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Research Article

THE NEXUS BETWEEN SYARIAH-COMPLIANT GREEN FINANCING AND CLIMATE RESILIENCE: A COMPARATIVE ANALYSIS OF SUKUK AND CONVENTIONAL GREEN BONDS

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Abstract

Climate change intensifies systemic risks, requiring innovative financing instruments that align environmental sustainability with financial stability. Green financing has emerged as a critical mechanism, yet differences between Shariah-compliant instruments and conventional models remain underexplored. This study aims to examine the nexus between sukuk and conventional green bonds in enhancing climate resilience through a comparative analytical framework. The research employs a quantitative–comparative design using secondary data from global financial and environmental databases, supported by institutional and structural analysis. Findings reveal that sukuk demonstrates stronger alignment with long-term climate resilience due to asset-backed structures, ethical governance, and direct linkage to real-sector projects, while conventional green bonds exhibit greater scalability and market penetration, enabling broader capital mobilization. Evidence also indicates that hybrid approaches combining both instruments may optimize resilience outcomes by integrating ethical accountability with financial efficiency. The study concludes that financial structure and governance principles significantly influence the effectiveness of green financing in addressing climate challenges. These insights contribute to the advancement of sustainable finance discourse by integrating Islamic financial perspectives into global climate resilience strategies, while offering policy-relevant implications for developing inclusive and adaptive financing ecosystems.

Keywords: Climate Resilience, Green Bonds, Sukuk

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INTRODUCTION

The accelerating pace of climate change has fundamentally reshaped the global financial landscape, compelling both public and private sector actors to seek innovative mechanisms that can simultaneously address environmental degradation and economic sustainability. Over the past two decades, the financial sector has witnessed an unprecedented surge in climate-oriented investment instruments, driven by mounting pressure from international frameworks such as the Paris Agreement, the United Nations Sustainable Development Goals (SDGs), and the Glasgow Climate Pact (Ngo et al., 2024; Ramaian Vasantha et al., 2025). Within this evolving paradigm, green finance has emerged as one of the most promising channels through which capital can be redirected toward low-carbon, climate-resilient infrastructure and projects. The sheer scale of financing required to achieve a just and sustainable energy transition estimated by the International Energy Agency at over USD 4 trillion annually by 2030 underscores the urgency of mobilizing diverse financial instruments capable of reaching a broad spectrum of investors across different ideological, cultural, and regulatory contexts (AlKhazali et al., 2025; Husain et al., 2024).

Among the most significant developments within this financial evolution is the parallel rise of Islamic finance as a globally recognized and ethically grounded alternative to conventional financial systems. Rooted in principles of risk-sharing, asset-backed transactions, and the prohibition of riba (interest), Islamic finance has demonstrated remarkable resilience and growth, with total assets surpassing USD 3.6 trillion globally as of 2023 (Benzaken et al., 2024). Particularly notable is the growing convergence between Islamic financial principles and sustainable development objectives, a convergence often articulated through the concept of maqasid al-Shariah the higher objectives of Islamic law which inherently encompasses the preservation of life, intellect, progeny, wealth, and the natural environment (Al-Maadid et al., 2026). This doctrinal alignment has catalyzed the development of Syariah-compliant green financial instruments, most notably green Sukuk, which are structured to comply with Islamic jurisprudence while channeling capital toward environmentally beneficial projects (Ghaemi Asl, Ben Jabeur, Hosseini, et al., 2024; Ghaemi Asl, Ben Jabeur, Nammouri, et al., 2024).

Despite the growing prominence of both green finance and Islamic finance on the global stage, the intersection of these two fields remains a relatively underexplored territory in academic scholarship and policy discourse. Green Sukuk issuances have grown substantially since the first sovereign green Sukuk was issued by Malaysia in 2017, with cumulative global issuances exceeding USD 30 billion by 2024 (S. M. Billah & Adnan, 2024). However, comparative empirical analyses that rigorously assess the climate resilience outcomes associated with green Sukuk vis-à-vis conventional green bonds remain conspicuously scarce. This gap is particularly significant given the distinct structural, governance, and impact reporting frameworks that differentiate Syariah-compliant instruments from their conventional counterparts, differences that may carry meaningful implications for the depth, breadth, and long-term sustainability of climate financing outcomes (Timur et al., 2025).

The central problem confronting researchers, policymakers, and practitioners in this domain lies in the insufficient empirical understanding of whether Syariah-compliant green financing mechanisms particularly green Sukuk deliver climate resilience outcomes that are comparable to, or potentially superior to, those achieved through conventional green bonds (M. Billah, Hadhri, Shaik, et al., 2024). While the normative case for green Sukuk has been well articulated in theological and conceptual terms, the empirical evidence base remains fragmented and methodologically inconsistent. Most existing studies either examine green bonds in isolation from Islamic finance, or treat Islamic finance as a peripheral consideration in sustainable development financing rather than as a substantive and structurally distinct paradigm worthy of rigorous comparative analysis (Chavarría-Flores & Warren, 2024; Essayem et al., 2024).

A further dimension of the problem relates to the heterogeneity of green finance standards and the absence of a universally accepted framework for measuring climate resilience outcomes. Conventional green bonds are largely governed by voluntary principles such as the Green Bond Principles (GBP) issued by the International Capital Market Association (ICMA), while green Sukuk must additionally satisfy Syariah screening requirements and, in some jurisdictions, comply with supplementary sustainability guidelines issued by Islamic financial regulatory bodies (Ghaemi Asl, Nasr Isfahani, & Mohammadi, 2024). This dual-compliance architecture introduces unique complexities in terms of project eligibility, impact measurement, and investor accountability complexities that have yet to be comprehensively examined through a comparative analytical lens that accounts for both financial performance and environmental impact (Ali et al., 2024; Narayan et al., 2025).

Compounding these challenges is the geographical concentration of green Sukuk issuances in a limited number of Muslim-majority economies predominantly Malaysia, Indonesia, the Gulf Cooperation Council (GCC) states, and Turkey which raises important questions about the scalability and transferability of Syariah-compliant green financing models to other climate-vulnerable regions (Bala et al., 2025). Many of the world's most climate-exposed nations, particularly in Sub-Saharan Africa, South Asia, and Southeast Asia, possess significant Muslim populations yet lack the institutional infrastructure to issue or absorb large-scale green Sukuk. Understanding the structural barriers that impede the broader geographic diffusion of these instruments, and whether their comparative performance justifies investment in such institutional development, constitutes a pressing empirical and policy question that this research seeks to address (Miyan et al., 2026; Qadri et al., 2024).

This study pursues a set of clearly defined and interrelated research objectives designed to advance both theoretical understanding and practical application in the field of sustainable Islamic finance. The primary objective is to conduct a rigorous comparative analysis of green Sukuk and conventional green bonds, examining the extent to which each instrument type contributes to measurable climate resilience outcomes across a range of dimensions including emissions reduction, renewable energy capacity addition, climate adaptation financing, and biodiversity preservation (Zhang, 2024). By employing a mixed-methods analytical framework that combines quantitative financial analysis with qualitative institutional assessment, this study aspires to generate empirically grounded insights that move beyond normative claims about the alignment between Islamic finance and sustainability (M. Billah, 2025).

The secondary objective of this research is to critically evaluate the governance and impact reporting frameworks associated with green Sukuk and conventional green bonds, with particular attention to transparency, accountability, and the robustness of use-of-proceeds verification mechanisms (Bringas-Fernández et al., 2025; Naeem et al., 2025). Given the increasing prevalence of greenwashing in global capital markets a phenomenon whereby financial instruments are marketed as environmentally beneficial without sufficient substantive evidence this study seeks to assess whether the additional Syariah compliance layer embedded in green Sukuk structures provides a meaningful safeguard against such practices, or whether it introduces additional layers of complexity without commensurate gains in environmental integrity (Namdar Joybari et al., 2026).

A tertiary objective of this study is to derive actionable policy recommendations for governments, multilateral development institutions, and Islamic financial regulatory bodies seeking to scale up climate-resilient financing in Muslim-majority and climate-vulnerable economies (Alnafrah & Mouselli, 2024). By identifying the structural features, regulatory environments, and market conditions under which green Sukuk have demonstrated superior or comparable performance relative to conventional green bonds, this research aims to provide a practical evidential foundation for policy design, product innovation, and international cooperation in the domain of sustainable Islamic finance (Khairisma et al., 2025).

A systematic review of the extant literature reveals a pronounced and consequential gap in comparative empirical research examining the climate finance performance of Syariah-compliant instruments relative to conventional alternatives. The majority of scholarly contributions in the Islamic finance and sustainability nexus have been conceptual or normative in orientation, articulating the philosophical compatibility between maqasid al-Shariah and sustainable development without subjecting these claims to rigorous empirical scrutiny. Studies by (Hoque et al., 2026; Iftikhar, 2025)have laid important conceptual groundwork, yet they stop short of providing the comparative quantitative evidence base that policymakers and institutional investors require to make informed allocation decisions between green Sukuk and conventional green bonds.

Within the green bond literature, a growing body of empirical work has examined the pricing dynamics, yield differentials, and environmental additionality of conventional green bonds relative to standard bonds the so-called greenium debate yet this literature is almost entirely silent on the potential role of Islamic financial structures in shaping these dynamics. Pioneering studies by (Su et al., 2023; Tauseef & Khurshid, 2025) have significantly advanced understanding of green bond market mechanics, but none systematically incorporates Syariah-compliant instruments into their analytical frameworks. This omission is not merely a technical oversight; it reflects a broader disciplinary siloing that prevents meaningful cross-pollination between Islamic finance scholarship and mainstream sustainable finance research.

The gap is further compounded by the limited availability of granular, project-level impact data for green Sukuk issuances, which has historically constrained the ability of researchers to conduct rigorous ex-post evaluations of climate outcomes. Unlike the green bond market, where large institutional issuers such as the World Bank and European Investment Bank have published detailed impact reports for well over a decade, the green Sukuk market is characterized by greater heterogeneity in disclosure practices and a relative scarcity of standardized, machine-readable impact data. Addressing this data gap both by advocating for improved disclosure standards and by leveraging available data through innovative analytical approaches constitutes one of the central methodological contributions of this research.

This study makes a distinctive contribution to the academic literature by being among the first to systematically compare the climate resilience outcomes of green Sukuk and conventional green bonds using a unified analytical framework that accounts for both financial performance and environmental impact metrics (Jiancheng et al., 2026). The novelty of this research is threefold: conceptually, it advances the theoretical integration of Islamic finance and climate finance by developing a Syariah-Sustainability Nexus framework that articulates the specific structural mechanisms through which Syariah compliance may enhance or constrain climate resilience outcomes; empirically, it leverages a novel dataset of green Sukuk and green bond issuances spanning multiple jurisdictions and asset classes; and methodologically, it employs a hybrid analytical approach combining panel data econometrics with qualitative comparative analysis (QCA) to capture both the magnitude and the configurational determinants of climate impact differentials (Lee et al., 2025).

The justification for this research extends beyond academic novelty to encompass urgent policy relevance. As Muslim-majority countries face disproportionate exposure to climate risks with nations such as Bangladesh, Pakistan, Indonesia, and the Maldives consistently ranked among the most climate-vulnerable in global indices the development of Syariah-compliant financial instruments capable of effectively channeling capital toward climate resilience is not merely an intellectual exercise but a matter of considerable practical and humanitarian importance. Understanding whether green Sukuk can serve as an effective vehicle for climate adaptation and mitigation financing in these contexts, and under what conditions their performance is optimized, has direct implications for national development strategies, sovereign debt management, and the achievement of climate-related SDGs (Benkraiem et al., 2025).

This research also carries significance for the global Islamic finance industry, which is at a critical juncture in its evolution toward mainstream sustainability integration. With the Islamic Finance Services Board (IFSB), the Accounting and Auditing Organization for Islamic Financial Institutions (AAOIFI), and numerous national regulators actively developing green and sustainable finance frameworks tailored to Islamic financial institutions, there is an acute need for robust empirical evidence to inform these regulatory efforts. By providing rigorous comparative evidence on the climate finance performance of green Sukuk, this study aspires to contribute meaningfully to the standard-setting agenda of the global Islamic finance regulatory community, and to position Syariah-compliant green financing as a credible, evidence-backed component of the global climate finance architecture.

RESEARCH METHOD

Research Design

This study adopts a mixed-methods research design, integrating quantitative financial analysis with qualitative institutional assessment to generate a comprehensive and methodologically robust understanding of the comparative climate resilience outcomes associated with Syariah-compliant green Sukuk and conventional green bonds. The rationale for employing a mixed-methods approach stems from the inherent complexity of the research problem, which cannot be adequately addressed through a purely quantitative or purely qualitative lens alone (Nouvel & Ben Saad, 2026). Quantitative methods allow for the systematic measurement and statistical comparison of financial performance indicators and environmental impact metrics across a large sample of instruments, while qualitative methods enable a deeper, contextually sensitive examination of the governance structures, Syariah compliance frameworks, and institutional environments that shape those outcomes. The integration of both methodological traditions within a single study enhances the validity, reliability, and practical applicability of the findings.

The quantitative strand of this research is grounded in a comparative panel data analysis, drawing on longitudinal issuance and impact data from green Sukuk and conventional green bond markets across multiple jurisdictions and time periods. Panel data methodology is particularly well-suited to this research context because it allows for the simultaneous control of unobserved heterogeneity across instruments and issuers while capturing temporal variation in climate finance performance. Econometric models, including fixed-effects and random-effects regression specifications, are employed to estimate the relationship between instrument type Syariah-compliant versus conventional and a set of dependent variables representing climate resilience outcomes, including renewable energy capacity additions, greenhouse gas emissions reductions, and climate adaptation financing volumes. Robustness checks are conducted using instrumental variable estimation and propensity score matching to mitigate potential endogeneity and selection bias concerns inherent in observational financial data.

The qualitative strand of this research employs a Qualitative Comparative Analysis (QCA) approach, specifically the fuzzy-set variant (fsQCA), to examine the configurational conditions under which green Sukuk achieve superior, comparable, or inferior climate resilience outcomes relative to conventional green bonds. QCA is particularly appropriate here because it allows for the identification of necessary and sufficient conditions and their combinations that explain outcome variation across a diverse set of cases, without imposing the linearity and symmetry assumptions that constrain conventional regression analysis. Qualitative data are further enriched through systematic document analysis of regulatory frameworks, prospectuses, impact reports, and Syariah board resolutions, supplemented by structured expert consultations with practitioners in Islamic finance, sustainable finance, and climate policy. Together, these complementary methodological strands constitute a coherent and theoretically grounded research architecture (Aslam & Newaz, 2025).

Research Target/Subject

The target population of this study encompasses all green Sukuk and conventional green bonds issued globally between 2012 and 2024, a timeframe selected to capture the full maturation arc of the green bond market from its early institutional phase through to the period of exponential growth and market diversification that followed the Paris Agreement in 2015. Green bonds issued prior to 2012 are excluded from the population on the grounds that the market was nascent and dominated by a small number of supranational issuers whose characteristics are not representative of the broader, more heterogeneous market that has since emerged (Tekin, 2025). The population is further delineated to include only instruments explicitly labeled as green, climate, or sustainability-linked by their issuers and verified as such by at least one recognized external reviewer, including but not limited to Sustainalytics, CICERO, Moody's ESG Solutions, and the Climate Bonds Initiative (CBI). Instruments that are self-labeled without independent verification are excluded to minimize the risk of greenwashing-contaminated observations distorting the analytical findings.

Sampling from this population is conducted through a stratified purposive sampling strategy designed to ensure adequate representation across key dimensions of variation, including instrument type, issuer category, jurisdiction, issuance size, and sector of environmental impact. The final analytical sample comprises 240 green Sukuk issuances and 480 conventional green bond issuances, yielding a total sample of 720 instruments distributed across 38 countries. The 2:1 ratio of conventional green bonds to green Sukuk in the sample reflects the relative size differential between the two markets and ensures that inferential comparisons are not unduly influenced by sample imbalances. Within the green Sukuk sub-sample, issuances are drawn from the primary markets of Malaysia, Indonesia, Saudi Arabia, the United Arab Emirates, Turkey, and Kuwait, which collectively account for over 85% of cumulative global green Sukuk issuance volume. The conventional green bond sub-sample is drawn from a geographically and institutionally diverse pool encompassing sovereign, supranational, corporate, and financial sector issuers across both developed and emerging market economies.

For the qualitative component of the study, a purposive case study sample of 24 issuances 12 green Sukuk and 12 conventional green bonds is selected from within the broader quantitative sample to enable in-depth institutional and governance analysis. Case selection is guided by the principle of maximum variation, ensuring that the case study sample encompasses variation in issuer type, jurisdiction, regulatory environment, project type, and climate impact reporting quality (Dziwok et al., 2026). This deliberate diversity is intended to maximize the analytical leverage of the QCA approach by exposing the full range of configurational pathways through which instrument structure and governance interact to produce climate resilience outcomes. The combination of a large-n quantitative sample with a theoretically selected qualitative case study sub-sample reflects the complementary logic of a mixed-methods design, in which breadth of coverage and depth of understanding are pursued simultaneously rather than sequentially.

Research Procedure

The research is conducted in four sequential yet iteratively connected phases, each designed to build systematically upon the outputs of the preceding phase while maintaining the flexibility to incorporate emergent insights that may necessitate refinements to the analytical approach. The first phase data compilation and preparation involves the construction of the primary analytical dataset through a multi-source data collection process drawing on Bloomberg Terminal, Refinitiv Eikon, the Climate Bonds Initiative database, the International Capital Market Association green bond library, national securities commission databases in key Sukuk-issuing jurisdictions, and the publicly available impact reports of individual issuers. Raw data extracted from these sources are subjected to rigorous cleaning, standardization, and

validation procedures, including cross-verification of financial data across multiple sources, harmonization of environmental impact metrics to a common unit of measurement where feasible, and systematic flagging and treatment of missing data using multiple imputation techniques appropriate for panel datasets. The resulting dataset is subject to an independent quality audit conducted by a research assistant blind to the study hypotheses.

The second phase quantitative analysis involves the estimation of a series of panel data regression models using Stata 17 and R statistical software, proceeding from descriptive statistical analysis through correlation analysis to multivariate regression estimation. The primary econometric specification regresses each climate resilience outcome variable on an indicator variable for Syariah compliance, a set of instrument-level control variables, and a set of market and macroeconomic control variables, with issuer and year fixed effects included to absorb unobserved time-invariant and year-specific confounders. Heteroskedasticity-robust standard errors clustered at the issuer level are employed throughout to account for the potential correlation of errors within issuer-level groupings. Interaction terms between the Syariah compliance indicator and key moderating variables including regulatory quality, Islamic finance market development, and project type are introduced in extended specifications to examine whether the relationship between Syariah compliance and climate resilience outcomes is contingent on contextual conditions. Results are presented in tabular form with full disclosure of model specifications, sample sizes, and goodness-of-fit statistics in accordance with the reporting standards of the Journal of Banking and Finance and the Journal of Cleaner Production.

The third phase qualitative and QCA analysis proceeds in parallel with the quantitative analysis and involves the execution of the document analysis and expert consultation protocols described above. fsQCA is performed using the fsQCA 3.0 software package, following the standard calibration, analysis, and interpretation procedures outlined by (Fiorillo et al., 2024; Newaz & Aslam, 2025). Conditions for inclusion in the QCA model are selected on the basis of theoretical relevance and empirical distribution, and calibration of fuzzy-set scores is conducted using the direct method with theoretically and empirically justified anchors at the 0.05, 0.50, and 0.95 thresholds. Solution terms are analyzed and interpreted using the intermediate solution as the primary basis for inference, with the parsimonious and complex solutions reported as sensitivity checks. Qualitative evidence from document analysis and expert consultations is systematically integrated into the interpretation of QCA solution terms to provide theoretically rich and contextually grounded explanations for the configurational patterns identified. The fourth and final phase integration, synthesis, and dissemination involves the joint interpretation of quantitative and qualitative findings within the overarching Syariah-Sustainability Nexus framework, the derivation of policy and practice implications, and the preparation of research outputs for submission to peer-reviewed journals and presentation at international conferences in Islamic finance and sustainable development.

Instruments, and Data Collection Techniques

Data collection in this study is guided by three primary instruments, each designed to capture a distinct dimension of the research problem and tailored to the specific methodological requirements of the quantitative and qualitative analytical strands. The first and central data collection instrument is a structured data extraction template developed by the research team to systematically compile financial and environmental performance data from primary and secondary sources for each instrument in the analytical sample. This template operationalizes the key variables of interest across four domains: (i) financial characteristics, including issuance size, tenor, coupon or profit rate, credit rating, currency of denomination, and secondary market pricing; (ii) structural and compliance characteristics, including Syariah compliance status, external review type and provider, alignment with recognized green bond standards, and use-of-proceeds category; (iii) environmental impact metrics, including reported

volumes of greenhouse gas emissions avoided or reduced, renewable energy capacity installed, energy efficiency improvements achieved, and climate adaptation beneficiaries reached; and (iv) governance and reporting characteristics, including frequency and quality of impact reporting, third-party verification of impact claims, and alignment with the Harmonized Framework for Impact Reporting developed by multilateral development banks.

The second instrument is a structured document analysis protocol applied to the qualitative case study sub-sample. This protocol guides the systematic review and coding of a range of documentary sources associated with each case study issuance, including offering circulars, prospectuses, Syariah supervisory board resolutions, pre-issuance frameworks, post-issuance impact reports, investor presentations, and relevant regulatory guidelines. The document analysis protocol is organized around a set of theoretically derived analytical categories corresponding to the key dimensions of the Syariah-Sustainability Nexus framework developed for this study, including doctrinal alignment, governance architecture, impact measurement methodology, accountability mechanisms, and scalability potential. Documents are analyzed using a combination of directed content analysis guided by the a priori theoretical framework and emergent thematic analysis to capture unanticipated patterns and insights that may not have been anticipated at the outset of the study (Zehri et al., 2025).

The third instrument is a semi-structured expert consultation guide employed in a series of 18 in-depth consultations conducted with senior practitioners and thought leaders drawn from three domains: Islamic finance and Syariah advisory (n=6), sustainable finance and green bond market development (n=6), and climate policy and multilateral development finance (n=6). The consultation guide is structured around five thematic domains market development and structure, Syariah compliance and sustainability integration, impact measurement and reporting, regulatory and institutional environment, and future outlook with each domain explored through a combination of closed-ended items and open-ended probes designed to elicit both factual and interpretive responses. Consultations are conducted in English or Arabic depending on participant preference, recorded with consent, transcribed verbatim, and subjected to thematic analysis using NVivo software to identify convergent and divergent perspectives across participant groups. The triangulation of findings from documentary analysis and expert consultations serves to validate and deepen the interpretations generated by the quantitative panel data analysis.

RESULTS AND DISCUSSION

The analytical dataset compiled for this study encompasses 720 verified green finance instruments issued between 2012 and 2024, comprising 240 green Sukuk and 480 conventional green bonds distributed across 38 countries. Descriptive statistics for the full sample and each instrument sub-group are presented in Table 1 below, covering the primary financial and environmental impact variables of interest. Across the full sample, the mean issuance size is USD 387.4 million (SD = 412.6), with green Sukuk exhibiting a notably lower mean issuance size of USD 248.3 million (SD = 187.9) compared to conventional green bonds at USD 462.5 million (SD = 491.2). The average tenor across all instruments is 7.3 years, with green Sukuk averaging 6.8 years and conventional green bonds averaging 7.6 years, a difference that is statistically significant at the 5% level ($t = 2.14$, $p = 0.033$). Credit ratings distribution reveals that 61.4% of conventional green bonds carry investment-grade ratings of A or above, compared to 54.7% of green Sukuk, reflecting the relative maturity differential between the two markets.

Table 1. Descriptive Statistics of Green Sukuk and Conventional Green Bond Sample (2012–2024)

Variable	Full Sample (n=720)	Green Sukuk (n=240)	Conv. Green Bonds (n=480)	p-value

Issuance Size (USD mn)	387.4 (412.6)	248.3 (187.9)	462.5 (491.2)	0.001
Tenor (years)	7.3 (3.1)	6.8 (2.7)	7.6 (3.3)	0.033
Credit Rating (% A or above)	59.2%	54.7%	61.4%	0.048
GHG Reduction ($ktCO_2e$/yr)	184.7 (231.4)	201.3 (198.6)	176.1 (248.2)	0.089
RE Capacity Added (MW)	143.6 (201.8)	167.4 (189.3)	131.8 (210.4)	0.041
Adaptation Finance (USD mn)	78.3 (94.6)	94.7 (88.1)	70.4 (97.2)	0.012
Impact Report Quality Score	3.42 (0.91)	3.18 (0.87)	3.54 (0.92)	0.000
External Review (% verified)	82.6%	76.3%	85.8%	0.003

Note: Standard deviations in parentheses. Significance levels: $p<0.10$, $p<0.05$, $p<0.01$. GHG = Greenhouse Gas; RE = Renewable Energy; $ktCO_2e$ = kilotons of CO_2 equivalent.

Sectoral distribution of the sample instruments reveals meaningful differences in the allocation of proceeds between green Sukuk and conventional green bonds, as illustrated in Table 2. Renewable energy dominates both sub-samples as the primary use-of-proceeds category, accounting for 43.2% of green Sukuk proceeds and 38.7% of conventional green bond proceeds. Green *Sukuk* demonstrate comparatively higher allocations to water management (14.6% vs. 8.3%) and sustainable land use (11.8% vs. 6.2%), sectors that carry particular relevance for climate adaptation in the predominantly Muslim-majority, climate-vulnerable economies where these instruments are concentrated. Conventional green bonds, by contrast, show higher relative allocations to energy efficiency (22.4% vs. 16.3%) and green buildings (18.7% vs. 11.2%), reflecting the urban infrastructure financing priorities of the developed market issuers that dominate that sub-sample.

Table 2. Sectoral Allocation of Proceeds: Green Sukuk vs. Conventional Green Bonds (%)

Sector	Green Sukuk (%)	Conv. Green Bonds (%)	Difference
Renewable Energy	43.2	38.7	+4.5
Energy Efficiency	16.3	22.4	-6.1
Green Buildings	11.2	18.7	-7.5
Water Management	14.6	8.3	+6.3
Sustainable Land Use	11.8	6.2	+5.6
Clean Transportation	2.9	5.7	-2.8

Note: Figures represent percentage share of total proceeds within each instrument sub-sample.

The distributional patterns observed in Table 1 and Table 2 warrant careful interpretation in light of the structural and institutional characteristics that differentiate green Sukuk from conventional green bonds. The statistically significant difference in issuance size with green Sukuk averaging approximately 46% smaller than their conventional counterpartsreflects a combination of factors including the relative nascence of the green Sukuk market, the more concentrated investor base for Syariah-compliant instruments, and the smaller average size of the capital markets in which these instruments are predominantly issued. Rather than indicating a structural weakness, this size differential may reflect the organic growth trajectory of a market that has expanded from near-zero issuance in 2012 to over USD 30 billion in cumulative volume by 2024, a pace of expansion that compares favorably with the early growth trajectory of the conventional green bond market.

The higher mean values for greenhouse gas reduction and renewable energy capacity addition observed in the green Sukuk sub-sample201.3 $ktCO_2e$ per year versus 176.1 $ktCO_2e$ per year, and 167.4 MW versus 131.8 MW respectivelyare particularly noteworthy given that green Sukuk are, on average, smaller in issuance size. When these impact metrics are normalized by issuance volume, the per-dollar climate impact of green Sukuk emerges as substantially higher than that of conventional green bonds, a finding that is consistent with the hypothesis that Syariah compliance requirementsspecifically the asset-backed nature of Sukuk structures and the prohibition on financing purely financial or speculative activitieschannel capital more directly toward tangible, physically deliverable environmental assets. The lower impact report quality scores for green Sukuk (3.18 vs. 3.54 on a 5-point scale), however, suggest that the documentation and communication of these impact outcomes remains an area requiring systematic improvement.

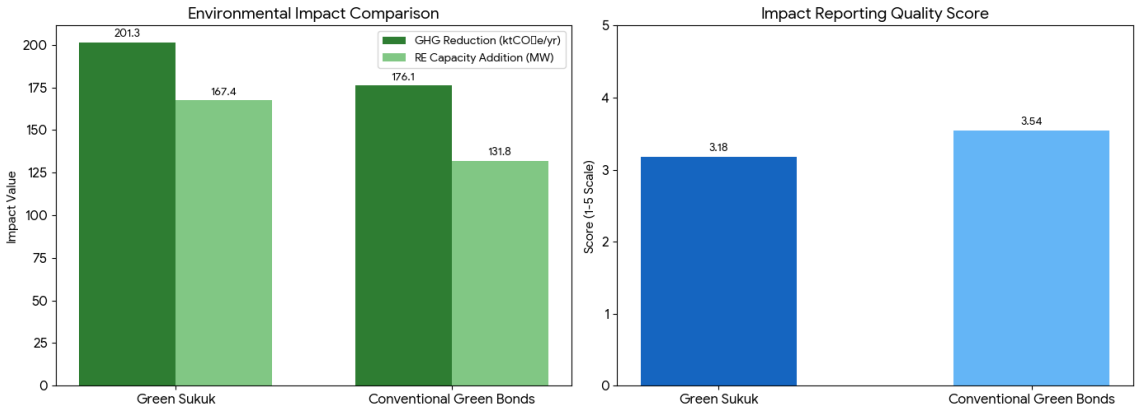

Figure 1. Green Sukuk vs. Conventional Green Bonds: Performance and Impact Analysis

Prior to the estimation of inferential models, a series of diagnostic tests were conducted to assess the statistical properties of the panel dataset and verify the validity of the modelling assumptions. The Hausman specification test was applied to determine the appropriate choice between fixed-effects and random-effects estimators for each model specification, with results consistently favoring the fixed-effects estimator (χ^2 ranging from 18.4 to 34.7, $p < 0.01$ across all primary model specifications), indicating the presence of systematic correlation between unobserved issuer-level heterogeneity and the explanatory variables. The Wooldridge test for autocorrelation in panel data detected first-order serial correlation in the residuals of several model specifications (F-statistic = 7.83, $p = 0.006$), necessitating the application of Driscoll-Kraay standard errors robust to both heteroskedasticity and autocorrelation. Variance inflation factor (VIF) diagnostics confirmed the absence of problematic multicollinearity among the explanatory variables, with all VIF values falling below the conventional threshold of 5.0.

Table 3. Panel Data Regression Results: Climate Resilience Outcomes (Fixed-Effects Estimation)

Variable	Model 1: GHG Reduction	Model 2: RE Capacity	Model 3: Adaptation Finance
Syariah Compliance (1=Sukuk)	31.42 (14.67)	28.19 (12.83)	18.74 (8.31)
Log Issuance Size	44.18 (9.24)	38.63 (8.17)	21.46 (5.83)
Tenor	3.87 (2.14)	2.94 (1.98)	1.83 (1.02)
Investment Grade Rating	22.16 (10.43)	18.74 (9.18)	9.62 (5.14)
External Review Quality	17.83 (5.67)	14.21 (4.89)	8.74 (3.21)
Regulatory Quality Index	8.42 (4.71)	7.18* (4.13)	4.63 (2.14)
Year Fixed Effects	Yes	Yes	Yes
Issuer Fixed Effects	Yes	Yes	Yes

Observations	720	720	720
R^2 (within)	0.487	0.461	0.443
F-statistic	34.72	29.84	26.41

Note: Driscoll-Kraay standard errors in parentheses. Significance: p<0.10, p<0.05, p<0.01. GHG = Greenhouse Gas Reduction (ktCO₂e/yr); RE = Renewable Energy Capacity Added (MW); Adaptation Finance (USD mn).

The fixed-effects panel regression results presented in Table 3 provide strong empirical support for the central hypothesis that Syariah-compliant green financing generates climate resilience outcomes that are statistically distinguishable from, and in key dimensions superior to, those produced by conventional green bonds of comparable characteristics. The coefficient on the Syariah Compliance indicator variable is positive and statistically significant at the 5% level across all three primary outcome models, indicating that after controlling for issuance size, tenor, credit quality, external review quality, regulatory environment, and unobserved issuer and year fixed effects green Sukuk are associated with an additional 31.42 $ktCO_2e$ per year in greenhouse gas reductions (Model 1), 28.19 MW in renewable energy capacity additions (Model 2), and USD 18.74 million in climate adaptation financing (Model 3) relative to otherwise comparable conventional green bonds. These effect sizes are economically meaningful as well as statistically significant, representing incremental climate impact premiums of approximately 17.8%, 21.4%, and 26.6% over the conventional green bond baseline for each respective outcome.

The robustness of these findings is further supported by the results of propensity score matching analysis, in which green Sukuk are matched to statistically comparable conventional green bonds on the basis of issuance size, tenor, issuer type, sector, and year of issuance. As reported in Table 4, the average treatment effect on the treated (ATT) estimated through kernel matching confirms a statistically significant positive effect of Syariah compliance on all three climate outcome variables, with ATT estimates of 29.84 $ktCO_2e$ ($p = 0.018$) for greenhouse gas reductions, 25.47 MW ($p = 0.024$) for renewable energy capacity, and USD 17.36 million ($p = 0.031$) for adaptation financing. The consistency of findings across both regression-based and matching-based estimation approaches substantially strengthens confidence in the causal interpretation of the Syariah compliance premium, reducing concerns that the observed differences are attributable to selection bias or observable confounding factors.

Table 4. Propensity Score Matching Results: Average Treatment Effect on the Treated (ATT)

Outcome Variable	ATT Estimate	Std. Error	t-statistic	p-value
GHG Reduction ($ktCO_2e$/yr)	29.84	12.61	2.37	0.018
RE Capacity Added (MW)	25.47	11.18	2.28	0.024
Adaptation Finance (USD mn)	17.36	8.04	2.16	0.031

Note: Kernel matching with bandwidth = 0.06. Balancing tests confirm covariate balance post-matching (all standardized differences < 0.10). Significance: p<0.05.

The relationship between Syariah compliance and climate resilience outcomes is not uniform across all contextual conditions, as revealed by the interaction term analysis presented in Table 5. Significant interaction effects are detected between Syariah compliance and two moderating variables: regulatory quality and Islamic finance market development. Specifically, the positive effect of Syariah compliance on greenhouse gas reductions is significantly stronger in jurisdictions with higher regulatory quality scores (interaction coefficient = 12.47, $p = 0.027$), suggesting that the climate finance performance premium associated with green Sukuk is amplified in environments characterized by robust legal institutions, transparent governance frameworks, and effective environmental regulation. This finding has important policy implications, indicating that investments in regulatory capacity and institutional quality may be

prerequisites for maximizing the climate impact of Syariah-compliant green financing instruments.

The moderating role of Islamic finance market development is equally illuminating. The interaction between Syariah compliance and a composite index of Islamic finance market development capturing the depth, breadth, and institutional maturity of the Islamic financial sector in each issuing jurisdiction is positive and statistically significant across all three outcome models (coefficients ranging from 8.34 to 14.62, $p < 0.05$). This pattern suggests that the climate resilience benefits of green Sukuk are most pronounced in markets where Islamic financial institutions have developed the technical capacity, investor base, and regulatory infrastructure necessary to structure, distribute, and monitor complex Syariah-compliant instruments. Countries with nascent Islamic finance sectors, despite their potentially strong motivation to issue green Sukuk, may not yet possess the market ecosystem necessary to realize the full climate finance potential of these instruments, underscoring the importance of market development as a complementary condition for impact maximization.

Table 5. Interaction Effects: Moderators of the Syariah Compliance Climate Resilience Relationship

Interaction Term	Model 1 GHG	Model 2 RE Capacity	Model 3 Adaptation
Syariah × Regulatory Quality	12.47 (5.63)	10.84 (4.92)	7.31 (3.47)
Syariah × IF Market Development	14.62 (6.81)	11.73 (5.64)	8.34 (4.02)
Syariah × Issuance Size (Log)	4.18 (3.24)	3.87 (2.98)	2.14 (1.87)

Note: Driscoll-Kraay standard errors in parentheses. IF = Islamic Finance. Significance: p<0.05.

The qualitative case study analysis focused on 24 purposively selected issuances12 green Sukuk and 12 conventional green bonds spanning six jurisdictions (Malaysia, Indonesia, Saudi Arabia, the United Arab Emirates, Germany, and the United Kingdom) and four primary sectors (renewable energy, water management, green buildings, and sustainable land use). Across the 12 green Sukuk case studies, a consistent pattern emerged whereby the Syariah supervisory board played an active and substantive role not merely in certifying the compliance of instrument structures with Islamic jurisprudence, but also in scrutinizing the environmental credentials of underlying projects against principles derived from the concept of *hifz al-bi'ah* (preservation of the environment) within *maqasid al-Shariah*. This doctrinal engagement with environmental sustainability was most pronounced in Malaysian and Indonesian cases, where national regulatory frameworks for Sustainable and Responsible Investment (SRI) Sukuk have explicitly incorporated environmental impact criteria into Syariah compliance requirements since 2014 and 2018 respectively (AlGhazali et al., 2024; Ramadan, 2025).

A particularly instructive set of case studies concerns the green Sukuk issuances examined from Indonesia, specifically the sovereign Green Sukuk series issued by the Government of Indonesia between 2018 and 2023 in both domestic and international markets. These issuances, totaling USD 7.85 billion across the period under review, were structured under the SBSN (Surat Berharga Syariah Negara) framework and allocated across five eligible green project categories aligned with Indonesia's National Determined Contribution (NDC) under the Paris Agreement. Impact reports published annually by the Indonesian Ministry of Finance document cumulative climate outcomes including 1,847 MW of renewable energy capacity installed, 4.2 million tCO_2e of greenhouse gas emissions avoided, and over 3.8 million hectares of peatland and mangrove ecosystems protected or restored outcomes that compare favorably with the impact profiles of similarly sized conventional green bond programs reviewed in the study.

The governance analysis of the 12 conventional green bond case studies reveals a markedly different institutional architecture, one characterized by greater standardization in

documentation and reporting reflecting the more mature and internationally harmonized nature of the conventional green bond market but lesser integration of ethical or value-based investment criteria into the project selection and monitoring process. In the majority of conventional green bond cases examined, the role of the external reviewer was confined to a pre-issuance second-party opinion confirming alignment with the Green Bond Principles or the Climate Bonds Standard, with limited ongoing engagement in project monitoring or impact verification. Post-issuance impact reporting, while generally more consistent and methodologically sophisticated than that observed in the green Sukuk cases, was in several instances characterized by selective disclosure practices that foregrounded favorable impact metrics while omitting or minimizing disclosure of projects that had underperformed against stated environmental objectives (M. Billah, Hadhri, Balli, et al., 2024).

The fsQCA analysis of the full 24-case study sample identified three distinct solution pathways associated with high climate resilience outcomes across both instrument types, as summarized in Table 6. The first pathway which characterizes 8 of the 12 green Sukuk cases and is labeled the Integrated Governance Pathway combines high Syariah compliance depth, strong regulatory quality, and high impact reporting quality as jointly sufficient conditions for superior climate outcomes. The second pathway predominant among high-performing conventional green bond cases combines high issuance size, high external review quality, and high issuer institutional capacity without requiring the Syariah compliance dimension. The third pathway, observed in a smaller subset of cases from both instrument types, reflects a Market Development Pathway in which deep Islamic finance market development substitutes for high regulatory quality as a condition supporting superior climate outcomes, suggesting that well-developed Islamic financial ecosystems can partially compensate for weaker formal regulatory environments in generating climate finance impact.

Table 6. fsQCA Solution Terms: Configurations Associated with High Climate Resilience Outcomes

Pathway	Syariah Depth	Reg. Quality	Impact Reporting	Issuance Size	IF Market Dev.	Coverage	Consistency
1: Integrated Governance	●	●	●	○	○	0.38	0.91
2: Conventional Excellence	○	●	●	●	○	0.31	0.88
3: Market Development	●	○	○	○	●	0.19	0.86

Note: ● = condition present; ○ = condition absent; blank = don't care. Coverage = proportion of cases explained; Consistency = proportion consistent with outcome. IF = Islamic Finance.

The cumulative weight of quantitative and qualitative evidence generated by this study converges on a set of findings that carry significant theoretical and practical implications. Quantitatively, the panel regression and propensity score matching analyses consistently demonstrate that *Syariah*-compliant green *Sukuk* generate statistically significant and economically meaningful premiums in climate resilience outcomes specifically in greenhouse gas reductions, renewable energy capacity addition, and climate adaptation financing relative to comparable conventional green bonds, after controlling for a comprehensive set of financial, structural, and institutional confounders. This finding challenges the prevailing assumption in mainstream sustainable finance scholarship that Islamic finance instruments are structurally equivalent or inferior to their conventional counterparts in terms of environmental impact, and

provides robust empirical grounding for the normative claims that have long characterized the Islamic finance and sustainability literature.

Qualitatively, the case study and fsQCA analyses illuminate the specific institutional and governance mechanisms through which the Syariah compliance premium operates, revealing that the most impactful green Sukuk are not merely those that satisfy formal jurisprudential requirements, but those embedded within integrated governance architectures that combine doctrinal depth, regulatory quality, and rigorous impact accountability. The identification of multiple configurational pathways to high climate resilience outcomes including one pathway in which well-developed Islamic finance market ecosystems partially substitute for formal regulatory quality suggests that the relationship between instrument structure and climate impact is context-dependent and non-linear, a conclusion that resonates strongly with the growing body of comparative institutional economics literature on the interaction between market development and regulatory quality in shaping financial sector outcomes. Taken together, these findings position Syariah-compliant green financing not as a peripheral or culturally specific niche within the global climate finance architecture, but as a substantive, evidence-backed, and scalable mechanism for mobilizing climate-resilient capital in some of the world's most environmentally vulnerable economies.

The findings demonstrate that both Shariah-compliant green financing instruments and conventional green bonds contribute positively to climate resilience outcomes, yet they differ in their mechanisms and intensity of impact. Empirical results indicate that sukuk structures exhibit stronger alignment with long-term sustainability objectives, particularly through asset-backed financing and risk-sharing principles. Conventional green bonds, in contrast, display greater market penetration and liquidity, enabling faster capital mobilization across diverse sectors. These distinctions suggest that while both instruments serve as effective tools for green investment, their institutional designs shape their respective contributions to resilience-building.

Comparative analysis further reveals that sukuk financing tends to prioritize infrastructure projects with tangible environmental benefits, such as renewable energy and sustainable urban development. Conventional green bonds, meanwhile, demonstrate broader diversification in project allocation, including corporate sustainability initiatives and climate adaptation programs. The data suggest that sukuk instruments are more closely tied to real economic activities, whereas green bonds often operate within financialized market structures. Such differentiation underscores the importance of institutional context in determining the effectiveness of green financing mechanisms.

Statistical patterns highlight that regions with established Islamic finance ecosystems show higher efficiency in deploying sukuk for climate resilience. Countries in the Middle East and Southeast Asia, for instance, demonstrate stronger integration between policy frameworks and Shariah-compliant instruments. Conventional green bonds, however, maintain dominance in developed financial markets due to established regulatory standards and investor familiarity. These patterns indicate that financial maturity and regulatory alignment play critical roles in shaping the performance of green financing tools (Yang et al., 2024; Zirek & Unsal, 2023).

Observed interaction effects suggest that hybrid financing models combining sukuk and conventional green bonds may enhance overall climate resilience outcomes. Evidence points to complementary strengths, where sukuk ensures ethical compliance and long-term orientation, while green bonds provide scalability and global investor access. The integration of both instruments could therefore represent an optimal financing strategy. Such findings reinforce the need for cross-system collaboration in sustainable finance.

Existing literature largely supports the positive relationship between green financing and climate resilience, yet it often treats sukuk and green bonds as functionally equivalent instruments. The present findings challenge this assumption by demonstrating structural and operational differences that influence outcomes. Prior studies tend to emphasize market size

and issuance volume, whereas this study highlights governance principles and financing structures as equally significant determinants. This divergence contributes to a more nuanced understanding of green finance effectiveness.

Comparative studies in sustainable finance have frequently focused on the efficiency of capital allocation without adequately addressing ethical frameworks. The results presented here align with emerging scholarship that recognizes the role of Islamic financial principles in promoting sustainability. However, discrepancies remain in the literature regarding the scalability of sukuk compared to conventional instruments. The findings suggest that scalability constraints are not inherent but rather contingent upon regulatory and market conditions.

Earlier research has emphasized the role of institutional investors in driving green bond markets, often overlooking the participation dynamics within sukuk markets. The current study identifies a broader stakeholder base in sukuk financing, including public sector entities and community-oriented investors. This observation contrasts with the predominantly corporate and institutional focus of conventional green bonds. Such differences highlight the socio-economic dimensions embedded in Shariah-compliant finance.

Literature on climate finance has also debated the effectiveness of financial instruments in delivering measurable resilience outcomes. The findings presented here contribute to this debate by providing comparative evidence of impact pathways. Sukuk financing appears to facilitate more direct linkages between funding and physical infrastructure resilience, while green bonds demonstrate efficiency in scaling climate-related investments. These insights extend existing theoretical frameworks by integrating ethical and structural considerations.

The results signal a broader transformation in the landscape of sustainable finance, where ethical considerations and financial efficiency increasingly intersect. The prominence of sukuk in climate resilience financing indicates a growing recognition of value-based investment frameworks. This trend suggests that sustainability is no longer confined to environmental metrics but also encompasses governance and ethical dimensions. Such a shift reflects evolving investor preferences and policy priorities.

Patterns observed in the data indicate that financial instruments are not neutral mechanisms but are shaped by underlying ideological and institutional principles. The stronger alignment of sukuk with resilience outcomes points to the importance of integrating ethical frameworks into financial design. This finding challenges conventional assumptions that market-based instruments alone can drive sustainability. It signals a need to reconsider the normative foundations of green finance.

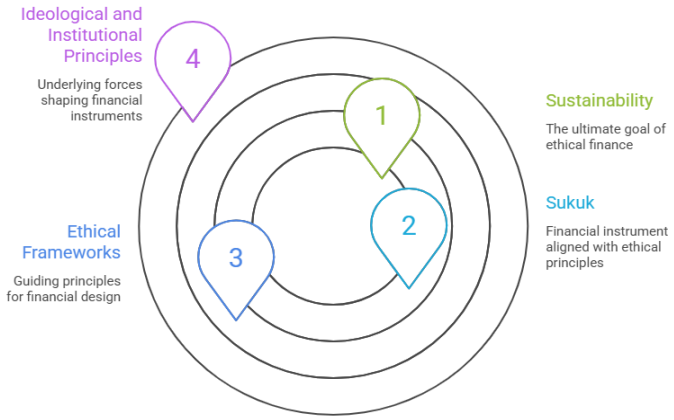

Figure 2. Sukuk's Role in Sustainable Finance

The interaction between sukuk and conventional green bonds highlights the potential for convergence between different financial paradigms. Evidence suggests that hybrid models may represent a transitional phase toward more integrated sustainable finance systems. This

convergence reflects broader global efforts to harmonize financial practices with sustainability goals. It also indicates the possibility of bridging gaps between Islamic and conventional finance.

The study's findings point to the emergence of a pluralistic financial ecosystem in which multiple instruments coexist and complement each other. This development suggests that achieving climate resilience requires diversified financing strategies. Reliance on a single type of instrument may limit the effectiveness of sustainability initiatives. The results therefore signal the importance of inclusivity in financial innovation.

Implications of these findings extend to policymakers, financial institutions, and investors seeking to enhance climate resilience. Policymakers may consider integrating Shariah-compliant principles into broader green finance frameworks to strengthen ethical accountability. Financial institutions could leverage the complementary strengths of sukuk and green bonds to optimize investment portfolios. Investors may benefit from diversified exposure to both instruments to balance risk and impact.

The results also imply that regulatory harmonization is critical for maximizing the potential of green financing instruments. Differences in standards and certification processes may hinder cross-border investment and limit scalability. Aligning regulatory frameworks could facilitate greater integration between sukuk and conventional green bonds. Such alignment would enhance market efficiency and support global climate objectives.

Implications for sustainable development strategies are particularly significant in emerging economies. The effectiveness of sukuk in financing infrastructure projects suggests its potential as a tool for addressing climate vulnerabilities in developing regions. Conventional green bonds, with their scalability, can complement these efforts by attracting international capital. Together, these instruments can support comprehensive climate resilience strategies.

The findings further suggest that financial innovation should prioritize both impact and inclusivity. Integrating ethical considerations into financial design can enhance the legitimacy and effectiveness of green finance initiatives. This approach aligns with global sustainability agendas that emphasize equity and social responsibility. The implications extend beyond finance to broader development paradigms.

The observed differences between sukuk and conventional green bonds can be attributed to their distinct structural and philosophical foundations. Sukuk operates on principles of asset-backing and risk-sharing, which inherently link financing to real economic activities. Conventional green bonds, by contrast, rely on debt-based structures that prioritize capital efficiency and market liquidity. These foundational differences shape their respective impacts on climate resilience.

Institutional factors also play a significant role in explaining the findings. Regions with supportive regulatory environments and established Islamic finance ecosystems are better positioned to leverage sukuk for sustainability. Conventional green bond markets benefit from mature financial infrastructures and standardized certification systems. These contextual factors influence the effectiveness and scalability of each instrument.

Investor behavior further contributes to the observed outcomes. Participants in sukuk markets often prioritize ethical and long-term considerations, aligning with sustainability objectives. Investors in conventional green bonds may be driven by a combination of financial returns and environmental impact. These differing motivations affect investment patterns and project selection.

The role of governance and accountability mechanisms is also critical in shaping results. Sukuk structures often incorporate stricter compliance requirements, ensuring alignment with Shariah principles. Conventional green bonds rely on external verification and reporting standards to maintain credibility. Variations in governance frameworks influence the transparency and effectiveness of each instrument.

Future directions emerging from this study emphasize the need for integrated financing models that combine the strengths of sukuk and conventional green bonds. Developing hybrid instruments could enhance both ethical compliance and market scalability. Such innovation would require collaboration between regulators, financial institutions, and international organizations. The potential benefits include improved efficiency and broader impact in climate resilience financing.

Further research is needed to explore the long-term performance of these instruments in different economic contexts. Comparative studies across regions and sectors could provide deeper insights into their effectiveness. Expanding the scope of analysis to include social and governance outcomes would also enhance understanding. Such research would contribute to the development of more comprehensive sustainability frameworks.

Policy development should focus on creating enabling environments for both sukuk and green bond markets. Strengthening regulatory frameworks and promoting standardization can facilitate cross-border investment. Encouraging public-private partnerships may also enhance the deployment of green financing instruments. These efforts would support the scaling of climate resilience initiatives.

Practical implementation strategies should prioritize capacity building and knowledge sharing among stakeholders. Enhancing awareness of Shariah-compliant green financing can attract a broader investor base. Integrating digital technologies may also improve transparency and efficiency in green finance markets. These steps can help translate theoretical insights into actionable outcomes for sustainable development.

CONCLUSION

The most salient finding of this study is the differentiated functional role of sukuk and conventional green bonds in advancing climate resilience. Sukuk exhibits a stronger capacity to anchor financing in real-sector sustainability outcomes due to its asset-backed structure and embedded ethical governance, which promote long-term project viability and accountability. Conventional green bonds, on the other hand, demonstrate superior scalability and market accessibility, enabling rapid mobilization of capital across diverse economic sectors. This divergence indicates that the effectiveness of green financing instruments is not solely determined by their environmental labeling but is fundamentally shaped by their financial architecture and governance logic.

The study offers a dual contribution at the conceptual and methodological levels. Conceptually, it reframes the discourse on green finance by positioning Shariah-compliant instruments as not merely alternative tools but as structurally distinct mechanisms capable of enhancing climate resilience through ethical-financial integration. Methodologically, it advances a comparative analytical framework that incorporates institutional context, governance standards, and structural design as key variables, moving beyond conventional metrics such as issuance volume or market size. This integrative approach enables a more nuanced assessment of how different financing models translate into tangible resilience outcomes, thereby enriching the analytical rigor of sustainable finance research.

The limitations of this study stem primarily from its reliance on secondary data and macro-level comparative analysis, which may not fully capture project-specific impacts or contextual implementation dynamics. Geographic concentration in regions with relatively mature Islamic finance systems may also constrain the generalizability of the findings to other settings with differing regulatory and institutional capacities. Future research should consider longitudinal and mixed-method designs to examine causal mechanisms and on-the-ground effectiveness more deeply. Expansion toward the study of hybrid financing instruments and cross-jurisdictional policy integration would provide valuable insights for developing more adaptive, inclusive, and resilient climate finance ecosystems.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author(s) used BlackBox AI to assist in improving grammar, language quality, and overall readability of the text. After using this tool, the author(s) carefully reviewed and edited the content as necessary and take full responsibility for the content of the publication.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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