Carbon Intensity and Climate Finance:
A Data-Driven Approach to India's Sustainable Economic Growth

Author (s): Madala Sasidhar, Vaibhav
Mentor : Dr. Ritu Kothiwal
Vishwa Vishwani Institute of Systems & Management

Problem Statement

India's economic growth poses significant environmental challenges, with rising CO_2 emissions linked to heavy reliance on non-renewable energy. While ESG indices and renewable energy investments offer solutions, their collective impact on carbon intensity and GDP remains underexplored. Moreover, a common perception persists that reducing emissions comes at the cost of economic progress. This study seeks to evaluate whether carbon intensity reductions, supported by climate finance, can foster economic growth, thus challenging the conventional trade-off narrative between sustainability and development.

Introduction

The global urgency to address climate positions carbon intensity as a vital metric for assessing sustainable development. For India, balancing rapid economic growth with the transition to a low-carbon economy is particularly challenging. The nation's heavy reliance on non-renewable energy sources increases carbon intensity, while renewable energy adoption and climate finance mechanisms like ESG (Environmental, Social, and Governance) indices serving as strategic levers for achieving sustainability goals. This research integrates macroeconomic variables and financial market data to explore how carbon intensity reduction, supported by climate finance, can drive sustainable growth. Using econometric models, it examines the dynamic relationships among GDP, energy generation, emissions, and financial instruments, providing actionable insights for achieving India's net-zero ambitions.

Objectives

- To analyze the relationship between carbon intensity and GDP, considering the contributions of renewable and non-renewable energy generation.
- To evaluate the role of ESG indices and other climate finance mechanisms in supporting carbon intensity reduction and economic growth.

Methodology

I. Data Collection

- **Timeframe**:
  - Macro Variables: 2000–2023 (Year-on-Year data).
  - Financial Market Data: April 4, 2019–July 31, 2024.
- **Variables:**
  - **Macro Variables**: Carbon intensity, GDP, renewable energy, non-renewable energy, CO_2 emissions.
  - **ESG Indices**: BSE CarbonEX, BSE GreenEX, NIFTY 100 ESG, BSE 100 ESG.

II. Analytical Framework

- Perform Descriptive Statistics to summarize key features of the data.
- Unit Root Test for data stationarity.
- Cointegration Analysis finding long-term equilibrium
- VAR to find dynamic interactions.
- Impulse Response Function assess the shock impact
- Variance Decomposition determining quality of influence
- Volatility Analysis (GARCH) examining the risk
- Granger Causality Test while directional relationships

Results

1. Descriptive Statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
BSE 100 ESG Returns	0.000609	0.001229	0.082858	-0.136088	0.012062	-1.526075	22.88179
BSE CarbonEX Returns	0.000605	0.001283	0.083121	-0.13961	0.01198	-1.703041	24.82949
BSE GREENEX Returns	0.000766	0.001535	0.080564	-0.125874	0.011945	-1.433349	18.68386
NIFTY 100 ESG Returns	0.000608	0.001057	0.037979	-0.052791	0.008338	-0.540972	6.988701
Carbon Intensity (R_CARBON)	-0.001591	0.002958	0.027231	-0.046171	0.01734	-0.651367	3.15975
GDP (R_GDP_TRILLIONS$)	0.088097	0.084073	0.258264	-0.058445	0.077719	0.304977	2.587077

Note- The Data shows BSE GreenEX index showed the highest mean returns, indicating strong performance among ESG-focused investments, while carbon intensity demonstrates a consistent decline, reflecting progress toward sustainable growth.

2. Unit Root Test

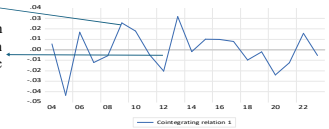
Variable	ADF Test Statistic	Critical Value (5%)	P-Value	Stationarity
BSE 100 ESG Returns	-12.5	-3.41	0	Stationary
BSE CarbonEX Returns	-12.3	-3.41	0	Stationary
BSE GreenEX Returns	-37.68	-3.41	0	Stationary
NIFTY 100 ESG Returns	-24.85	-3.42	0	Stationary

Note- The Data shows the ADF test results confirm that all variables (e.g., BSE 100 ESG, NIFTY 100 ESG, BSE CarbonEX, and BSE GreenEX) are stationary at level, ensuring robust time-series modeling.

3. Vector Error Correction (Cointegration Analysis)

Variable Relationship	Cointegration Equation	T-Statistic	Adjusted R^2
Carbon Intensity ↔ GDP	-157.87 (Carbon Intensity) + 1.85 (GDP)	-4.84	0.76
Carbon Intensity ↔ Renewable Energy	-47.26 (Carbon Intensity) - 27.52 (Energy)	-2.57	0.62

Note- The Data shows cointegration analysis highlights a long-term equilibrium relationship between carbon intensity and GDP, with adjustment mechanisms ensuring stability in emissions and economic growth over time.

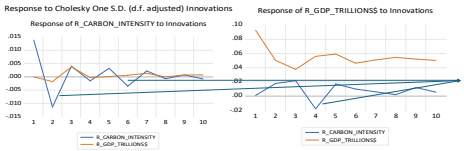


4. Granger Causality Test Results

Null Hypothesis	F-Statistic	P-Value	Conclusion
BSE CarbonEX does not Granger Cause Carbon Intensity	3.69	0.025	Causal Relationship
Carbon Intensity does not Granger Cause GDP	0.39	0.678	No Causality
Renewable Energy does not Granger Cause GDP	0.43	0.65	No Causality

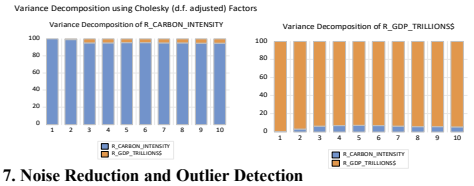
Note- The Data shows BSE CarbonEX Granger-causes carbon intensity, demonstrating that ESG investments significantly influence emissions reduction strategies, while no direct causality exists between renewable energy and GDP growth.

5. Impulse Response Function (IRF)

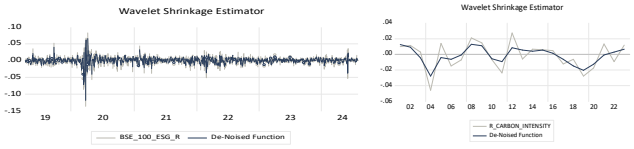


Graph shows the shocks to renewable energy investments lead to gradual and sustained positive impacts on GDP, while carbon intensity shows a declining trend in response to economic growth, indicating a transition to cleaner energy use.

6. variance decomposition



7. Noise Reduction and Outlier Detection



8. Volatility Analysis (GARCH)

Dependent Variable	BSE CARBONEX	BSE GREENEX	BSE100ESG	NIFTY 100ESG
C (Intercept)	0.000808	0.000954	0.000808	0.000882
GARCH (-1)	0.814555	0.807405	0.834833	0.57251
RESID (-1)^2	0.150828	0.14023	0.131727	0.21955
z-Statistic for C	3.643967	3.600336	3.56605	2.891918
z-Statistic for GARCH(-1)	48.51422	39.40738	49.06208	8.19603
z-Statistic for RESID(-1)^2	10.88501	9.313996	9.882277	6.098037

GARCH = C (3) + C(4) *RESID(-1)^2 + C(5)*GARCH(-1)

Note- The Data shows ESG indices exhibit stable volatility trends, with NIFTY 100 ESG and BSE CarbonEX indicating strong market stability and their role as reliable indicators of sustainable investments.

Conclusion

The research demonstrates that carbon intensity—a measure of CO_2 emissions per unit of GDP—is steadily declining, reflecting India's progress in balancing economic growth with emission reductions. Cointegration analysis revealed a significant long-term equilibrium relationship between carbon intensity, GDP, and renewable energy generation. Renewable energy investments were found to play a crucial role in reducing emissions while contributing to GDP growth. However, variance decomposition and causality tests indicated a weaker connection between non-renewable energy reductions and economic performance, highlighting the need for greater policy emphasis on renewable energy integration.

ESG indices, such as BSE GreenEX, NIFTY 100 ESG, and BSE CarbonEX, displayed strong performance and stability, making them reliable tools for channeling investments into sustainable enterprises. Volatility analysis using the GARCH model revealed that these indices are less prone to market shocks, indicating their viability for long-term, sustainability-focused investments. Granger causality analysis showed that ESG indices influence carbon intensity, proving their potential to guide emissions reduction strategies through targeted financial mechanisms.

The study established that carbon intensity reductions are most effective when supported by climate finance mechanisms. Renewable energy investments, bolstered by ESG indices, provide a dual benefit—driving GDP growth and reducing emissions. Noise reduction techniques further clarified trends, enabling a clearer understanding of how financial instruments and macroeconomic variables interact to support India's net-zero aspirations. This integrated approach underscores the importance of aligning sustainable financing with national energy and growth policies for a holistic transition to a low-carbon economy.

Policy Implications

- Mandate renewable energy targets for industries with compliance incentives.
- Promote ESG indices (e.g., BSE CarbonEX, NIFTY 100 ESG) as benchmarks for sustainable corporate performance and integrate them into national economic metrics.
- Develop and implement green bonds or similar mechanisms specifically linked to renewable energy generation and carbon intensity targets.
- Provide funding for research and development (R&D) in renewable technologies and expand grid capacities to handle variable energy flows from renewable sources.
- Align monetary and fiscal policies with climate finance goals, ensuring investments are directed toward green growth sectors.