

IMPACT OF MACRO-ECONOMIC VARIABLES ON ENVIRONMENTAL DEGRADATION IN INDIA: “PAVING THE WAY TOWARDS A GREEN ECONOMY”

Mehak Kohli, Shri Mata Vaishno Devi University Kakryal Katra
Roop Lal Sharma, Shri Mata Vaishno Devi University Kakryal Katra

ABSTRACT

Following the United Nations Sustainability Development Goals, this study explored the impact of macroeconomic variables on carbon dioxide emissions. By considering the significance of symmetries and asymmetries, this study investigates the symmetric (linear) impact of poverty, income inequality, population, economic growth, renewable energy consumption, and urbanization on CO₂ emissions in India, spanning the data from 1991 to 2019. To this end, the autoregressive distributed lag (ARDL) model is used to examine the symmetric impact of the variables on the environment. The symmetric results of the current study show that poverty, economic growth, and urbanization increase carbon dioxide emissions in both the short run and long run but on the other side, there can be seen a mixed impact of income inequality, and population on the environment degradation. In light of these results, this study also suggested some policy implications regarding the United Nation's sustainability development goals and future research avenues in the concluding section.

Keywords: Sustainability, Environment, Economic growth, Poverty.

JEL Classification: C50, Q56.

INTRODUCTION

In recent years, India has emerged as a dynamic economic powerhouse, experiencing rapid industrialization, urbanization, and technological advancement (George, 2023; Wang et al., 2020). This economic transformation has brought unprecedented growth and prosperity to the nation, but it has also raised concerns about its environmental footprint, particularly in terms of carbon dioxide (CO₂) emissions (Ali et al., 2023; Akhter et al., 2021). It becomes increasingly important to understand how macroeconomic variables affect CO₂ emissions in the context of India's pursuit of economic development and environmental sustainability. The economic expansion of rising nations hurts the environment by increasing the consumption of fossil fuels for industrialization and supporting economic growth (Li & Haneclaus, 2021; Yang et al. 2020; Hanif et al., 2019). On the other side, the argument that poverty is a cause and effect of environmental degradation has been discussed extensively, especially in developing nations where a sizable portion of the population lives at or below the poverty line and does not benefit from economic progress. A large portion of the impoverished population in emerging nations depends heavily on the agriculture sector, which relies heavily on natural resources (Masron & Subramaniam, 2019), due to which the poor people abuse the natural resources to make ends meet; for example, they clear forests to meet their energy demands and, in this way, it leads to an

indirect contribution to the rapid depletion of natural resources (Farooq et al., 2020). Poverty and the environment both are declared the most multifaceted problems faced by most countries (UNICEF, 2016). To bring humanity out of poverty and to protect the environment for future generations, several industrialized and developed countries from around the globe have come together to achieve these goals (Baloch et al., 2020; Maji, 2019) and attained more success by inspiring more industrialization and production levels (Islam & Ghani, 2018). However, to promote green economic growth, certain economic activities demand energy, which further leads to an upsurge in environmental degradation, undesirably disturbing social welfare and sustainable development (Qamruzzaman & Jianguo, 2020; Danish, 2019). But in addition to the escalating environmental crises, the modern era is marked by social crises brought on by the unequal distribution of income. As per Grossman and Krueger (1995), the hypothesis of EKC revealed a convex relationship between income inequality and the environment (Zhao et al., 2021; Hafeez et al. 2019; Hafeez et al. 2018). This also hypothesizes that after they reach a specific income level, the richer people lower the pollution emissions because they can afford and have higher demands for a better environment (Li et al. 2020, 2021a, b; Hafeez et al. 2019; Chiu & Lee, 2019).

Currently, India incorporates a share of 17% of the world's population but still emits only 7% of global emissions. Given that India's per-capita emissions are lower than the world average, this is encouraging from a sustainability standpoint (Ito & Ali, 2022). India is currently the third-largest global CO₂ emitter while emitting far less than developed countries like China and the US, which raises concerns for researchers and policy officials about how to combat this threat. On the other side, determining how urbanization affects a nation's green growth would enable identifying the necessary adjustments and tools for attaining green growth in light of urbanization (Kotowicz et al., 2022; Adamowicz, 2022; Rybalkin et al., 2021; Guo et al., 2020) because an increase in urbanization raises the concern in both energy consumption and environmental degradation. Firstly, most residents from urban areas straightly upsurge consuming coal, natural gas, oil, and other kind of energy. Secondly, these people are also influenced towards personal cards, tourist activities, and housing, which in further leads to an increase in energy consumption and CO₂ (Yan et al., 2022). Therefore, with the rise in population and urbanisation, it can be analysed that it also increases the demand for energy consumption which becomes very important to maintain the harmony with all the ongoing distractions and revolutions in the world (Zhang et al., 2017). However, the whole world has initiated paying their attention towards the problems related to environment connected with rising carbon dioxide emissions, and in that way, various countries recognised the usage and consequences of renewable energies like solar energies, hydropower, wind, geothermal, biomass etc. (Sinha et al., 2017). At the same time, renewable energy consumption and its share in total energy are constantly rising. As the massive demand for renewable energy and the continuously growing green-house gas emission levels, the nexus of emission- growth-renewable energy consumption needs to be properly analysed, which can further proved to be useful in removing the problem of global warming by encouraging the progress in renewable energy sources (Dong et al., 2019).

Likewise, over the past 20 years, there is continuous research is ongoing on the determinants of CO₂ emissions which has flourished (Dong et al., 2020; Andreoni & Galmarini, 2016). The main theoretical base behind this concept is to describe the long run relationships between various variables and CO₂ emissions which implied that there is an inverted U-shaped linkage between GDP per capita and environment variable like CO₂ emissions, also known as

Environment Kuznet Curve (EKC) framework. An expansion of the Economic growth paradigm, green growth promotes environmental protection while fostering economic advancement. Put differently, green growth is thought to be a successful strategy for promoting EG and resolving environmental conflicts within a nation. The main goal of "green growth" is to advance the economy while protecting the environment (Tereshchenko et al., 2023). Various policies are announced by the institutions worldwide to fortify the governments so that they can implement the green growth practices. These policies highlighted three essential challenges: energy use, social development and environmental deprivation. Hence, the green growth can be measured as the efficient method of economic development through protecting the environment ((Wahab et al. 2022). Green economic growth consists of nine SDGs goals out of sixteen SDGs and this study focused on SDG1 (No poverty), SDG7 (Affordable and clean energy), SDG8 (decent work and economic growth), SD10 (reduced inequalities), SDG13 (climate action). The present study has focused on the role of institutions in providing several policies which helps to attain the green economy by achieving various SDGs in case of India. There are several studies who have focused on various macro-economic determinants of CO₂ emissions (Farouq & Sulong, 2023; Anwar et al., 2023; Iqbal et al., 2023; Caglar et al., 2022; Shpak et al., 22; Aslam et al., 2021; Li et al., 2021; Cosmas et al., 2019). Defining the impact of macro-economic variables on the environment of a country permits the appropriate variations and tools for attaining the green growth in the country. Many studies have still not reached at an agreement with the green policies which directly shows that still some countries are facing this issue and their environment quality are continuously declining. As a result, it is very important for the countries to grab this opportunity so that they can initiate policies to gain the SDGs and the Green Deal policy.

In the previous perspective, this study is an effort to bridge the gap in literature in the context of India. The present study focuses on to incorporate various macro-economic variables in respect to the environmental degradation and develops an approach to achieve the "Green Economy" in the country India by extending the various parameters which has received very less or no attention before. Furthermore, the investigation is done by analysing the symmetric impact by applying the ARDL technique. To this extent, the outcomes from this study will help the policymakers, practitioners and researchers to suggest various green growth policies and aims to improve the environment sustainability within renewable energy consumption and economic progress without disturbing the environment quality.

The paper consists of following structure: Section 2 contains a review of literature. Section 3 consists of description of data and methodology incorporated in the study. Section 4 elaborate the empirical findings with proper justifications. Section 5 outlines the conclusion, suggesting the policy implications and future research aspects.

LITERATURE REVIEW AND HYPOTHESIS

Even though, there are large number of studies that have analyzed the impact of macro-economic variables on environment degradation but very few studies have targeted this examination towards achieving green growth. By considering this approach, we have divided the existing literature into the following broad titles and the latest studies under each section is assembled.

Poverty and CO₂ Emissions

The poverty- environment connection has been analysed in the various literature but the

relationship between them is quite complex and multifaceted because poverty exacerbates the strain on finite resources and degrades the environment when combined with rapid population growth and weak environmental regulations. (Kocak et al., 2019). Recent studies have shown that carbon emissions can be more than double with the poverty alleviation for both low and middle-income countries (Baloch et al., 2020; Dorband et al., 2019). It is also suggested that putting efforts to alleviate the poverty in these areas may lead to upsurge in CO₂ emissions but globally its effect becomes relatively less (Proskuryakova & Ermolenko, 2022). However, research on global carbon inequality suggests that lifting the world's poorest people out of poverty will result in considerable increase in worldwide carbon emissions, with China and India seeing increases of 4% and 7%, respectively (Hubacek et al., 2017). Moreover, a study by Radoine, 2022 has analysed that the quest of economic progress and industrialization, which are viewed as means of escaping poverty, is frequently associated with rising CO₂ emissions in emerging nations, especially those with high rates of poverty. But if left unchecked, this could result in worsening environmental damage. The main difficulty lies in striking a balance between environmental sustainability and economic development so that initiatives to combat poverty don't result in higher CO₂ emissions. According to another group of researchers, there is a causal relationship between poverty and environmental degradation that exists in both directions (Amin et al., 2023; Dhryfi et al., 2022). They proposed that both rich and poor people contribute to the overuse of natural resources and environmental degradation but the effects on the former are greater than those on the latter because the former are perceived as both representatives and victims of environmental degradation. Few more studies had incorporated their association but still these approximations are indecisive, where as many researchers are unable to provide a relevant and clear picture on their estimation towards attaining the green economy.

H₁: Poverty has an impact on CO₂ emissions in India.

Income Inequality and CO₂ emissions

Both the climate change and income inequality have become two persistent issues of the present time (Wolde-Rufaela & Idowub, 2016). Currently many researchers are interested in studying the relationship between income inequality and other economic indicators, such as economic growth. However, the association between income inequality and environmental degradation has not received enough attention, and as a result, it is now a popular topic of study in the empirical literature. Their relation can be understood with the two aspects. According to the first aspect, the positive association exists in between income inequality and environment degradation which in turn suggests that as income inequality increases, so do the emissions. (Khan et al., 2022; Zhou & Li, 2020; Zhang & Zhao, 2014). This is partly correct because the widening gap between the rich and the poor ones, which further leads to more extreme demands from low-income individuals, who are not motivated to contributing in reduction of climate change (Wollburg et al., 2023). Another study by Wang et al., 2024 concentrating on Africa and found that in the fastest-growing economies, there is a positive correlation between GDP per capita growth and CO₂ emissions, suggesting that rising income disparity might be linked to economic growth, which frequently results in higher CO₂ emissions. The intricate interactions of social justice, environmental sustainability, and economic development are highlighted by this relationship. Moreover, various studies analysed that economic development is positively correlated with an increase investment in human capital due to income inequality. Economic expansion also increases the supply and demand for services, which puts a brake on

environmental deterioration (Pata et al., 2020; Cao et al., 2019). Che et al., (2023) found that income inequality has a positive and significant effect on carbon dioxide emissions in case of both developing and developed countries with a more significant impact in developed countries. The findings of Zhang and Zhang (2021) demonstrate a long-term positive correlation between China's carbon emissions and income disparity.

As per the second thought, some researchers suggested that income inequality have an extenuating impact on the environment degradation (Dada et al., 2023). To substantiate, a study by Yang et al., 2020 found that upsurge in income- inequality always results in better environmental outcomes which may be challenged by the possibility that increased income inequality could lower carbon emissions in both developed and developing nations. Some studies reported an insignificant effect of income inequality for all the regions of the country Japan (Sun et al., 2023; Kasuga and Takaya, 2017) and in case of USA (Pata et al., 2023). Heerink et al. (2001) and Gassebner et al. (2008) reported that income inequality lowers per capita carbon emissions, hence lessens the degradation of the environment. This aspect depends on the concept of marginal propensity to emit (MPE) in which both the income inequality and environmental degradation changes. Even though these two perspectives are dissimilar but both proved that there is a significant correlation between income disparity and environmental degradation as measured by CO₂ emissions. The hypothesis can be considered as:

H₂: Income inequality has an impact on CO₂ emissions in India.

Population and CO₂ Emissions

The study incorporated the population due to its complex and multifaceted impact on environment degradation, which various studies have highlighted. A substantial amount of research shows that there is a direct relationship between CO₂ emissions and population size, indicating that CO₂ emissions tend to rise as population grows (Lee & Zhao, 2023). Moreover, some of the results, which are demonstrating a strong and inverse association between population size and carbon emissions—CO₂ emissions decreased by 0.17283% for every 1% rise in population size—underline this relationship (Zhang et al., 2023). The relationship between population and CO₂ emissions have been explored from various perspectives. Some of the studies have suggested that the primary ways by which the population growth impacts atmospheric carbon dioxide levels are through increased use of fossil fuels and forest destruction. Other research indicates that urban population and population growth dramatically reduce CO₂ emissions on average by 13–38 units, emphasising the importance of public knowledge and literacy in encouraging the switch to lower-emission products like renewable energy sources (Ashenafi, 2022). There has also been a lot of attention in the connection between population-related issues and carbon emissions. Research has demonstrated that various factors, including population density, household size, urbanisation rate, and size of population impact energy consumption and carbon emissions (Lian et al., 2024). This suggests that one of the primary factors influencing the projected CO₂ emissions is the population. In conclusion, a variety of factors, such as population increase, urbanisation, and demographic shifts, have an impact on the relationship between population and CO₂ emissions. These results highlight how crucial it is to take population-related issues into account when attempting to reduce CO₂ emissions and combat climate change.

H₃: Population has an impact on CO₂ emissions in India.

Economic Growth and Co2 Emissions

There are numerous studies, which examined the relationship between economic growth and CO₂ emissions on the basis of Environmental Kuznet's Curve (EKC) framework and found that it is quite complicated and influenced by a number of variables, such as industrial activity, patterns of energy consumption, and the acceptance of green technologies (Adebayo et al., 2022). A distinct correlation exists between both economic growth and CO₂ emissions in the long run which usually displays a positive association thereby showing an increase in economic growth rises the CO₂ emissions (Hundie, 2021; Balsalobre-Lorente & Leitao, 2020). However, the strength of this relationship varies with the economic status as mostly the wealthy countries often having less of an impact on carbon emissions than developing countries (Zaman and Abdel. Moemen, 2017). Some of the researchers have claimed that that when an economy is developing, CO₂ emissions increase initially but then start to decline once a certain degree of development is attained (Xu et al., 2020; Chen et al., 2016; Kasperowicz, 2015). Moreover, Riti et al., (2017); Zhang et al. (2017); Han et al. (2018) explored the connection between economic growth and co₂ emissions from the year 1970 to 2015 in the country China by incorporating the concept of environmental Kuznets curve (EKC). Bildirici (2017) proved a bi- directional relationship between the economic growth and environmental degradation. A study by Azam (2016) investigated the connection between economic expansion and the environmental damage caused by CO₂ emissions between 1990 and 2011 and demonstrated that environmental deterioration has a detrimental impact on economic expansion. In Austria, particularly in case of small open and industrialized countries, a cubic link between green -house gas emissions and GDP has found from the period 1960 to 1999. An inverted U- shaped connection between economic growth and Co₂ emissions has explored in both long and short run in the duration of 1980 to 2009 (Fujii & Managi, 2013fu). Zhao et al. (2017), demonstrated that the most crucial factor in raising CO₂ emissions is investment scale; the most essential factors in lowering CO₂ emissions are investment share, energy mix, process carbon intensity effect, carbon coefficient, and investment efficiency.

Few more studies explored the concept of decoupling the economic growth and co₂ emissions as a way to accomplish sustainable economic development and indicating that their relationship can differ greatly depending on the national and regional circumstances (Han, 2021; Dong et al., 2020). Various research methods such as extended Kaya identity and the LMDI method have been used to investigate the elements that influence carbon emissions and found that, although the energy consumption structure effect can be useful in lowering emissions, the economic intensity impact and population size effect are the primary drivers of carbon emissions. This implies that regulating CO₂ emissions may benefit greatly from policy initiatives aimed at these aspects. Research has also looked at the relationship between the use of renewable energy, economic growth, and CO₂ emissions. The results show that, when combined with economic growth, the use of renewable energy can significantly reduce CO₂ emissions (Imran et al., 2022). This emphasizes how crucial it is to switch to renewable energy sources to lessen the negative effects of economic activity on the environment. This proves how much economic growth analysis on environmental degradation is crucial. The hypothesis can be considered as:

H₄: Economic growth has an impact on CO₂ emissions in India.

DATA AND METHODOLOGY

After considering all the past studies, this empirical research incorporated variables like poverty, income inequality, population, and economic growth along with urbanization and renewable energy consumption to analyze their impact on environmental degradation in terms of CO₂ emissions in India from 1991 to 2019. The explanation of these variables (measuring units, data sources, and their expected signs) is listed in Table 1. According to Worldometer, India ranks fourth in renewable energy consumption after China, the United States, and Russia and is the third largest country in case of carbon dioxide emissions after China and the United States. Therefore, this study attempts to examine the symmetric impact of the selected variables on the environment in the case of the country India.

The study incorporated the model CO₂ emissions as a function of the variables under consideration is:

$$CO_2 = f(POV, INE, POP, EG, REC, URB) \quad (1)$$

Where CO₂, POV, INE, POP, GDP, REC, and URB represent carbon dioxide emissions, poverty, income inequality, population, economic growth, renewable energy consumption, and urbanization, respectively. In addition, all the variables have transformed into logarithmic forms to eradicate the problem of heteroscedasticity.

For the analysis purpose, the study used the yearly data, where most of the variables are taken from the World Development Indicators (WDI) and Poverty and Equality Platform (PIP). For the missing data, the study has applied the technique of linear imputation (LI). Table 2 describes all the descriptive statistics of the variables.

To assess the long run and short run dynamics of the model, the study has incorporated the unit root test to check the level of stationarity in each series. The previous studies revealed the concept of multiple tests in case of stationarity but in the current study, the most common unit root test i.e. "Augmented Dickey-Fuller" (ADF) along with "Phillips-Perron" (PP) has been used.

For the application of ADF test, the three forms of regression equations are generated:

$$\begin{aligned} \Delta Y_t &= \alpha_0 + \alpha_1 Y_{t-1} + \sum_{j=1}^p \gamma_j \Delta Y_{t-j} + \epsilon_t \\ \Delta Y_t &= \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t \sum_{j=1}^p \gamma_j \Delta Y_{t-j} + \epsilon_t \\ \Delta Y_t &= \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t \sum_{j=1}^p \gamma_j \Delta Y_{t-j} + \epsilon_t, \text{ here } \epsilon_t \text{ are white noise error terms.} \end{aligned} \quad (2)$$

The hypothesis on which the ADF test based is the following:

$$\begin{aligned} H_0 &= Y_0 \text{ is nonstationary.} \\ H_1 &= Y_0 \text{ is stationary. And here the } p \text{ value of the test is comparable for the results of the significance.} \end{aligned}$$

Empirical Model

Additionally, we calculated the empirical model following with the equation 1:

$$\begin{aligned} LnCO_{2it} &= \beta_i + \beta_{i1} LnPOV_{it} + \beta_{i2} LnINE_{it} + \beta_{i3} LnPOP_{it} + \beta_{i4} LnEG_{it} + \beta_{i5} LnREC_{it} + \beta_{i6} LnURB_{it} + e_t \\ LnCO_{2it} &= \beta_i + \beta_{i1} LnPOV_{it} + \beta_{i2} LnINE_{it} + \beta_{i3} LnPOP_{it} + \beta_{i4} LnEG_{it} + \beta_{i5} LnREC_{it} + \beta_{i6} LnURB_{it} + e_t \quad (3) \end{aligned}$$

Where the dependent variable LnCo2t represents the log form of CO2 emissions per capita and the independent variables that is: LnPOVt represents log form of poverty head count ratio, LnINET represents the ginni coefficient measure of income inequality, LnPOPt signifies the population density, LnEGt epitomize the logarithm form of GDP per capita, LnREct denotes the log form of renewable energy consumption, LnURBt indicates the urbanisation. In addition, small t represents the time period in terms of years, β_1 is the intercept and β_i are the variable coefficients and ET denotes the error term and residual in equation 3.

Equation 3 can be written in the auto regressive distributed lag (ARDL) framework as follows:

$$\Delta \ln CO_{2it} = \beta_1 + \sum_{j=1}^p \delta_j \ln CO_{2j,t-1} + \sum_{j=1}^{q_1} \beta_j \Delta \ln PO_{Vj,t-1} + \sum_{j=1}^{q_2} X_{ij} \Delta \ln INE_{j,t-1} + \sum_{j=1}^{q_3} \delta_j \Delta \ln POP_{j,t-1} + \sum_{j=1}^{q_4} \gamma_j \Delta \ln EN_{j,t-1} + \sum_{j=1}^{q_5} \phi_j \Delta \ln REC_{j,t-1} + \sum_{j=1}^{q_6} \tau_j \Delta \ln URB_{j,t-1} + \theta_1 \ln CO_{2j,t-1} + \theta_2 \ln PO_{Vj,t-1} + \theta_3 \ln INE_{2j,t-1} + \theta_4 \ln POP_{2j,t-1} + \theta_5 \ln EG_{2j,t-1} + \theta_6 \ln REC_{2j,t-1} + \theta_7 \ln REC_{2j,t-1} + \theta_8 \ln URB_{2j,t-1} + \epsilon_{jt}$$

(4)

The ARDL model has some advantages over the other traditional cointegration methods as it can be used with the variables that are I(0) or I(1) or mixed of I(0) and I(1). The test is more efficient in small or finite sample data.

In line with the previous studies by Baloch et al. (2018), Khemili and Belloumi (2018), and Lau et al. (2014), critical value constructed by the Bound Test was adopted to compare the F-statistic to the by Pesaran and Pesaran (1997). It is crucial to remember that there is neither a long-run relationship in the model nor a bottom bound value - I (0) - if the F-statistic value is below it. Nonetheless, the outcome is ambiguous if the F-statistic value falls between I (0) and I (1). To make sure the model was stable and robust enough to generate an unbiased estimate, a diagnostic test was also carried out. This involved utilizing the Jarque-Bera, Breusch-Godfrey LM, and Breusch-Pagan-Godfrey tests, respectively, to examine normalcy, the absence of autocorrelation, and homoscedasticity. If the probability is higher than 0.05, the null hypothesis (H0) should be accepted for all assumptions. Additionally, the CUSUM and CUSUM Square (CUSUMQ) tests were used.

Table 1 TABLE OF PARAMETERS			
Variables	Definition	Source	Expected Sign
CO2 emissions	CO2 emissions (metric tons per capita)	WDI	
POV	Poverty headcount ratio at \$2.15 a day (2017 PPP) (% of population)	Poverty and equality platform	+
INE	Gini index	Poverty and equality platform	+/-
POP	Population density (people per sq. km of land area)	WDI	+
EG	GDP per capita (constant 2015 US\$)	WDI	+/-
REC	Renewable energy consumption	WDI	-
URB	Urbanization	WDI	+

Source: Authors own compilation from WDI and PIP.

RESULTS AND DISCUSSIONS

Descriptive Statistics

Table 2 presented a summary statistics of variables used in the analysis. The highest mean is of GDP and the lowest for REC. However, the standard deviation of URB was low compared to GDP.

Measures	LNCO2	LNGDP	LNPOV	LNURB	LNREC	LNPOP
Mean	0.0753	6.8816	3.1667	0.0103	-0.0159	5.9463
Median	-0.0158	6.8541	3.5751	0.0113	-0.0145	5.9619
Maximum	0.5853	7.5726	3.8628	0.0129	0.0163	6.1424
Minimum	-0.3811	6.2707	0	0.0077	-0.0533	5.7003
Std. Dev.	0.3242	0.4055	0.9869	0.0018	0.0167	0.1351
Skewness	0.2082	1667	-2.3314	-0.4516	-0.4044	-2540
Kurtosis	1.5964	1.7982	7.953	1.5055	2.8296	1.8468

The below table 3 shows that poverty and income inequality are stationary at the level while the rest are not stationary. At first order difference, all variables are stationary which satisfies the condition for applying the ARDL framework.

Variables	ADF	PP	Variables	ADF	PP
At level	t- stat	t- stat	At first difference	t- stat	t- stat
lnCO2	0.0951	0.0198	Δ lnCO2	4.4321***	4.4885***
lnPOV	-3.998***	4.1015***	Δ lnPOV	----	----
lnGINI	107.83***	18.145***	Δ lnINC	----	----
lnPOP	0.1289	4.8869***	Δ lnPOP	2.0749***	----
lnGDP	1.5134	3.194	Δ lnGDP	4.2192***	4.1243***
lnURB	-0.6915	-0.8181	Δ lnINF	3.5093***	3.4208***
lnREC	-2.6342	-2.5208	Δ lnIND	7.5664***	7.5664***

Table 4 indicates the results for optimal lag selection criteria. All the criteria's under optimal lag selection that is, LR= sequential; modified likelihood ratio, FPF= final prediction error, AIC= akaike information criteria, SC= Schwarz information criterion, HQ= Hannan-Quinn information criterion) provides that lag length of 2 is optimal for the further estimation.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	539.5563	NA	3.82e-27	-40.96587	-40.62715	-40.86833
1	744.8327	284.2290	2.65e-32	-52.98713	-50.27739	-52.20682
2	831.8753	73.65137*	3.82e-33*	55.91348*	50.83271*	54.45040*

Table 5 represents the results of the bound test. The null hypothesis is, that there is a non-existence of a long-run relationship. If the F-value falls between the lower bound and upper bound, the result is inconclusive and restricts further analysis. For model 1, the computed F-value (11.71634) lies outside the lower and upper bound values for ten percent, five, and one percent levels of significance, thereby, rejecting the null and supported the existence of a long-run relationship.

Table 5 BOUND TEST				
F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
Asymptotic: n=1000				
F-statistic	11.71634	10%	1.99	2.94
K	6	5%	2.27	3.28
		2.5%	2.55	3.61
		1%	2.88	3.99

As reported in tables 6 and 7, the results indicate the long-run and short-run impact of economic growth, income inequality, poverty, urbanization, renewable energy consumption, and population on CO2 emissions. From the long-run estimation it can be seen that there exists a positive association between GDP and CO2 emissions with a 1% rise in GDP there is a 2.6% increase in CO2 emissions that reveals the grave situation of rising CO2 emissions which is largely driven by the country's rapid economic expansion, which has led to a higher demand for energy, particularly from non-renewable fossil fuel sources such as coal. This is consistent with the findings of previous studies (Li et al., 2022; Ahmad, 2016; Ohlan, 2015; Ruiz, 2020). Similar findings exist for the short-run impact of GDP on CO2 emissions. The impact of income inequality is statistically significant on CO2 emissions in India. In the short-run there is negative relation between Income inequality and co2 emissions with 1 % increase in income inequality led to 0.35 % decline co2 emissions aligning with findings that suggest a redistribution of wealth could be beneficial for environmental quality (Grunwald, 2017; Liu et al., 2019; Ghazouani & Beldi, 2022; Huang & Duan,2020). While the findings also highlight that co2 emissions and income inequality have positive association (0.15 elasticity) in the long run which is in line with results of existing literature (Mahalik et al., 2018; Mohapatra & Giri,2022; Khan & Yahong, 2022). Overall, the relationship between income inequality and CO2 emissions is dynamic and subject to change over time, with no one-size-fits-all solution for policy implications. The poverty found to be significant in short-run estimation indicating the positive association while in long-run it is insignificant which is in conformity with the finding of Jiang (2021). Also the finding underpin the interesting fact that poverty causes lack of education and poverty induces poor people to use wood for cooking fuel thereby increasing CO2 emissions highlighted in the study by Nabi et al.(2020). Furthermore, urbanization and co2 emissions depict a statistically significant positive relationship in the long-run and short-run (0.34% and 0.72%) as revealed by other studies also (Haldar & Sharma, 2021; Solarin & Lean, 2016; Abbasi, Parveen, et al., 2020; Sikder et al.,2022). The findings also show the negative association between renewable energy consumption and co2 emissions in both the long-run and short-run (0.33% and 0.47%) which is very remarkable for India's progress toward a green economy (Dong et al., 2017; Khattak et al., 2020; Anandarajah & Gambhir, 2014). The long-run impact of population was found to be non-

significant on CO2 emissions on the other hand in the short-run 1 % rise in population leads to 0.13% increase in CO2 emissions which is consistent with existing literature (S. Babbar & R. Babbar, 2018; Pachiyappan et al., 2021; Atmanti et al., 2022; Sikdar & Mukhopadhyay, 2017; Gurjar et al., 2016; Rahman, 2020). In addition to that the coefficient of error-correction mechanism (ECM) are negative and significant in the model (-0.36). This value signifies that the GDP, GINI, POV, URB, REC and POP adjust to their equilibrium with the speed of 0.36%.

Variables	Coefficient	t-stat	p-value
LnGDP	2.602656	1.906968	0.0930***
LnGINI	0.15037	2.061639	0.0732***
LnPOV	-0.742718	-4.00435	0.1983
LnURB	0.34996	-1.984677	0.0824***
LnREC	-0.333589	-3.258709	0.0115**
LnPOP	-0.10079	-1.502269	0.1714

Variables	Coefficient	t-stat	p-value
COINTEQ01	-0.361696	-13.25689	0.0000*
LnCO2(-1)	-0.469464	-6.600899	0.0002*
LnGDP	1.678545	1.067342	0.0004 *
LnGINI	-0.357768	-7.636052	0.0001*
LnPOV	0.144381	5.069288	0.0010*
LnURB	0.7291	-2.878542	0.0206**
LnREC	-0.478268	-14.27045	0.0000*
LnPOP	0.13676	13.98308	0.0000*
Mean dependent var	0.035126	S.D. dependent var	0.027575
S.E. of regression	0.006679	Akaike info criterion	-6.883724
Sum squared resid	0.000669	Schwarz criterion	-6.351452
Log likelihood	100.4884	Hannan-Quinn criter.	-6.730449

The results of the diagnostic tests for serial correlation, Heteroskedasticity, and normality for the model are reported in Table 8. They confirm the absence of serial correlation and heteroscedasticity problems in the model. The result of the Jarque-Bera test of normal distribution shows that the variables are normally distributed.

Diagnostic tests	F statistic	P-value	Hypothesis	Result
Serial Co-relation	7.3757	0.26	Null hypothesis: No serial Correlation	No serial correlation

(Breush-Godfrey test)				
Normality test	2.847	0.24	Null hypothesis: Normal distribution	Normal distribution
(Jarque-Bera test)				
Heteroskedasticity test	1.6777	0.175	Null hypothesis: Homoskedasticity	No heteroskedasticity
(Breusch-Pagan-Godfrey-test)				

The study has also applied stability techniques to check the structural stability of the models. The cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) stability tests presented by Brown et al. (1975) which show that their statistics are significant at the 5% significance level, implying that the coefficients in the models are structurally stable Figure 1.

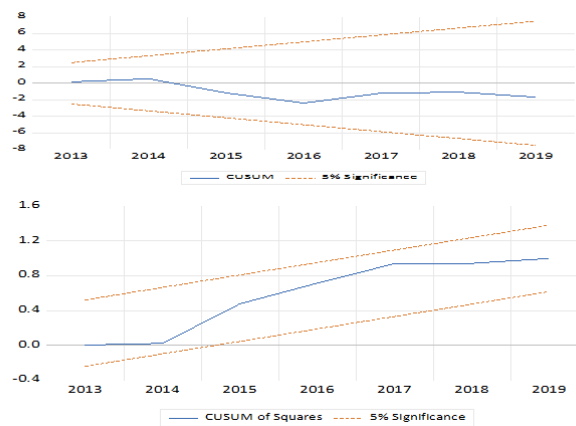


FIGURE 1
STRUCTURAL STABILITY TESTS

CONCLUSION AND POLICY SUGGESTIONS

The paper aims to investigate the impact of economic growth, income inequality, poverty, urbanization, renewable energy consumption, and population co2 emissions in India using the ARDL framework for the period of post-economic reforms of 1991 (1991-2019). The study comprehensively utilizes these variables to assess the progress of India towards a green economy and various sustainable development goals (SDG). The ARDL bound test result reveals the existence of a long-run relationship among the variables. The finding of the study shows that there is a positive association between GDP and CO2 emissions in the short and long run which indicates the grave situation of rising CO2 emissions which is largely driven by the country's rapid economic expansion, which has led to a higher demand for energy, particularly from non-renewable fossil fuel sources such as coal. However, in the short-run there is negative relation between Income inequality and co2 emissions with 1 % increase in income inequality led to 0.35 % decline co2 emissions aligning with findings that suggest a redistribution of wealth could be beneficial for environmental quality but on the other side in the long-run there is positive impact of income inequality on co2 emissions. The poverty found to be significant in short-run estimation indicating the positive association while in long-run it is insignificant. Furthermore, urbanisation and co2 emissions depict statistically significant positive relationship in long-run

and short-run. In the long-run and short-run renewable energy consumption have negative association with CO₂ emissions which highlight that India is gradually moving towards renewable energy sources. The long-run impact of population found to be non-significant on CO₂ emissions on the other hand in short-run the expansion in population lead to rise CO₂ emissions. The study also highlight that in some aspects India is progressing towards green economy and SDG while on some part India is lagging behind.

The study suggests that a persistent population stabilization policy could help in decreasing CO₂ emissions and sustaining long term economic growth. The findings stressed the concrete policy actions to utilise the renewable energy sources, and getting acclimatise towards greener technologies to mitigate CO₂ emissions without compromising with the pace of economic growth. The study also recognizes the need for policymakers to emphasize more on reducing income inequality and poverty through redistributing transfers, financing universal health and education access, imposing progressive tax laws and upholding the Clean India mission. All of these measures will help to lessen environmental degradation in India. Moreover, government initiatives are needed to help the urban industrial and residential sectors adopt green technology. Hence, it is pertinent to maintain the balance between sustaining economic growth and restoring environment.

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