INDIA'S ECONOMIC RISE: EXPLORING THE LINK BETWEEN ECONOMIC GROWTH AND CARBON EMISSIONS

Shanu Kumar[1], Shweta Sharma[2]

[1]*Assistant Professor, Amity School of Business, Amity University, Patna, (Bihar)*
[2]*Research Scholar, Department of Economics, Chaudhary Charan Singh University, Meerut, (UP)*

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ABSTRACT

This paper examines the relationship between economic growth and carbon emissions in India. The variables selected for understanding the relationship are GDP and CO_2 emissions. GDP, representing economic growth, and CO2 emissions are analyzed for the period from 1977 to 2022. The study employs Granger causality to determine the presence of unidirectional or bidirectional causal relationships between these variables. The findings indicate a unidirectional causality from carbon emissions to GDP. The VAR model is used to understand the relationship between the variables. The results revealed that past CO_2 emissions positively impact current GDP, suggesting a linkage between economic growth and CO_2 emissions. The findings suggest that efforts to reduce carbon emissions without incorporating energy efficiency measures could negatively impact the country's economic growth. These implications are significant for policymakers and researchers in the field of environmental sustainability and economic development.

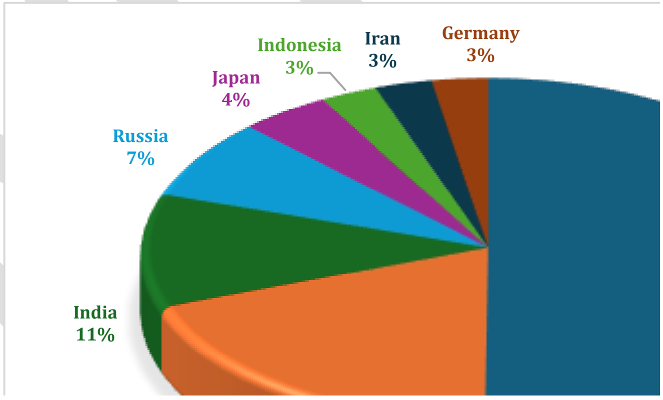
Keywords: *Carbon emissions, GDP, VAR model, Grange Causality.*

1. INTRODUCTION

Energy is a cornerstone of economic development, driving progress and fueling industry growth. Economic growth is of paramount importance, as it contributes to the reduction of poverty and unemployment. The demand for energy from various sectors of the economy has increased significantly. The heightened utilization of energy (fossil fuels) has resulted in environmental degradation on a global scale. Consequently, the current challenge is to mitigate carbon emissions without compromising economic growth. This objective can be achieved through two primary approaches: firstly, by implementing energy efficiency measures, and secondly, by adopting clean technology. Adopting clean technology requires significant investments and is achievable over the long term. However, energy efficiency offers a more immediate solution and should be prioritized as a key economic focus. As one of the fastest-growing nations, India recorded an impressive GDP growth rate of 8.2% in the financial year 2023-24, according to data released by the National Statistical Office.

The pie chart in Figure 1 illustrates the contribution of various countries to global CO_2 emissions. China is the primary emitter, accounting for 50% of global emissions, which is attributed to its extensive industrial base and reliance on coal. The United States accounts for 19%, reflecting its high energy consumption and advanced industrial sector, whereas India contributes 11%, driven by its expanding economy and coal dependency. The top three emitters, China, the U.S., and India- collectively constitute 80% of global emissions, underscoring the necessity for focused mitigation efforts in these economies to address environmental degradation and climate change.

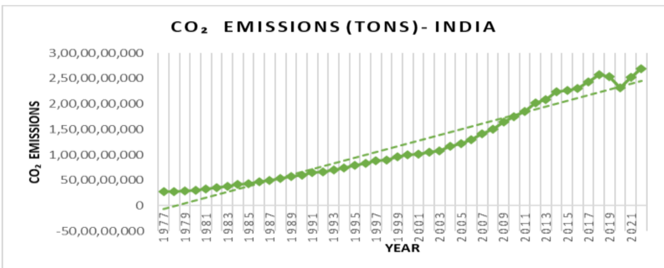
Figure 1: Share of World in Global CO_2 Emissions



Source: CO_2 Emissions from Fuel Combustion

Figure 2 Displays the trend of CO_2 emissions in India from 1977 to 2022, measured in tons. It underscores a consistent rise in emissions over the decades, reflecting India's economic and industrial growth, energy demands, and population expansion

Figure 2: Trend of CO_2 Emissions in India



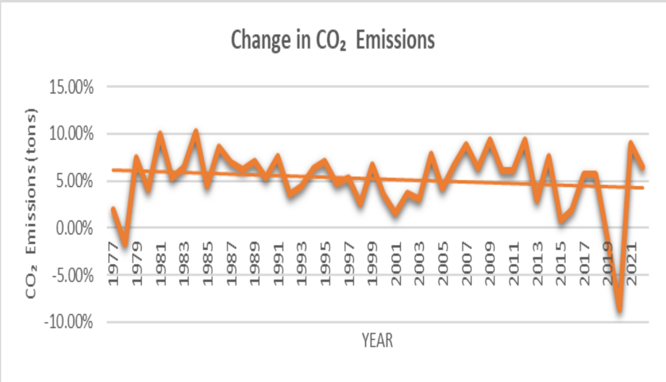
Source: Based on the data from IEA

The graph in Figure 3 shows India's year-on-year (YoY) percentage change in CO_2 emissions from 1977 to 2022. It highlights fluctuations in the growth rate of emissions over the years, influenced by economic activities, energy consumption patterns, and external factors. The sharp dip in

2020 underscores the impact of external shocks like the pandemic.

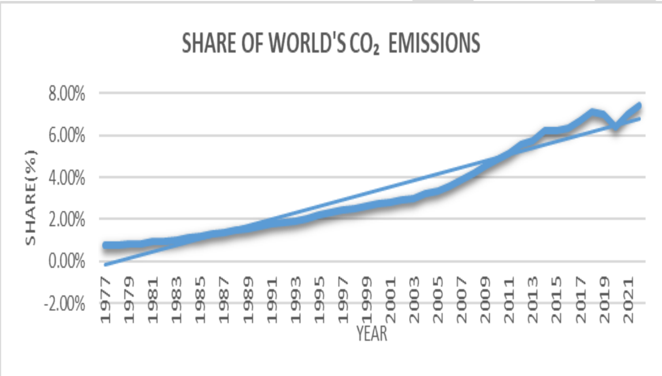
Similarly, Figure 4 shows that India's contribution to global emissions has grown steadily over the years, reflecting its expanding economy, industrialization, and energy demands.

Figure 3: Trend of year-on-year (YoY) percentage change in CO_2 emissions



Source: Based on the data from IEA

Figure 4: Trend of India's Share in World's CO_2 Emissions



Source: Based on the data from IEA

Currently, India faces the dual challenge of pursuing economic development to reduce poverty and unemployment while mitigating its carbon emissions to protect itself from the adverse effects of climate change. Identifying the primary sources of emissions is crucial, enabling India to implement mitigation strategies with minimal impact on its economic growth. This study analyzed the relationship between economic growth and emissions in India.

The remainder of this paper is organized as follows. The Introduction section highlights the current trend in CO_2 emissions, followed by a literature review on the relationship between economic growth and carbon emissions, data and methodology for the current analysis, and conclusions and policy implications.

2. LITERATURE REVIEW

Numerous studies have investigated the relationship between energy consumption and economic growth, each varying in terms of time periods, selected variables, methodologies, and findings. The energy-intensive economic growth model observed in developing countries has led researchers to explore the connection between CO_2 emissions and economic growth. Econometric studies on this relationship have produced two main conclusions: a positive or negative correlation. Typically, the use of traditional energy sources results in increased CO_2 emissions alongside economic growth.

Apergis and Payne (2010) conducted a study using a panel vector error correction model on 11 countries between 1992 and 2004, finding evidence that supported the EKC hypothesis. Similarly, Lean and Smyth (2010) analyzed the connection between electricity consumption and CO_2 emissions, identifying a nonlinear relationship between emissions and GDP, which also aligned with the EKC theory. In the case of BRIC countries, Pao and Tsai (2011) used Granger causality analysis to examine GDP and CO_2 emissions from 1980 to 2007. Their results revealed a bidirectional causal relationship in the short term and a unidirectional relationship from GDP to CO_2 emissions in the long term. Ahmed and Long (2012) utilized the Autoregressive Distributed Lag (ARDL) method in Pakistan and found an inverted U-shaped relationship between GDP and CO_2 emissions. Ghosh et al. (2014) analyzed the time series data from 1972 to 2011 and concluded that CO_2 emissions negatively impacted economic growth, while energy consumption had a positive effect. Adamu et al. (2020) conducted a study in Nigeria, revealing that rural-to-urban migration and economic growth significantly contributed to increased CO_2 emissions. Further research by Mongo et al. (2021) investigated the effects of various factors, including GDP, environmental innovation, and renewable energy consumption, on CO_2 emissions in 15 European countries. The study found that while environmental innovations reduced CO_2 emissions in the long term, they might have short-term adverse effects. Kong (2021), in China, discovered that economic growth had a significant positive impact on CO_2 emissions. Regmi and Rehman (2021) examined the relationship between energy use, fossil fuel consumption, and CO_2 emissions in Nepal, finding that fossil fuel consumption had a notable effect on emissions. The study confirmed a one-way Granger causality relationship.

Some recent studies have identified asymmetrical relationships between GDP and CO_2 emissions. Raggad (2020) analyzed Saudi Arabia's data and found that positive and negative GDP shocks led to increased CO_2 emissions, with positive shocks having a more significant long-term effect. Similarly, Musibau et al. (2021) used the NARDL method to conclude that GDP positively influenced environmental quality in Nigeria. Mujtaba and Jena (2021) found that in India, GDP growth reduced CO_2 emissions in both the short and long term, while a decline in GDP increased emissions.

3. DATA AND METHODOLOGY

3.1 Data and Variables

To examine the relationship between economic growth and carbon emissions in India, the study focused on two key variables: CO2 emissions and GDP, with GDP serving as a proxy for economic growth. The analysis covered the period from 1977 to 2022, chosen based on the availability of comprehensive data for all relevant variables. Data on India's GDP was sourced from the Reserve Bank of India (RBI) database, while CO2 emissions data were gathered from the World Development Indicators and the International Energy Agency (IEA).

3.2 Model Specification

This study utilized the ADF and PP unit root tests to assess the stationarity of the data series. In the absence of a cointegrating equation among the variables, a Vector Autoregression (VAR) model was applied to analyze the dynamic relationships between them. To explore directional causality, a Granger causality test was conducted to determine if one variable could predict another. Additionally, Impulse Response Function (IRF) graphs were used to illustrate the dynamic impact of a shock to one variable on the others over time.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

Table 1 provides descriptive statistics of the variables used in this study. The statistics revealed substantial variability and a right-skewed distribution in the data. The results further indicate high variability in both datasets, as indicated by the large standard deviations relative to their means.

Table 1: Summary Statistics

Variables	N	Mean	Median	Min	Max	Std. Dev.	skewness	kurtosis
CO_2 emission	46	1.19E+09	978619800	2.71E+08	2.69E+09	7.75E+08	0.58	1.943
gdp	46	1.08E+12	7.86E+11	2.53E+11	2.97E+12	8.21E+11	0.886	2.5

Source: Author's Calculation

4.2 Matrix of Correlation Between the Variables

The correlation matrix provides a comprehensive view of the relationship between the variables. Table 2 shows the correlation between the variables, suggesting a strong positive correlation. This suggests that, as GDP increases, CO_2 emissions tend to rise significantly during this period.

Table 2: Correlation Matrix

Variables	(1)	(2)
(1) CO_2 _emissions	1	
(2) GDP	0.988	1

Source: Author's Calculation

4.3 Lag Order Criteria

Table 3 indicates that lag 1 is preferred in this study, as it has the lowest AIC, HQIC, and SBIC values.

Table 3- Optimal Lag Length Selection Criteria

Sample:1981-2022								No. of Obs.: 42
lag	LL	LR	df	p-value	FPE	AIC	HQIC	SBIC
0	8.508	-	-	-	0.00252	-0.30989	-0.27956	-0.2271
1	192.3	367.53*	4	0	4.80E-07	-8.87015*	-8.77916*	-8.62191*
2	192.7	0.8136	4	0.937	5.70E-07	-8.69904	-8.54739	-8.2853
3	193.9	2.4485	4	0.654	6.60E-07	-8.56686	-8.35455	-7.9876
4	198.6	9.3827	4	0.052	6.40E-07	-8.59978	-8.32682	-7.8551

Source: Author's Calculation

4.4 Unit Root Test Results

The unit root test results in Table 4 suggest that both the variables are non-stationary at level forms but are stationary at first difference. This suggests that the original series are integrated of order one (I (1)).

Table 4- Results of ADF (Augmented Dicky Fuller) and PP(Phillips-Perron) Unit Root Test

Variable	Test	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value	p-value	Conclusion
Level							
log_CO_2	ADF	-2.216	-3.621	-2.947	-2.607	0.201	Non-Stationary
	PP	Z(rho) = -0.489 Z(t) = -1.531	-18.56	-13.14	-10.6	0.518	Non-Stationary
log_gdp	ADF	1.043	-3.621	-2.947	-2.607	0.995	Non-Stationary
	PP	Z(rho) = 0.261 Z(t) = 1.012	-18.56	-13.14	-10.6	0.994	Non-Stationary
First Difference							
d.log_CO_2	ADF	-4.005	-3.628	-2.95	-2.608	0.0014***	Stationary
	PP	Z(rho) = -41.530 Z(t) = -6.328	-18.492	-13.108	-10.58	0.000***	Stationary
d.log_gdp	ADF	-5.829	-3.628	-2.95	-2.608	0.000***	Stationary
	PP	Z(rho) = -45.877 Z(t) = -6.753	-18.492	-13.108	-10.58	0.000***	Stationary

Source: Author's Calculation

4.5 Cointegration Test Results

The Johansen cointegration test determines the long-term equilibrium relationship between the variables. The results in Table 5 indicate that trace statistics are less than their respective critical values, which confirms that there is no long-term equilibrium relationship between the variables. So, we model the relationship using the VAR model with first-differenced data.

Table 5: Johansen-Cointegration Test Result

Rank	Parameters	Log-Likelihood (LL)	Eigenvalue	Trace Statistic	5% Critical Value
0	2	186.7581	—	11.5233*	15.41
1	5	191.5555	0.19202	1.9284	3.76
2	6	192.5197	0.04195	—	—

Source: Author's Calculation

4.6 VAR Results

The results in Table 6 show strong persistence in both variables, with past GDP levels significantly predicting current GDP and past CO_2 emissions significantly predicting current CO_2 emissions. The results also reveal that past CO_2 emissions significantly positively impact current GDP, suggesting a linkage between economic growth and CO_2 emissions. So, it can be said that energy-intensive activities drive economic growth. However, past GDP levels do not predict current CO_2 emissions.

Table 6: VAR (Vector Autoregression Model) Results

VARIABLES	log_gdp	log_CO_2
L.log_gdp	0.899*** (0.0452)	-0.0249 (0.0528)
L.log_CO_2	0.117** (0.0488)	1.016*** (0.0571)
Constant	0.425 (0.267)	0.406 (0.312)
Observations	45	45

*Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

4.7 Granger Causality Results

The Granger Causality Wald Tests in Table 7 indicate a significant unidirectional causal relationship where CO_2 emissions Granger cause GDP, but not vice versa. This finding implies that historical CO_2 emissions data can help predict future GDP levels, suggesting that environmental factors may influence economic growth. On the other hand, within the framework of this model, GDP did not demonstrate a predictive influence on CO_2 emissions.

Table 7- Granger Causality Wald Test Results

Dependent Equation	Excluded Variables	Chi-Squared Statistic (χ^2)	Degrees of Freedom (df)	p-value (Prob > χ^2)	Conclusion
log_gdp	log_CO_2	5.7009	1	0.017	CO_2 Granger causes GDP
log_gdp	ALL	5.7009	1	0.017	CO_2 Granger causes GDP
log_CO_2	log_gdp	0.22199	1	0.638	GDP does not Granger cause CO_2
log_CO_2	ALL	0.22199	1	0.638	GDP does not Granger cause CO_2

Source: Author's Calculation

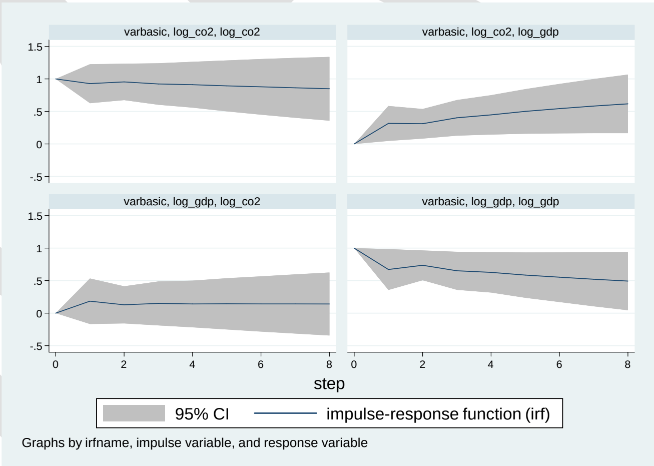
4.8 Impulse Response Function

An Impulse Response Function (IRF) traces the effect of a one-time shock to one of the variables in the VAR system on the current and future values of the endogenous variables. the IRF examines how shocks to log_gdp and log_CO_2 affect both log_gdp and log_CO_2 over stime.

Given the high persistence of log_gdp, a shock to log_gdp exhibits a strong and sustained positive response in subsequent periods. The Granger causality analysis indicates that log_CO_2 Granger causes log_gdp. Consequently, a shock to log_CO_2 demonstrates a statistically significant positive impact on log_gdp. As log_gdp does not Granger-cause log_CO_2, a shock to log_gdp is unlikely to impact log_CO_2 significantly. Considering the exceptionally high persistence of log_CO_2, a shock to log_CO_2 is expected to show a strong and sustained positive response.

The significant positive response of log_gdp to shocks in log_CO_2 aligns with the Granger causality result, indicating that CO_2 emissions predict GDP growth. This could imply that economic activities contributing to GDP growth are energy-intensive, thereby increasing CO_2 emissions.

Figure 5: Impulse Response Function Graphs



Source: Author's Creation

5. CONCLUSION AND POLICY IMPLICATIONS

The present study investigates the causal relationship between GDP and CO2 emissions within the VAR framework. To examine the presence of unidirectional or bidirectional causality between the variables, the Granger causality test is employed. A significant finding from the VAR model and Granger causality analysis is the unidirectional relationship wherein past CO_2 emissions substantially influence current GDP, while GDP does not significantly predict CO_2 emissions. This observation suggests that economic growth is predominantly driven by energy-intensive activities that result in CO_2 emissions, thereby underscoring the role of environmental factors in shaping economic trajectories. Moreover, impulse response function (IRF) analysis corroborates the sustained positive impact of CO_2 emissions shocks on GDP, indicating that the current economic structure is heavily dependent on emission-generating activities.

As a policy recommendation, the government of India should implement measures to reduce the utilization of conventional energy sources. Furthermore, it should provide financial incentives through subsidies to promote the adoption of low-carbon technologies. Additional efforts are necessary to establish a market for clean technology, accompanied by a robust financial system that encourages the implementation of low-carbon technologies across various sectors of the economy.

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