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The Impact of Foreign Direct Investment (FDI) Inflows on Carbon Dioxide (CO_2) Emissions in India: An Empirical Study

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Abstract

This study analyses the impact of Foreign Direct Investment (FDI) inflow on Carbon dioxide (CO_2) emissions in India in the last three decades from 1991 – 2022. In the current era of economic integration, FDI is regarded as an important driver of economic growth in developing countries such as India. By utilising time series data, the Augmented Dickey-Fuller test is employed to check the stationarity, after that the Robust Linear Regression Model to examine the relationship between FDI inflow and Carbon emissions. To ensure the reliability of the study, Diagnostic tests like Breusch–Pagan test for heteroskedasticity and Durbin's alternative test for autocorrelation are utilised, while Robust Standard Errors are used to mitigate the issue of autocorrelation. The results of the study indicate a significant positive relationship between FDI inflows and CO_2 emissions, according to the results, a 1% increase in FDI inflow corresponds to a 0.59% increase in CO_2 emissions, explains 95.5% of variations in CO_2. This implies that there may be significant environmental costs associated with FDI driven economic growth in India, highlighting the importance of including sustainability into investment policies. Future studies can look at how FDI affects emissions from different industries and how green investment can help to reduce the environmental implications of FDI; this will help policymakers to make FDI plans with India's environmental objectives.

Keywords: Foreign Direct Investment (FDI), Carbon Dioxide (CO_2), Robust Linear Regression Model, sustainability, economic growth.

JEL classification codes: C22, F21, Q53, Q56.

1. INTRODUCTION

The relationship between Foreign Direct Investment (FDI) and environmental sustainability has become a focal point of academic and policy discussions, especially in developing economies like India. According to environmental literature, global warming and climate change have been attributed to carbon dioxide (CO2) emissions from burning fossil fuels, deforestation, and agricultural activities (van Vuuren *et al.*, 2017). As nations strive for economic growth and industrialisation, they increasingly rely on FDI as a catalyst for development. According to Nayyar (2001), globalisation has boosted financial development and cross-border capital flow, leading to greater international business volume and frequency. FDI is often welcomed for bringing technological advancement, boosting industrial production, and generating employment. However, its potential environmental consequences, particularly concerning carbon dioxide (CO_2) emissions, have raised concerns about the sustainability of FDI-driven growth. As one of the largest recipients of FDI among developing nations, India provides a critical case study for understanding these dynamics.

India's economic liberalisation in 1991 marked a turning point, opening its doors to global investors and reshaping its economic trajectory. FDI inflows have significantly contributed to the expansion of key sectors, including manufacturing, infrastructure, and services, making India one of the fastest-growing economies in the world. Nevertheless, this rapid economic transformation has come with environmental trade-offs. As industries expanded and urbanisation accelerated, the country witnessed a substantial increase in CO_2 emissions, posing challenges to its commitments under international climate agreements such as the Paris Accord. The juxtaposition of economic aspirations and environmental obligations makes examining the role of FDI in CO_2 emissions in India both timely and relevant.

In the Indian case, it is particularly complex. While substantial FDI inflows have bolstered its economic growth, the environmental implications of these investments remain underexplored. The country's dependence on coal for energy and rapid industrialisation has made it one of the largest global emitters of CO_2. India is also a leader in renewable energy adoption and has ambitious targets for reducing its carbon intensity. This duality raises critical questions about how much FDI contributes to or mitigates environmental degradation. This study seeks to bridge this gap by analysing the impact of FDI inflows on CO_2 emissions in India over the past three decades (1991–2022). It aims to provide a nuanced understanding of this relationship using robust econometric techniques and time-series data.

The "pollution haven hypothesis" and the "pollution halo hypothesis" are the two hypotheses that form the theoretical foundation of the relationship between foreign direct investment (FDI) and carbon emissions in countries. The pollution haven hypothesis, developed by Copeland and Taylor (1994) under the North-South trade model, states that foreign direct investment (FDI) positively impacts carbon emissions in developing countries with low levels of environmental regulation. In fact, emerging countries compete with one another in terms of environmental standards in order to attract more foreign direct investment and guarantee rapid growth. As a result, the least developed countries and those with the most lenient environmental regulations will become pollution havens due to the relocation of the most polluting activities by foreign corporations to those countries. As a result of these companies competition with companies that have low-carbon technology, low-carbon environmental companies have chosen not to invest in research and development for environmental protection technologies. According to the halo pollution theory, which was developed by Birdsall and Wheeler (1993), the development of foreign direct investment (FDI) has the potential to introduce more environmentally friendly high-production technology and ideas for environmental protection to host countries, which in turn contributes to the reduction of carbon emissions.

2. REVIEW OF LITERATURE

The relationship between foreign direct investment (FDI) and carbon dioxide (CO_2) emissions has been extensively studied, with varying results across regions. Some studies suggest that FDI contributes to increased emissions, particularly in developing countries, supporting the Pollution Heaven Hypothesis. Others highlight the mitigating effects of factors such as trade openness, economic growth, and renewable energy consumption. While FDI inflows can raise emissions, their impact is often moderated by governance quality, technological advancements, and the level of economic development. The literature reveals a complex and context-dependent relationship, where various economic, social, and policy factors influence the overall effect of FDI on CO_2 emissions.

2.2. Empirical studies

Boubacar *et al.*, (2024) and Manocha (2024) analyse the relationship between foreign direct investment (FDI) and carbon dioxide emissions in African countries by utilising a generalised method of moments (GMM) approach. By supporting the Pollution Heaven Hypothesis (PHH) in Africa, the study found that FDI inflow in African countries increases carbon emissions. Sarpong *et al.*, (2024) analysed the impact of FDI on carbon-neutral growth across 54 African countries from 2004 to 2020. Employing econometric techniques, including GMM and 2SLS, the study found that trade openness reduces emissions through cleaner technologies, while economic growth initially increases emissions before a subsequent decrease. Another study by Boamah *et al.*, (2023) explored how FDI inflow influences CO2 emissions in 41 African countries from the year 2005 to 2019. The study used pooled least squares, fixed and random effects models, and GMM. The study also analysed either the Pollution Haven Hypothesis or the Pollution Halo Hypothesis. The results show that neither of the hypotheses is supported. However, FDI inflow influences CO2 emissions, and trade openness mitigates them. Sharmiladevi and Chandrasekaran (2024) utilised the ARDL model in their study to analyse the impact of FDI CO2 emissions, economic growth and trade openness in India from 1990 to 2002. The study found that FDI has no considerable long-run impact on Carbon dioxide emissions. Uddin *et al.*, (2023) analyse the impact of geopolitical risk (GPR), governance, technological advancements, energy consumption and foreign direct investment (FDI) on CO2 emissions in BRICS countries from 1990 to 2018 by using the CS - ARDL FMOLS AND DOLS econometric models. The research found that the government's effectiveness, regulatory quality, rule of law, FDI, and innovation reduce CO2 emissions, while GPR, corruption, political instability, and energy consumption increase the emissions. A study by Limazie and Woni (2024) utilising the Generalized Method of Moments (GMM) and Panel-Corrected Standard Errors (PCSE) found that both foreign investment inflows and governance quality collectively reduced CO2 emissions in ECOWAS from the period 2005 to 2016.

A study by Zhang *et al.*, (2023) investigated the relationships between FDI inflow, CO_2 emissions, renewable energy consumption and population health quality in China from 1980 to 2020. Using VECM, the study finds that FDI and renewable energy positively impact health quality in the long run, while CO_2 emissions negatively affect it. Apergis *et al.*, (2023) examine how FDI effects CO2 emissions in BRICS countries, focussing on FDI coming from OECD countries from 1993 to 2012. It was found that FDI from the UK and Denmark raises CO_2 emissions while FDI from France, Germany, and Italy reduces C02 emissions. Khan *et al.*, (2023) analyse the impact of FDI on CO_2 emissions in developing countries, focusing on human capital as a moderating factor. The research is based on data from 108 countries from 2000 to 2016, found that low educational attainment contributes to environmental degradation, while high human capital reduces emissions. Muhammad and Khan (2021) by using econometric techniques such as GMM and Fixed Effects models, analyse the impact of FDI, Globalisation, Energy Consumption and Economic Growth on CO2 emissions globally by using data from 170 countries for the period 1990 to 2018. The findings of the study reveal that exports of natural resources decrease CO2 emissions and FDI, Globalisation, Energy Consumption and Economic Growth increase CO2 emissions. Mujtaba and Jena (2021) examine the asymmetric impact of economic growth, energy consumption, FDI inflows, and oil prices on CO_2 emissions in India from 1986 to 2014, employing the NARDL model. Results indicate that positive economic growth reduces emissions, whereas economic downturns increase them. Zubair *et al.,* (2020) investigate the impact of gross domestic income, trade integration, foreign direct investment, GDP, and capital on CO_2 emissions in Nigeria over the period from 1980 to 2018. By employing ARDL and VAR Granger causality tests, the analysis reveals that long-term increases in FDI and GDP contribute to a reduction in CO_2 emissions. Huang *et al.*, (2022) analyse the impact of FDI on carbon emissions in G20 economies from 1996 to 2018. By the application of Feasible Generalized Least Squares (FGLS), the study's results indicate that FDI inflows generally increase carbon emissions. However, higher economic development and regulatory quality reduce FDI's environmental impact. Gökmenoğlu and Taspinar (2016) a study on Turkey's CO_2 emissions, economic growth, energy consumption and FDI shows a long-run equilibrium, with FDI and energy consumption increasing CO2 emissions and economic growth reducing CO2 emissions.

3. DATA AND METHODOLOGY

3.1. Data Collection

This study examines the relationship between Foreign Direct Investment (FDI) inflows and carbon dioxide (CO_2) emissions in India from 1991 to 2022. The data for CO_2 emissions (measured in metric tons) and FDI inflows (in million USD) were obtained from credible secondary sources, CO_2 data was obtained from the World Bank, and FDI inflow is obtained from the Department for Promotion of Industry and Internal Trade (DPIIT). To ensure consistency and facilitate analysis, both variables were transformed into their natural logarithmic forms (ln_CO2 and ln_FDI). The logarithmic transformation helps stabilise variance, reduces skewness, and allows the interpretation of regression coefficients as elasticities.

3.2. Econometric Approach

The analysis employs robust time-series econometric techniques to assess the relationship between FDI inflows and CO_2 emissions. These techniques include stationarity testing, regression analysis, and diagnostic evaluations to validate the reliability of the findings.

3.3. Stationarity Testing

To assess the long-term relationship among variables, it is essential to test the stationarity of the series. This study employs the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979 and 1981) for unit root analysis. Initially, all variables are tested for stationarity at level I(0). If any variable is identified as non-stationary at its level, it is further tested at the first difference I(1), and, if required, at the second difference I(2). The model is represented as:

$$\Delta Yt = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t + \sum_{j=2}^{p} \gamma_j \Delta Y_{t-j} + \varepsilon_t \qquad (1)$$

Where,
ΔYt: First difference of the time series Yt, which helps in testing for stationarity. $\Delta Yt = Yt - Yt\text{-}1$

α_0: The intercept term, also referred to as a drift term.
α_1 Yt-1: The lagged value of the series.
$\alpha_2 t$: The deterministic time trend component.
$\sum_{J=2}^{p} \gamma j\ \Delta Yt\text{-}j$: The sum of the lag first differenced values of the series.
ε_t: Error term with a random component ε_t.

3.4. Model Specification

The following Linear Regression Model is used to analyse the impact of FDI inflows on CO_2 emissions. A linear regression model is a statistical method used to model the relationship between a dependent variable and one or more independent variables by fitting a linear equation to observed data (Gujarati, 2002; Wooldridge, 2010). The model is expressed as:

$$ln\_CO_2 = \beta_0 + \beta_1 ln\_FDI + \varepsilon$$

Where:
ln_CO_2 : is natural logarithm of CO_2 emissions.
ln_FDI : is the natural logarithm of FDI inflows.
β_0: is the intercept term.
β_1: is the slope coefficient representing the elasticity of CO_2 emissions with respect to FDI inflows.
ε: is the error term.

3.5. Diagnostic Tests

To ensure the robustness and validity of the model, the following diagnostic tests were conducted:

Heteroskedasticity Test: The Breusch–Pagan/Cook–Weisberg test was employed to check for heteroskedasticity. The null hypothesis of constant variance was tested, ensuring the error terms have equal variance.

Autocorrelation Test: Durbin's alternative test was used to detect the presence of serial correlation in the residuals, which could bias the standard errors and lead to inefficient estimations.

Normality Test: The Shapiro–Wilk test was applied to assess whether the residuals of the regression model follow a normal distribution, a critical assumption for inference in regression analysis.

3.6. Robust Regression

The regression model was re-estimated using robust standard errors to address potential issues of heteroskedasticity and autocorrelation. This adjustment is commonly recommended to ensure that the coefficient estimates remain unbiased and consistent, even when the assumptions of homoskedasticity (constant variance of errors) and no autocorrelation are violated. Robust standard errors provide more reliable estimates of statistical significance by accounting for these issues, thus enhancing the robustness of the regression results (White, 1980; Wooldridge, 2010).

4. EMPIRICAL RESULTS AND DISCUSSION

4.1. Augmented Dickey-Fuller (ADF)

a. Variable ln_CO_2

	Test statistic	Dickey-Fuller critical value 1%	5%	10%
Z(t)	-8.026	-3.709	-2.983	-2.623

MacKinnon approximate *p*-value for Z(t) = 0.0000.

Source: Computed by the author using stata 17

b. Variable ln_FDI

	Test statistic	Dickey-Fuller critical value 1%	5%	10%
Z(t)	-4.264	-3.709	-2.983	-2.623

MacKinnon approximate *p*-value for Z(t) = 0.0005.

Source: Computed by the author using stata 17

The results from the Dickey-Fuller unit root test indicate that both the natural logarithms of CO_2 emissions (ln_CO_2) and FDI inflows (ln_FDI) are stationary at the 1% significance level. For ln_CO_2, the test statistic is -8.026, which is less than the critical values at the 1%, 5%, and 10% levels, and the p-value is 0.0000, confirming the absence of a unit root. Similarly, for ln_FDI, the test statistic is -4.264, which is also below the critical values, with a p-value of 0.0005, indicating stationarity. These results suggest that both variables are suitable for further regression analysis, as they do not exhibit unit roots and are integrated of order zero (I(0)).

4.2. Regression Analysis

. regress ln_CO2 ln_FDI

Source	SS	df	MS
Model	33.2575873	1	33.2575873
Residual	1.56539307	30	.052179769
Total	34.8229804	31	1.12332195

Number of obs	=	32
F(1, 30)	=	637.37
Prob > F	=	0.0000
R-squared	=	0.9550
Adj R-squared	=	0.9535
Root MSE	=	.22843

ln_CO2	Coefficient	Std. err.	t	P>|t|	[95% conf. interval]	
ln_FDI	.5937691	.0235192	25.25	0.000	.5457364	.6418018
_cons	-.7854563	.2187608	-3.59	0.001	-1.232225	-.3386872

Source: Computed by the author using Stata 17

A strong and statistically significant relationship is observed between Foreign Direct Investment (FDI) inflows and CO_2 emissions in India. The linear regression model, which includes FDI as the independent variable and CO_2 emissions as the dependent variable, explains 95.5% of the variation in CO_2 emissions, with an R-squared value of 0.9550. The coefficient for FDI ($\beta 1$ = 0.5938) indicates that a 1% increase in FDI inflows leads to a 0.59% increase in CO_2 emissions. This finding is statistically significant, as evidenced by the t-value of 25.25 and a p-value of 0.000. Additionally, the intercept term ($\beta 0$ = -0.7855) is statistically significant with a p-value of 0.001. These findings suggest that FDI inflows have a substantial positive impact on CO_2 emissions, underlining the need for policies that promote sustainable development alongside economic growth.

4.3. Robust Regression

```
. regress ln_CO2 ln_FDI, vce(robust)

Linear regression                               Number of obs     =         32
                                                F(1, 30)          =     672.06
                                                Prob > F          =     0.0000
                                                R-squared         =     0.9550
                                                Root MSE          =     .22843
```

ln_CO2	Coefficient	Robust std. err.	t	P>|t|	[95% conf. interval]	
ln_FDI	.5937691	.0229042	25.92	0.000	.5469925	.6405457
_cons	-.7854563	.2043244	-3.84	0.001	-1.202742	-.3681701

Source: Computed by the author using Stata 17

The robust linear regression analysis reveals a significant positive relationship between FDI inflows and CO_2 emissions. The coefficient for FDI inflows is 0.5938 (p-value < 0.000), indicating that a 1% increase in FDI leads to a 0.5938% rise in CO_2 emissions. The constant term is -0.7855 (p-value = 0.001), suggesting that, in the absence of FDI, CO_2 emissions would decline. The model demonstrates a high R-squared value of 0.9550, meaning that FDI inflows explain 95.5% of the variation in CO_2 emissions. The low root mean squared error (RMSE) of 0.22843 shows the model's high predictive accuracy, highlighting the significant role of FDI in influencing environmental outcomes.

4.4. Diagnostic Tests

a. Breusch–Pagan/Cook–Weisberg test for heteroskedasticity

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Assumption: Normal error terms
Variable: Fitted values of ln_CO2

H0: Constant variance

    chi2(1) =   0.74
Prob > chi2 = 0.3913
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b. Durbin's alternative test for autocorrelation

Durbin's alternative test for autocorrelation

lags(*p*)	chi2	df	Prob > chi2
1	14.097	1	0.0002

H0: no serial correlation

c. Shapiro–Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
residuals	32	0.93745	2.086	1.527	0.06340

Source: Computed by the author using Stata 17.

The diagnostic tests validate the robustness and credibility of the regression analysis. The Dickey-Fuller test establishes that both variables, ln_CO_2 and ln_FDI, are stationary at level I(0) eliminating the necessity for differencing or cointegration techniques. The Breusch-Pagan test confirms the absence of heteroskedasticity (p=0.3913p = 0.3913p=0.3913), ensuring consistent variance of residuals, while the Shapiro-Wilk test indicates approximate normality of residuals (p=0.0634p = 0.0634p=0.0634). Despite these favourable results, Durbin's alternative test detects significant first-order autocorrelation (p=0.0002p = 0.0002p=0.0002), which could undermine the validity of inference. This issue was effectively mitigated by employing robust regression, which adjusts for serial correlation and provides reliable standard errors and coefficients. The model, refined through these adjustments, is now well-suited for rigorous empirical interpretation.

4.5.CONCLUSION

The study concludes a significant positive relationship exists between Foreign Direct Investment (FDI) inflows and carbon dioxide (CO_2) emissions in India, based on data from 1991 to 2022. Using robust econometric methods, it was found that a 1% increase in FDI inflows leads to a 0.59% rise in CO_2 emissions, with FDI explaining 95.5% of the variation in emissions. This relationship underscores the environmental trade-offs associated with FDI-driven economic growth despite its contributions to India's industrialisation and infrastructure development. The findings align with the "Pollution Haven Hypothesis," suggesting that in the absence of stringent environmental regulations, FDI may exacerbate pollution. The study advocates for incorporating sustainability into investment policies to balance economic and environmental goals. It calls for future research to examine sector-specific impacts and explore how green investments can mitigate FDI's environmental footprint. It provides actionable insights for policymakers to design strategies that align FDI inflows with India's climate commitments.

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