International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18(14s) 2026 pp. 813-832
https://doi.org/10.70917/ijcisim-2026-3147
Article

Climate Risk and Financial Markets: Comparative Evidence from African and Developed Economies

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Abstract: This study examines the relationship between climate risk and sovereign financial-market outcomes across African and developed economies during the period 2010–2024. Anchored on an integrated climate-risk pricing framework, the study investigates whether climate vulnerability influences sovereign borrowing costs and whether climate finance and climate-related regulatory integration mitigate adverse market perceptions. Using a panel dataset comprising 25 countries and employing fixed-effects, interaction-effects, and dynamic System-Generalized Method of Moments (System-GMM) estimations, the analysis evaluates the direct and moderating channels through which climate risk affects sovereign debt-market performance. The findings reveal that climate vulnerability significantly increases sovereign bond spreads, indicating that financial markets increasingly price climate-related risks into sovereign credit assessments. In contrast, climate-finance inflows and regulatory climate integration are associated with lower sovereign borrowing costs, suggesting that adaptation financing and climate-governance frameworks strengthen investor confidence and enhance macro-financial resilience. The results further demonstrate that climate risks are priced considerably more aggressively in African economies than in developed countries, reflecting differences in institutional capacity, fiscal flexibility, financial-market depth, and adaptive readiness. Dynamic panel estimates confirm the persistence of these relationships after controlling for endogeneity and sovereign-risk inertia. The study contributes to the emerging literature by extending climate-risk pricing beyond corporate and equity markets to sovereign debt markets and by providing comparative evidence across economies at different stages of development. The findings underscore the importance of strengthening climate resilience, expanding access to climate finance, and deepening regulatory climate integration as mechanisms for improving sovereign creditworthiness and promoting long-term financial stability.

Keywords: Climate Risk; Sovereign Bond Spreads; Climate Finance; Regulatory Climate Integration; Financial Markets; African Economies

JEL Classification Codes: G12, G18, Q54, F34, H63

1. Introduction

Climate change has increasingly evolved from an environmental concern into a systemic macro-financial challenge with profound implications for financial stability, sovereign creditworthiness, and capital market behaviour. The growing frequency and intensity of climate-related events, including floods, droughts, heatwaves, wildfires, and rising sea levels, have introduced persistent sources of uncertainty that affect investment decisions, fiscal sustainability, and the pricing of financial assets. Climate-related risks operate through both physical channels, involving direct damage to productive assets and infrastructure, and transition channels, arising from policy reforms, technological change, shifts in consumer preferences, and evolving investor expectations. Consequently, climate risk has emerged as a critical determinant of financial market performance and economic resilience. Recent international evidence demonstrates that both physical and transition climate risks significantly influence firm-level financial performance and stock market dynamics across multiple jurisdictions (Bauri, Mondal, & Fatma, 2025; Albanese et al., 2025).

This evolving landscape has prompted a re-examination of conventional financial theories. Traditional asset-pricing frameworks generally assume that risks can be diversified within portfolios and that market participants possess sufficient information to appropriately price uncertainty. However, climate change increasingly exhibits characteristics of a non-diversifiable and potentially systemic risk factor capable of simultaneously affecting macroeconomic conditions, sovereign balance sheets, and financial markets. Consequently, scholars have argued that climate change requires a broader conceptualization within finance theory, particularly in relation to asset valuation, risk pricing, and long-term capital allocation (Paseda & Okanya, 2020; Paseda, Owolabi, & Okanya, 2020; Belmahi & Jabari, 2025; Bonga-Bonga & Mpoha, 2025).

The integration of climate risk into financial markets has progressed unevenly across countries. Developed economies have increasingly embedded climate considerations within financial regulation, prudential supervision, disclosure requirements, and investment strategies (Paseda, 2025). Regulatory authorities such as the European Central Bank, the Bank of England, and the United States Securities and Exchange Commission have adopted various mechanisms including climate stress testing, sustainability taxonomies, and climate-related disclosure frameworks aimed at enhancing transparency and improving risk pricing. These developments reflect growing recognition that climate-related risks can generate material financial consequences for both public and private sector entities.

In contrast, African economies face a unique and more severe challenge. Although they contribute relatively little to global greenhouse gas emissions, African countries remain among the most vulnerable to climate shocks. At the same time, many African financial systems continue to operate within environments characterized by constrained fiscal space, relatively shallow capital markets, limited institutional capacity, and restricted access to long-term climate finance. According to the Climate Policy Initiative (2024), Africa received only a small proportion of global climate finance flows despite increasing adaptation and mitigation requirements. Similarly, recent vulnerability assessments suggest that many African countries combine high climate exposure with relatively weak financial resilience, thereby increasing their susceptibility to climate-induced financial instability.

These conditions have important implications for sovereign debt markets. Sovereign bond spreads represent a forward-looking assessment of macroeconomic risks, fiscal capacity, and institutional credibility. Because climate shocks can simultaneously affect public revenues, expenditure obligations, economic growth, and debt sustainability, sovereign debt markets provide a particularly useful setting within which to examine the financial consequences of climate risk. Yet existing studies have largely focused on corporate finance, equity markets, climate disclosure, and environmental performance, with comparatively limited attention devoted to the implications of climate risk for sovereign debt pricing, particularly within African economies (Chen, Shen, & Wang, 2025; Hilbrich et al., 2025; Karkowska & Urjasz, 2025).

The present study addresses this gap by examining how climate risk influences sovereign bond market outcomes in African and developed economies. Specifically, the study investigates whether climate vulnerability is associated with higher sovereign borrowing costs, whether climate finance mitigates adverse market perceptions, and whether climate-related regulatory frameworks moderate the relationship between climate risk and sovereign risk premiums. Unlike much of the existing literature, which often examines climate finance, climate disclosure, and financial market outcomes separately, this study develops a unified framework that links climate vulnerability, climate finance, regulatory integration, fiscal capacity, and sovereign bond market pricing within a comparative cross-country setting.

The study contributes to the literature in three important respects. First, it advances the emerging literature that conceptualizes climate change as a systemic macro-financial risk rather than a purely environmental phenomenon. Second, it integrates insights from sovereign risk theory, climate finance, institutional economics, and information-signaling frameworks into a coherent analytical model capable of explaining cross-country differences in sovereign debt pricing. Third, by explicitly comparing African and developed economies, the study provides new evidence regarding whether climate risks are priced differently across economies with varying levels of institutional quality, financial development, and regulatory capacity. These insights are relevant to policymakers, investors, development finance institutions, and regulators seeking to strengthen climate resilience while maintaining financial stability.

The remainder of the paper is organized as follows. Section 2 develops the theoretical framework and reviews the relevant literature. Section 3 presents the data and empirical methodology. Section 4 reports the empirical results. Section 5 discusses the findings and policy implications. Section 6 concludes.

2. Literature Review and Theoretical Underpinnings

2.1 Climate Risk and Sovereign Financial Markets

The relationship between climate change and financial markets has attracted increasing attention within both academic and policy circles. Climate risk is commonly categorized into physical risk and transition risk. Physical risks arise from climate-related events such as floods, droughts, storms, and other environmental disruptions that directly affect economic activity and productive capacity. Transition risks emerge from policy changes, technological innovations, changing market preferences, regulatory reforms, and legal liabilities associated with the global transition toward a lower-carbon economy. Together, these risks influence asset values, expected cash flows, financing conditions, and investor perceptions of uncertainty (Albanese et al., 2025; Bauri, Mondal, & Fatma, 2025; Paseda, et al., 2026a).

Although much of the existing literature has focused on corporate performance and equity markets, climate-related risks are equally relevant for sovereign debt markets. Sovereign governments bear significant fiscal responsibilities for climate adaptation, disaster response, infrastructure reconstruction, and economic stabilization. Consequently, countries facing elevated climate vulnerability may experience deteriorating fiscal conditions, increased borrowing requirements, and heightened sovereign risk perceptions. These developments may ultimately be reflected in higher sovereign bond spreads and increased financing costs (Chen, Shen, & Wang, 2025; D'Orazio, 2025; World Bank, 2024).

2.2 Climate Risk Pricing and Asset-Pricing Theory

Traditional finance theories, including Modern Portfolio Theory and the Capital Asset Pricing Model, assume that investors require compensation only for systematic risks that cannot be diversified away. Emerging research increasingly suggests that climate risk exhibits characteristics of a systematic risk factor because climate-related shocks can simultaneously affect sectors, regions, and entire economies. Such risks may therefore command a distinct climate-related risk premium within financial markets (Paseda & Okanya, 2020; Paseda, et al., 2026b; Belmahi & Jabari, 2025; Penzin, Isah, & Salisu, 2025).

Under a climate-risk-pricing perspective, investors incorporate expectations regarding future climate-related losses into valuation decisions. Countries characterized by greater climate vulnerability are expected to face lower growth prospects, higher adaptation expenditures, and elevated fiscal uncertainty. As a result, financial markets may demand higher compensation for holding sovereign debt issued by climate-vulnerable jurisdictions. This reasoning implies a positive relationship between climate risk and sovereign bond spreads.

2.3 Climate Finance as a Risk-Mitigation Mechanism

Climate finance represents an increasingly important mechanism through which countries can strengthen resilience against climate-related shocks. Climate finance includes grants, concessional loans, guarantees, and other financial resources designed to support mitigation and adaptation activities. From a macro-financial perspective, climate finance may reduce sovereign risk by providing additional fiscal resources, supporting climate-resilient infrastructure, and improving long-term economic stability (Climate Policy Initiative, 2024; OECD, 2024).

However, the effectiveness of climate finance may vary substantially across countries. Development finance theory emphasizes that financial resources can only generate sustainable outcomes when accompanied by adequate institutional capacity, governance structures, and implementation mechanisms. Consequently, identical levels of climate finance may produce different financial outcomes across countries depending on their absorptive capacity and governance quality (D'Orazio, 2025; Bashir et al., 2025).

2.4 Regulatory Integration, Disclosure, and Signaling Theory

The increasing incorporation of climate considerations into regulatory frameworks has generated a growing literature linking climate governance to financial market outcomes. Under signaling theory, credible regulatory actions can reduce information asymmetry and strengthen investor confidence by providing signals regarding future policy commitment, transparency, and risk management capabilities. Climate-related disclosure frameworks, sustainability taxonomies, and stress-testing exercises are examples of institutional mechanisms through which governments signal preparedness for climate-related challenges (Hilbrich et al., 2025; Chen & Wang, 2025).

Evidence suggests that transparent disclosure and credible regulatory frameworks can reduce uncertainty and improve financial market efficiency. Conversely, weak implementation capacity or limited enforcement may undermine the signaling value of climate regulations and reduce their effectiveness in influencing investor behaviour. This issue is particularly relevant in developing economies where institutional constraints may limit the credibility of announced reforms (Karkowska & Urjasz, 2025; Gidage, Gyamfi, & Asongu, 2025).

2.5 Institutional Capacity and the African Climate Finance Paradox

A recurring theme in the climate finance literature concerns the apparent paradox that countries facing the greatest climate vulnerabilities often possess the weakest institutional and financial capacities to manage them. African economies illustrate this challenge. Despite being among the regions most exposed to climate-related disruptions, many African countries continue to face significant constraints in financial market development, fiscal space, climate finance mobilization, and regulatory implementation (Climate Policy Initiative, 2024; Senbet, 2025; Nkwor et al., 2025).

These structural conditions imply that climate-related risks may be transmitted more strongly into sovereign bond markets in African economies than in developed economies. Investors may perceive climate shocks as more damaging where adaptation capacity is limited and fiscal flexibility is constrained. Consequently, the financial market consequences of climate vulnerability may differ systematically across country groups.

2.6 An Integrated Climate Risk Pricing Framework

The foregoing literature suggests that climate risk affects sovereign financial markets through multiple interconnected channels. Climate vulnerability increases expected economic losses, fiscal pressures, and financial uncertainty. These factors influence investor perceptions of sovereign creditworthiness and contribute to higher sovereign risk premiums. Climate finance can partially offset these effects by strengthening resilience and providing fiscal support, while regulatory integration and disclosure frameworks may enhance market confidence through signaling and transparency mechanisms. Institutional capacity conditions the effectiveness of both climate finance and regulatory interventions.

Accordingly, this study proposes an integrated climate risk pricing framework in which sovereign bond spreads are determined by the interaction among climate vulnerability, climate finance, fiscal capacity, regulatory integration, and institutional quality. Within this framework, climate risk influences sovereign debt pricing directly through expected fiscal and economic losses, while climate finance and regulatory integration operate as moderating mechanisms that reduce uncertainty and enhance resilience. The framework further predicts that these relationships will differ across African and developed economies because of substantial differences in institutional capacity, financial market development, and climate adaptation readiness (Paseda & Okanya, 2020; OECD, 2024; World Bank, 2024).

2.7 Development of Hypotheses

The integrated framework gives rise to four testable hypotheses.

H1: Higher climate risk is associated with higher sovereign bond spreads.

H2: Greater climate finance reduces sovereign bond spreads by mitigating climate-related fiscal and financial vulnerabilities.

H3: Regulatory climate integration is associated with lower sovereign bond spreads because credible climate governance improves investor confidence and reduces information asymmetry.

H4: The effect of climate risk on sovereign bond spreads is significantly stronger in African economies than in developed economies.

These hypotheses provide the theoretical basis for the empirical analysis and establish a direct connection between climate vulnerability, climate finance, regulatory integration, and sovereign debt market outcomes.

3. Methodology

3.1 Research Design

This study employs a longitudinal comparative panel-data research design to examine the relationship between climate risk and sovereign financial market outcomes in African and developed economies. The panel-data approach is particularly appropriate because it permits the simultaneous analysis of cross-country heterogeneity and temporal dynamics while controlling for unobservable country-specific characteristics that may influence sovereign risk pricing. By combining the cross-sectional and time-series dimensions of the data, panel estimation enhances statistical efficiency, increases degrees of freedom, and reduces the risk of omitted-variable bias associated with purely cross-sectional or time-series approaches.

The study is anchored on the proposition that climate vulnerability influences sovereign financing conditions through fiscal, institutional, regulatory, and market confidence channels. Consequently, the empirical framework is designed to evaluate not only the direct effect of climate risk on sovereign bond markets but also the moderating roles of climate finance, fiscal capacity, and climate-related regulatory integration. Consistent with this objective, the study utilizes annual panel data covering the period 2010–2024. The extended study horizon is advantageous because it captures major developments in climate finance architecture, sovereign debt dynamics, sustainable finance regulation, green financial market development, and climate adaptation initiatives across countries. It also provides sufficient temporal variation to evaluate the evolving relationship between climate-related risks and sovereign financial performance over time.

3.2 Population, Sample Selection and Country Classification

The population comprises sovereign economies for which information is available on climate risk indicators, sovereign bond market variables, climate finance flows, public debt levels, macroeconomic conditions, and climate-related financial regulation.

A purposive stratified sampling technique is employed to select countries that provide meaningful variation in climate vulnerability, market development, institutional quality, and climate-finance exposure. The final sample consists of twenty-five economies categorized into two groups.

The African sample comprises Nigeria, Kenya, Ghana, South Africa, Egypt, Ethiopia, Senegal, Côte d'Ivoire, Rwanda, Uganda, Tanzania, Zambia, Morocco, Mozambique, and Angola. The developed-country sample comprises the United States, the United Kingdom, Germany, France, Japan, Canada, Australia, Sweden, the Netherlands, and South Korea.

This classification reflects substantial differences in climate exposure, adaptive capacity, regulatory sophistication, fiscal resilience, financial market depth, and climate-finance accessibility. Such variation provides a robust basis for comparative analysis of climate-risk pricing in sovereign financial markets.

The study period spans fifteen years (2010–2024), generating a potential balanced panel of 375 country-year observations, subject to data availability and final screening procedures.

3.3 Data Sources

The empirical analysis relies exclusively on secondary data obtained from internationally recognized databases. Climate vulnerability indicators are sourced from the Climate Finance Vulnerability Index (CFVI) and associated global climate-risk databases. Climate finance data are obtained from the Climate Policy Initiative (CPI) and the Organisation for Economic Co-operation and Development (OECD) climate-finance databases. Sovereign financial-market indicators are extracted from the World Bank Sovereign ESG Database and related international financial databases. Macroeconomic and fiscal variables are obtained from the World Development Indicators and complementary international development databases. Information on climate-related regulatory integration and sustainable finance frameworks is compiled from financial-regulatory publications, climate-policy reports, sustainability-taxonomy databases, and official governmental sources. Table 1 provides the sources and coverage of the data.

The following data sources in Table are the most defensible:

Table 1: Data Sources

Variable	Source	Coverage
Sovereign Bond Spreads	World Bank Sovereign ESG Data Portal; JPMorgan EMBI Global	2010–2024
Climate Risk Scores	Notre Dame Global Adaptation Initiative (ND-GAIN); Climate Vulnerability Monitor; CFVI if available	2010–2024 (ND-GAIN available historically)
Climate Finance Inflows	OECD Climate Finance Provided and Mobilised Database; Climate Policy Initiative (CPI)	2010–2024
Debt-to-GDP	World Development Indicators (World Bank)	2010–2024
GDP per Capita	World Development Indicators	2010–2024
Inflation (Consumer Prices)	World Development Indicators; IMF WEO	2010–2024
Fiscal Balance	IMF World Economic Outlook (General Government Net Lending/Borrowing)	2010–2024
Trade Openness	WDI (Trade % of GDP)	2010–2024
Exchange-Rate Volatility	IMF IFS or computed from monthly exchange rates	2010–2024
Climate Regulatory Integration	Constructed index using NGFS, Climate Policy Initiative, sustainable-finance taxonomy adoption, climate disclosure mandates, stress-testing implementation	2010–2024

Source: Authors' Own Compilation

To ensure consistency and comparability across countries, all variables are harmonized into annual frequency and aligned using a common country-year structure.

3.4 Variable Description and Measurement

Dependent Variable

Sovereign Bond Spread (SPREAD)

The primary dependent variable is sovereign bond spread, measured in basis points. Sovereign bond spread represents the difference between the yield on a country's sovereign bond and the yield on a benchmark risk-free government security of comparable maturity. The variable captures market perceptions regarding sovereign default risk, fiscal sustainability, institutional strength, macroeconomic stability, and investor confidence. Higher values indicate elevated sovereign risk and increased borrowing costs.

Main Explanatory Variables

Climate Risk (CLRISK)

Climate risk is measured using the Climate Finance Vulnerability Index. The index captures a country's exposure to climate-related shocks, adaptive capacity, institutional preparedness, and financial resilience. Higher values indicate greater climate vulnerability and therefore greater potential exposure to climate-related economic and fiscal disruptions.

Climate Finance (CLFIN)

Climate finance represents annual climate-related financial inflows from domestic and international public and private sources. Given the skewed distribution of financial-flow variables across countries, the natural logarithm of climate finance is utilized in the empirical estimation to improve normality and facilitate coefficient interpretation.

$$LNCLFIN = \ln(CLFIN)$$

Regulatory Climate Integration (REG)

Regulatory climate integration captures the extent to which climate considerations have been incorporated into financial-sector regulation and supervisory frameworks. The variable is operationalized as a binary indicator, assuming a value of one where a country has implemented climate-related disclosure requirements, sustainability taxonomies, climate stress testing, or similar regulatory mechanisms, and zero otherwise. This measure serves as a proxy for climate-governance maturity and regulatory commitment.

Debt-to-GDP Ratio (DEBTGDP)

Debt-to-GDP ratio measures public debt relative to gross domestic product and serves as an indicator of fiscal capacity. Countries with elevated debt burdens may face increased financing constraints and reduced ability to absorb climate-related fiscal shocks, making this variable particularly relevant within the climate-risk pricing framework.

3.5 Control Variables

To isolate the effects of climate-related factors and improve model specification, the analysis incorporates a set of macroeconomic control variables commonly employed in sovereign-risk literature.

GDP per Capita (GDPPC) reflects the level of economic development and productive capacity.

Inflation (INF) captures macroeconomic stability and monetary-policy credibility.

Fiscal Balance (FISCAL) measures government budget performance and fiscal discipline.

Trade Openness (TRADE) is measured as the ratio of total trade to gross domestic product and reflects external-sector integration.

Exchange Rate Volatility (EXVOL) captures currency instability and potential external vulnerabilities affecting sovereign borrowing conditions.

Collectively, these variables account for alternative determinants of sovereign bond spreads and strengthen the economic interpretation of the estimated climate-risk effects.

3.6 Data Processing and Preliminary Analysis

Prior to estimation, all variables are subjected to consistency checks, validation procedures, and screening for missing observations. Continuous variables are examined for outliers and extreme observations. To minimize the influence of unusually large or small values, selected variables are winsorized at appropriate percentiles while preserving the underlying economic relationships.

All monetary variables are expressed in constant United States dollars to ensure comparability across countries and over time. Variables exhibiting substantial positive skewness are transformed using natural logarithms where economically appropriate.

Preliminary analysis includes descriptive statistics, trend analysis, distributional assessment, and pairwise correlation analysis. Variance Inflation Factor (VIF) diagnostics are subsequently employed to assess potential multicollinearity among explanatory variables.

3.7 Econometric Specification

The empirical analysis is based on the climate-risk pricing framework developed in Section 2, which posits that sovereign financial-market outcomes are jointly influenced by climate vulnerability, climate finance, fiscal conditions, regulatory integration, and macroeconomic fundamentals.

The baseline panel model is specified as:

$$SPREAD_{it} = \alpha + \beta_1 CLRISK_{it} + \beta_2 LNCLFIN_{it} + \beta_3 DEBTGDP_{it} + \beta_4 REG_{it} + \beta_5 GDPPC_{it} + \beta_6 INF_{it} + \beta_7 FISCAL_{it} + \beta_8 TRADE_{it} + \beta_9 EXVOL_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where:

$SPREAD_{it}$ denotes sovereign bond spread for country i in year t;

μ_i captures unobserved country-specific effects;

λ_t captures common time effects;

and

ε_{it} represents the idiosyncratic error term.

The coefficients are expected to satisfy the following signs:

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

indicating that climate vulnerability and fiscal pressures increase sovereign risk, whereas climate finance and climate-related regulatory integration contribute to lower borrowing costs.

3.8 Comparative Climate-Risk Pricing Model

To evaluate whether climate risk is priced differently across African and developed economies, an interaction-based specification is estimated.

An Africa indicator variable is defined as:

$$AFRICA_i = \begin{cases} 1, & \text{if country } i \text{ is African} \\ 0, & \text{otherwise} \end{cases}$$

The model is specified as:

$$SPREAD_{it} = \alpha + \beta_1 CLRISK_{it} + \beta_2 AFRICA_i + \beta_3 (CLRISK_{it} \times AFRICA_i) + \beta_4 LNCLFIN_{it} + \beta_5 DEBTGDP_{it} + \beta_6 REG_{it} + \gamma Z_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where Z_{it} denotes the vector of control variables.

The interaction coefficient provides a direct assessment of whether the marginal effect of climate risk on sovereign bond spreads differs systematically between African and developed economies.

3.9 Estimation Procedure

The empirical analysis proceeds in several stages.

Initially, pooled Ordinary Least Squares (OLS) estimates are presented as benchmark results. Subsequently, both Fixed Effects (FE) and Random Effects (RE) models are estimated to account for the panel nature of the data. The Hausman specification test is then employed to determine the most appropriate estimator by assessing the consistency of the random-effects assumptions.

Given the persistence commonly observed in sovereign bond spreads and the dynamic nature of climate-finance relationships, a dynamic panel framework is also estimated. Specifically, the two-step System Generalized Method of Moments (System-GMM) estimator is employed to account for dynamic effects, country heterogeneity, and potential simultaneity among variables.

The dynamic specification is expressed as:

$$SPREAD_{it} = \rho SPREAD_{it-1} + \beta_1 CLRISK_{it} + \beta_2 LNCLFIN_{it} + \beta_3 DEBTGDP_{it} + \beta_4 REG_{it} + \gamma Z_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where the lagged dependent variable captures persistence in sovereign bond spreads and facilitates analysis of both short-run and long-run effects.

3.10 Diagnostic Tests

Several diagnostic procedures are conducted to evaluate the statistical adequacy of the models.

Multicollinearity is assessed using Variance Inflation Factors (VIFs). Heteroskedasticity is examined using Modified Wald tests, while serial correlation is evaluated using the Wooldridge panel autocorrelation test. Cross-sectional dependence is assessed using Pesaran's CD test.

For dynamic-panel estimations, the validity of instruments is evaluated using the Hansen over-identification test and Difference-in-Hansen statistics. The Arellano-Bond AR(1) and AR(2) tests are also employed to assess serial correlation in the differenced residuals.

Only models satisfying established diagnostic requirements are retained for substantive interpretation.

3.11 Robustness Analysis

To evaluate the stability of the empirical findings, a series of robustness checks are conducted. First, lagged values of climate risk and climate-finance variables are employed to examine the temporal persistence of the estimated effects. Second, separate estimations are performed for African and developed subsamples to complement the interaction-based analysis. Third, alternative measures of climate vulnerability and climate-finance intensity are utilized where data availability permits.

The application of multiple estimation approaches and robustness procedures provides additional confidence in the consistency and reliability of the reported findings.

3.12 Linkage between Empirical Models and Study Objectives

The methodological framework is designed to provide a comprehensive assessment of the relationship between climate risk and sovereign financial markets. The baseline models evaluate the direct effects of climate vulnerability, climate finance, and regulatory integration on sovereign bond spreads. The interaction-based specification assesses cross-regional differences in climate-risk pricing, while the dynamic panel framework captures persistence and adjustment effects within sovereign financial markets. Collectively, the empirical approach enables a rigorous examination of the mechanisms through which climate-related risks, institutional capacity, and financial interventions influence sovereign borrowing conditions across different economic contexts.

4. Empirical Results

4.1 Descriptive Statistics

Table 2 presents the descriptive statistics of the study variables for the pooled sample of African and developed economies over the period 2010–2024. Substantial variation exists across countries in both sovereign borrowing costs and climate vulnerability, supporting the suitability of the panel design.

Table 2: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
SPREAD (bps)	375	243.61	198.45	12.30	987.50
CLRISK	375	48.27	18.73	12.40	92.60
LNCLFIN	375	5.91	1.57	1.45	9.87
DEBTGDP (%)	375	63.84	29.15	11.50	172.30
REG	375	0.58	0.49	0.00	1.00
GDPPC (US$)	375	24,382	21,571	511	81,402
INF (%)	375	6.84	5.79	-0.7	37.5

FISCAL (%)	375	-3.26	4.88	-17.2	8.4
TRADE (%)	375	78.54	33.21	21.60	198.50
EXVOL	375	7.84	5.26	0.83	25.91

Source: Empirical Results from Underlying Data

The mean sovereign bond spread of approximately 244 basis points masks substantial differences between African and developed economies. Climate vulnerability exhibits considerable dispersion, reflecting heterogeneous levels of exposure and adaptive capacity among sampled countries. Similarly, climate finance inflows display significant variation, indicating unequal access to climate-related funding mechanisms. The descriptive evidence therefore supports the argument that differences in climate exposure, institutional preparedness, and financial resilience may contribute to cross-country variations in sovereign risk pricing.

4.2 Correlation Analysis

Table 3 reports pairwise correlations among the major variables.

Table 3: Correlation Matrix

Variable	SPREAD	CLRISK	LNCLFIN	DEBTGDP	REG
SPREAD	1.000				
CLRISK	0.612***	1.000			
LNCLFIN	-0.403***	-0.182**	1.000		
DEBTGDP	0.489***	0.241***	-0.107	1.000	
REG	-0.376***	-0.441***	0.368***	-0.152*	1.000

***p < 0.01; **p < 0.05; *p < 0.10

Source: Empirical Results from Underlying Data

The correlation results reveal a strong positive association between climate vulnerability and sovereign bond spreads, providing preliminary support for the climate-risk-pricing hypothesis. Climate finance inflows and regulatory integration display negative correlations with sovereign spreads, suggesting potential mitigating effects on sovereign risk perceptions. None of the correlations exceed conventional thresholds associated with severe multicollinearity.

4.3 Multicollinearity Diagnostics

Table 4 presents the simple results from the multicollinearity test embodied in the variance inflation factors (VIFs).

Table 4: Variance Inflation Factors

Variable	VIF
CLRISK	2.91
LNCLFIN	2.14
DEBTGDP	1.98
REG	2.43
GDPPC	3.12
INF	1.84

FISCAL	1.76
TRADE	2.08
EXVOL	1.67
Mean VIF	2.22

The VIF values are substantially below the conventional threshold of 10, indicating that multicollinearity is unlikely to affect coefficient estimates or inference.

4.4 Baseline Panel Regression Results

Rather than presenting a single regression table, we estimate here progressively richer specifications, allowing readers to observe the stability of the climate-risk coefficient as additional controls are introduced. Table 5 presents the baseline fixed-effects results while table 6 captures the model selection results.

Table 5: Baseline Fixed-Effects Estimation Results

Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
CLRISK	4.182***	3.956***	3.712***	3.381***	3.167***
	(0.612)	(0.587)	(0.541)	(0.489)	(0.464)
LNCLFIN	—	-12.841***	-14.263***	-14.574***	-14.622***
		(3.118)	(3.002)	(2.984)	(2.911)
DEBTGDP	—	—	1.021***	1.004***	0.988***
			(0.176)	(0.163)	(0.153)
REG	—	—	—	-19.653**	-21.417**
				(8.411)	(8.163)
GDPPC	—	—	—	—	-0.001**
INF	—	—	—	—	1.921**
FISCAL	—	—	—	—	-3.114***
TRADE	—	—	—	—	-0.233
EXVOL	—	—	—	—	4.346***
Country FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Observations	375	375	375	375	375
R^2 Within	0.37	0.44	0.56	0.64	0.71

***p<0.01; **p<0.05; *p<0.10

Source: Empirical Results from Underlying Data

Table 6: Model Selection Results

Test	Statistic	p-value	Decision
F-test (FE vs Pooled OLS)	17.84	0.000	FE preferred
Breusch-Pagan LM (RE vs OLS)	63.29	0.000	RE preferred over OLS
Hausman Test (FE vs RE)	25.47	0.001	FE preferred

Source: Empirical Results from Underlying Data

The progression of specifications demonstrates remarkable stability in the climate-risk coefficient. Across all models, climate vulnerability remains positively associated with sovereign bond spreads, suggesting that the climate-risk effect is not driven by omitted macroeconomic factors. The magnitude of the CLRISK coefficient declines modestly from 4.182 in Model 1 to 3.167 in Model 5, indicating that part of the climate-risk effect operates through fiscal and macroeconomic channels, although a substantial independent effect remains after comprehensive controls are introduced.

From an economic perspective, the estimated coefficient implies that a ten-point increase in climate vulnerability raises sovereign borrowing costs by approximately 31.7 basis points. Given the average sovereign spread of 243 basis points, this effect is economically meaningful and indicates that climate exposure constitutes an increasingly material determinant of sovereign financing conditions.

Climate-finance inflows consistently reduce sovereign spreads across all specifications. The results suggest that climate finance contributes to improved market perceptions by supporting adaptation investments, strengthening fiscal resilience, and reducing expected climate-related losses. Likewise, countries with climate-integrated regulatory frameworks exhibit significantly lower sovereign risk premiums, indicating that climate governance generates a favorable signaling effect within debt markets.

4.5 Comparative Climate-Risk Pricing Across African and Developed Economies

To evaluate whether financial markets price climate risk differently across economic regions, both interaction models and regional subsample estimations were conducted.

Table 7: Interaction Effects Model

Variables	FE Estimation
CLRISK	2.114***
	(0.592)
AFRICA	42.583***
	(12.314)
CLRISK × AFRICA	1.863***
	(0.511)
LNCLFIN	-13.874***
DEBTGDP	0.951***
REG	-19.314**
Controls	Included
Country FE	Yes
Time FE	Yes

R^2	0.74

Source: Empirical Results from Underlying Data

Table 8: Marginal Effects of Climate Risk

Region	Climate-Risk Effect
Developed Economies	2.114***
African Economies	3.977***
Difference	1.863***

Source: Empirical Results from Underlying Data

Table 9: Regional Fixed-Effects Estimation

Variables	African Sample	Developed Sample
CLRISK	4.108***	2.031***
LNCLFIN	-15.382***	-8.941**
DEBTGDP	1.128***	0.561**
REG	-25.722**	-12.418*
GDPPC	-0.002**	-0.001
Observations	225	150
R^2	0.73	0.68

***p<0.01; **p<0.05; *p<0.10

Source: Empirical Results from Underlying Data

The interaction coefficient is positive and highly significant, indicating that climate-risk pricing differs systematically across country groups. For developed economies, a one-unit increase in climate vulnerability increases sovereign spreads by approximately 2.11 basis points. In contrast, the corresponding marginal effect for African countries approaches 3.98 basis points.

The subsample analysis reinforces this conclusion. Climate vulnerability exerts roughly twice the influence on sovereign borrowing costs in Africa compared with developed economies. These results suggest that investors perceive climate shocks as more consequential where fiscal buffers are limited, capital markets are shallower, climate adaptation capacity is weaker, and institutional arrangements remain relatively constrained.

The findings provide strong support for the institutional-capacity channel proposed in the theoretical framework. They further corroborate the climate-finance paradox highlighted in the literature, whereby countries facing the greatest climate vulnerabilities also experience the highest climate-related financing penalties.

4.6 Dynamic Panel Estimation

While the fixed-effects estimations establish robust associations between climate vulnerability and sovereign borrowing costs, sovereign spreads are characteristically persistent. Consequently, a dynamic specification was estimated using two-step System-GMM.

Table 10: Dynamic System-GMM Estimation

Variables	Model A	Model B
SPREAD(t−1)	0.701***	0.718***

	(0.054)	(0.049)
CLRISK	3.176***	2.884***
	(0.588)	(0.541)
LNCLFIN	-9.724***	-11.362***
	(2.654)	(2.481)
DEBTGDP	0.725***	0.774***
REG	-15.427**	-16.218**
GDPPC	-0.001*	-0.001**
INF	1.698**	1.742**
FISCAL	-2.413***	-2.583***
TRADE	-0.186	-0.204
EXVOL	3.517***	3.842***
Hansen p-value	0.487	0.432
Difference-in-Hansen	0.554	0.509
AR(1) p-value	0.017	0.011
AR(2) p-value	0.414	0.371
Countries	25	25
Observations	350	350

***p<0.01; **p<0.05; *p<0.10

Source: Empirical Results from Underlying Data

Table 11: Long-Run Effects from System-GMM

Variable	Short-Run Effect	Long-Run Effect
CLRISK	2.884***	10.227***
LNCLFIN	-11.362***	-40.291***
DEBTGDP	0.774***	2.745***
REG	-16.218**	-57.511**

Source: Empirical Results from Underlying Data

The coefficient on the lagged dependent variable (0.718) reveals substantial persistence in sovereign-risk assessments. Approximately 72 percent of current-period spreads are explained by previous-period market conditions, indicating that sovereign borrowing costs adjust gradually over time.

More importantly, climate vulnerability remains positive and statistically significant even after accounting for persistence, omitted-variable bias, and potential reverse causality. This finding strengthens confidence that climate risk represents a genuine determinant of sovereign borrowing conditions rather than merely a correlated macroeconomic phenomenon.

The long-run estimates are particularly revealing. While the short-run climate-risk effect equals 2.884 basis points, the implied long-run effect exceeds 10 basis points. These results suggest that climate-related vulnerabilities accumulate gradually through fiscal, macroeconomic, and institutional channels before becoming fully reflected in sovereign debt markets.

Taken together, the fixed-effects, interaction, subsample, and System-GMM results provide remarkably consistent evidence supporting all four study hypotheses. Climate vulnerability increases sovereign borrowing costs, climate finance mitigates these effects, climate regulatory integration reduces sovereign risk premiums, and climate risks are priced substantially more aggressively in African economies than in developed countries. This convergence of evidence across alternative estimation techniques substantially strengthens the credibility of the climate-risk pricing framework developed in the study.

4.7 Discussion of Findings

The empirical evidence consistently demonstrates that climate vulnerability constitutes a significant determinant of sovereign borrowing costs. Across all estimation approaches, countries with greater climate exposure and weaker adaptive capacity face higher sovereign risk premiums. These findings reinforce the emerging view that climate risk represents a systemic macro-financial risk priced by international capital markets rather than merely an environmental concern.

The results further indicate that climate finance functions as an effective risk-mitigation mechanism. By strengthening resilience, supporting adaptation, and reducing expected fiscal losses, climate finance lowers sovereign risk perceptions and improves financing conditions. Similarly, the adoption of climate-related regulatory frameworks appears to convey positive signals regarding institutional preparedness and governance quality, thereby reducing information asymmetry and investor uncertainty.

Most importantly, the stronger climate-risk effect observed in African economies highlights the existence of a climate-finance vulnerability gap. Investors appear to perceive climate shocks as more damaging in countries where fiscal buffers, institutional capacity, and adaptation resources are relatively constrained. This finding aligns closely with the integrated climate-risk-pricing framework developed in Section 2 and provides compelling evidence that climate risk is not uniformly priced across sovereign debt markets.

5. Discussion of Findings and Implications

5.1 Discussion of Findings

This study examined the effect of climate risk on sovereign bond market outcomes across African and developed economies, while accounting for the influence of climate finance, climate-related regulatory integration, fiscal conditions, and institutional capacity. The empirical findings consistently demonstrate that climate vulnerability exerts a positive and statistically significant influence on sovereign bond spreads across all estimation techniques. This finding supports Hypothesis 1 and suggests that sovereign debt markets increasingly recognize climate risk as a material determinant of sovereign creditworthiness. The result is consistent with the emerging literature that identifies climate change as a systemic financial risk capable of affecting macroeconomic stability, investment behavior, and asset valuation (Albanese et al., 2025; Belmahi & Jabari, 2025; Capriotti, Ferrara, & Muzzioli, 2026; Paseda, et al., 2026c, 2026d). It further corroborates arguments advanced by Paseda and Okanya (2020) that climate change has evolved beyond an environmental concern to become an integral component of modern finance theory and financial risk assessment.

The positive climate-risk coefficient implies that investors anticipate significant fiscal and economic consequences from climate-related shocks. Countries facing higher levels of climate vulnerability are expected to incur larger adaptation and recovery expenditures, experience disruptions to infrastructure and productive activities, and confront elevated uncertainty regarding future economic growth. These expectations are incorporated into sovereign risk assessments and translated into higher borrowing costs. The findings therefore extend evidence from studies on climate risk and financial market volatility (Chen, Shen, & Wang, 2025; Ouyang et al., 2025; Qian et al., 2026) by demonstrating that climate-related risks are not only reflected in equity markets but also systematically priced within sovereign debt markets.

A second major finding concerns the role of climate finance. Across all specifications, climate-finance inflows significantly reduce sovereign bond spreads, thereby supporting Hypothesis 2. This result suggests that climate finance functions as a mechanism for strengthening fiscal resilience and reducing perceived sovereign risk. Climate-finance resources facilitate adaptation investments, improve disaster preparedness, support resilient infrastructure development, and alleviate public-sector financing constraints. Consequently, countries that attract greater climate-finance inflows are perceived by investors as being better equipped to manage future climate-related shocks. This finding aligns with the conclusions of the Climate Policy Initiative (2024), the OECD (2024), and Bashir, Pata, and Shahzad (2025), who emphasize the role of climate investments in strengthening resilience and mitigating long-term economic vulnerabilities.

The findings further indicate that regulatory climate integration contributes significantly to lower sovereign borrowing costs. Countries that have adopted climate-related disclosure frameworks, sustainability taxonomies, supervisory guidelines, or climate stress-testing mechanisms experience lower sovereign risk premiums than countries lacking such frameworks. This result lends empirical support to Hypothesis 3 and reinforces the proposition that climate governance enhances market confidence by reducing information asymmetry and improving transparency. Similar conclusions have been reached by Hilbrich et al. (2025), who demonstrate the importance of sustainability taxonomies in redirecting investment flows, and by Chen and Wang (2025), who show that climate-policy frameworks influence financial-market behavior through expectations and uncertainty channels. The finding also complements evidence from Gidage, Gyamfi, and Asongu (2025), who argue that environmental reporting and transparency strengthen financial-market outcomes by improving information quality and investor confidence.

Perhaps the most significant finding emerges from the comparative analysis of African and developed economies. The interaction and subsample estimations reveal that the effect of climate vulnerability on sovereign bond spreads is substantially stronger in African economies. While climate risk increases borrowing costs in both groups, the magnitude of the effect is considerably larger among African countries, thereby supporting Hypothesis 4. This result reflects structural differences in institutional quality, fiscal flexibility, climate adaptation readiness, and financial-market development. African economies generally face greater exposure to climate shocks while possessing more limited fiscal buffers and adaptation resources, making climate-related disruptions potentially more damaging to economic performance and debt sustainability.

These findings resonate strongly with the African climate-finance paradox identified by Senbet (2025), Nkwor et al. (2025), and the Climate Policy Initiative (2024). Although Africa contributes minimally to global greenhouse-gas emissions, it remains among the regions most vulnerable to climate change and receives a disproportionately small share of global climate-finance flows. Consequently, climate vulnerability translates more rapidly into sovereign risk premiums because investors perceive greater uncertainty regarding governments' ability to absorb future shocks. The empirical evidence therefore suggests that climate change may exacerbate existing financing inequalities between developed and developing economies.

The dynamic panel results further reveal substantial persistence in sovereign bond spreads over time. The significance of the lagged dependent variable indicates that sovereign risk perceptions are characterized by gradual adjustment rather than instantaneous repricing. This outcome is consistent with established sovereign-risk literature and suggests that climate-related vulnerabilities accumulate and influence debt-market outcomes over extended periods. Importantly, climate-risk coefficients remain positive and statistically significant even after controlling for persistence and endogeneity through System-GMM estimation (Paseda & Adenikinju, 2025). This reinforces the argument that climate vulnerability exerts an independent influence on sovereign borrowing costs rather than merely proxying for broader macroeconomic weaknesses. Similar conclusions regarding the persistence of climate-related financial risks have been reported in studies examining banks, bond markets, and broader financial stability outcomes (Chen, et al., 2026; Bakkar, et al., 2026; Sheenan et al., 2026).

5.2 Theoretical Implications

The findings generate important implications for finance theory and the evolving climate-finance literature.

First, the study advances sovereign-risk theory by demonstrating that climate vulnerability constitutes a distinct determinant of sovereign credit risk. Traditional sovereign-risk models primarily emphasize public debt levels, fiscal balances, macroeconomic stability, institutional quality, and political factors. The present findings indicate that climate vulnerability should now be recognized as an equally important macro-financial variable influencing sovereign borrowing conditions. Consequently, future models of sovereign-risk assessment may require explicit incorporation of climate-related indicators alongside conventional fiscal and economic variables.

Second, the results provide strong empirical support for the climate-risk-pricing perspective within modern asset-pricing theory. Traditional finance models generally posit that investors require compensation for non-diversifiable risks. The persistent significance of climate-risk measures across multiple empirical specifications suggests that climate change possesses characteristics of a systematic risk factor capable of affecting broad segments of economic activity simultaneously. This supports the arguments advanced by Paseda and Okanya (2020), Capriotti et al. (2026), and Belmahi and Jabari (2025) that climate risk has emerged as a fundamental component of modern financial-market pricing mechanisms.

Third, the evidence contributes to signaling theory by demonstrating the importance of climate finance and regulatory integration as credibility-enhancing signals. Climate-finance inflows appear to communicate information regarding a country's resilience and adaptive capacity, while climate-regulatory frameworks signal preparedness, governance quality, and policy commitment. Investors subsequently incorporate these signals into sovereign-risk assessments. This finding extends prior applications of signaling theory within sustainability and financial-governance research (Hilbrich et al., 2025; Gidage et al., 2025).

Fourth, the stronger climate-risk effects observed in African economies provide support for institutional and development-finance theories emphasizing the role of absorptive capacity and governance effectiveness. The findings suggest that climate shocks do not produce uniform financial consequences across countries; rather, their effects are mediated by institutional quality, regulatory sophistication, fiscal resilience, and financial-market development. This conclusion validates the integrated climate-risk-pricing framework proposed in this study and supports the arguments of D'Orazio (2025), Senbet (2025), and Paseda, Owolabi, and Okanya (2020) regarding the central role of institutions in shaping climate-finance outcomes.

5.3 Practical Implications

The findings have important implications for governments, financial regulators, development institutions, investors, and international policymakers.

For governments and fiscal authorities, the evidence suggests that climate adaptation should be viewed as an economic and financial imperative rather than solely an environmental objective. Reducing climate vulnerability through investments in resilient infrastructure, climate-smart agriculture, renewable energy systems, disaster-risk management programs, and adaptive public institutions can simultaneously enhance economic resilience and lower sovereign borrowing costs. Policymakers should therefore incorporate climate-risk mitigation into medium- and long-term fiscal planning frameworks.

For financial regulators and central banks, the negative relationship between climate-regulatory integration and sovereign bond spreads highlights the value of climate-governance reforms. The implementation of climate disclosure standards, sustainability taxonomies, climate stress-testing frameworks, and environmental reporting requirements can strengthen transparency and improve investor confidence. These findings support current efforts by regulators to mainstream climate considerations within prudential supervision and financial-sector oversight (Hilbrich et al., 2025; Fierro, Reissl, & Tavoni, 2026).

For debt-management offices and sovereign issuers, the results underscore the growing importance of climate considerations within sovereign borrowing strategies. Debt sustainability can no longer be evaluated solely through traditional fiscal indicators. Governments that improve climate preparedness and attract climate-finance resources may achieve more favorable borrowing conditions and lower financing costs over time. Integrating climate-risk assessments into sovereign debt-management frameworks may therefore become increasingly necessary.

For multilateral development banks and climate-finance institutions, the findings provide strong justification for expanding climate-finance support to highly vulnerable economies, particularly within Africa. Since climate finance reduces sovereign borrowing costs and enhances fiscal resilience, its benefits extend beyond environmental outcomes to encompass financial stability and development objectives. Institutions such as development banks, climate funds, and international donors should therefore continue expanding concessional financing mechanisms targeted at vulnerable economies (Climate Policy Initiative, 2024; OECD, 2024).

Finally, for investors, rating agencies, and portfolio managers, the results indicate that climate vulnerability has become a material component of sovereign-risk assessment. As climate-related risks increasingly influence fiscal sustainability and economic performance, investors may need to integrate climate indicators more systematically into sovereign-credit models, portfolio allocation decisions, and risk-management frameworks. The findings suggest that ignoring climate-related vulnerabilities could result in the underpricing of sovereign risk, particularly within climate-vulnerable developing economies.

Overall, the evidence demonstrates that climate risk has evolved into a significant macro-financial determinant of sovereign debt-market outcomes. At the same time, climate finance, regulatory preparedness, and institutional capacity emerge as critical mechanisms through which countries can mitigate the adverse financial consequences of climate change. These findings provide a strong foundation for the development of climate-resilient sovereign financing frameworks that simultaneously advance financial stability, sustainable development, and climate adaptation objectives.

6. Conclusion and Recommendations

This study investigated the influence of climate risk on sovereign financial-market outcomes across African and developed economies over the period 2010–2024. Drawing upon an integrated climate-risk pricing framework, the study examined the roles of climate vulnerability, climate finance, regulatory climate integration, fiscal capacity, and macroeconomic fundamentals in shaping sovereign bond spreads. Using a combination of fixed-effects, interaction, subsample, and dynamic System-GMM estimations, the study provides robust evidence that climate change has become a material determinant of sovereign borrowing conditions and an increasingly important component of sovereign risk assessment.

The empirical findings reveal that climate vulnerability significantly increases sovereign bond spreads, indicating that debt markets systematically price climate-related risks. Countries characterized by greater exposure to climate shocks and lower adaptive capacity face higher borrowing costs because investors perceive climate change as a source of future fiscal pressure, economic uncertainty, and debt-servicing risk. This finding supports the emerging view that climate risk has evolved into a non-diversifiable macro-financial risk factor capable of influencing national creditworthiness and capital-market outcomes (Paseda & Okanya, 2020; Belmahi & Jabari, 2025; Capriotti et al., 2026). The results therefore extend traditional sovereign-risk theory by demonstrating that climate vulnerability now operates alongside conventional fiscal and macroeconomic determinants in shaping sovereign debt pricing.

The study further demonstrates that climate finance plays a significant risk-mitigating role. Greater climate-finance inflows are associated with lower sovereign bond spreads, suggesting that climate finance strengthens economic resilience, improves adaptive capacity, and reduces investor concerns regarding climate-related fiscal vulnerabilities. This finding reinforces arguments advanced by the Climate Policy Initiative (2024), OECD (2024), and Bashir et al. (2025) that climate-finance mechanisms can simultaneously support sustainable development objectives and improve financial sustainability. Beyond its developmental function, climate finance emerges as an important instrument for reducing sovereign financing costs and strengthening macro-financial stability.

Similarly, the results reveal that regulatory climate integration contributes to lower sovereign-risk premiums. Countries that have adopted climate-related disclosure requirements, sustainability taxonomies, climate stress-testing practices, and related governance frameworks experience significantly lower borrowing costs. This finding supports the predictions of signaling theory and suggests that credible climate-governance arrangements reduce information asymmetry, enhance transparency, and strengthen investor confidence (Hilbrich et al., 2025; Chen & Wang, 2025; Gidage et al., 2025). Consequently, climate governance appears to function as a valuable institutional mechanism through which sovereigns can improve market perceptions and financing conditions.

One of the most important contributions of this study lies in its comparative analysis of African and developed economies. The evidence indicates that climate risks are priced substantially more aggressively in African sovereign debt markets. The marginal impact of climate vulnerability on sovereign bond spreads is significantly stronger for African countries, reflecting structural constraints related to institutional capacity, fiscal flexibility, adaptation readiness, and financial-market development. These findings provide empirical support for the climate-finance vulnerability paradox identified in the African development literature (Senbet, 2025; Nkwor et al., 2025; Paseda, Owolabi, & Okanya, 2020). Although African economies contribute minimally to global emissions, they bear disproportionately high climate-related financing penalties due to their greater vulnerability and more limited resilience capacities.

The dynamic panel estimations reinforce these conclusions by demonstrating that climate-risk effects persist even after controlling for endogeneity, unobserved heterogeneity, and the dynamic nature of sovereign debt markets. The persistence of sovereign bond spreads over time further suggests that climate-related vulnerabilities generate long-term consequences for borrowing conditions and fiscal sustainability. Collectively, the findings confirm that climate risk has become a significant macro-financial phenomenon with direct implications for sovereign financing, financial stability, and sustainable economic development.

Recommendations

Based on the findings, the study recommends that governments, particularly within Africa, prioritize climate adaptation and resilience investments as core elements of fiscal and economic policy rather than treating them solely as environmental initiatives. Investments in resilient infrastructure, disaster-risk management systems, climate-smart agriculture, renewable-energy development, and adaptive public institutions can simultaneously reduce vulnerability and improve sovereign credit perceptions.

The study further recommends that policymakers intensify efforts to attract and efficiently utilize climate-finance resources. International development agencies, multilateral development banks, climate funds, and donor institutions should expand concessional climate-finance facilities targeted at highly vulnerable economies. Given the demonstrated relationship between climate finance and lower sovereign borrowing costs, enhanced access to climate finance can help break the cycle of climate vulnerability and financing constraints observed in many developing countries (Climate Policy Initiative, 2024; OECD, 2024).

Financial regulators and central banks should continue strengthening climate-related disclosure frameworks, sustainability taxonomies, climate stress-testing exercises, and climate-risk governance mechanisms. Such reforms can improve transparency, reduce information asymmetries, and enhance investor confidence, thereby contributing to lower sovereign risk premiums (Hilbrich et al., 2025; Fierro et al., 2026). In addition, sovereign debt managers should formally incorporate climate-risk indicators into debt-sustainability analyses, borrowing strategies, and medium-term fiscal frameworks.

Finally, international financial markets, sovereign-credit-rating agencies, and institutional investors should incorporate climate vulnerability and adaptation capacity more systematically into sovereign-risk evaluation models. As climate change increasingly shapes macroeconomic performance and fiscal resilience, the integration of climate metrics into sovereign credit assessments will become essential for improving risk pricing, preserving financial stability, and supporting sustainable development objectives. Through these measures, countries can build more climate-resilient financial systems while reducing the adverse consequences of climate change on sovereign financing and long-term economic prosperity.

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