative gets more benefit, the main reason is that developing nations levy hassle-free environment regulation to attract FDI and henceforth have proportional get benefits in polluting manufacturing. The next form is the strong environmental regulations in developed nations, which will show outcomes curbing hazardous harsh environment through FDI inflow in developing nations. The last form is the enormous debility of the capitals of emerging nations predominantly non-renewable energy by international corporates.

Understandably, the paper has determined the specific characteristics of developing nations related to FDI and CO2 emission, these factors play a very significant role in the overall economic growth of the nation, Arminen and Menegaki (2019). Because of India, Paul and Bhattacharya (2004), invention a constructive relationship with FDI inflow and CO2 emission, although others inventions have indicated the negative impact during the short run at the states level, He (2006), from the Evidence of study recommends that the FDI networks with CO2 emission over different networks that are composition, scale, and technique effects of the on CO2 emission., Richard (2010). Wherever the scale effect techniques are states to the business's operation activities and their size of capital, this one can decrease the supply for inputs and increase the demand for inputs, Amri (2016). However, the study predicts that the current modification cannot adjust with the FDI and CO2 emission and finally the study determines the overall relationship between FDI and Co2 emission indicates the positive in India, from the above discussion the study frames the hypothesis as follow.

Hypothesis: Is there any positive or negative relationship between FDI and CO2 Emissions?

Relationship between crude oil and CO_2 emission

Globally, Crude oil is an essential commodity and crude oil is one of the most significant fuel sources, Indian imports 1.5 billion barrels of crude oil each year. This comes up to around 86% of its annual crude oil requirement, so crude oil plays a very significant role in the development of the economy. Though, the differences in crude oil rate inversely affect the world economy of a crude oil importing to exporting nations literature recommends that crude oil export is a very significant source for the revenue generation for the exporting nations, Boutabba (2014). Which are the developing countries being highly dependent on crude oil energy and crude oil energy is a very foremost source for the development of nations, like Indian and china etc., either crude oil energy importing or exporting, have a sophisticated outcome on economic determinants, where the data review recommends s that the shortage of crude oil shown the negative impact on growth and it will increase inflation and decrease the production output, Varghese (2017). The secondary data evidence also recommends that an increase in crude energy led to a decrease in crude oil utilization, thus outcomes are shown on the lower CO2 emission, An et al. (2021). Though an upsurge in crude oil price replicates the insufficiency of crude oil, which boosts crude energy-importing nations to move toward economic substitutions, thus can influence CO2 emissions.

However, crude oil signifies the fundamental factor of domestic manufacturing production; however, the researchers have initiated an adverse association between crude oil prices and crude oil consumption, Lv (2017). From the data, the evidence also recommends that increasing crude oil prices also bring innovation, Ponce and Alvarado (2019). which ultimately outcomes in making different crude oil sources rather economical than traditional crude oil sources. Rehman and Rashid (2017), has discussed in his research paper more consumption of crude oil indicates positive effects on economic development as well as improve the production output in the nations, additionally also examines in his paper high crude oil price its decrease traditional energy uses but will improve R&D in the field of renewable energy. EKC also recommends that developing countries improve income and per capita income, and at the same time improve in the development of more research & technology, according to the international crude oil Agency (2018. Concerning crude oil energy uses sectors are more persistent, the best example is the transport sector, the transport sector is a prime user of crude oil in India. With help of the above discussion the researcher has concluded the impact of the crude oil price on CO2 emission is negative, based on this review the paper framed the hypothesis that is;

Hypothesis: Is there any positive or negative relationship between crude oil prices and CO2 Emissions?

Summary of Findings from the previous studies

Authors	Year	Outcomes
Oxelheim, L., & Ghauri, P,	2008	FDI allows knowledge sharing and technology spillover, and also enhance production capacity and employment
Haug, A. A., & Ucal, M.	2019	The relationship between carbon emission and foreign direct investment (FDI) is to be positive
Jiang, L., Zhou, H. -f., Bai, L., & Zhou, P	2017	The relationship between carbon emission and foreign direct investment (FDI) is to be negative
Grossman, G. M., & Krueger, A. B.	1995	Support the EKC hypothesis
Schmalensee, R., Stoker, T. M., & Judson, R. A	1998	Support the EKC hypothesis
Selden, T. M., & Song, D.	1994	Support the EKC hypothesis
Galeotti, M., Lanza, A., & Pauli, F.	2006	Do not support the EKC hypothesis
Apergis, N.	2016	Countries after attaining inverted U -shape have to start degrading their environment for additional economic growth
Lee, J. W.	2013a, b, c	The developed countries have the choice to allow environmentally friendly investment in the country
Levinson, A., & Taylor, M. S.	2008	Mostly, developing countries fall in the domain of pollution heaven hypothesis where their key points for attracting FDI is either cheap resources and environmental policies or both
Behera, S. R., & Dash, D. P.	2017a, b	The relationship between carbon emission and FDI is more significant and positive in high and medium-income countries in comparison to low-income countries, which have a negative relationship
Agras & Chapman	1999	As, low income developing countries are either unable to attract the FDI or only attracts the FDI in the service sector, which cast a lower impact on carbon emission
Seker, F., Ertugrul, H. M., & Cetin, M.	2015	While other studies using the data of high-income developing countries find the relationship between the two to be positive
Pao, H. -T., & Tsai, C.M.	2011	Supporting pollution halo hypothesis
Sbia, R., Shahbaz, M., & Hamdi, H.	2014	Country-specific characteristics play a significant role in terms of defining the relationship between FDI and carbon emission
Chen T, Gozgor G, Koo CK, Lau CKM	2020	additionally found an inverted U-shaped link between CO2 emissions and EG in 35 OECD nations through the PMG estimation technique
Rehman MU, Rashid M	2017	found an insignificant association between EG and environmental debasement.
Antón A	2020	as asymmetric (nonlinear) association of economic growth with CO2 emissions is concerned, few studies are available
Toumi S, Toumi H	2019	also found that positive change in EG affects positively CO2 emissions and negative change in EG affects negatively but insignificantly CO2 emissions in India
Raggad B	2020	also collected the data of Saudi Arabia from 1971 to 2014, applied NARDL model, and found that the positive and negative changes in EG affect positively CO2 emissions.
Shahbaz M, Sharma R, Sinha A, Jiao Z	2020	collected the data of India from 1980 to 2019, applied NARDL model, and found that the positive change in energy consumption increases the CO2 emissions and negative change in EC decreases the CO2 emissions.

Source: summary of findings prepared by Author.

Research methodology

The present research paper adopted the methodology based on the above literature, which is the present to import and export parameters as computed barometers for marketing along with FDI to examine the influence of trade marketing and FDI on the CO_2 emissions. The paper determines the association between climate quality and PCI (per capita income) by applying the following model:

Table 1 Variables and sources

Variables	Full form of the variable	Statues	Source
IN	Inflation rate	C_V	CMIE Report
GG	Good governance	C_V	World bank
HCG	Human capital growth	C_V	World bank
FSD	Financial service development	C_V	RBI& World bank
EX	Export of goods and services	C_V	RBI& World bank
COP	Crude oil price per barrel	M_V	CMIE Report
FDI	Foreign director investment inflow per capita income in India	M_V	RBI &CMIE Report
GDP	Gross domestic product -per capita	M_V	World bank & RBI
CO2E	Carbon Dioxide emission	M_V	World bank & CMIE Report

Source: author calculations and author have collected from literature review (C_V= Control Variables and M.V = Main Variables)

$$C_{it} = \alpha_0 + \alpha_1 X_{it} + \alpha_2 \ X_{it}^2 + \epsilon_{it} \quad (1)$$

From Eq. 1, the paper demonstrates the variables. Where C_{it} denotes $PCCO_2E$ (per capita carbon emission), X_{it} is PC-GDP (per capita_ GDP), $\propto_{it}$ is indicated as the ET (error term), I denote the whole country, and t denotes the time. In instruction to validate the EKC, X and X^2 presented into the model as independent variables, crude oil and control variables (see Table 1). The paper has used the natural logarithm model for selected variables and based on the logarithm model can control the heteroscedasticity. Table 3 illustrates the significance of the variables for the validate purpose, the variables are, macroeconomic variables and control variables listed in Table 1. with help of Eq. 2, the paper uses the practical model is as follows (Table 2):

$$LCO2E_t = \alpha_0 + \alpha_1 LGDP_t + \alpha_2 LGDPpci_t^2 + \alpha_3 LFDI_{it} + \alpha_4 LCOP_t + \gamma_5 \ LC\_V_t + \epsilon_t \quad (2)$$

Equation 2, hereby explain the variables, where $LCO2E_t$ is stands for the log of CO2 emissions and its per capita income; $LCO2E_t$ is stands for the log of GDP $_{\text{pc (per capita income)}}$; $LGDPpci_t^2$ is indicates that the log of the square root of $GDP_{\text{pc (per capita income)}}$; $LFDI_{It}$ is representing the log of FDI I inflow; $LCOP_t$ is indicating the log of the crude oil prices per barrel. While LC_V_t is that the control variables, this variable parameter indicates in Eq. 2, the control variables in this paper are inflation per capita income, human capital, export of goods and services per capita income, accountability and transparency of good governance and financial development, these variables are representing with symbols $LIPC_t$ (log of inflation per capita), LHC_t (log of human capital), $LEGSPC_t$ (log of export services and per capita income), LGG_t (log of good governance) and LFD_t (log of financial development. ϵ_t is the residual variable of Eq. 2, above all variables explain in every detail and it's represented in Table 1 As per the EKC, the paper signifying the relationship between the environmental quality and growth of GDP per capita and the values has been shown in the form of inversely U -shaped curve and the EKC results shown as negative. So, if the sign of α_1 is positive and the sign of α_2 is negative, then the EKC hypothesis evidenced may be significant in the Indian context. For this analysis, we used the annual data and the data has been covered from 1990 – to 2020, the data has been collected from various sources are RBI, the World Bank and the ministry of environment, while secondary information for crude oil prices collected by CMIE reports, human capital related data collected from RBI, and governance data collected from good governance index of India. Further, the paper also uses the main variables and control variables to examine the

Table 2 Descriptive statistics

Variables	Mean	Minimum	Maximum	Median	Observations
IN	0.895	0.482	1.328	0.735	37
GG	0.951	0.847	1.046	0.753	37
HCG	0.285	0.163	0.738	0.227	37
FSD	0.682	-2.581	1.739	0.867	37
EX	3.207	3.316	3.741	2.358	37
COP	2.135	2.045	2.145	3.072	37
FDI	0.821	0.867	2.427	-2.174	37
GDP	4.284	4.782	5.381	5.782	37
CO2E	-0.413	-0.019	-1.005	-0.314	37

Source: author calculation

Table 3 Lag Length Selection

Lag	LR	FPE	AIC	SC	HQ
0	234.613	3.27E-13	-13.080	-11.611	-13.112
1	455.022	5.21E-22	-21.671	-18.041	-23.651
2	587.651	0.72e-23**	-24.310**	-21.517**	-21.517**

Source: ** shows lag order carefully chosen by the criterion; LR: sequential modified statistical significance at 5 per cent level;

Note: "FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion".

sensitivity analysis and also assess the relationship of the individual variables with CO2 emission. The following variables are provided based on the literature review (Table 3).

Results of lag length test

The paper used a lag length test that is very significant for the cointegration of the variables. All lag length is considered based on the selected five criteria, these criteria are LR, FPF, AIC, SC and HQ represent the lag length directing for cointegration of variables. Further lag length test indicates the appropriate decision for the policymaker and implications.

ARDL

Furthermore, the paper also applied Cointegration Analyses (ARDL and Cointegration Analyses), to observe the long-run cointegration association between the selected variables, based on the literature review the paper has provided numerous econometric techniques. The ARDL method used for the suitable lag option and sufficiently put up the sequential correlation as well as endogeneity of variables, additional also provides the robust estimation of the variables. The paper examines the connection among variables GDP, per capita income crude oil price, FDI and CO2 emission in the same order. With these variables the paper develops the following equation:

$$\Delta LogCO2E_t = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \Delta logCO2E_{t-1} + \sum_{i=1}^{p} \alpha_2 \Delta \log GDP_{t-1} + \sum_{i=1}^{p} \alpha_3 \Delta \log FDI_{t-1} + \sum_{i=1}^{p} \alpha_4 \Delta \log COP_{t-1} + \gamma_2 \log GDP_{t-1} + \gamma_3 \log FDI_{t-1} + \gamma_4 \log COP_{t-1} + \propto_t \quad (3)$$

From Eq. 3, the paper illustrates the Unrestricted Error Correction Model consistent with the Autoregressive Distributed Lag bound test, where $\Delta LogCO2E$, $\Delta LogGDP$, $\Delta LogFDI$, $\Delta LogCOP$ denote their corresponding values. The symbols of α_2 to α_4 signify the positive relationship during the short-term period, while γ_2 to γ_4 signify the positive relationship during the long-run period. The P-value signifies the lag period determination for the explicated and explanatory variable purpose, correspondingly. In the view of Bhattacharya et al. (2017) explore, the ARDL bound test and F statistic applies for a dual significance to control the cointegration association among the selected variables. The hypothesis uses the F-statistical significance test are $\gamma 1 = \gamma 2 = \gamma 3 = \gamma 4 = 0$, these values results indicate that there is no significant cointegration and relationship between the variables. According to the F-test value is lower than the lower bound test value, the null hypothesis can be accepted but the alternative hypothesis indicates their insignificant relationship and no cointegration between variables. if in case F-statistics values are higher than the upper bound test value, the Ho hypothesis can be rejected.

Non-linear ARDL

The ARDL method is suitable for generating the long and short-run cointegration relations and elasticities for small sample sizes; even though the asymmetric theory has been ignored in this selection of samples. The asymmetric theory has been applied to determine the association between variables for cointegration, the paper has been considered the non-linear ARDL model. Thus, the ARDL and NARDL model developed based on the specified as the Eq. (2), the non-linear ARDL model as the driven equation is as follows:

$$\log CO_2E = \alpha_0 + \alpha_1 \log GDP_t^2 + \alpha_2 \log FDI_t^+ + \alpha_3 \log COP_t^+ + \alpha_4 \log HCG_t^+ + \propto_t \quad (4)$$

From Eq. (4), the paper illustrated the variables are logFDIt+FDI^2 signifies the - and + fractional sum of process disparity in foreign direct investment, while logCOP+ and logCOP$_t$ also signify – and + partial sum of variation in COP value derived based on the Eq. 5.

$$\begin{aligned} \log FDI_t^+ &= \sum_{k=1}^{t} \triangle \log FDI_k^+ \\ &= \sum_{k=1}^{t} minimum\left(\triangle \log FDI_k, 0\right) \log FDI_t^- \\ &= \sum_{k=1}^{t} maximum\left(\Delta \log FDI_k, 0\right) \end{aligned} \quad (5)$$

$$\begin{aligned} \log COP_t^+ &= \sum_{k=1}^{t} \triangle \log COP_k^+ \\ &= \sum_{k=1}^{t} minimum\left(\triangle \log COP_k, 0\right) \log COP_t^- \\ &= \sum_{k=1}^{t} maximum\left(\Delta \log COP_k, 0\right) \end{aligned} \quad (6)$$

From Eqs. 5 & 6, the parallel phases as taken under the ARDL model, the study have examined the lag length selection and summary of statistics of the GDP, FDI, COP and CO2 released have found that the significant impact on mention variables. While lag length selection model has recommended a lag length value of 2 to be suitable for the non-linear model. Then the non-linear model examines the asymmetric relation among the study variables. Equation 7 is framed based on Eqs. 5 & 6, the Eq. 7 is as follows:

$$\begin{aligned} \Delta \log CO2_t^+ &= \sum_{t=1}^{q} \gamma_t \triangle \log CO2E_{t-1} + \sum_{t=1}^{q} \gamma_t \triangle \log GDP_{t-1} \\ &+ \sum_{t=1}^{q} \left(\gamma_t \Delta \log FDI_{t-1}^+ + \gamma_t^- \Delta \log FDI_{t-1}^-\right) \\ &+ \sum_{t=1}^{q} \left(\gamma_t \Delta \log COP_{t-i}^+ + \gamma_t^- \Delta \log COP_{t-1}^-\right) \\ &+ \varnothing_i EC_{t-i} + \propto_t \end{aligned} \quad (7)$$

Table 4 ARDL Bound Test Estimations

ARDL Bound Test Estimations				
ARDL Bound Test Statistical Values		Ho Hypothesis		
		Significance level	I (0)	I (1)
F-statistic	6.528***	1%	1.628	2.107
K	3	5%	1.085	2.138
		10%	2.174	2.174

Source: *, ** and *** illustration significance level at 10%, 5% and 1% level correspondingly.

From Eq. 7, the variables illustrate that the θiEC signifies error correction term (ECT), demonstrating the long-run symmetry of alteration after the COP (crude oil price) shockwave and the asymmetric relation indicates negative impact during the short -run with regards to the COP (crude oil price). The symbols of γi signify the coefficient values during the short run, while $\gamma i+$ and $\gamma i-$ denotes asymmetric changes during the short-run period. Like to ARDL bound test is directed applying the F- test values show that the significance to consider the cointegration affiliation and SWT (standard Wald test) and its shows to observe symmetry $\gamma = \gamma+ = \gamma-$ and asymmetry $\gamma\ 1 = \gamma\ 2 = \gamma\ 3 = \gamma\ 4 = 0$ during the short and long run for FDI, CO2E and COP. The validation of long-run relation is the multiplier impact is measured, from where 1%variation in $LogFDI_{t-1}^{+}$, $logCOP_{t-1}^{-}$.

Empirical results and analysis

Results of ARDL model

The ardl model Integrate the estimated data from the structural break period and lag-length assortment, the F-statistical significance values we can apply from Eq. 3, and it determines the contradiction to the critical values. The F-test has considered the starting point from Eq. 3, and it demonstrates

Table 5 ARDL Estimates – long run

ARDL Long run Estimates						
Variables	Model -1	Model-2	Model-3	Model-4	Model-5	Model-6
GDP	0.215*** (0.266)	0.004** (0.315)	0.738*** (0.246)	0.741** (0.241)	0.410* (0.151)	0.830*** (0.203
FDI	-0.052*** (0.018)	-0.624** (0.022	-0.027*** (0.131)	-0.151** (0.116)	-0.036* (0.108)	-1.152** (0.113)
COP	0.057*** (0.011)	0.173*** (0.121)	0.124*** (0.100)	0.144*** (0.107)	0.164*** (0.106)	0.133** (0.730)
IN		-0.227 (0.015) *				
HCG			0.825*** (0.171)			
EX				0.016* (0.162)		
GG					0.013* (0.028)	
FSD						0.117** (0.106)
Constant	-2.610*** (0.088)	-1.825*** (1.254)	-3.288*** (0.016)	-2.137*** (0.114)	-1.102*** (0.028)	-1.455*** (0.112)
ARDL Bound Test						
F-statistics	8.623***	2.003**	4.326***	2.516**	2.011**	2.241***
Model selection.	1, 0, 0,0, 2	1, 0, 0, 0,2,	2, 0, 0,0, 2	1, 0, 0, 0,2,	2, 0, 0,0, 2	2, 0, 0, 0, 1,
Model Statistics						
R-Square	0.664	0.664	0.665	0.664	0.664	0.665
Adjusted R-Square	0.662	0.662	0.663	0.662	0.662	0.663
F-statistics	743.18***	433.12***	673.01***	534.36***	548.51***	645.14***
Diagnostic Tests						
Normality	0.363	0.782	0.693	1.041	0.937	0.842
CUSUM	Stable	Stable	Stable	Stable	Stable	Stable
CUSUM - Sq.	Stable	Stable	Stable	Stable	Stable	Stable

Source: *, ** and *** illustration significance level at 10%, 5% and 1% level correspondingly and CUSUM stability test; CUSUM -Sq. stability test

the determined relationship is the positive impact of CO2 emission in the long run, as revealed in Table 4.

Table 4, explored the ARDL bound test statistical values with related to the K- test and F-test significant value are higher than the upper bound critical value, according to Narayan and Narayan (2010) illustrates in Table 5 under the continuous approach of K-statistics value and after examines the test value found that there is no trend found at 5% level and the f -statistic found that the statistically significant at 1% level. The alternative procedure to check the existence of the critical point test values during the long run and the long-run association value is cointegrating variables with the error correction term (ECT_{t-1}). Based on the F-statistics values and k-test values if ECT lagged value is statistically significant, the tolerates show a negative impact on the study variables, and the relationship among the CO2E, PCI (per capita income), FDI, and COP may be positive. moreover, the paper, omits the operational break period has considered the dummy variable from the various statistical approach, as it is statistically insignificant values in Table 4.

The ARDL method results are presented in Tables 5 & 6 for the long-run and short-run. The result from Table 5 illustrates the association between economic development and CO2 emission are indicated that the optimistic and substantial during the long-run and short-run, further also discussed based on the Table 5 result that the economic development of the nation is rising and decrease the environmental quality in the short run. The present paper results, while the double economic growth has shown statistically positive but at the same time CO2 emission showing negative relationship with environment quality during the long-run period, the result provided the being of the EKC hypothesis in the Indian context. Based on the Table 5 results, the researcher draws the conclusion, the EKC hypothesis has to disagree with the increased economic growth, the significant reason is that the EKC hypothesis U shape curve determines the high stringent climate policies for the improved environmental quality. The results of this paper are similar to Yaduma et al. (2015), which sustenance the existence of the EKC hypothesis in India. In the point of foreign direct investment output shown the significant impact on CO2 emission during the long run and short run. After 2008, Indian has invited more FDI inflow in the service sector moderately than the primary industry, the literature review has highlighted which nation invited more FDI in the service sector to have an adverse association between FDI and CO2 emission. While comparing with other nations like China, USA and UK have shown moderately positive impact FDI on CO2 emission. In the same order, Table 5 values support to check the robustness of output, the study examined the dynamic stability of the model using the cumulative sum of recursive residuals (CUSUM) and cumulative sum of recursive residual square (CUSUMQ), the table value indicates the outcomes s for CUSUM and CUSUMQ, which indicates that the overall model is stable and constant.

Table 6 illustrates the ARDL results in shoer run, However, the secondary information has advised that the energy consumption if reduced immediately may decrease the CO2 emission, the decreasing energy consumption may not be appropriate for India, thus, the only way for the developing countries like India, the FDI is to play a very significant role for the development of economic to move towards renewable

Table 6 ARDL Estimates – short run

ARDL short-run Estimates						
Variables	Model -1	Model-2	Model-3	Model-4	Model-5	Model-6
GDP	0.411*** (0.226)	0.254** (0.034)	0.158*** (0.121)	0.402*** (0.224)	0.317*** (0.255)	0.178** (0.241)
FDI	-0.125*** (0.117)	-0.114** (0.101	-0.163*** (0.106)	-0.125*** (0.116)	-0.138*** (0.121)	-0.131** (0.127)
COP	0.116*** (0.259)	0.107*** (0.102)	0.101*** (0.114)	0.113*** (0.116)	0.136*** (0.116)	0.153*** (0.117)
IN		-0.147* (0.125)				
HCG			-0.261 (0.544)			
EX				0.047 (0.025)		
GG					0.137* (0.017)	
FSD						0.238** (0.142)
Cointegration	-0.286*** (0.132)	-0.217*** (0.201)	-0.461*** (0.188)	-0.344*** (0.212)	-0.348*** (0.205)	-0.316*** (0.175)

Source: *, ** and *** illustration significance level at 10%, 5% and 1% level correspondingly.

energy invention. Though methods like CO2 pricing is more important to India in two directions, the first direction is that can decrease the CO2 emission by using the carbon tax rebates. The second benefit is that it may get extra revenue generation based basic CO2 pricing method, with help of the CO pricing method approximately India can earn 65 USD per ton of CO2 emission. The ARDL model results indicate the association between crude oil price and CO2 emission shows a positive impact on economic development in the short -run, at the same time tables, 5 and 6 show an adverse influence on economic growth in the long run. From Table 6, results indicate that a difference in oil price and the oil price shows the direct relationship with the inflation rate and economic growth in India, for inflation, most of the nation's provides the subsidy to protect or control the sudden inflation. However, the subsidy originally protects the internal economy from any kind of fluctuation and negative effect of crude oil price; though the durability of subsidy eventually disturbs fiscal shortfall, in this connection, it can increase inflation reduces the currency value. Table 6, draw the conclusion the subsidy controls the domestic crude oil price from the international market which we are importing, the crude oil importing countries providing subsidy lesser than the exporting countries, thus the Tables 5 & 6 results illustrate that the very difficult to protect the volatility in international crude oil prices.

Results of non-linear ARDL (NARDL) model

As specified in Table 7, the F-statistic illustrates the critical factor bound results, the outcomes of Table 7 show that the upper critical bound indicates the significant factors of constant value of lower bound and there is no trend found at 5% significant level of critical bound. Another method to determine the presence of long-run relation is the value of the CIE (cointegrating equation), the value can be indicated with help of the error correction term (approach) (*ECTt*– 1). The presence of the long-run relationship among the CO2 emission, PCI (per capita income), FDI, and crude oil price

Table 7 Non-linear ARDL Bound test

Critical Bound test		
Significant percentage	I (0)	I (1)
1%	1.22	2.14
5%	1.52	2.51
10%	2.16	2.83
Test -Statistic		Value
F-Statistic		6.251

Source: *, ** and *** illustration significance level at 10%, 5% and 1% level correspondingly.

Table 8 Non-Linear ARDL estimates – long run

Variables	ρ =Coefficient	t-statistic	P(A) =Probability
GDP	0.312***	1.815	0.010
FDI-Positive	-1.201***	-1.488	0.010
FDI-Negative	0.150*	1.1101	0.023
COP- Positive	0.137	1.528	0.221
COP- Negative	-1.181*	-0.674	0.074
CO2E- Positive	0.023*	1.765	0.068
CO2E- Negative	0.081***	0.381	0.021
Constant	-3.045***	-2.188	0.000
Model Statistics			
R^2		0.784	
Adj. R^2		0.764	
F-statistic		526.715	
P		0	
Diagnostic	X^2		Probability
Normality	13.201		0.273
Serial correlation	0.627		0.341
Heteroscedasticity	133.201		0.358

Source: *, ** and *** illustration significance level at 10%, 5% and 1% level correspondingly.

is authorized if the Critical Bound Values of the L$ECTt-1$ statistically significant and accepts a negative value shown (sign). The factor of the $ECTt-1$ (error correction term) is shown a negative impact and is statistically insignificant, which indicates that any imbalance in previous data and literature was modified within the stipulated time duration, which indicates rational merging to long-run symmetry in Table 8.

The paper also used NARDL structural breaks introduced by Ali et al. (2017) is used to test the nonlinearity, related to the study sampling period, to report this argument, Ali et al. (2017) test is applied. The outcomes of the NARDL model are portrayed in Table 8, which shows

Table 9 Non-Linear ARDL estimates- short run

Variables	ρ =Coefficient	t-statistic	P(A) =Probability
GDP	0.530***	2.444	0.001
FDI-Positive	-0.039***	-1.325	0.001
FDI-Negative	0.017**	1.206	0.017
COP- Positive	0.021	1.524	0.002
COP- Negative	0.093	1.004	0.163
CO2E- Positive	0.052**	0.301	0.012
CO2E- Negative	0.180***	1.370	0.000
Cointegration from the Eq. 1	-0.231***	-1.681	0.000

Source: *, ** and *** illustration significance level at 10%, 5% and 1% level correspondingly.

the nonlinearity of the series after considering the different structural breaks. The outcomes are shown in Table 9, which designate the existence of two breaks, in the year 1992-1993 and 2007-2008. Throughout these periods, India challenged the most important changes in the macroeconomic indicators are privatization, and globalization in the initial 1900s to overcome the financial crises and provide opportunities. In an assenting projected by the United Nations for environmental change, India has certain to decrease its CO2 emissions by installing 55% of its energy from renewable resources associated to 2006 level by 2035 and under the guidance of UNFCCC (United Nations Framework Convention for Climate Change), causing a structural change in the environmental strategies during 2006-2007.

The non-linear ARDL results are presented in Tables 8 & 9 during the long and short -run. the non-linear ARDL outcomes present the association between economic development and CO2 emission, the relationship between two variables shows statistically significant and positive, which is reliable with the autoregressive distributed lag model outcomes. While the non-linear autoregressive distributed lag model outcomes also provision for the existence of the EKC hypothesis, in the same way as ARDL model outcomes. in this circumstance, the asymmetric association between FDI inflow and CO2 emission shows a positive in the long - run, if the increased FDI inflow means automatically will increase CO2 emission, while the reduction in FDI means will reduce CO2 emission in the short run. The outcomes of both models during the short-run, the relationship shows the statistically insignificant. These outcomes under non -linear autoregressive distributed lag model also recommend the effluence haven hypothesis in the Indian context. Though, the Wald test outcomes also measuring the connection of the positive and negative shockwaves of FDI inflow do not sustenance asymmetry theory in Table 10,

In this situation of the long-run association between COP (crude oil price) and CO2 emission, an increase in the COP than the decreases CO2 emission, while a reduction in the COP than the increases CO2 emission. The Wald test outcomes for measuring the likeness of positive and negative shockwaves of COP also sustenance asymmetry theory, as shown in Table 10, because it is significant in the long -run. While an upsurge in the COP does not cast any statistical values indicating a significant impact on CO2 emission, a reduction in the COP means upsurges CO2 emission in the short -run.

Table 10 Wald Test

Exogenous Variable	Long run		Short-run	
	F-statistic	Probability	F-statistic	Probability
GDP	0.371	0.121	0.163	0.216
FDI	0.751	0.261	1.130	0.013
COP	0.827	0.110	2.582	0.020

Source: *, ** and *** illustration significance level at 10%, 5% and 1% level correspondingly.

Robustness check analysis

The paper used different sole equation formula estimator techniques such as DOLS to check out the robustness of the paper's long-run period estimates attained from the autoregressive distributed lag estimator. The foremost advantage of the dynamic ordinary least square model is that it studies the diverse order integration of variable quantity in the co-integrated background. Meanwhile, it also resolves the difficulties like endogeneity and small size sample period data. The dynamic ordinary least square outcomes are reliable with outcomes of long-run autoregressive distributed lag estimates and having the same directions and significances level. The result of the dynamic ordinary least square is obtainable in Table 11. The long-run outcome of the non-linear and autoregressive distributed lag model is in line with dynamic ordinary least square outcomes. The outcomes demonstrate that the dynamic ordinary least square hypothesis grasps in the Indian context under all procedures.

Conclusion

The conclusion of the paper determines based on the symmetric and asymmetric relationship with the PCI, FDI, and COP on CO2 emission by applying ARDL and non-linear ARDL models. The outcomes indicate that the increase in COP (crude oil price) would decrease CO2 emissions,

Table 11 DOLS (dynamic ordinary least square)

Variables	Coefficient	Std. Error	t-Statistic	Probability
IN	0.018***	0.116	3.775	0.0001
GG	-1.171***	0.106	-3.624	0.010
HCG	1.101**	0.113	1.734	0.014
FSD	-1.142***	0.217	-3.007	0.012
EX	1.172	0.100	0.120	0.131
COP	0.148**	0.358	1.572	0.108
FDI	1.146**	0.131	1.737	0.021
GDP	1.029***	0.106	5.273	0.001
CO2E	1.061***	0.117	4.018	0.002
R^2	0.553			
Adj. R^2	0.638			

Source: ***, ** and * show significance at 10, 5 and 1% levels correspondingly.

while a decrease in economic growth would raise CO2 emissions. the positive and negative shockwaves in COP have a favourable and significant impact on CO2. the relationship between FDI inflows and CO2 emissions supports the pollution heaven hypothesis. the asymmetric causality test illustrates a bi-directional connection between positive shocks of economic growth and negative shocks of COP and between negative shocks of economic growth and positive shocks of COP. While, the ARDL and NARDL result also suggested that if the increase in COP decreases CO2 release during the long run, while, the outcomes of the paper shows that the decrease in COP increases the CO2 emission. With concern FDI, quarrying and mining industries are foremost attracting the foreign investors, which is not only increases energy consumption but also improves environmental dilapidation, thus supporting the finding of the present paper. Furthermore, the paper determined the relationship between COP and CO2 emission is that the deferred time effect on consumption due to subsidy in the short run. While, in the same way, the crude oil price increases the demand for energy-efficient products price, if the energy products price will be increased the overall energy uses will be increase and the CO2 emission will be decreased.

The paper recommends the following suggestion and policy implications. The government of India should target expanding or improving the energy consumption mix including renewable energy manufacture, confirming higher energy usage is not a major root cause of climate degradation. While, considering the CO2 pricing methods like CO2 taxation, and emission trading structure will not stop 100% emission but based on the CO2 pricing method, providing the extra source of revenue generation. The government of Indian framed policies should be given more benefits and to inspire industrialist and energy companies, in the direction of green investment like tax allowances on the green investment projects. Along with private financial institutions, the government of India should allow low expenditure credit facilities to renewable energy industries, sources like solar energy, this kind of source or facilities will decrease the load of energy consumption source and also decrease CO2 emission. According to the EKC hypothesis suggestion, the government should frame their environmental policies with more and more economic evolution, to decrease the effect of climate degradation. The policymakers, economists, and environmentalists need to immediately encourage green investment projects, green innovation to overcome the CO2 emissions. Hence, it is a big interrogation for policymakers to a resistor and overcomes the CO2 emissions from crude oil usage through pursuing energy-efficient and environmentally friendly technology alone. The FDI inflows play a negative role in accomplishing the maintainable environment. The increasing FDI rises the CO2 emissions, which is not a better perception. To overcome the negative influence of FDI inflows on the environment, the policymakers should take such enterprise and frame such policies which keep the determination to achieve sustainability. It is also suggested that policymakers should have a positive method that boosts investments and the attainment of resources in the clean energy segment. This method can offer motivations that are advantageous for boarding on projects that speedy renewable energy and decrease CO2 emissions. Finally, the paper has given direction to future research that will be focused on the association between CO2 emission and different arrays of environmental quality indicators and technology innovations in the Indian context.

Authors contributions for this paper the author only conceptualized the idea, design the method, literature review, analysis and overall developed the paper.

Data availability Not applicable

Declarations

Ethical approval and consent to participate No human participants involved in this research study

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