

Economic Growth and Carbon Emissions in India: An Analysis of the Changing Carbon Intensity of the Economy

Kaviya K

PSG College of Arts and Science

Abstract

This study assesses whether India's carbon intensity declined in the period of economic growth from 2000-2024. It uses annual data from the World Bank on real gross domestic product (GDP), carbon dioxide and carbon intensity. The analysis is based on descriptive statistics, annual growth rates, Tapio decoupling elasticity, stationarity diagnostics and simple time-trend regressions with heteroskedasticity and autocorrelation consistent (HAC) standard errors. The results show an increase of real GDP by 328.98% from 2000 to 2024 and an increase of CO₂ emissions by 216.37%. Over the same period carbon intensity was down 26.25%. The overall decoupling elasticity was estimated at 0.6577, showing weak or relative decoupling, with emissions growing, but at a slower rate than the growth of economic output. 9 years of weak decoupling, 10 years of expansive coupling and 3 years of expansive negative decoupling took place. In 2019 strong decoupling took place, while in 2020 recessive decoupling occurred. There is mixed evidence for an acceleration in the decline after 2014: the post-2014 slope-interaction test is statistically significant ($p = 0.010$ with small-sample HAC errors) but the comparison of average annual changes before and after 2014 ($p = 0.129$) and the block-bootstrap test ($p = 0.153$) are not. These results indicate some progress by India in reducing the emissions intensity of its economic activities, but absolute emissions are still far above the levels at the start of the period of study.

Keywords: economic growth; decoupling; India; sustainable development; carbon emissions; carbon intensity

1. Introduction

The nexus between economic growth and environmental quality is an important issue for developing economies. Economic expansion can increase the demand for energy and the industry and transportation activity that may boost carbon emissions. At the same time, technical innovation, structural reform and progress in energy efficiency can allow an economy to produce more output with fewer emissions per unit of GDP.

India is a relevant case because it has had substantial economic growth and is also pursuing climate and energy transition goals. However, new research from India still show a favorable association of economic development with absolute emissions. Gawas and Sarath Chandran (2026) provide data in support of an EKC link. Both trade openness and energy usage are linked with higher emissions. Similarly, Hung (2026) finds that economic growth is associated with higher CO₂ emissions, whereas green technology reduces

emissions and Singh (2025) reports a positive and significant long-run influence of GDP on CO₂ emissions as well as the importance of structural breaks for the growth–environment nexus of India . Other studies points to a more convoluted relationship. Das and Roy (2020) show that India is considerably decoupling economic growth from energy-related emissions and they credit this to energy-efficiency gains and structural changes. Similarly, the Economic Survey 2023-24 (Government of India, 2024, p. 183) states that GDP was growing faster than emissions for the period 2005-2019, consequently, the emission intensity was decreasing over the years.

This study raises a question of whether the carbon intensity of India fell with the expansion of the economy for the period 2000–2024? It provides a better transparent assessment, employing a common data set of 25 years, carbon-intensity patterns, and decoupling indicators. The objectives are to review trends in GDP and CO₂, to measure the change in carbon intensity, to assess if growth has been accompanied by a lower carbon intensity and to assess the level of decoupling.

2. Literature Review

2.1 Economic Growth and Environmental Degradation in India

Gawas and Sarath Chandran (2026) examine India over the period 1971–2021 using ARDL bounds testing and Bai-Perron multiple structural-break controls in three specifications: an economic-growth model, an environmental-quality model and a nonlinear EKC model. They find consistent long-run correlations across the parameters which is supportive of an EKC with a turning point around US \$6,300 per capita, a positive long-run influence of trade openness on emissions and energy consumption as a main driver of emissions. They discover structural breaks in 1978, 1984, 2009 and 2014 and underline the necessity to account for changes in the India's growth-emissions relationship.

Hung, (2026) studies the financial markets of India in the period 1990-2023 through wavelet quantile regression and quantile-on-quantile Granger causality. The study shows that economic development is positively associated to CO₂ emissions while green technology is negatively related to emissions.

Singh (2025) examines the growth-environment nexus in India by employing long historical data, different estimators and structural breaks, finding that GDP positively influences CO₂ emissions.

2.2 Economic Growth, Climate Conditions and Environmental Sustainability

Verma and Giri (2026) utilize annual Indian data for the period 1991-2023 with combination of ARDL and VAR based techniques. The results show that there exists a positive long term association between real GDP per capita and carbon emissions whereas temperature shocks have a negative influence on economic activity. The conclusion implies that environmental stress and the macro-economic outcome are closely interlinked.

2.3 Carbon Intensity and Decoupling

As discussed by Das and Roy (2020), India witnessed relative decoupling during 1990–91–2012–13 driven by increased energy efficiency and structural change. “India's GDP grew at an average rate of almost 7% per year between 2005 and 2019, while emissions grew at an average rate of 4% per year” (Economic Survey 2023 – 24 (Government of India, 2024, p.183), p. 183). Recently Kumar et al. (2025) have calculated the decoupling elasticity in India as 0.59 for the period 2012 – 2022 by employing Logarithmic Mean Divisia Index (LMDI) decomposition technique. The main driver of increased emissions is revealed to be economic development. We observed that improvements in energy efficiency and in structural change have considerably reduced emissions.

2.4 Research Gap

The literature documents a strong correlation between India's absolute emissions and economic activity, and other data suggests a decline in emissions intensity and episodes of relative decoupling. Many recent research employ complicated econometric frameworks. This study provides an additional easy updated evaluation up to 2024 with a focus on the carbon intensity and the annual decoupling, not arguing for a totally new decoupling phenomenon.

2.5 Summary

Historically, economic expansion has led to rising absolute emissions in India, but improvements in efficiency, technology, energy structure and structural transformation can lead to reductions in emissions per unit of output. The current study investigates if such tendency is evident in the 2000-2024 data.

3. Data and Methodology

3.1 Data Sources and Study Period

The analysis uses the annual Indian data of World Bank World Development Indicators for the period of 2000-2024. The three measures are GDP (NY.GDP.MKTP.KD), carbon dioxide emissions (EN.GHG.CO2.MT.CE.AR5) and carbon intensity of GDP (EN.GHG.CO2.RT.GDP.KD). GDP is measured in constant 2015 US dollars, emissions in Mt CO₂e, and carbon intensity in kg CO₂e per constant 2015 US dollar of GDP. The World Bank CO₂ indicator is defined as total CO₂ emissions excluding land use, land use change and forestry (LULUCF).

Variable	Indicator code	Unit	Role
GDP	NY.GDP.MKTP.KD	US\$ billion (constant 2015 US\$)	Economic output
CO ₂ emissions	EN.GHG.CO2.MT.CE.AR5	Mt CO ₂ e	Absolute emissions
Carbon intensity	EN.GHG.CO2.RT.GDP.KD	kg CO ₂ e per constant 2015 US\$ GDP	Emissions intensity

Table 1. Description of Variables and Data Sources.

3.2 Measures

Annual growth rates are calculated as $g_{X,t} = [(X_t - X_{t-1}) / X_{t-1}] \times 100$. Carbon intensity is used directly from the World Bank indicator. A decline indicates fewer emissions per unit of economic output.

3.3 Decoupling Elasticity

The annual decoupling elasticity is $D_t = g_{CO_2,t} / g_{GDP,t}$. According to the Tapio (2005) decoupling model, when both GDP and emissions increase at the same time, $0 < D_t < 0.8$ is weak decoupling, $0.8 \leq D_t \leq 1.2$ is expansive coupling, and $D_t > 1.2$ is expansive negative decoupling. The year of decoupling: GDP grows and emissions fall. $D_t > 1.2$ means a recessive decoupling, when both GDP and emissions are falling. - The total elasticity is computed as the cumulative percentage increases over the period 2000-2024.

3.4 Trend Regression

A time-trend regression is estimated as $CIt = \alpha + \beta \text{Year}_t + \epsilon_t$. A logarithmic specification, $\ln(CIt) = \alpha +$

$\beta \text{ Yeart} + \varepsilon_t$, is also estimated. HAC/Newey–West standard errors (Newey & West, 1987) with two lags are used to account for heteroskedasticity and serial correlation. These regressions are interpreted as deterministic trend tests, not causal estimates.

3.5 Stationarity Diagnostics and Test of H2

The stationarity of the data is tested using the Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1979) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski et al., 1992). The ADF null hypothesis is that the series has a unit root. The null hypothesis for the KPSS test is that the series is stationary. Both levels and first-difference forms are examined to check for the possibility of non-stationarity affecting trend regressions.

Variable / form	ADF statistic	ADF p-value	KPSS statistic	KPSS p-value
GDP — Level	2.356	0.999	0.731	0.011
GDP — First difference	−3.667	0.005	0.475	0.047
CO ₂ emissions — Level	2.590	0.999	0.733	0.011
CO ₂ emissions — First difference	−1.103	0.714	0.151	>0.10
Carbon intensity — Level	−0.712	0.844	0.636	0.019
Carbon intensity — First difference	−4.265	0.001	0.096	>0.10

Table 2. Stationarity Test Results for GDP, CO₂ Emissions, and Carbon Intensity

Note: For the ADF test, $p < 0.05$ rejects the null hypothesis of a unit root. For the KPSS test, $p < 0.05$ rejects the null hypothesis of stationarity. The level results indicate non-stationarity, while GDP and carbon intensity are stationary in first differences; the CO₂ first-difference diagnostics are mixed.

H2 is tested directly with a post-2014 slope-interaction model using $\ln(\text{CI}_t)$ as the dependent variable: $\ln(\text{CI}_t) = \alpha + \beta_1 t + \beta_2 \text{Post2014}_t + \beta_3 (t \times \text{Post2014}_t) + \varepsilon_t$, where Post2014 equals one from 2015 onward. The coefficient β_3 measures the change in the carbon-intensity trend after 2014. HAC/Newey–West standard errors with two lags, a small-sample correction and t-based critical values are used. Because HAC inference can over-reject with 25 observations and strongly autocorrelated residuals (Durbin–Watson = 0.76), H2 is also assessed with a Welch t-test and a permutation test on mean annual changes in log carbon intensity, and with a moving-block bootstrap (block length 4) of the slope-change coefficient under the null of a single linear trend. The 2014 break date comes from the visual pattern and is consistent with the break dates reported by Gawas and Sarath Chandran (2026); it is not estimated, so sensitivity to the break year is also reported.

The data were cleaned and analyzed in Python using pandas, matplotlib and statsmodels. The World Bank series were merged by year, checked for missing values, and restricted to 2000–2024.

4. Results and Discussion

4.1 Descriptive Results

Data were cleaned and analyzed using Python (pandas, matplotlib and statsmodels). World Bank series were merged by year, screened for missing values and restricted to 2000-2024.

Real GDP increased from roughly US\$800.5 billion in 2000 to US\$3.434 trillion in 2024. The CO₂ emissions increased from 996.89 Mt CO₂e to 3,153.83 Mt CO₂e. Carbon intensity decreased from 1.2453 to 0.9184.

Variable	Mean	Std. Dev.	Minimum	Maximum
GDP (US\$ billion)	1,855.85	802.06	800.53	3,434.12
CO ₂ emissions (Mt CO ₂ e)	1,934.28	669.68	996.89	3,153.83
Carbon intensity	1.0813	0.1026	0.9184	1.2453

Table 3. Descriptive Statistics of Study Variables.

4.2 Trends in GDP, CO₂ Emissions and Carbon Intensity

Data were cleaned and analyzed using Python (pandas, matplotlib and statsmodels). World Bank series were merged by year, screened for missing values and restricted to 2000-2024.

Real GDP increased from roughly US\$800.5 billion in 2000 to US\$3.434 trillion in 2024. The CO₂ emissions increased from 996.89 Mt CO₂e to 3,153.83 Mt CO₂e. Carbon intensity decreased from 1.2453 to 0.9184.

Indicator	2000	2024	Change
GDP (US\$ billion)	800.53	3,434.12	+328.98%
CO ₂ emissions	996.89 Mt CO ₂ e	3,153.83 Mt CO ₂ e	+216.37%
Carbon intensity	1.2453	0.9184	-26.25%

Table 4. Changes in GDP, CO₂ Emissions and Carbon Intensity, 2000–2024.

The reduction in carbon intensity was not steady. It increased significantly in 2007–2008 and 2011–2012 and then moved downward more strongly after 2015. It also went up a little in 2021–2023 and was 0.9184 in 2024.

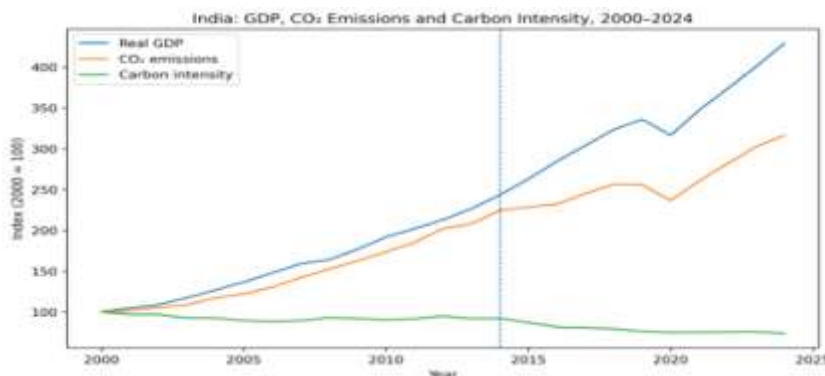


Figure 1. Indexed GDP, CO₂ emissions and carbon intensity in India, 2000–2024 (2000 = 100). The dashed vertical line marks 2014, the reference break used in the H2 test.

4.3 Decoupling Analysis

The total decoupling elasticity is 0.6577. The whole period shows a weak decoupling, with both GDP and emissions increasing, but emissions growing at a slower rate than GDP.

Type	Years	Share
Weak decoupling	9	37.50%
Expansive coupling	10	41.67%
Expansive negative decoupling	3	12.50%
Strong decoupling	1	4.17%
Recessive decoupling	1	4.17%

Table 5. Distribution of Annual Tapio Decoupling Types in India, 2001–2024

Based on the Tapio thresholds, 9 of the 24 years were classified as weak decoupling, 10 years as expansive coupling, 3 years as expansive negative decoupling, 2019 as strong decoupling, and 2020 as recessive decoupling.

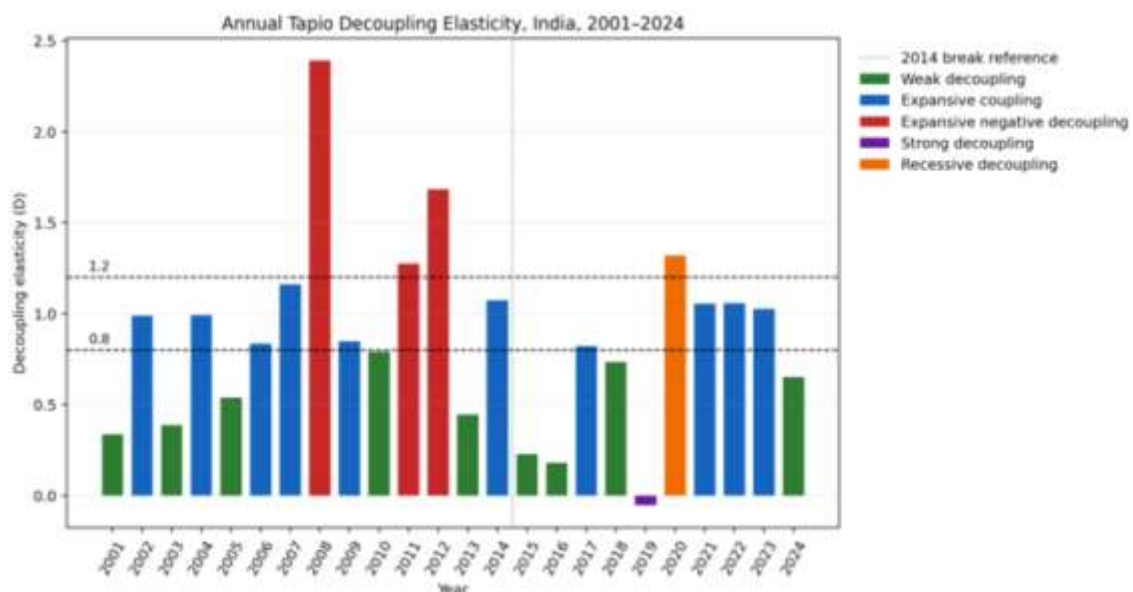


Figure 2. Annual Tapio decoupling elasticity, 2001–2024. Bars are coloured by decoupling classification; dashed horizontal lines mark the 0.8 and 1.2 Tapio thresholds, and the vertical dotted line marks 2014 as the reference break used in the H2 test.

4.4 Trend Regression Results

The level trend model has a year coefficient of -0.012573 (HAC SE = 0.001193), $p < 0.001$ and $R^2 = 0.813$. The log specification gives a coefficient on year of -0.011873 (HAC SE = 0.001155), $p < 0.001$ and $R^2 = 0.811$. Both specifications reveal a statistically significant negative time trend in carbon intensity and both remain significant at $p < 0.001$ with a small-sample HAC correction and t-based inference. Since the ADF/KPSS diagnostics suggest carbon intensity is non-stationary in levels, these estimates should be interpreted as evidence of a deterministic time trend, rather than a stationary level relationship or a causal effect.

Specification	Year coefficient	HAC SE	p-value	R ²
Level CI	-0.0126	0.0012	<0.001	0.813
Log CI	-0.0119	0.0012	<0.001	0.811

Table 6. Trend Regression Results for Carbon Intensity in India

The log coefficient implies roughly a 1.19% annual downward time trend in carbon intensity. This is not a causal estimate of the effect of GDP.

The estimated post-2014 slope difference is -0.0119 (HAC SE = 0.0042 with small-sample correction; t-based $p = 0.010$). The implied trend in log carbon intensity is approximately -0.35% per year before 2015 and -1.54% per year from 2015 onward. The result is not robust to the specification. The mean annual changes in log carbon intensity are -0.576% (2001-2014) and -2.239% (2015-2024) (Welch $p = 0.129$; permutation $p = 0.130$), and a moving-block bootstrap of the slope-change coefficient gives $p = 0.153$. The slope-interaction coefficient is significant for break years 2012–2015 ($p=0.007$ – 0.015) but not for 2016 ($p=0.111$). The corresponding means in simple percentage changes are -0.543% and -2.186%. The level-based p -values are probably too optimistic, because the residuals of the interaction-model are highly auto-correlated and because carbon intensity is non-stationary in levels. H2 is therefore treated as suggestive. Point estimates suggest a faster decline after 2014 but the evidence is not conclusive.

H2 test	Estimate / mean	p-value	Interpretation
Slope interaction (small-sample HAC, t-based)	-0.0119 (SE 0.0042)	0.010	Significant
Mean annual change, pre vs post (Welch)	-0.576% vs -2.239%	0.129	Not significant
Moving-block bootstrap of slope change	-0.0119	0.153	Not significant

Table 7. Robustness Tests for the Post-2014 Change in Carbon Intensity Trends (H2)

4.5 Discussion

The empirical results answer the main research question affirmatively in an overall descriptive sense. India's economy expanded substantially while carbon intensity declined. However, absolute CO₂ emissions also increased, so the evidence is better described as relative rather than absolute decoupling. The result is consistent with earlier Indian evidence of relative decoupling. Das and Roy (2020) identify energy efficiency and structural change as important contributors, while Kumar et al. (2025) report a decoupling elasticity of 0.59 for 2012–2022. At the same time, recent econometric studies continue to find positive associations between economic development and absolute emissions.

The Economic Survey reports a 33% decline in emissions intensity between 2005 and 2019, whereas the present WDI series gives a smaller decline of about 14.7% over the same years. The difference likely reflects differences in the underlying emissions concept and GDP/intensity construction: the Survey uses

India's national emissions and national-accounts framework, whereas this study uses the World Bank CO₂ indicator excluding LULUCF and GDP at constant 2015 US dollars.

The observed decline in carbon intensity should therefore not be attributed to economic growth alone. The present design does not separately identify energy structure, technology, policy, trade, industrial composition or other mechanisms.

5. Conclusion and Policy Implications

5.1 Conclusion

The study examined the reduction of carbon intensity of India with rising GDP over 2000 – 2024. GDP increased 328.98 %, CO₂ emissions increased 216.37 % and carbon intensity declined 26.25 %. The general decoupling elasticity is 0.6577, which means inadequate or relative decoupling. Expansive coupling was the most frequent classification (10 out of 24 years), followed by weak decoupling (9 years). Also identified were expansive negative decoupling (3 years), strong decoupling in 2019 and recessive decoupling in 2020. The trend regressions also demonstrate a statistically significant downward trend in carbon intensity. The evidence of an acceleration in the rate of reduction of carbon intensity after 2014 is intriguing, not definitive.

The key finding is that India's economy grew substantially, but it became less carbon intensive, and no absolute decoupling was observed during the whole period. "The continued growth in absolute emissions shows that emissions intensity reductions are not sufficient for a full low carbon transition.

5.2 Policy Implications

- Maintain the policy priority of lowering carbon intensity through energy efficiency, greener production and low-carbon technology. India's PAT program is a well-established energy-efficiency policy regime, and the 2015 NDC and subsequent climate pledges include explicit emissions-intensity and long-term transition targets (Government of India, 2015; Bureau of Energy Efficiency, 2026; Government of India, 2023).
- Cleaner energy use has to go hand in hand with the improvement of carbon intensity, as emissions in absolute terms continue to climb.
- The irregular annual pattern requires measures that facilitate decoupling in periods of fast economic recovery.
- Policy evaluation should take into account both carbon intensity and absolute emissions.
- Structural and technology change are the only means to sustain long-term economic growth with lower emissions intensity.

5.3 Limitations

The analysis is based on just 25 annual records from one source (World Bank WDI), and carbon intensity is non-stationary in levels, therefore the p-values for the trend and slope-interaction are based on assumptions that may be overly optimistic. The difference-based and bootstrap tests are less kind to H2. We do note that the chosen 2014 break date is based on visual pattern and existing research rather than estimation, the finding is not significant for a 2016 break, and the post-2014 timeframe includes the 2020 recession, so the split could be reflecting factors other than policy. A more demanding test would be a multiple-break approach such as Bai–Perron (Bai & Perron, 1998). The Tapio categorization is based on conventional thresholds (0.8 and 1.2) and the annual elasticities are not stable when the growth rate of the GDP is low, like in 2008 and 2019. National inventories or purchasing-power-adjusted GDP may show different results because the WDI emissions series does not include LULUCF and its intensity drop over

2005–2019 (about 14.7%) is less than the 33% decline indicated in the Economic Survey. The study does not simulate energy composition, renewable-energy adoption, technology, trade, industrial structure or policy. The trend regressions and decoupling indicators characterize temporal patterns rather than reasons. Finally, the results are exclusive to one country and should not be generalized to other economies.

5.4 Future Research

Further research may extend the period, include energy and structural variables, explore sectoral differences and employ more advanced time-series or panel-data approaches to better understand the mechanisms of India's drop in carbon intensity.

References

1. Bai, J., & Perron, P. (1998). Estimating and testing linear models with multiple structural changes. *Econometrica*, 66(1), 47–78.
2. Bureau of Energy Efficiency. (2026). Perform, Achieve and Trade (PAT). Ministry of Power, Government of India. https://beeindia.gov.in/view_content.php?lang=1&lid=613
3. Das, N., & Roy, J. (2020). India can increase its mitigation ambition: An analysis based on historical evidence of decoupling between emission and economic growth. *Energy for Sustainable Development*, 57, 189–199. <https://doi.org/10.1016/j.esd.2020.06.003>
4. Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74(366), 427–431.
5. Gawas, A., & Sarath Chandran, B. P. (2026). Trade openness, economic growth and carbon emissions in India: Evidence from ARDL models with structural breaks. *Millennial Asia*. Advance online publication. <https://doi.org/10.1177/09763996261472966>
6. Government of India. (2015). India's Intended Nationally Determined Contribution: At a glance. Ministry of Environment, Forest and Climate Change.
7. <https://www.pib.gov.in/newsite/PrintRelease.aspx?lang=2®=48&relid=128404>
8. Government of India. (2023). Net zero emissions target. Ministry of Environment, Forest and Climate Change. <https://www.pib.gov.in/Pressreleaseshare.aspx?PRID=1945472>
9. Government of India. (2024). Economic Survey 2023–24: Climate change and energy transition. Ministry Finance, p.183. <https://static.pib.gov.in/WriteReadData/specificdocs/documents/2024/jul/doc2024722351601.pdf>
10. Hung, T. V. (2026). Effects of economic policy uncertainty, economic growth and green technologies on environmental degradation in India. *Discover Sustainability*, 7, 476. <https://doi.org/10.1007/s43621-026-02851-4>
11. Kumar, M., Goel, S., Sharma, M., & Garg, M. (2025). Decoupling economic growth from emissions: A LMDI decomposition analysis. *RBI Bulletin*, March 2025, 99–110. https://www.rbi.org.in/Scripts/BS_ViewBulletin.aspx?Id=23261
12. Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of Econometrics*, 54(1–3), 159–178.
13. Newey, W. K., & West, K. D. (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica*, 55(3), 703–708.
14. Singh, T. (2025). On the economic growth and environmental quality nexus in India. *Applied Economics*, 57(41), 6536–6553. <https://doi.org/10.1080/00036846.2024.2385753>

15. Tapio, P. (2005). Towards a theory of decoupling: Degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. *Transport Policy*, 12(2), 137–151.
16. Verma, P. K., & Giri, A. K. (2026). Empirical evidence on the impacts of climate change on sustainable economic growth in India. *Discover Sustainability*, 7, 512. <https://doi.org/10.1007/s43621-026-02846-1>
17. World Bank. (2026a). Carbon dioxide (CO₂) emissions (total) excluding LULUCF (Mt CO₂e), indicator EN.GHG.CO2.MT.CE.AR5. World Development Indicators. Retrieved October 8, 2026, from <https://data.worldbank.org/indicator/EN.GHG.CO2.MT.CE.AR5>
18. World Bank. (2026b). GDP (constant 2015 US\$), indicator NY.GDP.MKTP.KD. World Development Indicators. Retrieved October 8, 2026, from <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD>
19. World Bank. (2026c). Carbon intensity of GDP (kg CO₂e per constant 2015 US\$ of GDP), indicator EN.GHG.CO2.RT.GDP.KD. World Development Indicators. Retrieved October 8, 2026, from <https://data.worldbank.org/indicator/EN.GHG.CO2.RT.GDP.KD>