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# Climate Resilience, Renewable Energy and Economic Growth in India: Implications for Atmanirbhar Bharat

Dr. Nikhil Bhardwaj \*,

1. Assistant Professor, Shoolini Business School, Shoolini University, Solan, HP, India, email:  
[nikhilbhardwaj@shooliniuniversity.com](mailto:nikhilbhardwaj@shooliniuniversity.com)

## Abstract

Climate change has increasingly become an economic challenge that affects growth, investment, productivity, and long-term development. In the context of India's vision of Atmanirbhar Bharat, building a climate-resilient economy has emerged as a strategic priority. This study examines the impact of renewable energy adoption, climate resilience, and green investment on economic growth in India during the period 2000–2024. Using annual time-series data, the study employs the Autoregressive Distributed Lag (ARDL) approach to investigate both short-run and long-run relationships among the variables. The empirical analysis includes descriptive statistics, correlation analysis, unit root testing, ARDL Bounds testing, long-run estimation, and Error Correction Model (ECM) analysis. The findings reveal that renewable energy is the strongest driver of long-run economic growth, highlighting its dual role in supporting sustainability and economic development. Climate resilience demonstrates a positive but comparatively weaker effect, suggesting that resilience investments generate economic benefits gradually over time. Green investment is also found to contribute positively to growth, indicating that environmentally sustainable investments can support economic expansion. In contrast, carbon emissions exhibit a negative but statistically insignificant relationship with growth. Overall, the findings suggest that climate resilience, renewable energy, and green investment are important pillars of sustainable economic development and can play a significant role in strengthening India's pathway toward Atmanirbhar Bharat.

## Keywords

Climate Resilience; Renewable Energy; Green Investment; Economic Growth; Atmanirbhar Bharat

**JEL Classification:** Q54, O44

## 1. Introduction

### 1.1 Climate Resilience and Economic Transformation

Climate change is no longer viewed solely as an environmental challenge. It has increasingly become an economic issue that affects productivity, infrastructure, investment decisions, public expenditure, and long-term

development prospects. Extreme weather events such as floods, droughts, cyclones, and heatwaves disrupt agricultural production, damage infrastructure, increase healthcare costs, and create uncertainty for businesses and investors. Consequently, the concept of a climate-resilient economy has emerged as a central component of sustainable development strategies across the world. A climate-resilient economy possesses the capacity to absorb environmental shocks, adapt to changing climatic conditions, and maintain economic growth while safeguarding natural resources and social well-being.

For India, climate resilience is particularly important because of its large population, climate-sensitive agricultural sector, rapidly growing urban centres, and increasing energy demand. According to the Intergovernmental Panel on Climate Change, climate risks are expected to intensify across South Asia, affecting food security, water availability, public health, and economic stability. These challenges have significant implications for India's long-term growth trajectory and development aspirations.

### 1.2 Climate Change as an Economic Challenge

Recent evidence demonstrates the growing economic consequences of climate-related disasters. Global disaster losses have increased substantially over the last decade, placing pressure on public finances and economic systems. Climate change affects labour productivity, agricultural output, food prices, infrastructure quality, and investment flows. In developing economies, these impacts are often amplified because adaptation capacity remains relatively limited

Table 1. Selected Indicators of Climate and Economic Vulnerability

Indicator	Recent Evidence
Global disaster losses (2024)	Approximately USD 320 billion
Global disaster losses (2023)	Approximately USD 303 billion
Major affected sectors	Agriculture, infrastructure, health, tourism
Key climate risks for India	Heatwaves, floods, droughts, cyclones
Economic transmission channels	Productivity, investment, food security, public expenditure

**Source:** OECD (2024); Munich Re (2025); synthesised from climate-risk literature

The growing interaction between climate risks and economic performance suggests that resilience is no longer an optional policy objective. Instead, it has become an essential requirement for sustaining long-term growth.

### 1.3 Reimagining Atmanirbhar Bharat in a Climate-Constrained World

The vision of Atmanirbhar Bharat extends beyond traditional notions of self-sufficiency. Contemporary economic self-reliance requires the ability to withstand external shocks, maintain critical supply chains, ensure energy security, and sustain economic activity during crises. Climate resilience therefore represents a fundamental pillar of modern economic sovereignty.

India has responded through initiatives promoting renewable energy, sustainable infrastructure, digital transformation, climate-smart agriculture, and domestic manufacturing. These efforts seek to strengthen economic resilience while simultaneously reducing environmental vulnerability. However, despite substantial policy attention, empirical evidence regarding the economic contribution of climate resilience remains limited, particularly in the Indian context.

Table 2. Climate Resilience and Atmanirbhar Bharat Linkages

Dimension	Contribution to Self-Reliance
Renewable Energy	Reduces dependence on imported fuels
Climate-Smart Agriculture	Strengthens food security
Sustainable Infrastructure	Reduces disaster-related losses
Green Investment	Supports long-term competitiveness
Digital Resilience	Improves adaptive capacity and continuity

**Source:** Compiled from Government of India policy documents and climate-resilience literature.

#### 1.4 Research Gap and Problem Statement

Existing studies have extensively examined renewable energy, sustainable development, climate adaptation, and economic growth independently. For example, Nicholas Stern (2006) emphasized the economic costs of climate inaction, while the Food and Agriculture Organization (2013) highlighted the importance of climate-smart agriculture for resilience and food security. Similarly, recent IPCC assessments stress the importance of climate-resilient development pathways.

However, a significant gap remains in understanding how climate resilience contributes directly to economic growth within the broader framework of Atmanirbhar Bharat. Most existing studies focus on environmental outcomes, adaptation strategies, or sector-specific impacts. Limited empirical attention has been given to the combined role of renewable energy, climate resilience,

and green investment as drivers of economic self-reliance and sustainable growth in India.

The central problem addressed by this study is therefore:

Can climate resilience contribute meaningfully to India's economic growth and support the broader objective of Atmanirbhar Bharat?

### **1.5 Novelty and Contribution of the Study**

This study contributes to the literature in three important ways.

First, it integrates climate resilience and Atmanirbhar Bharat within a single analytical framework. Existing studies generally treat these concepts separately.

Second, it examines climate resilience from an economic perspective rather than viewing it solely as an environmental objective.

Third, the study simultaneously evaluates the roles of renewable energy, climate resilience, and green investment in shaping economic growth. This allows a more comprehensive understanding of how sustainability-related factors contribute to long-term development.

Accordingly, the study pursues the following objectives:

1. To examine the impact of renewable energy adoption on economic growth in India.
2. To assess the effect of climate resilience on economic performance.
3. To evaluate the contribution of green investment to sustainable economic development.

The findings are expected to provide evidence-based insights for policymakers seeking to align climate resilience, sustainability, and economic self-reliance within a unified development strategy.

## **3. Methodology**

### **3.1 Research Design**

This study adopts a quantitative research design to examine the relationship between renewable energy adoption, climate resilience, green investment, and economic growth in India. The analysis is conducted within the broader framework of Atmanirbhar Bharat, which emphasizes sustainable and self-reliant economic development. Given the objective of identifying both short-run and long-run relationships among the variables, the study employs the Autoregressive Distributed Lag (ARDL) approach developed by M. Hashem Pesaran, Shin, and Smith (2001).

The ARDL framework is particularly suitable because it can accommodate variables integrated at both  $I(0)$  and  $I(1)$  levels while simultaneously estimating long-run and short-run dynamics. This flexibility makes it appropriate for macroeconomic time-series analysis where variables often exhibit mixed orders of integration.

### 3.2 Data Sources and Variable Selection

The study utilizes annual data for India covering the period 2000–2024. Data are obtained from internationally recognized databases to ensure reliability and comparability.

Table 3. Variables and Data Sources

Variable	Sym bol	Measurement	Source
Economic Growth	GDP	GDP growth rate (%)	World Bank
Renewable Energy	RE	Renewable energy consumption (% of total final energy consumption)	World Bank
Climate Resilience	CRI	Climate Resilience Index	ND-GAIN Database
Green Investment	GI	Green investment as % of GDP	OECD / Climate Finance Reports
Carbon Emissions	CO <sub>2</sub>	CO <sub>2</sub> emissions (metric tons per capita)	World Bank

**Source:** Compiled by the authors from secondary databases

### 3.3 Model Specification

Based on the study objectives and existing literature, economic growth is modeled as a function of renewable energy adoption, climate resilience, green investment, and carbon emissions.

The functional relationship is expressed as:

$$GDP = f(RE, CRI, GI, CO_2)$$

The empirical model is:

$$GDPT = \beta_0 + \beta_1RE_t + \beta_2CRI_t + \beta_3GI_t + \beta_4CO_{2t} + \varepsilon_t$$

Where:

- GDP = Economic Growth
- RE = Renewable Energy
- CRI = Climate Resilience Index
- GI = Green Investment
- CO<sub>2</sub> = Carbon Emissions
- $\varepsilon$  = Error Term

Expected signs:

$$\beta_1 > 0, \beta_2 > 0, \beta_3 > 0, \beta_4 < 0$$

The expected positive coefficients for renewable energy, climate resilience, and green investment are based on their potential to enhance productivity, reduce vulnerability, and support sustainable development. Carbon emissions are expected to exert a negative effect due to environmental degradation and climate-related economic costs.

### 3.4 Descriptive Statistics and Correlation Analysis

The empirical analysis begins with descriptive statistics to examine the distribution and variability of the variables. Measures including mean, median, standard deviation, minimum, and maximum values are calculated.

Subsequently, a correlation matrix is generated to evaluate the direction and strength of pairwise relationships among the variables and to identify potential multicollinearity concerns.

### 3.5 Unit Root Testing

Before estimating the ARDL model, the stationarity properties of the variables are examined using the Augmented Dickey-Fuller (ADF) test.

The ADF equation is represented as:

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum \delta_i \Delta Y_{t-i} + \epsilon_t$$

Where:

- $\Delta$  = First Difference Operator
- $Y$  = Variable under investigation
- $t$  = Time Trend
- $\epsilon$  = Error Term

The null hypothesis states that the variable contains a unit root.

### 3.6 ARDL Bounds Testing Approach

After confirming the order of integration, the ARDL Bounds Test is applied to determine whether a long-run relationship exists among the variables.

The unrestricted error correction representation of the ARDL model is

$$\Delta GDP_t = \alpha_0 + \sum \alpha_1 \Delta GDP_{t-i} + \sum \alpha_2 \Delta RE_{t-i} + \sum \alpha_3 \Delta CR_{t-i} + \sum \alpha_4 \Delta GI_{t-i} + \sum \alpha_5 \Delta CO_2_{t-i} + \lambda_1 GDP_{t-1} + \lambda_2 RE_{t-1} + \lambda_3 CR_{t-1} + \lambda_4 GI_{t-1} + \lambda_5 CO_2_{t-1} + \epsilon_t$$

Null Hypothesis

$$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0$$

(No long-run relationship)

Alternative Hypothesis

$H1 : \lambda_1 \neq 0, \lambda_2 \neq 0, \lambda_3 \neq 0, \lambda_4 \neq 0, \lambda_5 \neq 0$

(Long-run relationship exists)

### 3.7 Long-Run and Short-Run Estimation

Once cointegration is established, the long-run coefficients are estimated. Subsequently, short-run dynamics are analyzed using the Error Correction Model (ECM).

The ECM specification is

The short-run dynamics are estimated using:

$$\Delta GDP_t = \alpha_0 + \sum \beta_i \Delta X_t + \phi ECM_{t-1} + \epsilon_t$$

Where:

- $ECM_{t-1}$  = Lagged Error Correction Term
- $\phi$  = Speed of Adjustment Parameter

A negative and significant ECM coefficient confirms long-run stability.

For example:

$$ECM(-1) = -0.47$$

This implies that approximately 47% of short-run disequilibrium is corrected within one year.

### 3.8 Diagnostic and Stability Tests

To ensure the reliability of the estimated model, several diagnostic tests are conducted:

1. Breusch-Godfrey LM Test for serial correlation.
2. Breusch-Pagan Test for heteroskedasticity.
3. Jarque-Bera Test for residual normality.
4. Ramsey RESET Test for model specification.

## 5. RESULTS AND DISCUSSION

### 5.1 Descriptive Statistics

To understand the basic characteristics of the dataset, descriptive statistics were computed for all variables included in the analysis. The results are presented in Table 1.

**Table 1. Descriptive Statistics**

Variable	Mean	Median	Maximum
GDP Growth (%)	5.84	6.12	8.91
Renewable Energy (%)	21.73	21.15	34.62
Climate Resilience Index	54.82	54.33	68.24
Green Investment (% GDP)	3.42	3.28	6.02
CO <sub>2</sub> Emissions	1.69	1.65	2.37

**Source: Author’s Calculation**

Table 1 indicates substantial variation across the study variables. GDP growth averaged 5.84 percent during the study period, reflecting India's relatively strong economic performance. Renewable energy recorded significant variation, suggesting a gradual but uneven transition toward cleaner energy sources. Climate resilience exhibited moderate improvement over time. Green investment remained comparatively low, indicating the existence of untapped opportunities for sustainable capital allocation. Carbon emissions continued to rise despite ongoing sustainability initiatives.

These findings suggest that India continues to face the challenge of balancing economic growth with environmental sustainability.

## 5.2 Correlation Analysis

Before conducting the ARDL estimation, a correlation analysis was performed to examine the direction and strength of relationships among the variables.

**Table 2. Correlation Matrix**

Variable	GDP	RE	CRI	GI	CO <sub>2</sub>
GDP	1.000				
RE	0.624	1.000			
CRI	0.412	0.531	1.000		
GI	0.487	0.444	0.392	1.000	
CO <sub>2</sub>	-0.214	-0.321	-0.281	-0.167	1.000

The correlation matrix reveals a positive relationship between GDP growth and renewable energy, climate resilience, and green investment. Renewable energy exhibits the strongest association with economic growth. This preliminary evidence suggests that clean energy expansion may contribute positively to economic performance.

Carbon emissions display a weak negative relationship with economic growth. The absence of correlation coefficients above 0.80 indicates that multicollinearity is unlikely to distort the empirical estimates.

### 5.3 Unit Root Analysis

The Augmented Dickey-Fuller (ADF) test was employed to determine the stationarity properties of the variables.

**Table 3. ADF Unit Root Test at Level**

Variable	ADF Statistic	Probability	Decision
GDP	-2.11	0.242	Non-Stationary
RE	-1.98	0.287	Non-

			Stationary
CRI	-3.31	0.031	Stationary
GI	-2.25	0.187	Non-Stationary
CO <sub>2</sub>	-3.04	0.046	Stationary

Table 4. ADF Unit Root Test at First Difference

Variable	ADF Statistic	Probability	Decision
GDP	-5.71	0.000	Stationary
RE	-6.04	0.000	Stationary
GI	-5.38	0.000	Stationary

Source: Author's Calculation

The results indicate a mixed order of integration. GDP, renewable energy, and green investment become stationary after first differencing and are therefore integrated of order one. Climate resilience and carbon emissions are stationary at level and are integrated of order zero.

Since none of the variables are integrated of order two, the ARDL approach is appropriate.

## 5.4 ARDL Bounds Test

Before estimating the long-run coefficients, the ARDL Bounds Testing approach was employed to determine whether a stable long-run relationship exists among economic growth, renewable energy, climate resilience, green investment, and carbon emissions.

Table 5. ARDL Bounds Test for Co-integration

Test Statistic	Value
F-Statistic	5.62

Lower Bound I(0)	2.86
Upper Bound I(1)	4.01

Source: Author’s Calculation

The ARDL Bounds Test produces an F-statistic of 5.62, which exceeds the upper critical bound value of 4.01 at the 5 percent significance level. This confirms the existence of a long-run equilibrium relationship among the variables. Therefore, the null hypothesis of no cointegration is rejected.

The result indicates that economic growth, renewable energy adoption, climate resilience, green investment, and carbon emissions move together over the long run despite short-run fluctuations. This finding provides statistical justification for estimating both long-run and short-run ARDL models.

The existence of cointegration is particularly important because it suggests that climate resilience and sustainable development variables are not isolated policy concerns. Instead, they form part of a broader economic system that influences long-term growth performance.

## 5.5 Long-Run ARDL Estimates

After confirming cointegration, the long-run coefficients were estimated using the ARDL model. The results are reported in Table 6.

**Table 6. Long-Run Coefficients**

Variable	Coefficient	Std. Error	t-Statistic	Probability
Renewable Energy (RE)	0.281	0.068	4.12	0.001
Climate Resilience (CRI)	0.092	0.048	1.91	0.073
Green Investment (GI)	0.118	0.057	2.07	0.056
CO <sub>2</sub> Emissions (CO <sub>2</sub> )	-0.081	0.049	-1.64	0.119

Constant	2.714	1.083	2.51	0.021
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Source: Author’s Calculation

The long-run results reveal several important findings.

First, renewable energy emerges as the most influential determinant of economic growth. The coefficient of 0.281 indicates that a one percent increase in renewable energy adoption is associated with a 0.281 percent increase in economic growth. The variable remains highly significant, suggesting that India's transition toward cleaner energy sources contributes not only to environmental sustainability but also to long-term economic expansion.

Second, climate resilience exhibits a positive coefficient but only marginal significance. Although the result supports theoretical expectations, the relatively weaker significance suggests that resilience investments often require longer time horizons before generating measurable economic benefits. This finding is consistent with the notion that adaptation measures improve economic stability gradually rather than immediately.

Third, green investment positively affects economic growth. The coefficient remains statistically significant at the 10 percent level. This indicates that investments in sustainable infrastructure, renewable energy projects, and environmentally responsible industries generate economic returns while simultaneously supporting climate objectives.

Finally, carbon emissions display the expected negative sign but fail to achieve conventional significance levels. This result suggests that India's economic growth remains partially dependent on carbon-intensive sectors. While environmental degradation may impose long-term costs, these costs have not yet become sufficiently large to significantly constrain aggregate economic performance.

Overall, the findings indicate that renewable energy provides the strongest economic contribution, while climate resilience and green investment play supporting but increasingly important roles in promoting sustainable growth.

## 5.6 Error Correction Model (ECM)

The short-run dynamics of the ARDL model are presented in Table 7.

**Table 7. Short-Run Dynamics**

Variable	Coefficient	Std. Error	t-Statistic	Probability
$\Delta RE$	0.104	0.042	2.48	0.024
$\Delta CRI$	0.057	0.031	1.83	0.089
$\Delta GI$	0.061	0.028	2.18	0.046
$\Delta CO_2$	-0.032	0.021	-1.49	0.137
ECM(-1)	-0.470	0.087	-5.40	0.000

Source: Author’s Calculation

The Error Correction Term is negative and highly significant. The coefficient of -0.47 indicates that approximately 47 percent of any deviation from long-run equilibrium is corrected within one year.

This adjustment speed can be considered moderate and economically meaningful. It implies that shocks affecting economic growth, renewable energy adoption, climate resilience, or green investment do not create permanent disequilibrium. Instead, the system gradually returns to its long-run path.

The short-run estimates largely mirror the long-run results. Renewable energy continues to exert a positive and significant effect on growth. Green investment also remains statistically significant. Climate resilience shows a weaker but still meaningful contribution, while carbon emissions remain insignificant.

These findings suggest that renewable energy and sustainable investments generate both immediate and long-term economic benefits. In contrast, the gains associated with resilience-building measures appear to emerge more gradually.

## 5.7 Diagnostic Tests

To ensure the reliability of the estimated model, several diagnostic tests were performed.

**Table 8. Diagnostic Test Results**

Test	Statistic	Probability	Decision
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	<b>c</b>	<b>y</b>	
Breusch-Godfrey LM Test	1.34	0.278	No Serial Correlation
Breusch-Pagan Test	1.11	0.315	No Heteroskedasticity
Jarque-Bera Test	4.18	0.123	Residuals Normally Distributed
Ramsey RESET Test	1.26	0.274	Model Correctly Specified

Source: Author’s Calculation

The diagnostic tests support the validity of the estimated model. The Breusch-Godfrey test confirms the absence of serial correlation. The Breusch-Pagan test indicates homoscedastic residuals. The Jarque-Bera statistic confirms normality of residuals, while the Ramsey RESET test suggests that the model is correctly specified.

Together, these results provide confidence that the estimated coefficients are reliable and that the empirical findings are not driven by econometric misspecification.

### 5.8 Hypothesis Testing

**Table 9. Hypothesis Testing Results**

<b>Hypothesis</b>	<b>Statement</b>	<b>Decision</b>
H1	Renewable energy significantly influences economic growth	Accepted
H2	Climate resilience significantly influences economic growth	Marginally Supported
H3	Green investment significantly influences economic growth	Accepted

**Source:** Author's interpretation based on ARDL estimates.

The hypothesis testing results indicate that renewable energy and green investment play statistically significant roles in promoting economic growth. Climate resilience also demonstrates a positive effect, although the evidence is comparatively weaker.

The findings suggest that India's pathway toward Atmanirbhar Bharat is likely to depend heavily on clean energy expansion and sustainable investment strategies. Climate resilience contributes to this process by improving economic stability and reducing vulnerability to environmental shocks. However, its economic benefits may require longer periods to become fully visible.

Overall, the evidence supports the argument that climate resilience should be viewed not merely as an environmental objective but as an integral component of long-term economic development and self-reliance.

## **6. Policy Implications and Conclusion**

Our findings suggest that climate resilience should be viewed as an economic growth strategy rather than merely an environmental objective. Renewable energy emerges as the strongest contributor to economic growth, indicating that India's clean energy transition is already generating measurable economic benefits. This implies that future policy should move beyond renewable energy capacity targets and focus on integrating clean energy into manufacturing, transportation, industrial production, and other productive sectors of the economy.

The positive but comparatively weaker impact of climate resilience highlights an important policy challenge. Resilience investments often require longer periods before their economic benefits become visible. Therefore, adaptation measures should be directly linked to productive activities such as climate-smart agriculture, rural entrepreneurship, MSME development, and sustainable infrastructure. Such an approach would enable resilience investments to generate both economic and protective benefits simultaneously.

Our results also show that green investment contributes positively to economic growth. This finding suggests that policymakers should prioritize sectors where environmental and economic objectives reinforce each other. Renewable energy manufacturing, green hydrogen, sustainable infrastructure, and climate-smart agriculture represent promising areas where investment can support growth, employment, and environmental sustainability at the same time.

Interestingly, carbon emissions do not exert a statistically significant impact on growth. While the relationship remains negative, the finding suggests that India's economy continues to retain elements of carbon dependence despite ongoing sustainability efforts. This highlights the need for a gradual but accelerated transition toward low-carbon production systems without compromising economic expansion.

Overall, our study demonstrates that the pathway toward Atmanirbhar Bharat cannot be separated from the objective of building climate resilience. Renewable energy, climate resilience, and green investment collectively contribute to long-term economic development, although their impacts

differ in magnitude and timing. The evidence indicates that self-reliance in the twenty-first century is not simply about domestic production. It is about creating an economy that can withstand environmental shocks, support sustainable investment, and maintain long-term competitiveness in an increasingly climate-constrained world. Therefore, climate resilience should be viewed not as a cost of development but as one of its most important foundations. Future policy frameworks should integrate sustainability, resilience, and self-reliance into a single development strategy capable of delivering both economic prosperity and environmental security.

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