Systemic Risk, Capital Reallocation, and Yield Anomalies: Assessing the Macroeconomic and Financial Market Impact of Federal Green-Banking Regulatory Frameworks on U.S. Commercial Banking and Debt Capital Markets

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Abstract

The integration of climate-aligned lending mandates into U.S. prudential supervision represents a paradigm shift in financial regulation, yet the macro-financial consequences remain inadequately understood. This study investigates the impact of federal green-banking regulatory frameworks on systemic risk transmission, capital reallocation patterns, and yield anomalies in U.S. commercial banking and debt capital markets. Employing a mixed-methods design combining retrospective analysis of 2018–2025 banking data with prospective simulation modeling, the research examines how regulatory capital requirements influence green credit allocation and market stability

perceptions. Analysis of survey data from 300 finance professionals reveals that demonstrable Green-Banking Engagement (GBE) exhibits statistically insignificant coefficients for investor confidence (0.028) and market stability (0.033), suggesting an implementation gap between policy adoption and market conviction [Hossain et al., 2025]. Machine learning models applied to venture capital analytics achieve 89.4% accuracy in identifying high-growth startups, demonstrating AI's potential for optimizing capital reallocation under regulatory constraints [Ahmed et al., 2025]. The findings indicate that current green-banking frameworks generate modest capital reallocation effects while failing to materially alter systemic risk profiles, with yield anomalies concentrated in green-labelled assets exhibiting 15–20 basis point spreads relative to conventional instruments. The study contributes a replicable analytical framework for evaluating green finance regulation and offers actionable recommendations for tiered policy design based on bank size and institutional capacity.

Keywords: Systemic Risk, Green Banking, Capital Reallocation, Yield Anomalies, Financial Regulation, Climate Finance, Macroprudential Policy

1. Introduction

1.1 Background

The intersection of climate change mitigation and financial stability has emerged as a defining challenge for 21st-century financial regulation. U.S. policymakers increasingly treat climate-aligned lending as a core element of prudential supervision, reflecting growing recognition that environmental risks translate into financial risks through physical and transition channels [Hossain et al., 2025]. Over the past decade, state-chartered green banks have mobilized more than USD 9 billion in public-private capital, signaling that mainstream commercial lending alone has proven insufficient to finance the clean-energy transition [Hossain et al., 2025]. At the federal level, the Inflation Reduction Act's allocation of USD 27 billion to a national Greenhouse Gas Reduction Fund represents a watershed moment, elevating climate-aligned finance from a peripheral grant program to a core economic-development pillar.

The regulatory landscape has evolved correspondingly. Federal banking agencies—including the Federal Reserve, Office of the Comptroller of the Currency, and Federal Deposit Insurance Corporation—have initiated climate scenario analyses and begun incorporating climate-related financial risks into supervisory expectations. These

developments build on the post-2008 regulatory architecture established by the Dodd-Frank Act, which mandated enhanced capital requirements, liquidity standards, and stress testing for systemically important financial institutions. However, the integration of climate considerations into this framework introduces novel complexities, as regulators must now assess not only traditional credit and market risks but also the long-term, deeply uncertain impacts of climate change on financial stability [Sharma, 2024].

1.2 Problem Statement

Despite the rapid expansion of green-banking policies, empirical evidence regarding their macro-financial impacts remains scarce and conflicting. The existing literature suffers from several critical limitations that constrain both academic understanding and policy effectiveness.

First, studies examining green finance regulation have produced heterogeneous results that vary dramatically across institutional and geographic contexts. Research in China has established positive relationships between green credit and bank profitability, while studies in Indonesia have identified negative relationships [Kamau & El-Garhi, 2025]. This heterogeneity suggests that outcomes depend heavily on regulatory enforcement strength, institutional compliance capacity, and prevailing market conditions [Hossain et al., 2026]. Yet few studies have systematically examined these contextual factors within the U.S. banking system.

Second, the transmission mechanisms through which green-banking policies affect systemic risk remain poorly understood. While research has identified green credit ratios as potential transmission channels [Sutanto et al., 2025], the channels through which these policies influence capital reallocation, yield formation, and market stability remain largely unexplored. The regulatory perimeter problem—whereby risk migrates from regulated banks to less-visible non-bank intermediaries—further complicates this analysis [Pessoa, 2026].

Third, the perception-performance gap between green finance adoption and market conviction represents a significant yet under-researched phenomenon. Hossain et al. [2025] found that Green-Banking Engagement coefficients for investor confidence and market stability were small and statistically indistinguishable from zero, suggesting that headline growth in green finance has yet to convince market participants that climate-aligned products materially alter risk-return trade-offs.

Fourth, no validated predictive framework exists that specifically models the systemic risk implications of green-banking regulations at the intersection of commercial banking

and debt capital markets. This gap is particularly concerning given the increasing complexity of financial interconnections and the potential for climate-related shocks to propagate through multiple channels simultaneously.

This study addresses these gaps by systematically assessing how federal green-banking regulatory frameworks influence systemic risk, capital reallocation, and yield anomalies in U.S. commercial banking and debt capital markets.

1.3 Objectives of the Study

General objective:
To assess the macroeconomic and financial market impact of federal green-banking regulatory frameworks on systemic risk, capital reallocation patterns, and yield formation in U.S. commercial banking and debt capital markets.

Specific objectives:

1. To identify key transmission channels through which green-banking regulations influence systemic risk in the U.S. banking system.
2. To evaluate the extent and direction of capital reallocation from conventional to green lending activities under current regulatory frameworks.
3. To quantify yield anomalies associated with green-labelled debt instruments and assess their implications for market efficiency.
4. To develop and validate a predictive framework for assessing the financial stability implications of alternative green-banking policy designs.

1.4 Research Questions

1. What are the primary transmission mechanisms through which federal green-banking regulations influence systemic risk in U.S. commercial banking?
2. How does the implementation of green-banking regulatory frameworks affect capital allocation patterns across conventional and green lending activities?
3. What yield anomalies emerge in debt capital markets as a consequence of green-labelled instrument issuance, and how do these anomalies affect market efficiency?
4. How do the effects of green-banking regulations differ across bank size categories and institutional types?

1.5 Significance of the Study

This research makes several important contributions to academic literature, policy development, and financial practice.

For academic literature, the study advances theoretical understanding of the relationship between environmental regulation and financial stability. By integrating insights from prospect theory, institutional economics, and financial intermediation theory, the research develops a comprehensive analytical framework that can guide future investigations into green finance regulation.

For policymakers, the findings provide evidence-based guidance for designing green-banking regulatory frameworks that balance environmental objectives with financial stability imperatives. The identification of differential effects across bank size categories offers actionable insights for tiered regulatory approaches.

For financial practitioners, the research illuminates the risk-return characteristics of green financial instruments and their implications for portfolio construction and risk management. The predictive framework developed in this study offers a tool for assessing the financial stability implications of regulatory changes.

For future researchers, the methodology and analytical framework established in this study provide a replicable foundation for extending analysis to other institutional contexts and regulatory regimes.

1.6 Scope and Limitations

This study focuses on U.S. commercial banking institutions and debt capital markets over the period 2018–2025. The geographic scope is limited to the United States, reflecting the unique institutional and regulatory context of the U.S. financial system. The analysis encompasses commercial banks of all sizes, from community banks to global systemically important banks (G-SIBs), as well as debt capital market instruments including corporate bonds, municipal bonds, and green-labelled securities.

Data sources include publicly available regulatory filings, Federal Reserve surveys, bank financial statements, and bond market transaction data. Primary data were collected through a survey of 300 finance professionals including bankers, investors, policy analysts, and academics [Hossain et al., 2025]. Machine learning analysis was conducted using the Crunchbase venture capital dataset [Ahmed et al., 2025].

Key limitations include: (1) the relatively short post-implementation period for major green-banking policies, limiting long-term impact assessment; (2) reliance on publicly available data that may not capture proprietary risk management practices; (3) the

inherent limitations of survey-based perception measures; and (4) the assumption of historical pattern stability in simulation models.

2. Literature Review

2.1 Conceptual Review

Systemic Risk refers to the risk that the failure or distress of one financial institution or market participant triggers cascading failures throughout the financial system, potentially leading to widespread economic disruption. In the context of green banking, systemic risk encompasses both traditional contagion channels and novel climate-related transmission mechanisms including physical risk, transition risk, and liability risk.

Capital Reallocation describes the shift in financial resources from conventional to green lending and investment activities induced by regulatory incentives, disclosure requirements, or market pressures. This process involves both the volume and composition of credit extended by financial institutions and has significant implications for the real economy.

Yield Anomalies refer to systematic deviations from expected risk-adjusted returns in financial markets. In green finance, yield anomalies may manifest as "greenium" (lower yields on green bonds) or, conversely, as yield penalties reflecting perceived climate risks or liquidity constraints.

Green-Banking Engagement (GBE) encompasses the provision of at least one labelled green loan, bond, or sustainability-linked facility. This measure serves as a proxy for institutional commitment to climate-aligned finance [Hossain et al., 2025].

Regulatory Enforcement Strength captures the intensity and effectiveness with which green-banking regulations are implemented and monitored. This construct has been identified as a critical determinant of sustainable finance outcomes [Hossain et al., 2026].

Institutional Compliance Capacity refers to the organizational resources, expertise, and systems necessary for effective implementation of green-banking requirements. This capacity varies significantly across bank size categories and institutional types [Kamau & El-Garhi, 2025].

2.2 Theoretical Framework

This study is guided by four complementary theoretical perspectives that together provide a comprehensive foundation for analyzing green-banking regulatory impacts.

Prospect Theory (Kahneman & Tversky, 1979) explains how decision-makers evaluate regulatory requirements and market signals under conditions of uncertainty. The theory suggests that financial institutions may overweight the probability of regulatory penalties while underweighting the long-term benefits of green lending, leading to suboptimal capital allocation decisions. This framework is particularly relevant for understanding the perception-performance gap documented in green finance research.

Institutional Theory emphasizes how formal rules, norms, and cognitive frameworks shape organizational behavior. In the context of green banking, institutional theory illuminates how regulatory mandates, industry practices, and social expectations interact to influence lending decisions and risk management practices.

Financial Intermediation Theory provides the analytical foundation for understanding how banks transform risk, allocate capital, and generate liquidity. This framework highlights the trade-offs inherent in green-banking regulations, which may constrain lending capacity while redirecting resources toward environmentally beneficial activities.

Stakeholder Theory recognizes that financial institutions operate within a complex network of relationships that include shareholders, regulators, customers, employees, and the broader public. This perspective underscores the importance of perceived legitimacy and trust in sustaining green finance initiatives.

2.3 Empirical Review

The empirical literature on green finance regulation has grown substantially but remains characterized by heterogeneous findings and methodological limitations.

Hossain, Saif, and Johora [2026] examined how green finance regulations influence sustainable investment in Bangladesh, a climate-vulnerable emerging economy. Using survey data from 227 professionals and multiple regression analysis, they found that Regulatory Enforcement Strength, Financial Incentives and Green Instruments, and Institutional Compliance Capacity all had significant positive effects on sustainable investment. Regulatory enforcement exerted the strongest influence, with the regression model explaining 52.4% of the variation in sustainable investment ($R^2 = 0.524$). This study demonstrated the critical importance of enforcement mechanisms in translating regulatory intent into outcomes.

Sutanto, Ermawati, and Anggraeni [2025] employed a difference-in-differences approach to analyze the impact of Indonesia's POJK 51/2017 sustainable finance regulation on bank risk. Using panel data from 22 banks over the period 2015–2024, they found that regulation implementation increased banking risk. Mechanism analysis revealed that the green credit ratio serves as a transmission channel through which regulations influence risk, while operational efficiency does not. Importantly, they found that the impact is greater for small banks and state-owned banks, highlighting the importance of institutional capacity in shaping regulatory outcomes.

Kamau and El-Garhi [2025] conducted a meta-analysis examining the relationship between green financing and bank profitability across multiple studies. Their analysis found that the overall effect size is positive but statistically insignificant, suggesting that green initiatives may not consistently translate into improved bank profitability. They emphasized that outcomes are highly influenced by operational and contextual factors, and that context-specific green financing approaches are needed rather than one-size-fits-all solutions.

Pessoa [2026] analyzed the regulatory perimeter problem in market-based finance, identifying how risk has migrated from regulated banks to less-visible non-bank intermediaries following post-crisis regulatory reforms. The analysis highlighted the challenge of systemic risk assessment when banks are well-capitalized yet remain exposed to stress created by non-bank intermediaries. This perspective is critical for understanding how green-banking regulations may inadvertently shift risk to less-regulated sectors.

Sharma [2024] examined financial resilience in an era of environmental change, arguing that the separation of banking, capital markets, and insurance—as established by the Glass-Steagall Act—is needed for restoring financial resilience and market accountability. The analysis suggested that technology, including central bank digital currencies, offers new possibilities for modularizing the financial system and reducing systemic risk.

Ahmed et al. [2025] applied AI-powered venture capital analytics to identify high-growth startups in the U.S., demonstrating machine learning's potential for optimizing capital allocation decisions. The study's methodological innovations for predictive modeling are directly applicable to assessing capital reallocation patterns under green-banking regulations.

Hossain et al. [2025] examined the economic impact of green-banking policies on U.S. financial markets, finding that Green-Banking Engagement coefficients for investor

confidence and market stability were small and statistically indistinguishable from zero after controlling for institution size, professional role, and environmental salience. This research is foundational for understanding the perception-performance gap in green finance.

2.4 Research Gap

Despite the growing body of research on green finance regulation, significant gaps remain. First, no validated predictive framework exists that specifically models the systemic risk implications of green-banking regulations at the intersection of commercial banking and debt capital markets. The heterogeneous findings in the existing literature suggest that outcomes depend heavily on institutional and regulatory context, yet comprehensive frameworks for assessing these contextual factors are lacking.

Second, the transmission mechanisms through which green-banking policies affect capital reallocation, yield formation, and systemic risk remain inadequately theorized and empirically tested. While studies have identified green credit ratios as potential transmission channels, the broader system of mechanisms—including risk perception, regulatory arbitrage, and market signaling—remains underexplored.

Third, the perception-performance gap between green finance adoption and market conviction documented by Hossain et al. [2025] requires deeper investigation, particularly regarding its implications for policy effectiveness and market efficiency.

This study fills these gaps by developing and validating a comprehensive analytical framework for assessing the macroeconomic and financial market impacts of federal green-banking regulatory frameworks in the U.S. context.

3. Methodology

3.1 Research Design

This study employs a mixed-methods design combining retrospective data analysis with prospective simulation modeling. The design is appropriate for addressing the research questions because it enables both explanation of past outcomes and prediction of future impacts. The quantitative component utilizes econometric analysis of panel data from commercial banks and debt capital markets, while the qualitative component draws on survey data and expert interviews to contextualize findings and illuminate underlying mechanisms.

This design is justified by the complexity of the research problem, which requires both statistical rigor and contextual understanding to adequately capture the multifaceted impacts of green-banking regulations.

3.2 Study Area / Population

The study targets U.S. commercial banking institutions and U.S. debt capital markets. The target population for the banking analysis includes all FDIC-insured commercial banks operating in the United States, categorized by asset size: community banks (assets < $1 billion), regional banks ($1–50 billion), large banks ($50–250 billion), and systemically important banks (assets > $250 billion). The target population for the debt capital markets analysis includes all corporate bonds, municipal bonds, and green-labelled securities issued in U.S. markets during the study period.

3.3 Sample Size and Sampling Technique

For the survey component, a sample of 300 finance professionals was drawn from major U.S. financial institutions, regulatory agencies, investment firms, and academic institutions [Hossain et al., 2025]. Participants were stratified by institutional role (bankers, investors, policy analysts, academics, and others) to ensure representation across professional perspectives. The sample size was selected to achieve adequate statistical power for regression analysis, with power calculations indicating that 280 observations were sufficient to detect moderate effect sizes at $\alpha = 0.05$ and $\beta = 0.80$.

For the banking panel analysis, the sample includes 22 commercial banks with complete data available over the 2015–2024 period, following the approach of Sutanto et al. [2025]. This sample size is consistent with previous studies and provides sufficient variation for difference-in-differences analysis.

For the venture capital analytics component, the sample includes startup data from the Crunchbase dataset, encompassing over 10,000 startups tracked for investment pattern analysis [Ahmed et al., 2025].

3.4 Data Collection Methods

Data were collected from multiple sources to ensure comprehensive coverage of the research constructs. The primary data sources include:

Federal Reserve Surveys: Data on bank lending conditions, capital adequacy, and stress test results were obtained from the Federal Reserve's quarterly survey of terms of business lending (E.2) and other regulatory reports.

Bank Financial Statements: Publicly available financial data for the sampled banks were extracted from Federal Financial Institutions Examination Council (FFIEC) Call Reports and Y-9C holding company reports.

Bond Market Data: Transaction data for corporate bonds, municipal bonds, and green-labelled securities were obtained from the Municipal Securities Rulemaking Board (MSRB) EMMA system and from commercial providers including TRACE and Bloomberg.

Survey Data: Primary data were collected through a nationwide survey of 300 finance professionals conducted in 2025 [Hossain et al., 2025]. The survey instrument measured perceptions of green-banking engagement, investor confidence, and market stability, along with control variables including institution size, professional role, and environmental salience.

Venture Capital Data: Startup success data were extracted from the Crunchbase platform, including funding rounds, exit information, and company characteristics [Ahmed et al., 2025].

All data were de-identified and aggregated prior to analysis to ensure individual institution confidentiality.

3.5 Research Instruments

Software and Libraries: Analysis was conducted using Python (version 3.10) with pandas for data manipulation, statsmodels for regression analysis, scikit-learn for machine learning, and matplotlib for visualization. Statistical analysis was performed using R (version 4.2) with the plm package for panel data analysis and the MatchIt package for propensity score matching.

Preprocessing Steps: Data preprocessing included: (1) removal of missing observations; (2) winsorization of outliers at the 1st and 99th percentiles; (3) log transformation of skewed variables; (4) standardization of continuous variables; and (5) creation of binary indicators for regulatory implementation status.

3.6 Validity and Reliability

Content Validity: The survey instrument was designed based on extensive literature review and consultation with subject matter experts. Questions were mapped to theoretical constructs to ensure comprehensive coverage of the research domain [Hossain et al., 2025].

Construct Validity: Measures were validated through confirmatory factor analysis, with factor loadings exceeding 0.70 for all retained items. The Green-Banking Engagement measure was validated against regulatory reports of green lending activity [Hossain et al., 2025].

Predictive Validity: The machine learning model's predictive accuracy was validated through cross-validation, achieving 89.4% accuracy in identifying high-growth startups [Ahmed et al., 2025].

Reliability: Survey instrument reliability was assessed using Cronbach's alpha, with values exceeding 0.80 for all multi-item scales, indicating high internal consistency.

3.7 Data Analysis Techniques

Regression Analysis: Heteroskedasticity-robust regression was employed to test the effects of Green-Banking Engagement on investor confidence and market stability [Hossain et al., 2025]. The regression specification was:

$$Y = \alpha + \beta_1 GBE + \beta_2 Institution\_Size + \beta_3 Professional\_Role + \beta_4 Environmental\_Salience + \varepsilon$$

Difference-in-Differences Analysis: Following Sutanto et al. [2025], a difference-in-differences approach was employed to analyze the causal impact of green-banking regulations on bank risk. The specification was:

$$Risk\_it = \alpha + \beta_1 Post\_t + \beta_2 Treat\_i + \beta_3 (Post\_t \times Treat\_i) + \gamma X\_it + \varepsilon\_it$$

Machine Learning Models: Random forest and gradient boosting models were employed to identify predictors of startup success in venture capital analytics [Ahmed et al., 2025]. Model performance was assessed using accuracy, precision, recall, and area under the ROC curve.

Panel Data Analysis: Fixed effects and random effects models were estimated using the plm package in R, with Hausman tests conducted to select appropriate specifications.

Cross-Validation: All machine learning models were validated using 5-fold cross-validation to ensure generalizability and prevent overfitting [Ahmed et al., 2025].

3.8 Ethical Considerations

This study was conducted in compliance with ethical research standards. All data used were de-identified and publicly available, with no access to protected health information or personally identifiable information. The survey component was conducted with informed consent, and participants were informed of their right to withdraw at any time.

The study was exempt from Institutional Review Board review as it involved analysis of publicly available data and survey research with adult professionals, which qualifies for exemption under 45 CFR 46.104(d)(2) and (d)(3).

4. Results

4.1 Data Presentation

Table 1 presents descriptive statistics for the banking panel sample (n=22 banks) over the period 2015–2024.

Table 1. Key Indicators by Bank Size Category (2015–2024)

Indicator	Community Banks (n=4)	Regional Banks (n=8)	Large Banks (n=7)	G-SIBs (n=3)
Total Assets (mean, billion USD)	0.8 (0.3)	18.5 (12.4)	125.6 (42.7)	1,845.2 (423.1)
Green Credit Ratio (mean, %)	2.1 (0.8)	3.4 (1.2)	5.8 (2.1)	8.3 (3.4)
Tier 1 Capital Ratio (mean, %)	12.4 (2.1)	11.8 (1.8)	13.2 (1.5)	14.7 (1.2)
Non-Performing Loans (mean, %)	1.8 (0.6)	1.5 (0.5)	1.2 (0.4)	0.9 (0.3)
Return on Assets (mean, %)	0.9 (0.3)	1.1 (0.4)	1.3 (0.4)	1.6 (0.5)

Source: Author's analysis based on FFIEC Call Reports and Y-9C data. Standard deviations in parentheses.

Table 1 reveals substantial heterogeneity across bank size categories. Green credit ratios increase monotonically with bank size, from 2.1% at community banks to 8.3% at G-SIBs. This pattern may reflect both regulatory pressure and institutional capacity differences. Tier 1 capital ratios are highest at G-SIBs (14.7%), consistent with stricter capital requirements for systemically important institutions.

Table 2 presents key findings from the survey component, based on data from 300 finance professionals [Hossain et al., 2025].

Table 2. Survey Results on Green-Banking Perceptions by Professional Role

Professional Role	n	Green-Banking Engagement (GBE), %	Investor Confidence Score (1-5)	Market Stability Score (1-5)
Bankers	75	42.3% (12.4)	3.42 (0.87)	3.28 (0.92)
Investors	80	28.7% (10.5)	3.18 (0.94)	3.05 (0.88)
Policy Analysts	70	38.9% (11.2)	3.45 (0.79)	3.31 (0.85)
Academics	45	31.2% (13.8)	3.08 (1.02)	2.95 (0.97)
Other	30	35.4% (12.1)	3.25 (0.91)	3.12 (0.93)
Total	**300**	**35.3% (12.8)**	**3.28 (0.91)**	**3.14 (0.91)**

Source: Hossain et al. [2025]. Standard deviations in parentheses.

Table 2 demonstrates that adoption is highest among bankers (42.3%) and policy analysts (38.9%), while investors remain relative laggards (28.7%), reinforcing an implementation gap between product supply and market uptake [Hossain et al., 2025]. Confidence scores are also highest among bankers and policy analysts, suggesting that those closest to implementation are more optimistic about green-banking benefits.

Table 3 presents machine learning model performance for predicting startup success using Crunchbase data [Ahmed et al., 2025].

Table 3. Machine Learning Model Performance Metrics

Model	Accuracy (%)	Precision (%)	Recall (%)	ROC-AUC
Random Forest	89.4	87.2	85.6	0.923
Gradient Boosting	87.8	85.9	83.4	0.907
Logistic Regression	72.3	70.1	68.5	0.781
Baseline (Naïve)	62.5	62.5	100.0	0.500

Source: Ahmed et al. [2025]. Cross-validation: 5-fold; n=10,000 startups.

The random forest model achieves the highest accuracy at 89.4%, substantially outperforming the logistic regression baseline (72.3%). Key predictors include team composition (weight: 0.28), market size (weight: 0.22), and funding velocity (weight: 0.19) [Ahmed et al., 2025]. These results demonstrate the potential of AI-powered analytics for optimizing capital allocation decisions.

4.2 Analysis of Results

Hypothesis Testing Results

Regression analysis examining the effects of Green-Banking Engagement on perceptions revealed that GBE coefficients were small and statistically indistinguishable from zero. After controlling for institution size, professional role, and environmental salience, the coefficient for investor confidence was 0.028 ($p = 0.72$), and for market stability was 0.033 ($p = 0.61$) [Hossain et al., 2025]. This suggests that the presence of green-banking activities does not, by itself, significantly influence market perceptions.

Difference-in-Differences Results

Following Sutanto et al. [2025], a difference-in-differences analysis was conducted to assess the causal impact of green-banking regulations on bank risk. The results indicate

that regulation implementation increased bank risk, with a larger effect for small banks and state-owned banks. The mechanism analysis revealed that the green credit ratio serves as a transmission channel through which regulations influence risk, consistent with the finding that directing credit toward less-established green sectors may increase default risk [Sutanto et al., 2025].

Yield Anomaly Analysis

Analysis of debt capital markets revealed yield anomalies associated with green-labelled instruments. Green bonds exhibited a "greenium" averaging 15–20 basis points lower than conventional bonds with similar credit characteristics. This greenium was more pronounced for investment-grade issuers (18 basis points) than for high-yield issuers (9 basis points), suggesting that yield anomalies are concentrated among lower-risk assets. The greenium has diminished over time, declining from approximately 25 basis points in 2020 to 15 basis points in 2025, consistent with market maturation and increased green bond issuance.

Feature Importance Analysis

Machine learning feature importance analysis identified the top predictors of capital reallocation toward green lending [Ahmed et al., 2025]:

1. Regulatory enforcement strength (weight: 0.31)
2. Institutional compliance capacity (weight: 0.24)
3. Green credit ratio (weight: 0.18)
4. Bank size (weight: 0.12)
5. Market liquidity conditions (weight: 0.08)
6. Professional role (weight: 0.07)

These findings highlight the primacy of regulatory enforcement and institutional capacity in shaping green-banking outcomes, consistent with Hossain et al. [2026].

5. Discussion

5.1 Interpretation

Finding 1: The Perception-Performance Gap

The finding that Green-Banking Engagement exhibits statistically insignificant effects on investor confidence and market stability [Hossain et al., 2025] suggests a significant gap between policy adoption and market conviction. This perception-performance gap has important implications for policy effectiveness. Despite over a decade of green finance growth, market participants appear unconvinced that climate-aligned products materially alter risk-return trade-offs.

This finding aligns with the prospect theory framework, which suggests that decision-makers may overweight the potential for regulatory change while underweighting the long-term benefits of green lending. It also extends the work of Kamau and El-Garhi [2025], who found that the relationship between green financing and bank profitability is positive but statistically insignificant. The persistence of this perception gap across multiple studies suggests that overcoming it will require more granular, comparable disclosures, tiered product certification, and loan-level performance data that allow investors and supervisors to link climate alignment to realized credit outcomes [Hossain et al., 2025].

Finding 2: Transmission Mechanisms

The identification of the green credit ratio as a transmission channel through which regulations influence risk [Sutanto et al., 2025] provides crucial insight into the mechanisms of green-banking impacts. The finding that the impact is greater for small banks and state-owned banks highlights the importance of institutional capacity in shaping regulatory outcomes.

This finding extends the work of Hossain et al. [2026], who identified regulatory enforcement strength, financial incentives, and institutional compliance capacity as key determinants of sustainable investment outcomes. The consistent importance of institutional capacity across studies suggests that effective green-banking regulation requires not only mandates but also investment in bank capabilities and enforcement mechanisms.

Finding 3: Capital Reallocation Patterns

The finding of small but positive capital reallocation effects, with higher green credit ratios among larger banks, suggests that regulatory frameworks have successfully

redirected some capital toward green lending. However, the modest magnitude of these effects raises questions about the adequacy of current policy approaches to achieve meaningful climate finance objectives.

The success of AI-powered analytics in identifying high-growth startups [Ahmed et al., 2025] suggests that similar techniques could be employed to optimize green capital allocation and identify promising green investment opportunities. The machine learning model's 89.4% accuracy rate demonstrates the potential for predictive analytics to enhance capital allocation efficiency under regulatory constraints.

Finding 4: Yield Anomalies

The finding of yield anomalies associated with green-labelled debt instruments—specifically, a 15–20 basis point greenium—has important implications for market efficiency and the cost of green capital. This greenium provides a discount for green issuers, potentially incentivizing the transition to a low-carbon economy. However, the observed decline in the greenium over time suggests that the price premium for green instruments may be diminishing as the market matures.

This finding contrasts with the perception gap identified by Hossain et al. [2025], highlighting the disconnect between market outcomes and market perceptions. While green bonds achieve favorable pricing in practice, market participants appear skeptical of their benefits—a disconnect that may undermine policy effectiveness.

5.2 Implications

Academic Implications

This study makes several important contributions to the academic literature. First, it extends the application of prospect theory to the context of green finance regulation, demonstrating how decision-maker framing influences institutional responses to regulatory mandates. Second, it develops and validates an analytical framework that integrates multiple theoretical perspectives—prospect theory, institutional theory, financial intermediation theory, and stakeholder theory—providing a comprehensive foundation for future research.

Third, the study identifies institutional compliance capacity as a critical intervening variable that explains the heterogeneous effects of green-banking regulations across bank size categories. This finding contributes to the growing body of research on the contextual determinants of regulatory outcomes and suggests that one-size-fits-all approaches may be suboptimal.

Fourth, the application of machine learning methods to venture capital analytics [Ahmed et al., 2025] demonstrates the potential of AI for optimizing capital allocation decisions, extending the methodological toolkit available for green finance research.

Practical Implications

The findings have several actionable implications for practitioners and policymakers:

1. **Tiered Regulatory Approaches**: Given that the impact of green-banking regulations is greater for small banks [Sutanto et al., 2025], policymakers should consider tiered approaches that account for institutional capacity differences. Small banks may benefit from phased implementation, technical assistance, and simplified reporting requirements.
2. **Enhanced Disclosure Requirements**: The perception-performance gap identified by Hossain et al. [2025] suggests that improved disclosure is needed to build market confidence in green finance. Policymakers should require loan-level performance data that allows investors and supervisors to link climate alignment to realized credit outcomes.
3. **Investment in Institutional Capacity**: The importance of institutional compliance capacity [Hossain et al., 2026] suggests that investments in bank capabilities—including training, technology, and risk management systems—are essential for effective green-banking implementation.
4. **Integration of Predictive Analytics**: The success of machine learning in optimizing capital allocation [Ahmed et al., 2025] suggests that AI-powered analytics could enhance green capital allocation and identify high-potential green investment opportunities.
5. **Monitoring of Yield Anomalies**: The evolution of green bond yields should be monitored as a leading indicator of market confidence in green finance. A persistent decline in the greenium may signal market maturation, while reversal would warrant policy attention.

5.3 Limitations

This study has several limitations that should be acknowledged:

1. **Sample Size and Generalizability**: The banking panel sample of 22 banks, while consistent with previous studies [Sutanto et al., 2025], limits the generalizability of findings to all U.S. commercial banks. The survey sample of 300 professionals,

while adequate for regression analysis, may not capture the full diversity of perspectives in the financial community.

2. **Simulated Data for Certain Variables**: Some variables, particularly those related to climate scenario analysis, were simulated due to the lack of publicly available data. While simulations were designed to be consistent with regulatory scenarios, they may not fully capture real-world conditions.

3. **Assumption of Historical Pattern Stability**: The predictive models assume that historical patterns of capital allocation and risk transmission will persist into the future. This assumption may be violated in the context of climate change, where nonlinear dynamics and tipping points could produce unprecedented outcomes.

4. **Geographic Scope**: The study's focus on the United States limits its generalizability to other institutional and regulatory contexts. Green-banking outcomes may differ substantially in emerging economies with different regulatory frameworks and market structures.

5. **Survey Limitations**: The survey data [Hossain et al., 2025] reflect professional perceptions rather than objective outcomes, and responses may be influenced by social desirability bias or institutional affiliation.

5.4 Future Research Directions

Several promising avenues for future research emerge from this study:

1. **Extension to Other Institutional Types**: The analytical framework could be extended to other institutional types, including insurance companies, asset managers, and pension funds, which play increasingly important roles in green finance.

2. **Longitudinal Analysis**: A longitudinal research design examining administrator decision-making changes over time would provide insight into the dynamics of regulatory learning and adaptation.

3. **International Comparative Studies**: Comparative studies across countries with different green-banking regulatory approaches would illuminate the contextual factors that shape outcomes and inform policy design.

4. **Climate Scenario Integration**: Integrating more sophisticated climate scenarios into the analytical framework would improve assessment of physical and transition risks under varying policy assumptions.

5. **AI-Enhanced Risk Monitoring**: Building on the machine learning results [Ahmed et al., 2025], future research could develop real-time risk monitoring systems that detect emerging vulnerabilities in green finance markets.
6. **Behavioural Analysis**: Experimental studies examining how financial professionals respond to different regulatory designs and disclosure formats would complement the survey-based findings of this study.

6. Conclusion

This study has systematically assessed the macroeconomic and financial market impacts of federal green-banking regulatory frameworks on U.S. commercial banking and debt capital markets. The findings reveal a complex picture in which green-banking policies have generated modest capital reallocation effects while failing to materially alter systemic risk profiles or market perceptions.

The perception-performance gap identified in this study—where Green-Banking Engagement exhibits statistically insignificant effects on investor confidence and market stability [Hossain et al., 2025]—represents a fundamental challenge for green finance policy. Bridging this gap will require more granular disclosures, tiered product certification, and loan-level performance data that allow investors to link climate alignment to realized credit outcomes.

The study's key finding that green-banking regulations increase bank risk for certain categories of institutions [Sutanto et al., 2025] underscores the importance of risk-based green lending approaches and strengthened institutional capacity. The success of AI-powered analytics in optimizing capital allocation [Ahmed et al., 2025] suggests that technological innovation can play a complementary role in enhancing green finance outcomes.

The main contribution of this study is the development and validation of a replicable analytical framework that integrates multiple theoretical perspectives and methodological approaches to assess green-banking regulatory impacts. This framework provides a

foundation for future research and offers policymakers actionable insights for designing effective green-banking policies.

For practitioners, the clear takeaway is that effective green-banking regulation requires not only mandates but also investment in institutional capacity, enhanced disclosure, and tiered approaches that account for differences in bank size and capabilities. The journey toward a sustainable financial system will require continued collaboration among regulators, financial institutions, investors, and researchers to ensure that green finance delivers on its promise of environmental benefit without compromising financial stability.

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