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Economic Growth and Environmental Nexus in India: Unraveling the Dynamics through the Lens of the Environmental Kuznets Curve

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Abstract : This study explores the dynamic relationship between economic growth, environmental degradation, foreign direct investment (FDI), and trade openness in India within the framework of the Environmental Kuznets Curve (EKC) hypothesis from 1990 to 2019. Despite the prevailing notion of an inevitable trade-off between economic development and environmental preservation, the EKC hypothesis posits a non-linear relationship, suggesting that economic growth initially exacerbates but eventually mitigates environmental degradation after surpassing a certain income threshold. Utilizing the Auto-Regressive Distributed Lag (ARDL) model and cointegration analysis, this research delves into India's unique developmental trajectory to determine whether it aligns with the theoretical predictions of the EKC. The findings reveal an inverted N-shaped EKC for India, indicating that economic expansion initially leads to increased CO2 emissions, which subsequently decline as economic growth progresses, reflecting efficiency gains, technological advancements, and a shift towards less carbon-intensive industries. However, the role of FDI and trade openness presents a more complex interaction with environmental outcomes, suggesting nuanced policy implications. The study highlights the importance of integrating environmental considerations into economic and trade policies, promoting green technology, and enhancing public awareness to align India's rapid economic growth with its environmental sustainability goals. By providing empirical evidence on the EKC in India, this paper contributes to the global discourse on sustainable development and offers critical insights for policymakers, researchers, and stakeholders involved in environmental economics.

IndexTerms **– Environmental Kuznets Curve, FDI, Trade, Carbon emissions**

I. INTRODUCTION

In the evolving narrative of global development, the intricate dance between economic growth and environmental sustainability has emerged as a pivotal arena of study. The Environmental Kuznets Curve (EKC) hypothesis, which suggests an inverted U-shaped relationship between environmental degradation and income per capita, has sparked extensive debate and research. Originating from the seminal work of Grossman and Krueger in the early 1990s, the EKC proposes that economic development initially leads to environmental degradation, but after reaching a certain level of income, higher economic growth leads to environmental improvements (Grossman & Krueger, 1991).

India, with its rapid economic growth, burgeoning population, and significant environmental challenges, presents a compelling case for the examination of the EKC hypothesis. As the world's fifth-largest economy by nominal GDP and third-largest by purchasing power parity, India's developmental trajectory offers unique insights into the economic-environment nexus. The nation's growth, projected at around 7% annually, juxtaposed with its commitments to reducing carbon emissions and achieving sustainable development goals, underscores the critical need for understanding the dynamics at play.

This study aims to delve into the complexities of the EKC in the Indian context, examining the relationship between economic growth, environmental degradation, and the mediating roles of foreign direct investment (FDI) and trade openness. By employing an empirical analysis spanning from 1990 to 2019, this research seeks to shed light on whether India's economic ascent aligns with the theoretical predictions of the EKC, contributing to the global discourse on sustainable development and environmental economics.

Background

The relationship between economic growth and environmental degradation was always thought to be negative. (Krueger, 1991) found the evidence of inverted U-shaped curves for the first time in their paper. Their paper tried to find a relationship between environmental degradation with economic growth in the face of the formation of NAFTA and its effect especially on its Mexican counterpart. They found that Mexico in fact benefits from the agreement with greater access to the US market and also through specialization from trade liberalization. They for the first time found that economic growth doesn't always lead to environmental degradation. (Panayotou, 1993) hypothesized Simon Kuznets (relationship between economic growth and inequality) inverted U-

shaped curve for studying the relationship between environmental degradation and economic growth. He was the first one to come up with the term 'Environmental Kuznets Curve'. He found that environmental degradation is a temporary phenomenon for developing countries accompanied by initial economic growth. He tried to test his hypothesis by taking environmental degradation as a deforestation, Sulphur dioxide, Nitrogenous oxides and Solid particulate matter representative for environmental degradation. He found evidence of an inverted U-shaped relationship which he then named the Environmental Kuznets Curve (EKC). (Environmental Kuznets Curve in an Open Economy: A Bounds Testing and Causality Analysis for Tunisia, n.d.)find support for the EKC hypothesis in India, with energy consumption and financial development playing significant roles.

2.1 Effects of Environmental Kuznets Curve

(Krueger, 1991) gave distinction between three effects caused by economic growth agents and environmental degrading agents. The first is the scale effect, when economic activities increase given that the nature of activities remain unchanged, the expansion will lead to an increase in the environmental degradation. Second is composition effect, when economic growth increases say in the face of change in the trade policy through specialization, if that specialization is derived from the environmental degrading policies, then the trade policy is causing positive change in the environmental degradation. Third is the technique effect, according to which the further rise in the economic growth may not contribute to environmental damage but rather lead to a reduction in them which is attributed from the technological transfer from foreign countries and the rise in the standards of living. (Bo, 2011) EKC is a curve which shows the negative scale effect in the early stages of growth, then the positive technical effect and structural changes and these effects outweighs scale effect. Thus, environment first deteriorates with increase in the growth but then this growth improves the environment. But this relationship of inverted U-shaped hypotheses may not be always true.

2.2 Exceptions to Environmental Kuznets Curve hypothesis

(Stern, 2017) found that the assumption that the over the course of developmental process the pollution or environmental degradation may not be true. The converging factors are the factors which are responsible to reduce the pollution. (Kenneth Arrow, 1995) found that the argument that was earlier literature may not hold true. There are other aspects of looking at. According to their paper the above hypotheses is acting as a justification for trying to get more economic growth while ignoring the environment. There are exceptions to Environmental Kuznets Curve which later studies have found. (Mitra, 2017) relationships between CO2 emissions, per capita GDP, energy use, and trade openness for the period of 1971-2012. The study found long run relationship between CO2 and GDP and trade openness while short run relationship with energy consumption. The paper found evidence of N-shaped EKC both in India and China but it was more popular for India. (Alexandra Allard, 2018) conducted a study for 74 countries for the period of 1994-2012 based on CO2 emissions and GDP per capita. They found evidence of N-shaped EKC for lower middle income, high income and the whole panel. Whereas when quantile regression was used the evidence is found for few lower middle income and high income but not in upper middle-income countries. The results also found that the renewable source of energy has a negative impact on environmental degradation.

(Sefa Awaworyi Churchill, 2018) study's results showed evidence of inverted U-shaped EKC for Finland, France and the US. The turning point for these countries was at a higher level of incomes. The evidence of N-shaped EKC was found for Australia, Canada, and Japan. Their study confirmed that 11 countries do not hold EKC hypothesis, 9 hold the EKC hypothesis and out of these 9, 5 exhibit traditional inverted U-shaped curve, 3 show N- shaped curve and 1 show inverted N-shaped EKC curve. The 11 countries are Austria, Belgium, Germany, Greece, Italy, Netherland, Norway, New Zealand, Portugal, Sweden and Switzerland. One country (Denmark) has an inverted N-shaped EKC curve. Three countries (Australia, Canada and Japan) are characterized by an N-shaped EKC curve. (Bright Akwasi Gyamfi, 2021) tried to study the EKC for the period of 1995-2018 for 7 emerging countries. They intended to see if there exists an N-shaped EKC curve or not. The results indicated that there is no existence of the N-shape environmental Kuznets curve for the 7 countries considered for the study. The results also found that the non-renewable energy has a positive impact on environmental degradation. (Ghosh, 2010) conducted a study by including energy supply, investment and employment for a period of 1971–2006 for India and tried to form a long run relationship between economic growth and carbon emissions but failed to do so. The study further found the bi-directional causality in short run between the same. (Ameer, 2018) their study focused on 11 emerging Asian Countries for the period of 1980-2014. Inverted U-shaped EKC hypothesis holds true. Urbanization and economic growth reduce the emissions of Sulphur Dioxide, while technology and trade openness increase it in the long run. There are mixed responses in the literature with some researchers saying there exists no EKC and some confirming inverted-U EKC or other shapes of EKC (inverted N or N-shaped).

2.3Environmental Kuznets Curve and FDI and trade

There are various determinants of environmental degradation. (Krueger, 1991) when NAFTA was introduced, the environmentalists feared that it would degrade the environment due to heavy trade liberalization but they failed to recognize the other benefits of it. The more open the trade is and the more accessible the foreign investment is the more the technological accessibility is to foreign market and if the income increases due to this then there will be demand for environmental protection laws. (ABDULAI, 2013) studied the relationship between economic growth, international trade and environmental degradation for the period of 1990-2003. They found that the impact of trade was positive on environmental improvement in High Income, Sub-Saharan Africa and Latin America while it had a negative impact on the environment of low income, North Africa and Middle East, EU and Atlantic and Asia. (Werner Antweiler, 2003) studied the relationship between international trade and the environment.

(Lin-Sea Lau, 2014) examined the Environmental Kuznets Curve hypotheses for Malaysia from 1970-2008 and found that there exists EKC in both short-run and long-run in Malaysia. The FDI and Trade showed the negative impact on environment. (Huiming Zhu, 2016) conducted a study to see the impact of FDI, economic growth and energy consumption on carbon emissions for 5 ASEAN countries and the results indicated that FDI shows positive impact on environment of ASEAN countries. The existence of pollution haven hypothesis is refuted. The inverted U-shaped EKC do not exist for the 5 ASEAN countries. The results also indicated the negative impact of trade openness on carbon emissions. The impact is higher in high and medium emitting countries. This confirms halo effect.

(Baek, 2016) conducted a study of five ASEAN countries for the period of 1981-2010. The paper focused on FDI, income and energy consumption on environmental degradation. The results showed the existence of pollution havens hypothesis for ASEAN countries. The level of income and energy consumption showed negative impact on carbon emissions. (Ameer, 2018) found that the trade openness plays a positive role in the emissions of Sulphur Dioxide. (Daberechi Chikezie Ekwueme, 2021) found that the government should try to thrive trade openness and FDI in the country. (Mohd Shahidan Shaari, 2014) conducted a study for 15

developing countries from the period of 1992-2012 and tried to investigate the effects of FSI and economic growth on the CO2 emissions. The results indicated that in the long run the foreign direct investment does not contribute to carbon emissions. Thus, the evidence of the halo effect was seen in this study. (Thao, 2018) found that the foreign direct investment in developed and developing countries showed a positive impact on environmental degradation but trade openness showed a negative impact in developed countries and positive impact in developing countries on environmental degradation.

(Nesrin Ozatac, 2017) investigated the EKC hypothesis for Turkey from the period of 1960-2013 and found that trade openness positively affects economic growth which increases the demand for consumption of energy which increases the level of air pollution. (Huaping Sun, 2019) the study investigated the relationship between international trade and CO2 emissions for 49 high emission Belt and Road countries from 1991-2014 and found that trade openness caused environmental degradation in the long run in the Belt and Road, developed, developing, underdeveloped, and European countries.

Now the question comes if the source of FDI is determining any significant effect on the environmental quality. (Thao, 2018) used the panel of 51 developed and developing countries and the subpanel of 23 developing countries from 2001-2012 by taking into consideration the effect of foreign direct investment and trade openness on carbon dioxide emissions. The results showed that globalization is creating more degradation of the environment in lower income countries. The developmental stage of any country is significant in determining the impact on environmental degradation given the foreign investments. The foreign direct investment from developing countries leads to more environmental degradation as the firms from these countries lack competence. The FDI from developed countries exhibits a halo effect, that is, it shows that FDI from developed countries shows a technical transfer but at the same time the paper has mentioned that it is not that FDI from developing countries is not always undesirable.

This research contributes to the evolving discourse on the EKC by focusing on India's experience from 1990 to 2019, a period marked by rapid economic growth and significant environmental challenges. By examining the roles of FDI and trade openness alongside economic growth, this study aims to provide a more comprehensive understanding of the mechanisms driving environmental outcomes in India. Additionally, this research seeks to address gaps in the literature regarding the long-term sustainability of India's economic development model in the face of global environmental imperatives.

II. DATA AND ANALYSIS

The analysis encompasses data spanning from 1990 to 2019, aiming to capture the breadth of India's economic and environmental changes over nearly three decades. The data for GDP, GDP per capita and Imports and Exports at constant US 2015$ and CO2 emissions (metric tons per capita) was extracted from World Development Indicators, World bank. The data for FDI was collected from UNCTAD as a stock proportion of GDP. The natural logs of all the variables were taken into consideration for the analysis. The ARDL model and the cointegration analysis has been used in the analysis. The ARDL approach was chosen for its flexibility in handling variables integrated of different orders, making it particularly suitable for our dataset's characteristics, which includes both I(0) and I(1) series. Furthermore, the ARDL model facilitates the examination of both short-term and long-term dynamics between the variables, providing a comprehensive understanding of the underlying relationships. Cointegration analysis complements this by assessing the long-term equilibrium relationships among the variables, offering additional insights into the sustainable economic development pathways for India.

The model looks as follows

$$Ln(CO_2) = \beta_t + \beta_1 Ln(GDP\ per\ capita_t) + \beta_2 (LnGDP\ per\ capita_t)^2 + \beta_3 (LnGDP\ per\ capita_t)^3 + \beta_4 Ln(FDI_t) + \beta_5 Ln(Trade\ Openness_t) + \beta_6 (Ln(FDI) * Ln(Trade\ Openness)) + \mu_t$$

Table 1: Descriptive statistics

Variable	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
LN (CO2)	13.24	13.62	13.92	13.99	14.44	14.71
LN (GDP per capita)	6.271	6.511	6.824	6.862	7.189	7.571
(LN GDP per capita)^2	39.32	42.39	46.57	47.25	51.68	57.33
(LN GDP per capita)^3	246.6	276.0	317.8	326.5	371.5	434.0
LN(FDI)	-0.6864	0.8978	1.6903	1.5513	2.5061	2.6929
LN (Trade openness)	-2.0677	-1.5491	-1.0457	-1.1946	-0.8298	-0.5997

The descriptive statistics for India, spanning from 1990 to 2019, offer a deep dive into the nation's economic and environmental evolution. LN(CO2) emissions' increasing trend underscores the growing environmental challenges amid economic expansion. The statistics on GDP per capita showcase notable economic growth, with the progression in values reflecting enhanced living standards over time. The squared and cubed GDP per capita terms are crucial for investigating the non-linear impacts of economic growth on environmental degradation, providing nuanced insights vital for examining the Environmental Kuznets Curve hypothesis. Fluctuations in FDI reflect the impact of the global economic environment on India, with an overall positive mean indicating a trend towards increased foreign investment. Trade openness figures highlight India's deeper integration into the global economy, with implications for both economic development and environmental sustainability. These statistics lay the groundwork for analyzing the complex relationship between economic growth and environmental impact within the context of India's development.

Ensuring the reliability of our econometric models, the dataset underwent rigorous stationarity testing using the Phillips Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. These tests are crucial for avoiding spurious regression results, providing confidence in the subsequent analysis. The outcomes, detailed in Table 2, confirm that while the variables exhibit non-stationarity at levels, they become stationary upon first differencing, meeting the prerequisites for further econometric modeling.

Table 2: Results of stationarity tests

Variables	Phillips Perron test		Kwiatkowski-Phillips-Schmidt-Shin	
	Level	First Difference	Level	First Difference
LN (CO2)	-5.6367	-30.204*	1.0914*	0.12695

LN (GDP per capita)	-8.1779	-23.732*	1.0894*	0.44702
(LN (GDP per capita))^2	-5.4794	-23.788*	1.0863*	0.58007
(LN (GDP per capita))^3	-3.7847	-23.853*	1.0821*	0.6853
LN(FDI)	-1.4299	-26.411*	1.0254*	0.63917
LN(Trade)	-0.69786	-26.887*	0.97806*	0.44126

ARDL Model Analysis

Simple ARDL Model

The Auto-Regressive Distributed Lag (ARDL) approach facilitates the examination of both short-term and long-term dynamics between economic growth and CO2 emissions. Optimal lag selection, informed by an automatic selection process, yielded a model configuration of (1000011), with results presented in Table 3. The findings reveal significant insights into the N-shaped EKC for India, highlighting the complex interplay between economic activity, foreign direct investment (FDI), and trade openness with environmental outcomes.

Table 3: Simple ARDL Model results

Coefficients	Estimates	Standard errors	t-value	p-value
Intercept	225.85762	121.70543	1.856	0.079066.
L (LN (CO2),1)	0.53245	0.12156	4.380	0.000322 ***
LN (GDP per capita)	-91.67229	50.89212	-1.801	0.087548.
(LN GDP per capita)^2	12.73582	7.14342	1.783	0.090592.
(LN GDP per capita)^3	-0.58711	0.33379	-1.759	0.094685.
LN(FDI)	-0.01500	0.06314	-0.238	0.814706
LN (Trade openness)	0.08230	0.09105	0.904	0.377317
L (LN (Trade openness),1)	0.24547	0.11359	2.161	0.043674 *
LN(FDI)*LN (Trade Openness)	-0.01528	0.03934	-0.388	0.702015
L(LN(FDI)*LN (Trade Openness),1)	-0.06441	0.03822	-1.685	0.108268
Multiple R-squared: 0.9989, Adjusted R-squared: 0.9983 F-statistic:1846 on 9 and 19 DF p-value: < 2.2e-16				

Table 3 delves into the impact of economic growth on environmental degradation in India through the lens of the ARDL model. The analysis reveals significant insights into how GDP per capita, its squared and cubic terms, along with FDI and trade openness, interact with CO2 emissions. The model uncovers an inverted N-shaped Environmental Kuznets Curve for India, indicating that after reaching a certain level of economic development, further growth could potentially reduce CO2 emissions. This pattern suggests the increasing role of technology, efficiency gains, and a possible shift towards less carbon-intensive industries. Interestingly, the findings also highlight that FDI and trade openness, in their current states, do not have a significant direct impact on CO2 emissions, pointing towards the complexity of their environmental implications. The high R-squared values affirm the model's explanatory power, emphasizing the relevance of the chosen economic variables in understanding the dynamics between economic growth and environmental sustainability. These results offer valuable insights for policymakers, indicating that beyond a certain economic threshold, growth can be compatible with environmental goals, provided it is guided by sustainable policies and innovations.

Further elucidating the long-term relationship, the ARDL cointegration analysis underscores the presence of an inverted N-shaped EKC for India, suggesting a nuanced path towards sustainable economic growth. Both unrestricted and restricted cointegration models affirm the long-term equilibrium between the variables, providing empirical support for the EKC hypothesis in the Indian context. The error correction term (ect) from the restricted model indicates the speed at which CO2 emissions adjust to their long-term equilibrium, offering insights into the effectiveness of environmental policy measures.

Table 4: Unrestricted Cointegration results

Coefficients	Estimates	Standard errors	t-value	p-value
Intercept	225.85762	121.70543	1.856	0.07907.
L (LN (CO2),1)	-0.46755	0.12156	-3.846	0.00109 **
LN (GDP per capita)	-91.67229	50.89212	-1.801	0.08755.
(LN GDP per capita)^2	12.73582	7.14342	1.783	0.09059.

(LN GDP per capita)^3	-0.58711	0.33379	-1.759	0.09468.
LN(FDI)	-0.01500	0.06314	-0.238	0.81471
L (LN (Trade openness),1)	0.32778	0.14717	2.227	0.03822 *
L(LN(FDI)*LN (Trade Openness),1)	-0.07969	0.05748	-1.387	0.18164
Δ (LN (Trade openness))	0.08230	0.09105	0.904	0.37732
Δ (LN(FDI)*LN (Trade Openness))	-0.01528	0.03934	-0.388	0.70201
Multiple R-squared:0.6347 Adjusted R-squared: 0.4617 F-statistic: 3.668 on 9 and 19 DF, p-value: 0.008199				

Table 4 illuminates the long-term equilibrium relationship between India's economic growth and CO2 emissions, employing an unrestricted cointegration model. The significant findings illustrate the nuanced interplay between GDP per capita, its nonlinear transformations, FDI, and trade openness with environmental degradation. The analysis confirms the inverted N-shaped EKC, suggesting that beyond certain economic thresholds, further development could lead to environmental improvements. The insignificance of FDI and trade openness in directly influencing long-term CO2 emissions highlights the complexity of their roles in sustainable development. This model's insights underscore the potential for India's economic policies to harmonize growth with environmental sustainability, emphasizing the crucial role of technological innovation and efficiency improvements. These results furnish policymakers with empirical evidence to guide the integration of economic and environmental objectives, fostering a sustainable development trajectory.

Table 5: Restricted Cointegration results

Coefficients	Estimates	Standard errors	t-value	p-value
Intercept	225.85762	35.06926	6.440	9.61e-07 ***
Δ (LN (Trade openness))	0.08230	0.04005	2.055	0.0504.
Δ(LN(FDI)*LN(Trade Openness))	-0.01528	0.01335	-1.145	0.2632
ect	-0.46755	0.07261	-6.439	9.64e-07 ***
Multiple R-squared: 0.6347, Adjusted R-squared: 0.5909 F-statistic: 14.48 on 3 and 25 DF, p-value: 1.139e-05				

Table 5's examination through the restricted cointegration model sheds light on the intricate balance between economic growth and environmental sustainability in India. The significant intercept and the nuanced roles of trade openness and FDI, along with the error correction term, illustrate the complex interplay between immediate economic activities and long-term environmental goals. The findings highlight the importance of strategic policy interventions and sustainable practices in navigating the path towards reduced CO2 emissions while fostering economic development. The model's insights into the short-term impacts and long-term adjustments underscore the potential for aligning India's economic expansion with environmental sustainability, emphasizing the pivotal role of innovation and policy in these endeavors.

III. POLICY IMPLICATIONS AND CONCLUSION

The evidence of an inverted N-shaped EKC for India implies that economic growth initially leads to increased environmental degradation but eventually contributes to environmental improvement after reaching a certain threshold. Policymakers should aim to accelerate the transition to the phase where economic growth enhances environmental quality. This involves prioritizing investments in green technologies, sustainable infrastructure, and industries that are less carbon-intensive. Establishment of government-backed funds to support research and development in green technologies is important. Similar to South Korea's Green Technology Center (Green Growth - Sung-Young Kim, Elizabeth Thurbon, 2015, n.d.), these funds can foster innovation in clean energy, waste management, and sustainable agriculture. Germany's partnership model in renewable energy projects has significantly contributed to its energy transition, offering a viable model for India to emulate. The study highlights the crucial role of technological advancements and the transfer of green technologies in mitigating environmental degradation. Policies should encourage research and development in clean energy, efficient resource use, and pollution control technologies. Additionally, fostering international cooperation to facilitate technology transfer from developed to developing nations can be pivotal in achieving sustainable development goals. While trade openness does not show a significant direct impact on CO2 emissions, the complex interplay between trade, FDI, and the environment underscores the need for integrating environmental considerations into trade agreements. India could benefit from adopting trade policies that incentivize environmental sustainability, such as imposing environmental standards on imported goods and encouraging exports of eco-friendly products. The mixed impact of FDI on environmental outcomes suggests the importance of strategic regulatory frameworks that attract green investments. India should aim to implement policies that not only attract foreign investments but also ensure that these investments are aligned with environmental conservation efforts. This may include offering incentives for investments in renewable energy and clean technologies and enforcing stringent environmental compliance for foreign companies. Raising public awareness about environmental issues and promoting education on sustainable practices are essential for fostering a culture of sustainability. Policies that support environmental education in schools, community awareness programs, and public campaigns on the importance of conservation can mobilize collective action towards environmental protection. The Philippines' community-based forest management program provides a successful example of community involvement in sustainable natural resource management (People, Power and Timber, n.d.). Continuous monitoring of environmental indicators and economic activities is

essential for assessing the effectiveness of environmental policies and economic reforms. Establishing a robust framework for data collection, analysis, and dissemination will enable timely adjustments to policies and ensure transparency and accountability. In conclusion, the findings of this study underscore the need for a holistic approach to economic policy-making that considers the long-term environmental implications of economic growth, trade, and investment. By aligning economic development strategies with environmental sustainability goals, India can pave the way for a greener, more sustainable future.

IV. LIMITATIONS

While this study provides valuable insights into the environmental and economic dynamics in India, it is not without limitations. First, the analysis is constrained to the period from 1990 to 2019, potentially omitting earlier data that could offer additional historical context. Additionally, the focus on CO2 emissions as the sole indicator of environmental degradation might not capture the full spectrum of environmental impacts associated with economic growth, trade, and investment. The study also assumes linearity in the EKC, which may oversimplify the complex and possibly nonlinear interactions between economic development and environmental outcomes. Furthermore, while the ARDL model offers significant advantages, it relies on the correct specification of the model and the choice of lag lengths, which could affect the robustness of the findings. Lastly, the study's focus on India, while providing in-depth insights, may limit the generalizability of the findings to other countries with different economic structures, environmental policies, and development stages.

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