Climate Vulnerability and Sovereign Debt Pricing in Africa: Evidence from Creditor Heterogeneity*

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Abstract

This paper examines whether climate vulnerability raises the real cost of sovereign borrowing in Africa, and whether this effect differs across creditor types. Using the recently released African Debt Database (ADD) – an instrument-level dataset covering 68,598 government loans, bonds, and domestic securities issued by 54 African countries between 2000 and 2025 – I derive real ex-ante interest rates by adjusting nominal rates with currency-matched IMF inflation forecasts, enabling consistent comparison across creditors and currencies. The empirical strategy exploits within-country variation in borrowing terms across creditor types – multilateral, bilateral, commercial, and domestic – and interacts these with the ND-GAIN climate vulnerability index, controlling for year fixed effects, creditor-specific maturity structures, and country-year macroeconomic conditions. This isolates how climate vulnerability is priced by different creditors while holding constant country fundamentals at issuance. Four hypotheses guide the analysis: *multilateral climate insurance*, *commercial risk pricing*, *bilateral ambiguity*, and *macroeconomic mediation*. The paper distinguishes between direct pricing of climate risk, reflecting forward-looking risk premia, and indirect effects operating through climate-induced deterioration in macroeconomic fundamentals. Preliminary results show that climate vulnerability is priced heterogeneously across creditors, with implications for capital allocation to climate-exposed economies, the role of multilateral development finance, and the design of climate-contingent sovereign debt instruments.

Keywords: sovereign debt pricing, climate risk, Africa, creditor heterogeneity, climate transition, climate-contingent debt, multilateral development banks, climate finance

JEL Codes: F34, G12, G15, H63, Q54, O55

*This is still an early-stage paper. The results presented are preliminary and reflect the current stage of the empirical analysis; additional analysis, extensions, and robustness checks are in progress and will be finalised by June 2026 ahead of the NBER Climate Finance Conference in October. The author welcomes comments and suggestions.

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1 Introduction

Climate vulnerability is a well-documented determinant of sovereign borrowing costs. Cross-country evidence shows that more climate-vulnerable economies face higher yields and credit-rating downgrades (Beirne et al., 2021; Cevik and Jalles, 2020b; Klusak et al., 2023; Anyfantaki et al., 2025), with effects particularly large for developing countries. Yet the existing evidence rests almost entirely on country-year aggregates of secondary-market spreads, treating sovereigns as if they faced a single creditor. African sovereigns – where the most climate-vulnerable countries on earth are concentrated – borrow simultaneously from multilateral institutions operating under concessional mandates, bilateral creditors with mixed motivations, commercial markets pricing default risk, and increasingly deep domestic securities markets. Whether climate vulnerability is priced uniformly across these creditors, or whether multilateral mandates de-link pricing from climate risk while commercial markets price it directly, is a question the existing literature cannot answer at the level where sovereign rates are actually set.

That the answer depends on who is lending is itself a substantive claim. Multilateral lenders operate under developmental mandates that tie terms to income classification rather than market-implied default risk, generating a presumption of climate-pricing invariance that is testable. Bilateral lenders – Paris Club, China, Gulf – combine geopolitical, commercial, and resource-backed motivations whose response to climate exposure is theoretically indeterminate. Commercial spreads should reflect default-risk pricing of climate-induced fiscal deterioration, but whether climate exposure is priced *independently* of its observable macroeconomic consequences is an open empirical question. Domestic markets carry local-currency liquidity premia that are largely unrelated to external climate risk pricing. Estimating creditor-specific climate gradients in sovereign rates therefore speaks directly to the supply of finance to climate-vulnerable economies, the climate transition in lower-income countries, and the effectiveness of multilateral climate action.

The African Debt Database (ADD) (Manger et al., 2025) used in this paper provides instrument-level data on 68,598 government debt instruments – loans, bonds, and domestic securities – issued by 54 African countries between 2000 and 2025. The unit of observation is an individual instrument at issuance, which enables within-borrower, within-year comparison of rates across creditor types and captures bilateral and domestic instruments invisible to secondary-market spread indices. The dependent variable is a real ex-ante interest rate at issuance, with construction details described in Section 4.

The empirical strategy regresses real rates on interactions between creditor-type indicators and the country-level ND-GAIN climate vulnerability score, conditional on year fixed effects, creditor-specific maturity controls, and country-year macroeconomic controls. Four hypotheses organise the analysis: *multilateral climate insurance*, *commercial risk pricing*, *bilateral ambiguity*, and *macro mediation*. The macro-mediation test discriminates between two policy regimes the existing literature tends to conflate: the design of climate-contingent sovereign instruments (warranted under direct pricing of climate exposure) versus fiscal stabilisation buffers (warranted under indirect pricing through climate-induced fiscal deterioration).

The findings speak to several research priorities at the intersection of climate change and capital markets: the asset-pricing of climate risk in primary debt markets; the supply of finance to climate-vulnerable, lower-income economies in the climate transition; the effectiveness of multilateral climate action; and the design of climate-contingent sovereign debt. The remainder of the paper is organised as follows. Section 2 sets out the research questions. Section 3 reviews the related literature and the paper's contribution. Section 4 describes the data; Section 5 the empirical strategy; and Section 6 the formal hypotheses. Section 7 reports preliminary results, in two parts: Section 7.1 presents stylised facts that establish the unconditional patterns in the data, and Section 7.2 reports regression estimates including sub-period heterogeneity and bilateral disaggregation. Section 8 outlines extensions; Section 9 discusses implications; and Section 10 concludes.

2 Research Question and Motivation

Do climate-vulnerable sovereigns pay more to borrow, and does the answer depend on who is lending? Standard sovereign default models predict that creditors price any factor correlated with debt-service failure; climate vulnerability raises that probability through both direct fiscal channels and indirect macroeconomic deterioration

(Beirne et al., 2021; Klusak et al., 2023). But MDBs operate under mandates tying lending terms to income classification rather than market-implied default risk, creating an institutional wedge that may produce systematically different responses to climate exposure. This is the *climate insurance hypothesis*: MDBs maintain concessional terms regardless of vulnerability while commercial creditors price it into yields. If the hypothesis holds, the magnitude of the multilateral–commercial differential at a given vulnerability level is the implicit price of multilateral concessional access – a magnitude this paper aims to quantify.

The second question concerns the transmission mechanism. Climate vulnerability may raise commercial spreads either because lenders directly assess climate exposure, or because it worsens the fiscal fundamentals all commercial lenders price regardless of climate. These mechanisms are observationally equivalent in cross-country spread regressions but have opposite policy implications: the direct channel motivates climate-contingent debt contracts; the indirect channel motivates fiscal stabilisation buffers. Distinguishing them is a question for the design of climate-contingent sovereign instruments and, more broadly, for understanding how climate risks are reflected in asset values when those values are observable only at primary issuance.

3 Related Literature and Contribution

3.1 Climate Risk and Sovereign Borrowing Costs

Beirne et al. (2021) provide cross-country evidence that climate vulnerability significantly raises sovereign borrowing costs. Cevik and Jalles (2020b) extend this to a panel of 98 advanced and developing countries over 1995–2017 and find that vulnerability and resilience to climate change have significant effects on sovereign bond yields and spreads, with magnitudes much greater for developing economies. Klusak et al. (2023) demonstrate through scenario analysis that physical climate risks will trigger sovereign rating downgrades for a large share of countries under moderate warming, with impacts concentrated in tropical developing economies – implying that current market pricing substantially understates forward-looking physical risk. Cevik and Jalles (2020) show that temperature anomalies and disaster frequency raise sovereign spreads partly through reduced GDP growth and partly through direct risk reassessment.

Recent global evidence is more nuanced. Anyfantaki et al. (2025), using a panel of 52 developed and developing economies over 2000–2023, find that transition risk (CO_2 emissions per capita) is associated with higher sovereign yields – particularly in developing and high-emitting countries after the Paris Agreement – while chronic physical risk does not appear to be consistently priced and acute physical risk binds primarily for high-debt sovereigns. In an OECD sample of 20 countries over 1996–2012, Capelle-Blancard et al. (2019) likewise report that the social and governance components of ESG performance are associated with lower sovereign yield spreads whereas the environmental component is not, suggesting that climate signals may bind unevenly across country groups and macro regimes. By contrast, in emerging markets, Avila-Yiptong et al. (2025) document that improvements in ESG factors – including environmental factors – reduce sovereign spreads in a panel of 79 emerging markets and developing economies over 2001–2021.

Arena et al. (2026) sharpen the OECD picture by decomposing the ND-GAIN index into specific transmission channels: in 31 OECD economies over 2001–2020, robust institutional and structural capacity is rewarded with lower borrowing costs, while extensive social-adaptation requirements show an ambiguous-to-positive association with yields, suggesting that markets price welfare commitments as a source of short-term fiscal constraint rather than as resilience. Gomez-Gonzalez et al. (2024) further document that sovereign-risk responses are asymmetric across the conditional distribution of credit spreads, with high-risk countries disproportionately affected by climate vulnerability – reinforcing that the pricing of climate risk is heterogeneous in the cross-section. Historical evidence is consistent with these recent findings: Huesler (2025) shows that hurricane strikes raised the returns on sovereign bonds issued by Cuba, the Dominican Republic, and Haiti by an average of about 0.9% in the month of impact over 1905–1930, indicating that an early-twentieth-century risk premium already attached to hurricane-prone sovereigns. Together, these papers establish a measurable but heterogeneous climate borrowing-cost signal that nonetheless relies on aggregate country-year data and secondary-market spreads, leaving open how the premium varies across creditor types at instrument level for primary issuances.

Kling et al. (2021) document the firm-level analogue using ND-GAIN and a panel of 15,265 firms in 71 countries:

climate vulnerability raises firms' cost of debt directly and indirectly through restricted access to finance – a parallel that motivates the sovereign-instrument-level question of this paper. Zenios (2024) synthesises this evidence into a climate–sovereign debt "doom loop" in which climate risks have begun to materialise but remain underpriced in sovereign markets.

On the macro mediation channel, Dell et al. (2012), Burke et al. (2015), and Kahn et al. (2019) establish that temperature deviations from historical norms have large and persistent negative effects on per-capita output growth, with effects disproportionately concentrated in developing countries. The natural-disaster literature, surveyed in Cavallo and Noy (2009), documents the analogous result for discrete shocks: Noy (2009) shows that countries with weaker institutions and more constrained finance face substantially larger output declines after disasters of similar relative magnitude. The fiscal counterpart is documented by Melecky and Raddatz (2011), who find – in a panel VAR of high- and middle-income countries over 1975–2008 – that climatic disasters widen budget deficits, with the deficit response broadest among lower-middle-income countries; financial development and insurance penetration moderate both the real and fiscal consequences. Bayoumi et al. (2021) sharpen this evidence with a growth-at-risk approach, showing that disaster preparedness and lower public debt are complementary policy levers: lower debt – and hence more fiscal space – is particularly valuable in the face of very large disasters. Together, these results provide the micro-foundation for the macro mediation channel: any climate borrowing-cost premium may operate either directly, through risk reassessment, or indirectly, through climate-induced fiscal deterioration.

3.2 Sovereign Spreads, Creditor Heterogeneity, and Market Access

The determinants of sovereign borrowing costs have been studied extensively as far back as Edwards (1984). Arellano (2008) and Eichengreen and Mody (1998) documented that both borrower fundamentals and global financial conditions explain primary market spreads for developing country bonds. The creditor heterogeneity dimension is less developed. Gelós et al. (2011) show that institutional quality and transparency are disproportionately important for access to commercial finance. On creditor heterogeneity, Horn et al. (2021) document that Chinese bilateral loans carry qualitatively distinct pricing dynamics – resource-backed collateral, commercial-adjacent rates, and rarely subject to Paris Club restructuring conditions – creating a qualitatively different pricing dynamic that may interact with climate vulnerability in non-obvious ways. Most directly relevant to the question this paper takes up, Diwan and Harnoys-Vannier (2025) argue that much of the gap between low- and lower-middle-income borrowing costs and those of upper-middle-income peers is driven by external factors that domestic policy cannot control: a senior-IFI debt structure that crowds out junior commercial recovery, weak coordination across heterogeneous creditors (Paris Club, China, private), and an inadequate global financial safety net. Their evidence on a $\sim$500 basis-point durable divergence between LLMICs and UMICs after 2022 highlights why creditor composition is itself a determinant of borrowing costs that any climate-risk study at the country level risks confounding.

3.3 African Sovereign Debt and Climate Finance

Africa's creditor composition has shifted twice over the sample period. The HIPC and MDRI initiatives of the early 2000s wrote down external debt and reset the multilateral share; the subsequent decade saw rapid accumulation of commercial debt – particularly Eurobonds – alongside diversification of bilateral creditors toward China and Gulf lenders (Horn et al., 2021). Domestic debt markets have deepened substantially, with many countries now financing significant shares of deficits domestically at market rates (IMF, 2023). The result is a complex multi-creditor landscape in which the same sovereign may simultaneously carry zero-coupon concessional loans from multilaterals, resource-backed bilateral loans from China, commercial Eurobonds, and high-yield domestic T-bills. Whether sovereign debt markets amplify Africa's climate disadvantage, by charging higher risk premia to countries already disadvantaged by exposure, is one of the empirical questions motivating this paper.

Mallucci (2020) formalises a related concern in a quantitative sovereign default model calibrated to seven Caribbean economies frequently hit by hurricanes: disaster risk reduces a sovereign's ability to issue debt, and intensifying climate risk further restricts access to financial markets. Brownbridge and Canagarajah (2024)

document an analogous tension on the public-debt side for Small Island Developing States: large tropical-cyclone events generate fiscal shocks of substantial magnitude, and the long-run financing requirements of effective adaptation strain debt sustainability when public debt is already high. Although the African creditor portfolio differs structurally from that of the Caribbean SIDS in both these studies, the basic mechanism – climate exposure that simultaneously raises financing needs and tightens market access – transposes directly, and motivates examining whether market-implied creditor pricing already reflects this constraint.

3.4 This Paper's Contribution

The paper makes three contributions, each tied to a specific limitation of the existing evidence base.

1. *Instrument-level evidence on climate-risk pricing across Africa's full sovereign-debt creditor landscape.* Existing estimates of the sovereign climate-risk premium rely on country-year aggregates of secondary-market spreads (Beirne et al. 2021; Cevik and Jalles 2020b; Anyfantaki et al. 2025) or on forward-looking rating simulations (Klusak et al. 2023). None combine instrument-level data, full creditor heterogeneity (multilateral, bilateral, commercial, domestic), primary-issuance rates, and within-borrower identification in a single empirical strategy. The African Debt Database used here brings into view bilateral loans and domestic securities that secondary-market indices systematically omit; the within-borrower comparison disciplines the climate-risk pricing estimates against country-specific factors that aggregate analyses cannot net out; and the African setting is the most climate-vulnerable region globally, making it the natural laboratory for studying how creditor mandates intersect with market-based pricing of climate exposure.

2. *Identification of the channel through which climate vulnerability raises commercial sovereign borrowing costs.* Existing estimates document a positive cross-sectional relationship between climate vulnerability and sovereign spreads but do not separately identify whether commercial creditors price climate risk directly – through forward-looking risk premia – or indirectly, through climate-induced deterioration in macroeconomic fundamentals. The two channels are observationally equivalent in country-year spread regressions but carry different first-best policy responses: direct pricing supports the case for climate-contingent sovereign instruments, while indirect pricing motivates fiscal stabilisation. The macro-mediation test in this paper provides the first instrument-level decomposition for African sovereign-debt markets.

3. *A methodological correction for inflation endogeneity.* Climate shocks affect inflation directly through agricultural supply and balance-of-payments channels (Dell et al. 2012), so nominal-rate specifications of climate-exposed asset returns are contaminated. The real ex-ante rate construction – subtracting currency-matched IMF inflation forecasts from nominal rates at issuance – permits identification of climate-vulnerability premia uncontaminated by inflation endogeneity.

4 Data

African Debt Database: The ADD covers 68,598 government debt instruments issued by 54 African countries between 2000 and 2025; 90.1% carry usable rate data. Each observation records key attributes including the nominal rate, maturity, currency, creditor type, and disbursement date. Crucially, it covers bilateral loans never traded on secondary markets and domestic instruments invisible to external spread indices – neither feature is available in the aggregate datasets used by existing studies.

Dependent variable: The real ex-ante rate at issuance is $r^{\text{real}}_{ict} = r^{\text{nom}}_{ict} - \pi^{e}_{ct}$, where π^{e}_{ct} is the currency-matched IMF WEO inflation forecast (domestic CPI for local-currency instruments; advanced-economy forecasts for hard-currency instruments). This avoids the endogeneity of inflation to climate vulnerability through agricultural supply shocks and balance-of-payments pressures (Dell et al., 2012). Rates are winsorised at the 1st and 99th percentiles.

Creditor categories: Four mutually exclusive types: *Multilateral* (World Bank, AfDB, IMF, etc.); *Bilateral* (Paris Club, China, Gulf, etc.); *Commercial* (Eurobonds, syndicated loans); *Domestic* (T-bills, T-bonds). As the

bilateral category aggregates structurally different, sub-type disaggregation is a key extension.

Climate vulnerability: The ND-GAIN Country Index (Notre Dame GRI, 2024) is the standard climate-vulnerability index in the sovereign-debt literature (used in Beirne et al. 2021, Cevik and Jalles 2020b, Kling et al. 2021, and Klusak et al. 2023, among others); it is the only annual country-level index that combines exposure, sensitivity, and adaptive capacity in a comparable cross-country form. The vulnerability score is available annually 1995–2023 and matches ≈97% of ADD instruments. For identification, I use the country-level time-averaged vulnerability score, normalised to zero mean and unit standard deviation; within-country variation in ND-GAIN is small (within-country standard deviation ≈ 0.04 per year), so identification rests on cross-country variation. Robustness checks re-estimate using the ND-GAIN sub-components (exposure, sensitivity, adaptive capacity) separately.

Controls: Country-year macroeconomic controls from the IMF WEO: current account balance/GDP, reserves/GDP, reserves/external debt, inflation, debt-to-GDP, GDP growth, GDP per capita. I also include governance controls (WGI) in selected specifications.

5 Empirical Strategy

Baseline specification: The estimating equation is:

$$r_{ict}^{\text{real}} = \sum_{k \neq M} \beta_k \left(\text{Vuln}_c \times \text{Cred}_i^k \right) + \sum_k \gamma_k \left(\text{Mat}_{it} \times \text{Cred}_i^k \right) + \delta X_{ct} + \alpha_t + \varepsilon_{ict} \tag{1}$$

where Vuln_c is the normalised ND-GAIN score; Cred_i^k indicates creditor category with Multilateral as the omitted baseline; Mat_{it} is contractual maturity at issuance; X_{ct} are macro controls; and α_t are year fixed effects. Standard errors are clustered at the country level. The $\hat{\beta}_k$ measure the rate premium per creditor type relative to multilateral lending per one standard deviation increase in vulnerability; $\hat{\beta}_{\text{Commercial}}$ is the central parameter. The maturity interactions γ_k are essential: multilateral instruments carry substantially longer maturities at substantially lower rates than commercial instruments, so creditor-specific maturity controls are necessary to avoid conflating term premia with climate risk pricing.

Identification: year fixed effects absorb common, time-varying global shocks (US rates, the VIX, oil prices), while X_{ct} controls for country-specific time-varying fundamentals. Since ND-GAIN varies predominantly cross-sectionally, identification comes from cross-country variation in vulnerability interacted with creditor-type composition, conditional on identical macro conditions. A complementary within-borrower strategy restricts the sample to country-years where the same sovereign simultaneously holds instruments from at least two creditor types; here the fixed effect absorbs all time-specific heterogeneity and $\hat{\beta}_k$ is identified from within-country cross-creditor rate differences in the same year – the most conservative test of the climate insurance hypothesis.

Macro mediation and selection. The H4 test compares $\hat{\beta}_{\text{Commercial}}$ across columns with and without X_{ct}. Full attenuation would indicate that the commercial premium operates entirely through climate-induced fiscal deterioration; partial attenuation pins down the residual direct premium. The results in Section 7 indicate *partial* attenuation: the commercial coefficient falls but remains significantly positive, supporting H2 (direct pricing) and H4 (macro mediation) as concurrent channels. Selection into commercial markets is addressed by the within-borrower subsample, in which the same sovereign appears with both creditor types in the same year.

6 Hypotheses

The empirical analysis tests four hypotheses as per equation (1).

H1. *Multilateral climate insurance.* $\hat{\beta}_{\text{Multilateral}} \approx 0$. MDB lending terms are invariant to climate exposure, consistent with concessional mandates that tie pricing to income classification rather than market-implied creditworthiness.

H2. *Commercial risk pricing.* $\hat{\beta}_{\text{Commercial}} > 0$. Commercial creditors charge a positive real premium in more vulnerable countries, consistent with market-based pricing of elevated default probability. The prior is

theoretically motivated; whether it survives at instrument level on African primary issuance, after the macro-mediation test, is empirically open.

H3. *Bilateral ambiguity.* $\hat{\beta}_{\text{Bilateral}}$ is ex-ante indeterminate. Paris Club lenders follow broadly market-referenced pricing and might exhibit a positive coefficient; Chinese and Gulf lenders use resource-backed collateralisation and strategic motivations that could produce a negative coefficient. The bilateral aggregate is a composite of structurally different relationships, and sub-type disaggregation is essential.

H4. *Macro mediation.* Climate-vulnerable countries tend to exhibit weaker fiscal positions, lower reserves, and higher inflation, all of which raise commercial borrowing costs independently of any direct climate signal. The macro-mediation hypothesis predicts that $\hat{\beta}_{\text{Commercial}}$ attenuates when X_{ct} enters; full attenuation would indicate pure macro-mediated pricing, while partial attenuation indicates joint operation of direct and indirect channels. The policy implication depends on the degree of attenuation: full attenuation supports fiscal stabilisation as the first-best response, while partial attenuation supports climate-contingent sovereign instruments alongside fiscal buffers.

7 Preliminary Results

This section reports preliminary results in two parts. Section 7.1 presents stylised facts produced directly from the ADD that establish the unconditional patterns the regression strategy in Section 5 is designed to interpret. Section 7.2 reports the preferred regression specification of equation (1) and its sub-period and bilateral-disaggregation extensions.

7.1 Stylized Facts

The following stylised facts are produced directly from the ADD and form the descriptive backbone of the empirical analysis. They establish the unconditional patterns that the regression strategy in Section 5 is designed to interpret. The raw ADD contains 68,598 instruments; after dropping observations with maturity equal to zero (3,350 cases that trigger division-by-zero errors) and observations with missing nominal interest rate (4,621 cases), the analysis sample contains 60,627 instruments. All statistics below use winsorised real ex-ante interest rates (1st–99th percentile).

Fact 1: The debt landscape is dominated by domestic instruments, with commercial market access highly concentrated

In the 60,627-instrument analysis sample, the distribution across creditor types is highly uneven (Table 1). Multilateral and bilateral lenders account for 5.8% and 4.1% of instruments, respectively; commercial creditors – Eurobonds and syndicated bank loans – account for just 0.4%; and domestic securities (T-bills, T-bonds, and domestic bank instruments) account for 90.7%. Commercial market access is highly selected: 227 instruments over the entire 25-year panel, drawn from a small subset of middle-income and resource-rich African sovereigns. This concentration motivates the within-country approaches in Section 5. Maturity profiles are also stark: multilateral loans average 28.7 years, bilateral 24.5, commercial 12.6, and domestic 3.7 years (median 1 year, reflecting the dominance of T-bills) – creditor-specific maturity controls in the regression specification are therefore essential.

Table 1: Sample Composition by Creditor Type

Creditor Type	N	Share (%)	Mean Mat. (Yrs)	Med. Mat. (Yrs)	Mean Amt. (USD m)
Multilateral	3,507	5.8	28.7	29.5	113.3
Bilateral	2,463	4.1	22.7	23.0	86.6
Commercial	227	0.4	12.6	10.0	1011.3
Domestic	54,430	90.7	3.7	1.0	76.1
Total	**60,600**	**100.0**	6.0	1.0	82.2

Notes: Sample after dropping maturity equal to zero and observations with missing nominal interest rate. Total of 59,990 reflects the further drop of instruments without a creditor-type assignment.

Fact 2: Real interest rates differ by a factor of five across creditor types

Table 2 documents the most striking unconditional fact in the data. Multilateral institutions charge an average real ex-ante rate of -1.12% – creditors are effectively paying African governments, in real terms, to borrow from them. Bilateral creditors are modestly negative in real terms (-0.23%). Commercial creditors charge a mean real rate of $+4.66\%$ – a spread of nearly six percentage points over multilaterals. Domestic instruments sit at $+1.73\%$ in real terms, reflecting domestic liquidity premia rather than external credit risk.

Table 2: Interest Rate and Maturity Statistics by Creditor Type (Winsorised, 1%–99%)

Creditor Type	N	Nom. Mean (%)	Nom. SD	Real Mean (%)	Real SD
Multilateral	3,507	0.90	0.73	-1.12	0.86
Bilateral	2,463	1.83	1.76	-0.23	1.88
Commercial	227	6.49	2.27	$+4.66$	2.44
Domestic	54,403	9.54	6.65	$+1.73$	4.98

Notes: Rates winsorised at 1st–99th percentile. Real ex-ante rate equals the nominal rate at issuance minus the currency-matched IMF WEO ex-ante inflation forecast.

The nominal-versus-real comparison is informative. Domestic instruments carry the highest nominal rates (9.54%), but their real rate (1.73%) is below commercial instruments (4.66%) once domestic inflation is netted out – confirming that nominal-rate comparisons confound currency environment and inflation with credit-risk pricing.

Fact 3: The climate insurance pattern is visible in unconditional data

Table 3 presents the central descriptive table of the paper: mean real interest rates by creditor type and ND-GAIN vulnerability quartile. Countries are ranked by their time-averaged vulnerability score and divided into four equally-sized groups (Q1 = least vulnerable; Q4 = most vulnerable). Figure 1 visualises the same pattern as a 4-creditor by 4-quartile bar chart.

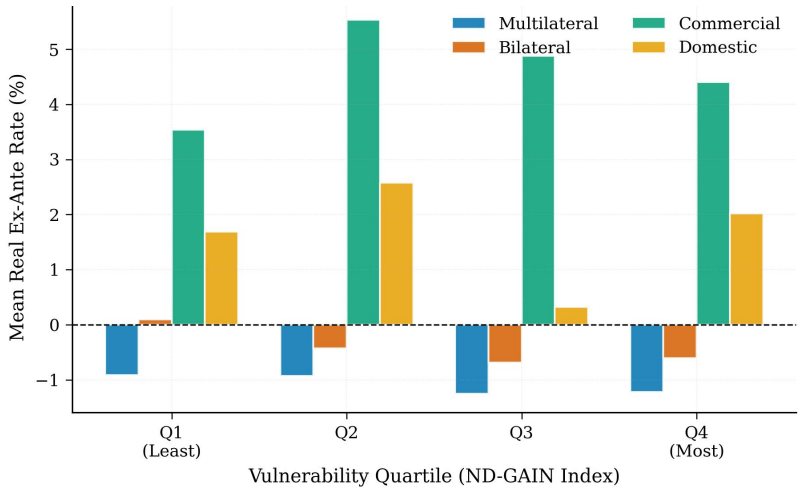


Figure 1: Mean Real Ex-Ante Rate by Creditor Type and Vulnerability Quartile

Table 3: Mean Real Ex-Ante Rate (%) by Creditor Type and Vulnerability Quartile

Creditor Type	Q1 (Least)	Q2	Q3	Q4 (Most)	Δ(Q4−Q1)
Multilateral	−1.01	−0.85	−1.03	−1.23	−0.22
Bilateral	+0.21	−0.44	−0.36	−0.45	−0.66
Commercial	+3.61	+6.24	+5.95	+4.58	+0.97
Domestic	+1.63	+1.81	+2.84	+0.46	−1.17

Notes: Countries ranked by time-averaged ND-GAIN vulnerability score. Q1 = least vulnerable, Q4 = most vulnerable. Real rates winsorised at 1st–99th percentile. The Δ column reports the difference in mean real rates between Q4 and Q1. Differences in commercial rates across quartiles partly reflect sample selection in commercial market access.

Three patterns in Table 3 are immediately striking. *First*, multilateral and bilateral real rates decline as vulnerability increases: MDBs charge their lowest real rates to the most climate-vulnerable countries (-1.23% in Q4 vs. -1.01% in Q1), and bilateral rates fall by 0.7 pp from Q1 to Q4 – both consistent with the climate insurance hypothesis. *Second*, commercial rates are highest in Q2–Q3 rather than Q4, which is a selection artefact: the most vulnerable countries (Q4) have almost no commercial market access, so the Q4 commercial mean reflects a small, unrepresentative subsample of creditworthy-but-vulnerable borrowers. *Third*, the unconditional commercial–multilateral spread widens substantially up the vulnerability distribution – the precise spread, computed within country-years where both creditor types are present simultaneously, is reported in Fact 5.

Fact 4: The most vulnerable countries depend almost entirely on multilateral and domestic finance

Table 4 shows the share of each creditor type in total instrument count, by vulnerability quartile. The most vulnerable countries (Q4) source 18.8% of their instruments from multilaterals, more than twenty times the Q1 share of 0.8%. Commercial market access is near-absent: commercial instruments represent 0.5% of the Q1 portfolio and just 0.2% of the Q4 portfolio. The countries most exposed to climate risk are the ones most structurally dependent on the creditors who provide the most favourable terms.

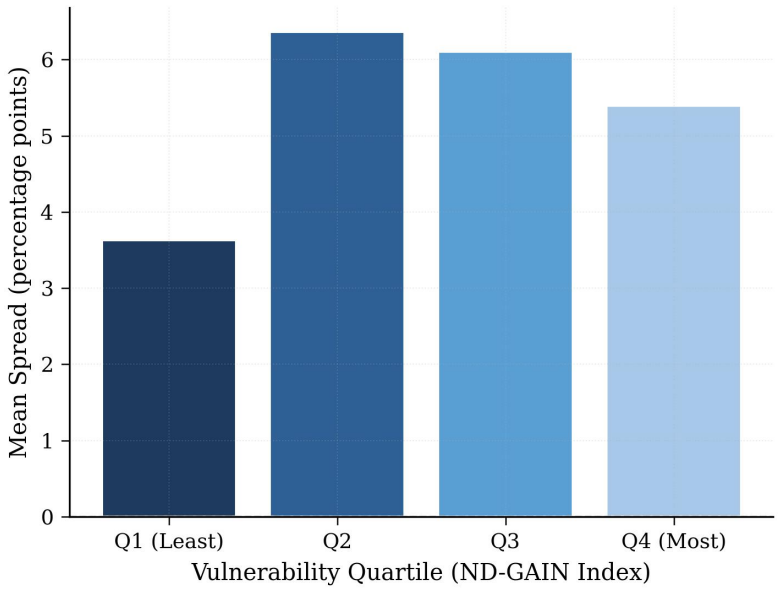
Table 4: Creditor Mix by Vulnerability Quartile (% of Instruments)

Creditor Type	Q1 (Least)	Q2	Q3	Q4 (Most)
Multilateral	0.8	7.1	11.4	18.8
Bilateral	2.6	3.1	3.0	4.9
Commercial	0.5	0.5	0.1	0.2
Domestic	96.0	89.3	85.5	76.0

Notes: Each cell shows the share of instruments in that vulnerability quartile accounted for by each creditor type. Columns sum to approximately 100%.

Fact 5: The within-country commercial–multilateral spread widens substantially with vulnerability

The cleanest descriptive test of the climate insurance hypothesis requires no regression at all. For country-year observations in which the same sovereign simultaneously holds both commercial and multilateral instruments, the within-country spread between real commercial and multilateral rates can be computed directly. Figure 2 plots this spread by vulnerability quartile.



Note: Spread = mean commercial rate minus mean multilateral rate (same country–year pair).

Figure 2: Within-Country Commercial–Multilateral Real-Rate Spread, by Vulnerability Quartile

The mean spread rises from approximately 3.6 percentage points in the least vulnerable quartile (Q1) to 5.4–6.4 percentage points in the more vulnerable quartiles (Q2–Q4). Because this comparison conditions on country-year identity, it eliminates all cross-country heterogeneity by construction. The 1.8–2.8 pp wider spread for vulnerable countries is direct evidence that MDBs provide larger effective concessional access to more climate-vulnerable sovereigns. The regression analysis in Section 5 quantifies and decomposes this gradient.

7.2 Regression Estimates

This subsection reports preliminary regression estimates from equation (1). Table 5 reports the preferred cross-sectional specification estimated on real ex-ante interest rates: column (1) includes year fixed effects only; column (2) – the preferred specification – adds country-year macroeconomic controls; column (3) further adds governance controls. Multilateral instruments are the omitted creditor category.

Table 5: Real Ex-Ante Interest Rate: Baseline Specifications

	(1) Year FE	(2) + Macro [Pref.]	(3) + Gov.
Vuln. × Bilateral	-0.206^{***}	0.709^{*}	-0.141
	(0.062)	(0.365)	(0.607)
Vuln. × Commercial	0.746^{**}	2.033^{***}	1.525
	(0.282)	(0.682)	(0.954)
Vuln. × Domestic	0.425	2.469^{***}	1.802^{***}
	(0.362)	(0.619)	(0.470)
Mat. × Multilateral	-0.086^{***}	-0.124^{***}	-0.156^{***}
	(0.017)	(0.037)	(0.038)
Mat. × Bilateral	-0.072^{***}	-0.113^{***}	-0.123^{***}
	(0.018)	(0.035)	(0.036)
Mat. × Commercial	0.152^{***}	0.021	0.010
	(0.055)	(0.054)	(0.068)
Mat. × Domestic	0.115	0.049^{*}	0.061^{**}
	(0.081)	(0.024)	(0.027)
ln(Amount)	0.206	0.535^{*}	0.680^{*}
	(0.168)	(0.284)	(0.320)
GDP growth		-0.106	-0.001
		(0.123)	(0.119)
Debt/GDP		0.034^{***}	0.031
		(0.011)	(0.018)
Reserves/GDP		-0.890	1.304
		(3.104)	(2.651)
Fiscal balance/GDP		-0.306^{*}	-0.323^{**}
		(0.145)	(0.118)
Govt. effectiveness			-2.423
			(1.897)
Rule of law			0.835
			(1.977)
Observations	60,393	12,507	12,284
Countries	52	17	16
Adj. R^2	0.102	0.314	0.284

Notes: Dependent variable: real ex-ante rate (%) = nominal minus IMF WEO 5-year-ahead inflation forecast (currency-matched), winsorised 1–99%. Year FE in all columns; no country FE (ND-GAIN within-country SD ≈ 0.04/yr; country FE absorbs identifying variation). Multilateral creditor type is omitted. SE clustered at country level in parentheses. Column (2) is the preferred specification. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

The preferred specification (column 2) shows positive vulnerability gradients for commercial, domestic, and – marginally – bilateral creditors, consistent with H2 (commercial creditors price climate vulnerability) and partly with H3 (bilateral creditors also price vulnerability, though more weakly). The multilateral baseline is invariant to vulnerability by construction (omitted category), consistent with H1.

The sample drops substantially when macro controls are introduced – from 60,393 instruments and 52 countries in column (1) to 12,507 instruments and 17 countries in column (2). This reflects limited availability of macroeconomic controls (particularly debt-to-GDP) for many African sovereigns. The preferred specification therefore identifies effects from a meaningfully selected subsample; expanding macro coverage is one of the priorities for subsequent drafts and is one reason the results in this section are read as preliminary.

Sub-period heterogeneity in the commercial vulnerability premium. Table 6 reports preliminary estimates of the commercial vulnerability coefficient when equation (1) is estimated separately by sub-period.

Table 6: Commercial Vulnerability Premium by Sub-Period (Real Ex-Ante Rates, Preliminary)

Sub-period	$\hat{\beta}_{\text{Commercial}}$	Interpretation
2000–2009	-2.07^{**}	Selection: only most creditworthy issuers had market access
2010–2015	$+1.52^{***}$	Frontier-market Eurobond boom, climate pricing emerging
2016–2025	$+4.20^{***}$	Post-Paris explicit climate-risk pricing

Notes: Each row is a separate estimate of equation (1) restricted to the indicated sub-period: real ex-ante rates, year fixed effects, and macro controls. SE clustered at country level. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

The pre-2010 negative coefficient is consistent with selection: in that decade, only the most creditworthy African sovereigns – and therefore typically the least climate-vulnerable – accessed commercial markets, so the within-commercial-issuer gradient runs opposite to the population-level gradient. From the 2010–2015 frontier-market Eurobond boom onward, as more vulnerable sovereigns entered commercial markets, the commercial vulnerability premium turned positive; it increases further in 2016–2025, the period coinciding with the Paris Agreement and the global emergence of climate-finance policy frameworks.

Status of this section. The sub-period results in Table 6 are preliminary. The full preferred-specification estimates of equation (1) across creditor types, the macro-mediation decomposition (with and without macro controls), the within-borrower spread specification, the bilateral creditor sub-type disaggregation (China versus Western bilateral), and the robustness checks outlined in Section 8 are in progress and will be reported in subsequent drafts. The findings in this section should therefore be read as illustrative of the temporal pattern in the data rather than as the paper's final empirical conclusions.

8 Possible Extensions

1. **Within-borrower spread specification:** Using $\Delta r_{ct} = r_{ct}^{\text{Comm}} - r_{ct}^{\text{Multi}}$ as the dependent variable, restricted to country-years with instruments from both creditor types, eliminates all cross-country heterogeneity by construction – the cleanest joint test of H1 and H2.

2. **Bilateral sub-type disaggregation:** Disaggregating into Paris Club, China, and other bilateral categories will reveal whether the aggregate conceals any different Chinese and Paris Club coefficients, in which case H3 can only be resolved at the sub-type level.

3. **Realised climate shocks from natural disasters:** Substituting EM-DAT disaster frequency or economic damage (CRED, 2024) for the ND-GAIN structural index tests whether creditors respond to realised shocks or forward-looking exposure – two distinct pricing mechanisms.

9 Discussion

The preliminary evidence in Section 7 – a positive commercial vulnerability premium that survives macroeconomic controls, alongside weaker bilateral and significant domestic gradients and an invariant multilateral baseline – bears on a number of debates at the intersection of climate finance and sovereign-debt research. The framework also extends beyond the African sample: the creditor-heterogeneity setup and instrument-level method apply directly to Caribbean small island developing states (cf. Brownbridge and Canagarajah 2024), to Pacific small states, and to climate-vulnerable South and Southeast Asian sovereigns where similar multi-creditor structures prevail. Five implications follow:

1. **Pricing of climate risk in sovereign debt.** The creditor-specific vulnerability coefficients quantify how climate exposure enters the risk premia of one of the largest, longest-duration classes of climate-exposed assets. Because primary-market rates are observed at issuance and disaggregated by creditor, the estimates are not contaminated by the liquidity and benchmark effects that confound aggregate secondary-market

spread indices, sharpening the measurement of climate-risk pricing in capital markets.

2. **Climate transition, capital flows, and geopolitics.** Africa's creditor portfolio – concessional multilaterals, Paris Club, China, Gulf lenders, commercial markets, and domestic securities – intermediates the climate transition for these sovereigns through institutions with very different mandates and geopolitical alignments. The creditor-type vulnerability gradient is therefore informative about how climate risk shapes the flow of capital to lower-income, climate-vulnerable economies and the broader distribution of resources across nations.

3. **Effectiveness of multilateral climate action.** The climate insurance hypothesis is, in effect, a test of whether MDB concessional lending operates as a de facto insurer-of-last-resort against climate exposure – a measurable form of climate action by a major institutional lender. A near-zero $\hat{\beta}_{\text{Multilateral}}$ would establish that preserving multilateral access is itself a climate risk management instrument, not merely a source of cheap finance – particularly salient as African sovereigns face the shift from concessional toward commercial external finance and the post-HIPC market transition.

4. **Design of climate-contingent debt instruments.** If the commercial premium survives conditioning on macro fundamentals, commercial creditors are embedding an assessed climate exposure factor into yields not captured by contemporaneous fiscal data – the logic supporting state-contingent and climate-linked sovereign instruments. If, however, climate pricing operates through macroeconomic channels, fiscal stabilisation buffers are the first-best response. The decomposition this paper provides distinguishes which of these regimes prevails in African primary debt markets and informs which of the available instrument-design levers – state-contingent clauses, climate-linked securities, debt-for-climate swaps, or fiscal stabilisation – is best matched to the underlying transmission mechanism.

5. **Spillovers to domestic financial systems.** The creditor-specific vulnerability gradient has direct implications for domestic banking-sector exposure to climate risk in Africa. Sovereign securities are a substantial share of bank assets across the continent – in Kenya, for instance, government securities constitute approximately 28% of total banking-sector assets (CBK, 2024). The climate gradient in sovereign pricing therefore transmits mechanically to bank balance sheets, linking sovereign climate risk to domestic capital markets and to the financial-stability frameworks that supervise them.

10 Conclusion

This paper studies the pricing of climate vulnerability in primary sovereign debt issuance across Africa's full creditor landscape, using instrument-level data from the African Debt Database covering 68,598 government loans, bonds, and domestic securities issued by 54 countries between 2000 and 2025. The empirical strategy interacts the ND-GAIN vulnerability score with creditor-type indicators and identifies creditor-specific real-rate premia under year fixed effects and country-year macroeconomic controls.

Preliminary results suggest that climate vulnerability is priced heterogeneously across creditors. Commercial creditors charge a positive vulnerability premium that survives macroeconomic controls; domestic securities also price vulnerability significantly; bilateral creditors price more weakly; and multilateral terms are invariant by construction, consistent with their concessional mandate. The macro-mediation decomposition speaks directly to the central instrument-design question facing climate-finance policy: whether the residual direct pricing of climate exposure justifies climate-contingent sovereign instruments, or whether the bulk of the premium operates through climate-induced fiscal deterioration and is better addressed by fiscal stabilisation buffers.

These findings are preliminary. The full identification programme – including the within-borrower spread specification, bilateral creditor sub-type disaggregation, robustness to alternative climate-vulnerability measures, and EM-DAT realised-disaster extensions – is in progress and will be incorporated in subsequent drafts ahead of the conference. The instrument-level African evidence and the creditor-heterogeneity setting are well-positioned to inform the climate-finance literature on capital flows to climate-vulnerable economies, the effectiveness of multilateral climate action, and the design of climate-contingent sovereign debt instruments.

By taking up these questions in primary sovereign-debt markets and across the full creditor landscape, the paper directly engages several themes of the NBER Climate Finance Conference: how climate risk transmits to government-debt asset prices, how the supply of finance to climate-vulnerable, lower-income economies depends on creditor mandates, the effectiveness of multilateral climate action through concessional pricing, and the design of climate-contingent sovereign instruments alongside fiscal stabilisation tools.

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