AI-Enabled Green Banking and Sustainable Financial Performance: An Empirical Framework for Indian Commercial Banks

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***Abstract*—The integration of artificial intelligence (AI) and environmental sustainability is creating new opportunities for commercial banks to improve operational processes, strengthen customer relationships, and support long-term financial performance. Green banking initiatives, including, digital service delivery, energy-efficient processes and environmentally accountable lending, paperless transactions are increasingly relevant to the transformation of the banking industry. However, the financial benefits of combining AI adoption with green banking practices require further empirical examination, particularly in the Indian banking context. This study develops an integrated framework to examine the relationship between AI adoption, green banking practices, operational efficiency, customer satisfaction, environmental, social, and governance (ESG) orientation, and sustainable financial performance in Indian commercial banks. The proposed research uses a quantitative survey design involving bank employees and customers, with a target sample of 400 respondents from selected public- and private-sector banks. Data analysis is designed around descriptive statistics, reliability and validity assessment, correlation analysis, and partial least squares structural equation modelling (PLS-SEM). Mediation and moderation analyses are proposed to investigate the mechanisms through which green banking practices may influence financial outcomes.**

An illustrative numerical example demonstrates how path coefficients, coefficients of determination, indirect effects, and interaction effects can be reported and interpreted. These example results are not based on an experiential respondent dataset and therefore do not establish empirical support for the planned hypotheses. The study offers a structured approach to evaluating the potential contribution of AI-enabled green banking to sustainable financial performance and provides a basis for future evidence-based banking strategies.

***Index Terms*—Artificial intelligence, ESG orientation, operational efficiency, sustainable financial performance, customer satisfaction, green banking Indian commercial banks.**

I. INTRODUCTION

Banks drive economic development by collecting savings, issuing loans, processing transactions, and channelling funds into productive business activities. In recent years, banks have also faced increasing expectations to reduce their environmental footprint and incorporate sustainability considerations into business decisions. These developments have encouraged financial institutions to adopt green banking practices alongside digital transformation initiatives.

Green banking generally refers to banking operations and financial services that seek to reduce environmental impacts and encourage environmentally responsible economic activities. Examples include paperless documentation, electronic payments, digital customer service, energy-efficient branches, renewable-energy financing, and the valuation of environmental risks allied with lending. Such practices may help banks reduce resource consumption while supporting broader sustainability objectives.

At the same time, artificial intelligence has expanded the technological capabilities available to financial

institutions. Machine learning, predictive analytics, natural language processing, robotic process automation, and intelligent customer-service systems can support fraud detection, credit-risk assessment, customer communication, and operational decision-making. Research on digital financial services suggests that technology can improve service delivery and process efficiency, although its benefits depend on implementation quality, governance, and customer acceptance (Vives, 2019).

The combination of AI and green banking presents an opportunity to integrate technological efficiency with environmental responsibility. For example, AI-supported document processing may reduce manual paperwork, while predictive analytics may help identify operational inefficiencies. Digital networks help bridge gaps in financial access and accelerate the introduction of eco-friendly financial options. Nevertheless, AI systems themselves require computing resources and may introduce risks involving privacy, cybersecurity, algorithmic bias, and energy consumption. Their contribution to sustainability should therefore be evaluated rather than assumed.

The Indian commercial banking sector provides a relevant context for examining these relationships. Public- and private-sector banks operate within a rapidly evolving digital financial environment, while sustainability reporting, climate-related financial risks, and responsible finance are receiving increasing attention. The Reserve Bank of India has also discovered climate-related financial risks and the suggestions of sustainable finance for the financial system (Reserve Bank of India, 2022).

Despite these developments, AI adoption, green banking, and financial performance are often examined as related but separate research areas. An integrated model is needed to understand whether AI adoption is associated with stronger green banking practices and whether these practices relate to financial outcomes through operational efficiency and customer satisfaction. It is also important to examine whether ESG orientation strengthens the relationship between green banking practices and sustainable financial performance.

Against this background, the present study proposes a framework connecting AI adoption, green banking practices, operational efficiency, customer satisfaction, ESG orientation, and sustainable financial performance. The intended contribution is to explain the potential mechanisms linking technological transformation and environmental responsibility in Indian commercial banks, while establishing a transparent analytical structure for empirical testing.

1.1 Statement of the problem

Indian commercial banks are investing in digital infrastructure and introducing sustainability-oriented practices. However, the implementation of AI does not automatically lead to lower environmental impacts or improved financial performance. Banks may encounter implementation costs, customer resistance, cybersecurity concerns, data-quality problems, and difficulties measuring the benefits of sustainability initiatives.

The central problem is therefore whether and how AI adoption supports green banking practices and whether these practices are associated with improved operational efficiency, customer satisfaction, and sustainable financial performance. A related question is whether stronger ESG orientation helps banks translate green banking initiatives into better long-term outcomes.

1.2 Research objectives

1. To examine the relationship between AI adoption and green banking practices.
2. To assess the influence of green banking practices on operational efficiency.
3. To investigate the relationship between green banking practices and customer satisfaction.
4. To examine the relationships of operational efficiency and customer satisfaction with sustainable financial performance.
5. To evaluate the mediating roles of operational efficiency and customer satisfaction.
6. To assess whether ESG orientation moderates the relationship between green banking practices and sustainable financial performance.
7. To develop and empirically evaluate a structural model of AI-enabled green banking in Indian commercial banks.

1.3 Research questions

- Does adopting artificial intelligence help advance green banking practices?
- How are green banking practices associated with operational efficiency and customer satisfaction?

- Do operational efficiency and customer satisfaction help explain the relationship between green banking and sustainable financial performance?
- Does ESG orientation strengthen the relationship between green banking practices and sustainable financial performance?

II. REVIEW OF LITERATURE

2.1 Green banking practices and environmental sustainability

Green banking has become an important part of the wider movement towards sustainable finance. It involves reducing the environmental impact of banking operations while encouraging financial activities that support environmental objectives. Common initiatives include electronic transactions, reduced paper usage, energy-efficient branches, green lending, and environmental risk assessment.

Thapliyal et al. (2025) examined green banking practices, environmental performance, and sources of green finance in India. Their study used survey data from banking employees in Uttarakhand and employed structural equation modelling. The research provides relevant evidence for investigating the relationship between green banking practices and sustainability outcomes in the Indian context.

Other research has explored how green banking, green finance, CSR, and environmental performance relate to one another in Indian banks. Such work supports a broader view of green banking that includes both operational changes and the allocation of financial resources towards environmentally responsible activities.

2.2 Artificial intelligence in banking

AI has extended the capacity of banks to progression information, identify patterns, automate tasks, and personalize services. Its applications include customer-service chatbots, fraud detection, credit-risk assessment, transaction monitoring, and predictive analytics. These applications may improve the speed and consistency of banking processes, although outcomes depend on data quality, governance, and the suitability of the technology.

Vives (2019) discussed how digital disruption and fintech affect banking competition and business models. This provides a foundation for considering AI adoption as part of a wider transformation in the way banks deliver services and manage operations. However, improvements in digital efficiency should not automatically be equated with environmental benefits or higher profitability.

2.3 ESG orientation and sustainable financial performance

ESG orientation reflects the extent to which environmental responsibility, social considerations, and governance practices are incorporated into organizational decisions. For banks, this may include climate-risk assessment, responsible lending, transparent sustainability reporting, data protection, and effective oversight of AI systems.

The Reserve Bank of India's 2022 discussion paper on climate risk and sustainable finance highlighted the importance of assessing how banks understand and manage climate-related financial risks. Its associated survey covered public-sector, private-sector, and foreign banks, providing institutional context for the growing significance of sustainable finance in India.

ESG orientation may influence whether green banking initiatives are incorporated into wider organizational strategy or remain limited to individual projects. A bank with stronger ESG governance may be better positioned to connect environmental objectives with risk management, investment decisions, and long-term performance. This relationship requires empirical testing rather than an assumption that ESG commitments always produce immediate financial gains.

2.4 Operational efficiency and customer satisfaction

Operational efficiency concerns how effectively an organization uses its resources to deliver services. In banking, relevant indicators include processing time, transaction costs, error rates, service availability, and employee productivity. AI and digital banking can potentially improve these indicators by automating routine activities and supporting faster decisions.

Customer satisfaction concerns customers' evaluations of service quality, convenience, reliability, trust, and responsiveness. Digital services may increase convenience, but poorly designed systems, privacy concerns, inaccessible interfaces, and service interruptions can reduce satisfaction. The relationship between green banking and customer satisfaction

therefore depends on the quality and accessibility of the services provided.

2.5 Research gap

The literature provides a foundation for studying green banking, digital transformation, and sustainability. However, the proposed research focuses on integrating these areas within one explanatory model for Indian commercial banks.

The specific gaps addressed are:

1. The relationship between AI adoption and green banking implementation requires examination within an integrated framework.
2. The roles of operational efficiency and customer satisfaction as potential explanatory mechanisms need to be tested together.
3. The moderating role of ESG orientation in the relationship between green banking and sustainable financial performance requires explicit statistical assessment.
4. Survey-based perceptions should be distinguished from independently verified financial and environmental performance indicators.
5. The proposed framework needs empirical evaluation using validated measurement instruments and a clearly specified SEM model.

2.6 Theoretical foundation

Three theoretical perceptions can support the proposed framework.

- Resource-based view: Technology, organizational knowledge, and sustainability capabilities may provide strategic value when they are effectively integrated into banking operations.
- Dynamic capabilities perspective: Banks must adapt their processes, skills, and technology in response to changing customer expectations, regulation, and environmental risks.
- Stakeholder theory suggests that banks shape their responsible banking strategies to meet the demands of customers, regulators, employees, investors, and communities.

Together, these perspectives explain why AI adoption alone may be insufficient. The potential benefits depend on how technological capabilities are translated into green banking processes, service improvements, and effective sustainability governance.

2.7 Hypotheses development

The below hypotheses are planned for empirical testing.

Code	Hypothesis
H1	AI adoption is positively associated with green banking practices.
H2	Green banking practices are positively associated with operational efficiency.
H3	Green banking practices are positively associated with customer satisfaction.
H4	Operational efficiency is positively associated with sustainable financial performance.
H5	Customer satisfaction is positively associated with sustainable financial performance.
H6	ESG orientation positively moderates the relationship between green banking practices and sustainable financial performance.
H7	AI adoption has a positive direct association with sustainable financial performance, after accounting for the other specified predictors.

Additionally, the framework will assess how green banking practices exert indirect influences through customer satisfaction and operational. H7 represents a direct effect and should not be interpreted as the combined effect of all AI-driven green banking pathways.

III. RESEARCH METHODOLOGY

3.1 Research design

The proposed study adopts a quantitative, cross-sectional research design. A structured questionnaire will be used to examine the perceptions of employees and customers of selected Indian commercial banks. The design is appropriate for assessing associations among hidden constructs at a particular point in time, although it cannot by itself establish causal relationships.

3.2 Population and sample

The target population consists of employees and customers associated with five selected commercial banks:

- State Bank of India
- HDFC Bank
- ICICI Bank

- Axis Bank
- Punjab National Bank

A target of 400 completed responses is proposed. This is a planning assumption rather than a claim that 400 responses have already been collected. The final sample size should be justified through a statistical power analysis that considers the model's complexity, the smallest effect of interest, and the number of predictors.

Purposive sampling may be used to recruit employees familiar with banking operations and customers with experience using the banks' services. If convenience sampling is also used, the resulting limitations in representativeness should be acknowledged.

A critical design decision is whether employee and customer responses will be analyzed together. Since employees assess internal processes and customers assess external service experiences, separate measurement models or carefully justified multi-group analysis may be more appropriate than assuming that every construct has the same meaning for both groups.

3.3 Sources of data

Primary data: Structured questionnaire responses using a five-point Likert scale, from 1 (strongly disagree) to 5 (strongly agree).

Secondary data: RBI publications, bank annual reports, sustainability disclosures, ESG reports, and peer-reviewed academic literature. Where possible, audited financial indicators and documented environmental measures should supplement survey-based perceptions.

3.4 Measurement of variables

Table 1. Proposed operational definitions

Construct	Example measurement dimensions
AI Adoption	Use of AI tools, automation, predictive analytics, intelligent customer services
Green Banking Practices	Paperless transactions, digital documentation, energy conservation, green lending
Operational Efficiency	"Execution velocity, asset optimization, expenditure reduction, and minimized human mistakes"
Customer Satisfaction	Convenience, reliability, responsiveness, trust, overall satisfaction
ESG Orientation	Sustainability governance, environmental risk oversight, social responsibility, disclosure quality
Sustainable Financial Performance	Perceived long-term efficiency, financial resilience, sustainable growth, risk management

Each construct should be measured through multiple clearly worded questionnaire items adapted from appropriate validated scales and reviewed for relevance to Indian banking. The final questionnaire should be pilot-tested, and the full item wording should be reported in an appendix.

For a stronger study, sustainable financial performance should ideally be measured using a combination of survey-based perceptions and objective indicators, such as operating expenses, return on assets, return on equity, and documented sustainability outcomes, where data are available and comparable.

3.5 Statistical tools

The proposed analytical sequence is:

1. Frequency and percentage analysis.
2. Mean and standard deviation.
3. Cronbach's alpha and composite reliability.
4. Indicator loadings and convergent and discriminant validity.
5. Correlation and collinearity assessment.
6. PLS-SEM path analysis using SmartPLS 4.
7. Bootstrapped mediation and moderation analysis.
8. Explanatory and predictive assessment, including R^2, f^2, and suitable prediction procedures.

PLS-SEM is proposed because the study aims to explain and predict relationships among multiple constructs. AMOS-based covariance SEM is an alternative if the research emphasizes theory confirmation and covariance-based model fit. The choice should be made before the final analysis and the appropriate criteria should be reported for the selected method.

3.6 Ethical considerations

Participation should be intentional and based on informed consent. The questionnaire should avoid collecting unnecessary personal or confidential

banking information. Responses should be anonymized, securely stored, and reported in aggregate. Institutional ethical approval should be obtained where required.

IV. RESULTS AND NUMERICAL ANALYSIS

Significant reporting note: The numerical results under form a hypothetical demonstration of the proposed analysis. They are not derived from 400 actual survey responses. They show how the Results section can be structured, but must not be described as the study's empirical findings until verified using respondent-level data.

4.1 Respondent distribution

Table 2. Illustrative sample distribution

Commercial bank	Respondents	Percentage
SBI	100	25.00
HDFC Bank	85	21.25
ICICI Bank	80	20.00
Axis Bank	70	17.50
PNB	65	16.25
Total	400	100.00

Interpretation: The example allocates 25% of respondents to SBI, followed by HDFC Bank at 21.25%. The distribution illustrates how bank-level coverage can be reported. Actual recruitment records must be used for the final table, and the sample distribution should not be interpreted as representing each bank's market share.

4.2 Descriptive statistics

Table 3. Construct-level descriptive statistics

Variable	Mean	Standard deviation
AI Adoption	3.84	0.72
Green Banking Practices	3.91	0.68
Operational Efficiency	3.78	0.75
Customer Satisfaction	3.96	0.66
ESG Orientation	3.65	0.81
Sustainable Financial Performance	3.72	0.73

Interpretation: In this example, customer satisfaction has the highest mean (3.96), while ESG orientation has the lowest mean (3.65). All means are above the neutral scale midpoint of 3.00. If similar patterns are found in the actual survey, they may indicate that respondents view customer-facing digital services more positively than the banks' ESG implementation. This conclusion would require actual data and suitable group comparisons.

4.3 Reliability and validity

Table 4. Measurement-model assessment

Construct	Cronbach's alpha	Composite reliability	AVE
AI Adoption	0.89	0.92	0.69
Green Banking Practices	0.91	0.93	0.72
Operational Efficiency	0.87	0.91	0.67
Customer Satisfaction	0.90	0.93	0.70
ESG Orientation	0.88	0.92	0.66
Sustainable Financial Performance	0.92	0.94	0.72

Interpretation: The hypothetical values exceed common minimum thresholds for internal consistency and convergent validity. The composite reliability values are between 0.91 and 0.94, while AVE ranges from 0.66 to 0.72. If confirmed by actual model estimates, this would provide evidence of satisfactory reliability and convergent validity. Discriminant validity would still need to be checked separately, for example through HTMT ratios.

4.4 Correlation analysis

Table 5. Illustrative correlation matrix

Variables	AIA	GBP	OE	CS	ESG	SFP
AI Adoption (AIA)	1.00					
Green Banking Practices (GBP)	0.62	1.00				
Operational Efficiency (OE)	0.48	0.58	1.00			
Customer Satisfaction (CS)	0.45	0.54	0.61	1.00		

ESG Orientation (ESG)	0.42	0.51	0.46	0.49	1.00	
Sustainable Financial Performance (SFP)	0.50	0.63	0.65	0.60	0.57	1.00

Interpretation: In this example, operational efficiency has a correlation of 0.65 with sustainable financial performance, while green banking practices have a correlation of 0.63. These coefficients suggest positive associations. They do not establish statistical significance or causation, and the actual analysis must report appropriate significance tests and confidence intervals.

4.5 Structural model results

Table 6. Illustrative direct path coefficients

Hypothesis	Path	β	t-value	p-value

| H1 | AI Adoption → GBP | 0.620 | 12.40 | All estimates are hypothetical. H6 is an interaction effect rather than a conventional direct path. H7 is included as a separate direct path in this illustrative model.

Interpretation: The illustrative coefficient for AI adoption and green banking practices is 0.620, suggesting a positive relationship. Green banking practices are also positively associated with operational efficiency (β = 0.580) and customer satisfaction (β = 0.540). Operational efficiency and customer satisfaction have positive coefficients of 0.350 and 0.280, respectively, for sustainable financial performance.

If actual estimates were comparable and statistically significant, they would be consistent with the proposed framework. However, the relative importance of these relationships should be evaluated using confidence intervals, effect sizes, and predictive performance rather than the coefficient values alone.

4.6 Explanatory power of the model

Table 7. Illustrative R^2 values

Endogenous construct	R^2	Variance explained
Green Banking Practices	0.384	38.4%
Operational Efficiency	0.336	33.6%
Customer Satisfaction	0.292	29.2%
Sustainable Financial Performance	0.518	51.8%

Interpretation: The illustrative R^2 for sustainable financial performance is 0.518, indicating that the specified predictors account for 51.8% of its variance in the example. The remaining 48.2% is not explained by the model. R^2 should be interpreted in the context of the research area, model complexity, and predictive performance rather than against a universal acceptance threshold.

V. FINDINGS, SUGGESTIONS, CONCLUSION

1. Findings of the Study

The following findings are written in a journal-style format based on the illustrative numerical analysis presented earlier. The numerical values are hypothetical and must be verified using actual survey data before being reported as empirical findings.

1. AI adoption shows a positive relationship with green banking practices, with an illustrative path coefficient of β = 0.620, indicating the potential importance of digital technologies in supporting environmentally responsible banking operations.
2. Green banking practices demonstrate a positive relationship with operational efficiency (β = 0.580). Digital documentation, paperless transactions, and automated banking processes may help reduce manual work and improve resource utilization.
3. Green banking practices are positively associated with customer satisfaction (β = 0.540), suggesting that convenient, accessible, and reliable digital banking services may contribute to improved customer experiences.
4. Operational efficiency (β = 0.350) and customer satisfaction (β = 0.280) exhibit positive relationships with sustainable financial performance in the illustrative model. These relationships suggest that internal process improvements and customer relationships may be relevant to long-term banking performance.
5. The illustrative coefficient of determination for sustainable financial performance is R^2 = 0.518, indicating that the predictors in the example collectively explain 51.8% of the variance in the outcome variable.
6. The hypothetical indirect effect through operational efficiency is 0.203, compared with 0.151 through customer satisfaction. This suggests that operational efficiency may represent a comparatively stronger

pathway linking green banking practices with sustainable financial performance.

7. ESG orientation demonstrates a hypothetical positive moderating effect ($\beta = 0.120$, $p = 0.014$), suggesting that stronger ESG orientation may reinforce the relationship between green banking practices and financial performance. This conclusion requires confirmation using actual interaction-effect estimates.

2. Suggestions

1. Increase AI-enabled green banking investment. Commercial banks should adopt suitable AI technologies for digital documentation, automated customer service, fraud detection, and operational monitoring, while evaluating their costs and environmental impacts.
2. Strengthen paperless banking practices. Banks should expand electronic statements, digital applications, online documentation, and secure electronic transactions to reduce paper consumption and improve processing efficiency.
3. Improve customer satisfaction and digital inclusion. Banks should develop user-friendly digital platforms, multilingual services, accessible interfaces, and responsive customer support to ensure that technological innovation benefits customers from different backgrounds.
4. Integrate ESG into banking strategy. Environmental, social, and governance objectives should be incorporated into lending decisions, risk assessment, internal controls, sustainability reporting, and long-term strategic planning.
5. Monitor measurable financial and environmental outcomes. Banks should regularly assess operating costs, transaction-processing time, customer retention, paper consumption, energy usage, and relevant financial performance indicators to determine whether green banking initiatives deliver tangible benefits.
6. Establish responsible AI governance. Banks should strengthen data protection, cybersecurity, algorithmic transparency, bias monitoring, and human oversight to maintain customer trust and reduce technology-related risks.
7. Provide continuous employee training. Employees should receive regular training in AI applications, digital banking systems, sustainable finance, ESG reporting, and responsible data management.
8. Encourage evidence-based regulatory initiatives. Banking regulators and policymakers should promote credible sustainability disclosures, responsible AI governance, climate-risk assessment, and appropriate monitoring of digital and green banking initiatives.

3. Conclusion

The integration of artificial intelligence and green banking practices presents an important opportunity for Indian commercial banks to combine technological advancement with environmental responsibility. AI-supported banking systems can potentially improve operational processes, facilitate paperless transactions, strengthen customer service, and support sustainability-related decision-making. However, these benefits depend on effective implementation, appropriate governance, customer acceptance, and the ability to measure outcomes.

The proposed research framework examines the relationships among AI adoption, green banking practices, operational efficiency, customer satisfaction, ESG orientation, and sustainable financial performance. It also considers the potential mediating roles of operational efficiency and customer satisfaction and the moderating influence of ESG orientation. The illustrative numerical analysis demonstrates how these relationships can be examined through structural equation modelling.

The practical implication is that banks should evaluate AI-enabled green banking not merely in terms of technological adoption but also through measurable improvements in efficiency, customer experience, environmental performance, and financial resilience. ESG governance, employee capabilities, digital inclusion, and responsible AI practices are important considerations in this process.

Nevertheless, the numerical results presented in this draft are hypothetical rather than verified findings from Indian commercial banks. The proposed relationships must be tested using actual survey responses and, where possible, audited financial and environmental indicators. This approach will provide a more reliable basis for determining how AI-driven green banking contributes to sustainable financial performance in India.

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