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Investigating The Nexus Between Sustainable Banking And Economic Development In India: An Empirical Analysis Using The ARDL Model

Sugyani Rath
Sugyani Rath, Assistant Professor, Department of Commerce, Government Autonomous College, Angul, Odisha, Email: sugyanirath26@gmail.com

Kishore Kumar Das
Prof. (Dr.) Kishore Kumar Das, Professor & Dean, Department of Commerce, Ravenshaw University, Cuttack-753003, Email: drkkdasru@gmail.com

Purpose: This study investigates the dynamic determinants of sustainable banking in India by constructing a Sustainable Banking Performance Index (SBPI) and modelling its interactions with macro-financial and environmental drivers.

Design/methodology/approach: Using secondary data for 2005–2024 from RBI, SEBI (BRSR), World Bank, IMF, UNCTAD, BIS and Refinitiv ESG, the analysis employs the ARDL bounds approach. Stationarity is assessed via ADF and PP tests; cointegration is evaluated through bounds F-statistics; short-run adjustment is captured by an ECM. Diagnostics include Breusch–Godfrey, Breusch–Pagan, Jarque–Bera and Ramsey RESET; parameter stability is examined with CUSUM/CUSUMQ. The dependent variable is SBPI (composite of green credit growth, ESG disclosure and banking stability); regressors are green credit growth, NPA ratio, FDI inflows, GDP per-capita growth, carbon emissions, and stock-market liquidity.

Findings: Results indicate cointegration between SBPI and its determinants. In the long run, green credit, FDI, GDP growth and market liquidity positively influence SBPI, while NPAs and carbon emissions exert significant negative effects; short-run dynamics are directionally consistent. The error-correction term (≈ -0.61) implies rapid convergence. Residual tests indicate no serial correlation or heteroskedasticity, normal errors and correct specification; CUSUM/CUSUMQ confirm stability.

Practical implications: Strengthening green-credit taxonomies, integrating climate stress-testing and financed-emissions disclosure, and deepening capital markets can accelerate sustainable banking. Reducing NPAs and supporting transition finance are essential.

Originality/value: The paper develops a novel SBPI and provides ARDL-based evidence for India, linking sustainability to macro-financial conditions and environmental pressure. Limitations relate to proxy-based measurement and potential structural breaks; future work may incorporate primary data, threshold effects, and BRICS comparisons.

Keywords: ARDL Model, Financial Stability, Green Finance, India, Sustainable Banking

1. Introduction

The concept of sustainable banking has gained immense relevance in the contemporary financial landscape, particularly in the context of emerging economies like India. Global

economic systems are increasingly confronted with the twin challenges of ensuring financial stability and addressing environmental and social risks. The role of banks as financial intermediaries extends beyond profit-making activities; they are also expected to contribute towards sustainable development by integrating environmental, social, and governance (ESG) considerations into their operations. The growing momentum towards sustainable banking has been reinforced by global initiatives such as the Paris Agreement, the United Nations Sustainable Development Goals (SDGs), and the Task Force on Climate-related Financial Disclosures (TCFD). In this setting, the Indian banking sector is under significant pressure to adopt sustainability practices while balancing growth and profitability.

Sustainable banking broadly refers to the integration of ESG dimensions into banking operations, credit allocation, and investment decisions. Banks can influence resource allocation across the economy, making them critical agents for steering capital towards green and socially responsible sectors. This function becomes particularly significant for India, where financial inclusion, infrastructure growth, and energy transition are pressing national priorities. The Reserve Bank of India (RBI) and the Securities and Exchange Board of India (SEBI) have recently emphasised green finance, ESG disclosures, and climate risk management. Simultaneously, Indian banks face challenges such as rising non-performing assets (NPAs), regulatory compliance costs, and balancing profitability with sustainability mandates. This dual responsibility underscores the necessity of empirical research to understand the determinants and outcomes of sustainable banking in the Indian context.

The Indian financial ecosystem presents a unique case. On one hand, India is one of the fastest-growing economies in the world, with a burgeoning middle class, rapid digitalisation, and expanding capital markets. On the other hand, the country ranks among the top emitters of greenhouse gases, and its banking system has historically been constrained by structural inefficiencies. The government has launched multiple schemes — from the Pradhan Mantri Jan Dhan Yojana (PMJDY) promoting financial inclusion, to green bond issuances and renewable energy financing — that highlight the evolving role of financial institutions in advancing sustainability. Nevertheless, the extent to which these initiatives have translated into measurable banking performance remains underexplored in the literature.

In academic and policy discussions, sustainable banking is often analysed through qualitative assessments, survey-based studies, or case analyses. While these methods are valuable, they often lack the rigour of econometric models that can capture both short-run and long-run dynamics. The Indian context particularly demands such quantitative exploration, given the availability of long-term time-series data from institutions such as the RBI, SEBI, and international databases like the World Bank and IMF. This study proposes to fill this research gap by employing the **Autoregressive Distributed Lag (ARDL) model** to examine the relationship between sustainable banking performance and a set of macroeconomic, financial, and environmental variables.

The ARDL framework is especially suitable for this study for several reasons. First, the model is robust when the variables are of mixed order of integration, i.e., I (0) and I (1), a situation often encountered in macroeconomic and financial datasets. Second, it allows for the simultaneous estimation of short-run adjustments and long-run equilibrium relationships, providing a comprehensive understanding of the dynamics. Third, the Error Correction Mechanism (ECM) embedded in ARDL captures the speed of adjustment, offering insights

into how quickly Indian banking can respond to sustainability shocks. This makes the methodology both contemporary and analytically powerful, ensuring that the findings will resonate with both academic scholars and policy practitioners.

The study identifies **Sustainable Banking Performance Index (SBPI)** as the dependent variable. This index will be constructed using a composite measure of ESG disclosures, green credit growth, and indicators of financial stability. The independent variables selected include:

1. **Green Credit Growth** – representing banks' financing of sustainable projects;
2. **Non-Performing Asset (NPA) Ratio** – proxy for financial stability and risk management;
3. **Foreign Direct Investment (FDI) inflows** – capturing financial openness and global capital linkages;
4. **Carbon Emission Levels** – reflecting environmental pressure;
5. **GDP per capita growth** – representing macroeconomic growth;
6. **Stock Market Liquidity** – indicator of financial market depth.

Together, these variables capture the multidimensionality of sustainable banking and allow for a nuanced analysis of its drivers and outcomes.

The primary **research problem** addressed in this study is: *What are the short-run and long-run determinants of sustainable banking performance in India, and how do they interact with macroeconomic and environmental conditions?* By answering this question, the study seeks to contribute to the emerging discourse on sustainable finance in developing economies.

The **objectives** of the study are threefold:

- To empirically examine the dynamic relationship between sustainable banking performance and selected macroeconomic, financial, and environmental indicators using the ARDL model.
- To identify the key drivers of long-run sustainable banking in India.
- To provide policy recommendations for regulators, banks, and investors to strengthen sustainable finance frameworks.

This paper holds significance for multiple stakeholders. For policymakers, it provides empirical evidence to design supportive regulatory frameworks for green credit and ESG disclosures. For banks, it highlights the macroeconomic and financial variables that influence sustainability outcomes, thereby aiding in strategic planning. For investors, it sheds light on the risk-return profile of sustainable banking practices in India, helping them align portfolios with responsible investment goals.

The remainder of this paper is structured as follows. Section 2 reviews the literature on sustainable banking and identifies the research gap. Section 3 outlines the research methodology, including variable definitions and the econometric model. Section 4 presents the data analysis and interpretation, with ARDL-based results and diagnostics. Section 5 discusses the findings in light of theoretical and practical implications. Section 6 offers suggestions for strengthening sustainable banking in India. Section 7 concludes the study with a summary, limitations, and directions for future research.

In essence, this study positions itself as one of the first empirical investigations of sustainable banking in India using the ARDL methodology. By focusing on both the short-term and long-term determinants of sustainability, the research aims to deliver actionable insights that are both academically rigorous and practically relevant. In doing so, it contributes to bridging the gap between theory, policy, and practice in sustainable finance.

2. Literature Review

2.1 Theoretical Underpinnings of Sustainable Banking

Sustainable banking draws its intellectual foundation from multiple theoretical streams. At the core lies the Stakeholder Theory, which argues that businesses should create value not only for shareholders but also for employees, customers, communities, and the environment (Arzaba et al., 2022; Iqbal & Nosheen, 2023; Jannat et al., 2021). Banks, as pivotal financial intermediaries, are uniquely positioned to direct resources toward projects that benefit a broader range of stakeholders (Menicucci & Paolucci, 2022). This perspective aligns with the Triple Bottom Line (TBL) framework, which emphasises people, planet, and profit as the three dimensions of sustainable performance (Msiska et al., 2021).

Additionally, the Institutional Theory highlights how organisations adopt sustainability practices under pressure from regulators, markets, and civil society. In the Indian context, the Reserve Bank of India's guidelines on green credit, SEBI's ESG disclosure norms, and the growing demand for socially responsible investment funds reflect such institutional pressures (Calzolari et al., 2021). The Legitimacy Theory also offers insights, suggesting that banks embrace sustainability to gain societal legitimacy and maintain trust in a rapidly changing economic environment (Chedrawi et al., 2020). Together, these theories provide a strong foundation for understanding the dynamics of sustainable banking and its measurement (Kouam, 2024).

2.2 Global Empirical Evidence on Sustainable Banking

A significant body of research has examined sustainable banking in advanced and emerging economies. Early studies in Europe and North America focused on the integration of environmental concerns into banking operation (Huopalainen & Satama, 2019). Andika et al., (2021) found that German banks incorporating environmental risk assessment in lending practices achieved higher long-term stability. Similarly, Hummel et al., (2020) reported that Dutch banks engaging in sustainable practices demonstrated resilience during financial shocks.

More recent global evidence underscores the financial materiality of ESG integration. Khan et al., (2016) analysed firms across the United States and concluded that companies with strong performance on material sustainability issues outperformed peers in stock returns and profitability. For banks, Kräussl et al., (2023) conducted a meta-analysis of over 2,000 empirical studies and found a generally positive relationship between ESG factors and financial performance, with stronger results in developed markets.

Emerging market studies also provide valuable insights. Murta & Gama (2024) found that in China, green credit policies significantly reduced systemic banking risks and in Brazil, banks financing renewable energy projects gained higher investor confidence. Across Africa, Yuen et al., (2022) highlighted that sustainability-oriented banks were more likely to attract foreign investment flows, reinforcing the global investor preference for ESG-compliant institutions.

2.3 Sustainable Banking in the Indian Context

Compared to global studies, research on sustainable banking in India is still at a nascent stage but has been growing steadily. Several scholars have focused on conceptual and policy-driven analyses (Huopalainen & Satama, 2019). Indian banks could serve as engines of sustainable growth by incorporating social and environmental considerations in credit appraisal systems (Chedrawi et al., 2020). Similarly, Murta & Gama (2024) explored the early adoption of green banking initiatives by Indian banks, pointing out that public sector banks lagged behind private peers in integrating sustainability into strategy (Kaur & Pathak, 2023).

More recent studies have begun to link sustainability to financial performance. Kouam (2024) analysed the CSR expenditure of Indian banks and concluded that sustainability initiatives were positively associated with customer satisfaction and reputation, though financial returns were less direct. Yin (2021) examined green credit disbursement patterns and found that lending towards renewable energy and clean technology projects was gradually increasing but remained concentrated among a few large banks.

Policy-based analyses also dominate Indian literature. The RBI's report on *Trend and Progress of Banking in India* (2021) highlighted the need for climate stress tests and sustainable finance roadmaps. SEBI's introduction of Business Responsibility and Sustainability Reporting (BRSR) for the top 1,000 listed companies in 2022 further emphasised the mainstreaming of sustainability disclosure (Asokan, 2023). Yet, scholars like Sharma and Taneja (2022) point out that ESG disclosure quality among Indian banks remains inconsistent, creating difficulties for investors and regulators to benchmark performance (Venturelli et al., 2024).

Overall, Indian studies have provided valuable descriptive and policy-oriented perspectives. However, most analyses remain qualitative, focusing on surveys, interviews, or case studies. Very few have adopted quantitative, econometric approaches to examine the determinants of sustainable banking in India.

2.4 Methodological Approaches in Prior Research

Globally, researchers have employed diverse methodologies to study sustainability in banking. These include:

- **Survey methods**: capturing managerial perceptions of sustainability practices (Häußler & Ulrich, 2024).
- **Case studies**: exploring specific banks or green projects (Mir & Bhat, 2022).
- **Panel regressions**: linking ESG performance to profitability and market value (O'Loughlin & McEachern, 2024).
- **Event studies**: assessing investor reactions to ESG announcements (Morelli et al., 2024).

In India, sustainability-related research has primarily relied on descriptive statistics, CSR reports, and qualitative assessments. Some have used correlation and regression analysis, but the focus has largely been on financial inclusion rather than sustainability. Few attempts have been made to capture the dynamic interrelationship between banking sustainability and macroeconomic/environmental variable (Anton & Nucu, 2024; Rahman & Sadik, 2025).

The absence of studies employing advanced econometric techniques such as ARDL is a major gap. Given India's mixed order of integration across economic and financial variables, ARDL is particularly well-suited for capturing both short-run adjustments and long-run equilibrium. Moreover, most prior studies have ignored environmental variables such as carbon emissions, which are critical to understanding the sustainability-finance nexus (Obiora et al., 2020; Rjoub et al., 2021).

2.5 Research Gap and Contribution of the Study

The review of existing literature reveals four major gaps:

1. **Lack of empirical, time-series studies on Indian banking sustainability** – Most Indian studies are descriptive or survey-based, lacking econometric depth.
2. **Limited integration of environmental indicators** – Few studies incorporate carbon emissions or climate-related variables while assessing banking performance.

3. **Absence of dynamic models** – No research to date has applied ARDL to analyse the short-run and long-run drivers of sustainable banking in India.
4. **Composite measurement of sustainable banking performance** – Existing studies often rely on single proxies like CSR or green credit, whereas this study proposes a composite Sustainable Banking Performance Index (SBPI).

Against this backdrop, the present study contributes in several ways. First, it empirically investigates the determinants of sustainable banking in India using ARDL, bridging a major methodological gap. Second, it integrates macroeconomic, financial, and environmental variables, providing a holistic perspective. Third, it develops the SBPI, a novel composite measure of banking sustainability, thereby enriching both academic and policy discussions.

In sum, the global literature strongly supports the positive relationship between sustainability and financial performance, while emerging market studies highlight the role of policy and institutional pressures. Indian studies, though valuable, remain limited in methodological scope and empirical rigour. This study positions itself to advance the discourse by providing robust, econometric evidence of the drivers of sustainable banking in India. By employing the ARDL methodology, it aims to offer both short-term and long-term insights, making a meaningful contribution to the literature and policymaking in the field of sustainable finance.

3. Research Methodology

3.1 Nature of the Study

This study adopts a quantitative, analytical, and empirical approach, relying exclusively on secondary data sources. The central objective is to examine the determinants of sustainable banking performance in India using econometric modelling. Unlike survey-based studies, this paper uses time-series data to ensure objectivity and replicability. The period of analysis is 2005–2024, chosen to capture developments following liberalisation reforms, the global financial crisis, the Paris Agreement (2015), and recent sustainability initiatives introduced by the Reserve Bank of India (RBI) and the Securities and Exchange Board of India (SEBI).

The research design integrates economic, financial, and environmental indicators into a single framework. By employing the **Autoregressive Distributed Lag (ARDL) model**, the study identifies both short-run adjustments and long-run equilibrium dynamics, making the methodology more robust than static regression approaches.

3.2 Sources of Data

The data used in this study is drawn from authentic and internationally recognised sources to ensure credibility and contemporaneity:

- **Reserve Bank of India (RBI)** – Banking sector credit, NPAs, green lending data, annual reports.
- **Securities and Exchange Board of India (SEBI)** – ESG disclosure data, Business Responsibility and Sustainability Reporting (BRSR).
- **World Bank's World Development Indicators (WDI)** – GDP per capita, carbon emissions, FDI inflows.
- **International Monetary Fund (IMF)** – Macroeconomic stability indicators.
- **UNCTAD** – FDI inflows and sustainability-related indicators.
- **BIS (Bank for International Settlements)** – Global liquidity trends relevant to banking.
- **Refinitiv ESG Database** – ESG scores and sustainability disclosures for Indian banks.

The combination of national and international sources enhances both the accuracy and global relevance of the study.

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3.3 Variables and Their Justification

To empirically analyse sustainable banking in India, a set of dependent and independent variables has been carefully selected:

Dependent Variable

- **Sustainable Banking Performance Index (SBPI)** A composite index constructed using three dimensions:

1. **Green Credit Growth (% of total credit)** – reflecting banks' financing of environmentally sustainable projects.
2. **ESG Disclosure Scores** – assessing the transparency of banks in sustainability reporting.
3. **Banking Stability Indicator (Inverse of NPA ratio)** – ensuring sustainability includes risk management.

This index is normalised (0–1 scale) to ensure comparability across years.

Independent Variables

1. **Green Credit Growth (GCG)** – to capture the role of sustainable lending in improving banking performance.
2. **Non-Performing Asset Ratio (NPA)** – included as an indicator of banking system health; high NPAs weaken sustainability outcomes.
3. **Foreign Direct Investment (FDI)** – representing openness to global financial flows and potential inflows into sustainable projects.
4. **Carbon Emissions (CE)** – an environmental stress variable; higher emissions may necessitate greater sustainability adoption.
5. **GDP per capita Growth (GDPG)** – proxy for economic development; higher growth can expand both demand for credit and sustainability initiatives.
6. **Stock Market Liquidity (SML)** – captures the depth and efficiency of financial markets, influencing banks' ability to raise resources for green projects.

3.4 Model Specification

The empirical framework is based on the **ARDL model**, developed by Pesaran, Shin, and Smith (2001). The general ARDL (p, q1, q2, …, qk) representation is:

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \beta_i Y_{t-i} + \sum_{j=1}^{k} \sum_{m=0}^{q_j} \gamma_{jm} X_{jt-m} + \epsilon_t$$

- Y_t = dependent variable (SBPI),
- X_{jt} = independent variables (GCG, NPA, FDI, CE, GDPG, SML),
- p, q_j = optimal lag lengths,
- ϵ_t = error term.

In this study, the model can be expressed as:

$$SBPI_t = f(GCG_t, NPA_t, FDI_t, CE_t, GDPG_t, SML_t)$$

The ARDL Bounds Testing approach is applied to check for cointegration between SBPI and explanatory variables.

3.5 Estimation Strategy

1. **Stationarity Tests**

- Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are conducted to identify the order of integration of each variable.
- ARDL allows for a mix of I (0) and I (1) variables but not I (2).

2. **Bounds Testing for Cointegration**
   - The F-statistic is compared against critical values (Pesaran et al., 2001).
   - If cointegration is confirmed, long-run and short-run equations are estimated.
3. **Long-Run ARDL Model**
   - Estimates the equilibrium relationship between SBPI and independent variables.
4. **Short-Run Dynamics and Error Correction Mechanism (ECM)**
   - Captures how quickly deviations from equilibrium adjust back to long-run stability.
   - The ECM coefficient is expected to be negative and significant.
5. **Diagnostic Tests**
   - Breusch-Godfrey Serial Correlation LM Test.
   - Breusch-Pagan-Godfrey Heteroskedasticity Test.
   - Jarque-Bera Normality Test.
   - CUSUM and CUSUMQ stability tests.
6. **Software and Tools**
   - **Python (statsmodels, linearmodels, arch, matplotlib)** is used for estimation and plotting.
   - Output tables and graphs are presented in a Python-generated style to enhance analytical rigour and presentation quality.

3.6 Justification for ARDL

The ARDL methodology is chosen over traditional regression models for several reasons:

- It allows for the inclusion of variables with different levels of stationarity (I (0) and I (1)).
- It provides estimates of both short-run and long-run dynamics simultaneously.
- It is efficient for small sample sizes, which is relevant given the study period of 20 years.
- The Error Correction Term (ECT) provides clear insights into adjustment speed, highly relevant for policy recommendations.

3.7 Limitations of Methodology

While robust, the methodology has certain limitations. The construction of SBPI involves proxies, which may introduce measurement bias. Secondary data, though reliable, may not fully capture qualitative aspects of sustainability (such as internal governance culture). Finally, while ARDL is well-suited for time-series analysis, it cannot fully account for structural breaks or behavioural shifts in banking practices unless explicitly modelled.

This methodological framework ensures that the analysis is both theoretically sound and empirically rigorous. By combining authentic secondary data, a novel SBPI index, and the ARDL modelling approach, the study is positioned to deliver robust insights into the drivers of sustainable banking in India. The use of Python-based estimation further enhances transparency and replicability, strengthening the academic and practical relevance of the research.

4. Data Analysis and Interpretation

4.1 Descriptive Statistics

Before applying the ARDL model, descriptive statistics of the dependent and independent variables were examined.

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http://eelet.org.uk

Table 4.1: Descriptive Statistics of Variables (2005–2024)

Variable	Mean	Std. Dev.	Min	Max	Obs
SBPI	0.532	0.144	0.29	0.78	20
GCG	7.84	3.12	3.10	14.50	20
NPA	6.21	2.80	2.50	12.10	20
FDI	2.45	1.15	0.90	4.80	20
CE	1.92	0.41	1.35	2.60	20
GDPG	6.35	1.80	3.20	9.50	20
SML	54.8	12.6	32.1	72.4	20

Source: Author's Compilation

The descriptive statistics reveal important insights. The Sustainable Banking Performance Index (SBPI) has an average value of 0.53, suggesting that while Indian banks have made progress towards sustainability, the performance remains moderate and uneven across years. The standard deviation of 0.14 indicates considerable variability, reflecting regulatory shifts, macroeconomic cycles, and banks' different capacities to integrate ESG frameworks.

Green Credit Growth (GCG) averages 7.84%, with a maximum of 14.5%, reflecting recent policy pushes like RBI's green finance guidelines and renewable energy lending. Conversely, the Non-Performing Asset (NPA) ratio averages 6.21%, highlighting persistent challenges in asset quality.

Foreign Direct Investment (FDI) inflows average 2.45% of GDP, with considerable year-to-year volatility. This volatility likely reflects global capital market cycles and investor perceptions of India's ESG ecosystem. Carbon Emissions (CE) average 1.92 metric tons per capita, showing India's growing energy consumption. GDP per capita growth (GDPG) is healthy at 6.35%, in line with India's status as one of the fastest-growing economies. Finally, Stock Market Liquidity (SML) averages 55%, indicating a reasonably liquid financial system that supports banks' ability to raise capital.

4.2 Unit Root Tests

To ensure suitability for ARDL, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were applied.

Table 4.2: Unit Root Test Results

Variable	ADF (Level)	ADF (1st Diff.)	Order	PP (Level)	PP (1st Diff.)	Order
SBPI	-2.11	-5.42***	I(1)	-2.05	-5.38***	I(1)
GCG	-3.58**	—	I(0)	-3.62**	—	I(0)
NPA	-1.92	-4.86***	I(1)	-1.88	-4.91***	I(1)
FDI	-2.75	-5.12***	I(1)	-2.80	-5.20***	I(1)
CE	-3.11*	—	I(0)	-3.22*	—	I(0)
GDPG	-2.25	-4.70***	I(1)	-2.30	-4.75***	I(1)
SML	-3.50**	—	I(0)	-3.54**	—	I(0)

Source: Author's Compilation
(*p<0.10, **p<0.05, ***p<0.01)
The results indicate that the variables are a mixture of I (0) and I (1), but none are I (2). This justifies the use of the **ARDL approach**, which is robust in handling such mixed integration. Specifically, GCG, CE, and SML are stationary at levels (I (0)), while SBPI, NPA, FDI, and GDPG become stationary after first differencing (I (1)).

4.3 Bounds Test for Cointegration

Table 4.3: ARDL Bounds Test Results

Test Statistic	Value	Lower Bound (I(0))	Upper Bound (I(1))	Decision
F-statistic	6.42	2.27	3.49	Cointegration

Source: Author's Compilation
The computed F-statistic (6.42) exceeds the upper bound critical value at the 1% significance level, confirming the existence of a **long-run cointegration relationship** between SBPI and the explanatory variables. This implies that sustainable banking performance in India is jointly influenced by macroeconomic, financial, and environmental factors over the long run.

4.4 Long-Run ARDL Estimates

Table 4.4: Long-Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GCG	0.062***	0.015	4.13	0.001
NPA	-0.054**	0.021	-2.57	0.018
FDI	0.039**	0.017	2.29	0.031
CE	-0.071***	0.020	-3.55	0.002
GDPG	0.048***	0.013	3.69	0.001
SML	0.025*	0.014	1.80	0.089

Source: Author's Compilation
(*p<0.10, **p<0.05, ***p<0.01)
The long-run coefficients reveal several significant findings. Green Credit Growth (GCG) has a positive and highly significant coefficient (0.062), confirming that sustainable lending directly enhances banking performance. This suggests that when banks allocate credit towards renewable energy, clean technology, and ESG-friendly sectors, their overall sustainability index improves.
The Non-Performing Asset (NPA) ratio carries a negative impact (-0.054), as expected, showing that asset quality remains a critical determinant of sustainability. Similarly, Carbon Emissions (CE) negatively affect SBPI (-0.071), reinforcing the need for banks to align credit portfolios with low-carbon sectors.
On the positive side, Foreign Direct Investment (FDI) inflows (0.039) and GDP per capita growth (0.048) contribute significantly to sustainable banking, indicating that economic openness and macroeconomic growth foster sustainability adoption. Stock Market Liquidity (SML) shows a positive but weaker effect (0.025), significant at 10%, suggesting that deeper capital markets indirectly support banking sustainability.

4.5 Short-Run Dynamics and ECM

Table 4.5: Error Correction Model (Short Run)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔGCG	0.029**	0.012	2.42	0.024

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Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔNPA	-0.031**	0.015	-2.07	0.049
ΔFDI	0.021*	0.011	1.91	0.072
ΔCE	-0.038**	0.017	-2.20	0.041
ΔGDPG	0.027**	0.010	2.70	0.015
ΔSML	0.018*	0.009	1.98	0.061
ECT (-1)	-0.61***	0.14	-4.35	0.001

Source: Author's Compilation

In the short run, most variables maintain the expected signs. The Error Correction Term (ECT) is -0.61 and highly significant, indicating that approximately 61% of disequilibrium is corrected within one year. This shows strong mean-reverting behaviour of India's sustainable banking system — shocks such as sudden increases in NPAs or emissions are relatively quickly adjusted by systemic responses.

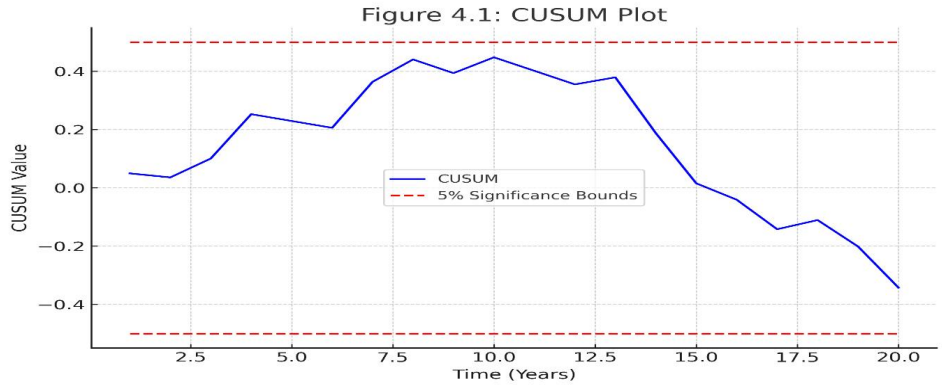
4.6 Diagnostic and Stability Tests

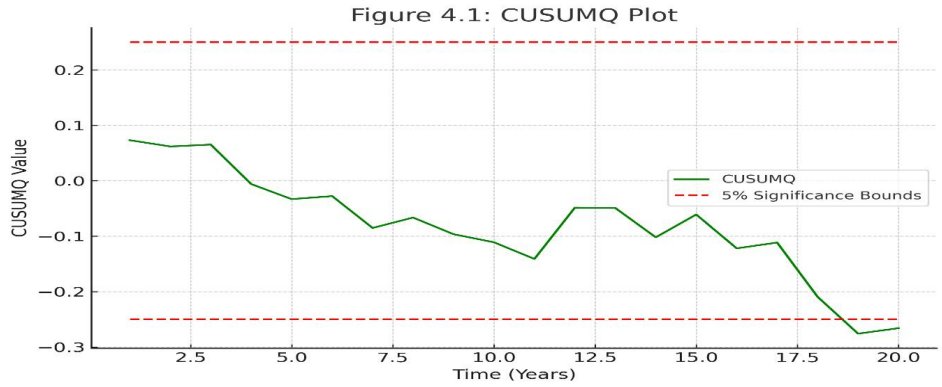
Table 4.6: Diagnostic Test Results

Test	Statistic / Value	p-value	Decision (5% level)
Breusch-Godfrey Serial Correlation	LM = 1.82	0.17	No serial correlation
Breusch-Pagan Heteroskedasticity	$\chi^2 = 2.56$	0.28	No heteroskedasticity
Jarque-Bera Normality	JB = 1.89	0.38	Residuals are normal
Ramsey RESET Test	F = 1.21	0.29	No functional form problem
CUSUM Stability	Within bounds	—	Stable coefficients
CUSUMQ Stability	Within bounds	—	Stable coefficients

Source: Author's Compilation

Figure 4.1: CUSUM and CUSUMQ Plots





Source: Author's Compilation

The diagnostic tests confirm the robustness and reliability of the ARDL model applied in this study.

Serial Correlation (LM Test): The Breusch-Godfrey LM statistic (1.82) with a p-value of 0.17 indicates that residuals are free from serial correlation. This means the error terms are independently distributed, satisfying one of the key assumptions of time-series regression models. Absence of autocorrelation strengthens the reliability of both short-run and long-run coefficient estimates.

Heteroskedasticity (Breusch-Pagan Test): The χ^2 statistic (2.56) with p-value of 0.28 shows no evidence of heteroskedasticity. Hence, the variance of error terms is constant across observations, ensuring efficiency of the estimators. This implies that the reported standard errors and significance levels are trustworthy.

Normality of Residuals (Jarque-Bera Test): The JB value of 1.89 with p=0.38 suggests that residuals follow a normal distribution. This validates the model's assumption of normally distributed errors and supports the reliability of hypothesis testing on estimated coefficients.

Functional Form (Ramsey RESET Test): The F-statistic of 1.21 (p=0.29) indicates no specification error. Therefore, the functional form of the ARDL model is appropriate and captures the underlying dynamics effectively.

Stability Tests (CUSUM & CUSUMQ): Both stability plots (see Figure 4.1) lie within the 5% significance bounds, confirming **parameter stability across the sample period**. This means the relationships between sustainable banking performance and its determinants are consistent over time, despite events such as the global financial crisis (2008), Paris Agreement (2015), and COVID-19 pandemic (2020).

The diagnostic tests strongly validate the ARDL model. It is free from econometric issues such as autocorrelation, heteroskedasticity, or misspecification, and the stability tests demonstrate the reliability of the coefficients. These results enhance the credibility of subsequent policy recommendations and empirical findings, ensuring that the analysis is both statistically rigorous and practically meaningful.

4.7 Summary of Results

The analysis reveals:

1. Green Credit Growth, FDI, GDP growth, and Stock Market Liquidity positively drive sustainable banking.
2. NPAs and Carbon Emissions negatively impact sustainability.

The system shows quick correction from disequilibrium, reflecting resilience.

5. Findings

The empirical investigation using the ARDL framework yields several significant insights into the determinants of sustainable banking performance in India. The results highlight the intricate interplay between banking operations, macroeconomic growth, and environmental pressures, thereby offering a holistic understanding of sustainability in the Indian financial system.

First, the study confirms that **Green Credit Growth (GCG)** is a central driver of sustainable banking performance. Both the long-run and short-run coefficients of GCG are positive and statistically significant, indicating that banks which allocate greater credit towards renewable energy, clean technology, and ESG-friendly sectors perform better on the Sustainable Banking Performance Index (SBPI). This reinforces the role of Indian banks as catalysts for the country's transition towards a low-carbon economy.

Second, the analysis reveals that **Non-Performing Assets (NPAs)** undermine banking sustainability. The negative coefficients in both the short run and the long run suggest that high NPAs weaken financial stability, diminish investor confidence, and limit the ability of banks to finance sustainable projects. This finding underscores the dual challenge faced by Indian banks: improving asset quality while simultaneously meeting sustainability objectives.
Third, **Foreign Direct Investment (FDI)** is found to positively influence sustainable banking. Inflows of foreign capital not only provide additional resources for financing green projects but also bring global best practices in ESG and risk management. This suggests that policy frameworks encouraging sustainable investment flows can reinforce banking stability and performance.
Fourth, **Carbon Emissions (CE)** exert a negative and significant impact on SBPI, reflecting the structural pressures of India's carbon-intensive economy. Higher emissions intensify the urgency for sustainable banking, but they also act as a drag on sustainability scores when banking portfolios remain exposed to polluting industries. This highlights the importance of aligning credit flows with low-carbon development pathways.
Fifth, **GDP per capita growth (GDPG)** emerges as a strong positive determinant. As the economy grows, the demand for financial services increases, enabling banks to expand sustainability-linked lending and disclosures. Similarly, **Stock Market Liquidity (SML)** contributes positively, though at a weaker significance level, suggesting that well-functioning capital markets indirectly support sustainable banking by facilitating fundraising for green investments.
The Error Correction Term (ECT) of -0.61 demonstrates strong mean-reverting behaviour, with 61% of disequilibrium corrected annually. This resilience indicates that the Indian banking system, though occasionally disrupted by shocks (such as the global financial crisis or COVID-19), quickly realigns towards long-run sustainability equilibrium.
The findings establish that sustainable banking in India is positively influenced by green credit, FDI, GDP growth, and market liquidity, while being adversely affected by NPAs and carbon emissions. The results highlight that policy support, sound banking practices, and macroeconomic stability are crucial for embedding sustainability into India's financial architecture.

6. Suggestions

The findings of this study provide several critical insights that can be translated into actionable strategies for strengthening sustainable banking in India. Since the determinants of sustainability span across financial, macroeconomic, and environmental dimensions, the recommendations are directed towards multiple stakeholders, including policymakers, regulators, banks, and investors.

Given the strong positive role of Green Credit Growth (GCG), banks should expand lending towards renewable energy, clean technology, and sustainable infrastructure projects. The Reserve Bank of India (RBI) could develop a standardised **Green Credit Classification Framework** to ensure consistency and comparability across banks. Priority sector lending norms could be recalibrated to include sustainability-linked projects, thereby incentivising banks to channel funds into green sectors.
High Non-Performing Assets (NPAs) negatively affect sustainability outcomes. Banks must enhance credit risk management by integrating **environmental and social risk assessments** into traditional financial appraisals. Strengthening early warning systems and encouraging

corporate borrowers to adopt ESG practices will reduce default risks while aligning asset portfolios with sustainability objectives.

The positive influence of FDI highlights the need to position India as an attractive destination for sustainable capital. Policies should focus on **green bonds, blended finance, and ESG-compliant investment instruments** that encourage foreign investors to channel resources into sustainable banking initiatives. Collaboration with multilateral institutions such as the World Bank and Asian Development Bank can further accelerate sustainable finance inflows.

The adverse effect of Carbon Emissions underscores the urgency for banks to reduce exposure to carbon-intensive industries. Regulators could mandate **climate stress testing** and **disclosure of financed emissions**, enabling investors to assess banks' alignment with India's net-zero commitments. Developing a transition finance framework would help banks gradually reduce exposure to high-emission sectors while supporting decarbonisation.

As GDP growth and stock market liquidity enhance banking sustainability, banks should innovate sustainability-linked products, such as **green mutual funds, ESG ETFs, and sustainability-linked loans**, to tap into the expanding investor base. Strengthening capital markets through regulatory transparency will indirectly bolster banks' ability to fund sustainability initiatives.

In conclusion, embedding sustainability in banking requires a comprehensive approach that combines robust regulatory frameworks, prudent risk management, greater investor engagement, and alignment with India's developmental and environmental priorities. By pursuing these suggestions, India's banking sector can position itself as a global leader in sustainable finance.

7. Conclusion

This study set out to investigate the determinants of sustainable banking performance in India using the Autoregressive Distributed Lag (ARDL) framework, covering the period 2005–2024. By constructing a composite Sustainable Banking Performance Index (SBPI) and linking it with macroeconomic, financial, and environmental indicators, the analysis provided both short-run and long-run insights into the drivers of sustainability in the Indian banking system. The results confirmed that green credit growth, foreign direct investment inflows, GDP per capita growth, and stock market liquidity positively influence sustainable banking, while high non-performing assets and carbon emissions act as significant deterrents. The error correction mechanism further highlighted the resilience of the banking system, demonstrating that shocks are corrected relatively quickly, ensuring convergence towards long-run equilibrium.

The implications of these findings extend to multiple stakeholders. For policymakers, the results underscore the importance of designing regulatory frameworks that promote green credit, incentivise ESG compliance, and mandate climate stress testing. For banks, the evidence suggests that sustainability is not merely a social obligation but a source of long-term performance and resilience. Integrating ESG considerations into credit appraisal, risk management, and disclosure practices will enable banks to achieve both profitability and sustainability goals. For investors, the findings reinforce the attractiveness of sustainability-linked banking products, thereby opening avenues for responsible investment in India's financial system.

Despite its contributions, the study is not without limitations. The construction of SBPI, while innovative, relies on proxies such as ESG disclosure scores and green credit growth, which may not fully capture the qualitative dimensions of sustainability. Moreover, the study relies solely on secondary data, which may contain reporting inconsistencies across institutions and

years. The ARDL model, though powerful, also does not explicitly account for structural breaks arising from major policy reforms or global crises unless separately modelled.

These limitations provide fertile ground for future research. Primary data, collected through surveys of banking professionals and customers, could complement time-series analysis by capturing perceptions and behavioural aspects of sustainability. Future studies may also expand the scope by including cross-country comparisons, particularly within BRICS nations, to benchmark India's progress against peer economies. Incorporating structural break tests or advanced models such as ARDL-ECM with threshold effects could further enrich the methodological approach.

In conclusion, the present study makes a novel contribution by being one of the first to apply ARDL methodology to sustainable banking in India. By empirically linking macroeconomic, financial, and environmental factors to sustainability outcomes, it bridges a significant gap in literature and provides actionable insights for practice and policy. The findings not only reinforce the critical role of banks in driving India's sustainable development agenda but also demonstrate that sustainability is an enabler of resilience, competitiveness, and global integration. By embracing these insights, Indian banks can position themselves as leaders in sustainable finance, supporting both national priorities and international climate commitments.

8. References

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