Climate Vulnerability and Sovereign Debt Accumulation: A Panel Cointegration Study of Small Island Developing States

Jorge D. Ballestero
Columbia University

March 2026

Abstract

I test whether structural climate vulnerability has a long-run cointegrating relationship with sovereign debt accumulation across 27 Small Island Developing States over 2000–2023. Using a panel Vector Error Correction Model, I find that a one-unit increase in the ND-GAIN vulnerability score is associated with approximately 105 percentage points more sovereign debt in the long run, independently of income, fiscal policy, and global shock regimes. The error correction is asymmetric: debt adjusts toward its vulnerability-implied equilibrium at 16% per year while vulnerability adjusts upward—a ratchet dynamic consistent with the structural constraints on SIDS debt management. The coefficient is stable across four nested specifications. Regional heterogeneity confirms the mechanism: the relationship is strongest where structural exposure is most severe, and weakest in Pacific SIDS where grant-based financing partially decouples debt from vulnerability. These findings provide direct empirical support for the UN Multidimensional Vulnerability Index (Resolution A/78/L.98, August 2024): if vulnerability drives long-run debt independently of income, income-based eligibility criteria systematically exclude the countries most in need.

JEL: F34, Q54, O19, H63 **Keywords:** sovereign debt, climate vulnerability, SIDS, panel VECM, cointegration, concessional finance, MVI

Contents

1 Introduction

This paper addresses an apparent paradox: the countries least responsible for climate change are accumulating the most debt, and the international finance system is not built to see why. Small Island Developing States (SIDS), 39 countries formally recognized by the United Nations (UN) as a distinct group on the basis of their shared structural vulnerabilities, including small size, remoteness, and disproportionate exposure to climate hazards, contribute less than 1% of global greenhouse gas emissions, yet face disaster costs averaging 18% of GDP annually. For comparison, this number is approximately 3% globally Saghir and Ijjasz-Vasquez (2025). Moreover, more than 70% of these countries show indicators of impending or deepening debt distress UN Office of the High Representative for LDCs, LLDCs and SIDS (2024).

Debt is perceived in fundamentally different ways by different countries. The international finance system allocates "concessional loans" primarily on the basis of *income per capita*. These loans are "extended on terms substantially more generous than market loans" United Nations Economic and Social Commission for Western Asia, which allow beneficiary countries to take on a more 'accessible' debt, enabling them to fund public works and innovations. Based on the current allocation rubric, middle-income SIDS do not qualify, even as their structural vulnerabilities quietly erode their fiscal positions year after year. Lack of access to these financing programs hinders SIDS in their restructuring following a disaster. If a long-run relationship between these structural vulnerabilities and debt exists irrespective of income, then it follows that *income-based eligibility criteria will systematically exclude the countries most in need.*

I believe that this question has not been answered before, by and large due to the following three reasons. (1) SIDS are almost always excluded from empirical finance panels because their capital market data is thin; (2) the climate-finance literature has focused on short-run spread responses to discrete disaster events, not long-run structural debt dynamics; (3) no paper has tested panel cointegration between structural climate vulnerability and sovereign debt in a sample built around SIDS. The absence of this evidence is not merely an academic gap; it has direct consequences for ongoing policy reforms.

In August 2024, the United Nations General Assembly (UNGA) formally adopted Resolution A/78/L.98, establishing the Multidimensional Vulnerability Index (MVI). The MVI is designed to replace income per capita as the sole criterion for concessional finance access, incorporating structural dimensions of vulnerability that income-based measures miss. The reform was decades in the making, with the first call for a global vulnerability index dating back to 1992.[1] Yet the reform lacks what any durable policy change requires: an empirical foundation demonstrating that vulnerability, not just income, drives the fiscal outcomes it is designed to address.

This paper is concerned with understanding whether structural climate vulnerability drives long-run debt accumulation, independent of income and fiscal policy. It provides the quantitative

[1] This references the 1992 UN Conference on Environment and Development

empirical foundation the MVI reform is missing: evidence that structural vulnerability,[2] not just income, drives long-run financial stress in SIDS. To do so, this paper estimates a Vector Error Correction Model (VECM), using data from 27 SIDS over 2000-2023. Structural climate vulnerability is measured via the ND-GAIN Country Index vulnerability sub-score Notre Dame Global Adaptation Initiative (2026). Sovereign debt is sourced from the World Bank International Debt Statistics and the IMF World Economic Outlook.

I find that *structural climate vulnerability cointegrates with sovereign debt accumulation*. A one-unit increase in the ND-GAIN vulnerability score is associated with approximately 105 percentage points more debt in the long run, independently of income, GDP growth, current account balance, fiscal balance, and remittances. The coefficient is stable across four nested specifications: a baseline model, and models enriched with financial and remittance controls, with structural break dummies for the 2008 GFC, 2014-2016 commodity shock, and COVID-19. Debt error-corrects toward its long-run vulnerability-implied level at approximately 16% per year. Vulnerability adjusts upward in response to disequilibrium; the correction is *asymmetric*

This paper proceeds as follows. Section 2 establishes the fiscal paradox of small island states, and situates the paper within the sovereign debt and climate-finance literatures. Section 3 develops the ratchet hypothesis—the theoretical prediction of asymmetric error correction that motivates the empirical design. Section 4 describes the data and sample. Section 5 lays out the empirical strategy. Section 6 addresses identification and robustness. Finally, Section 7 presents results and draws the policy implications.

2 Background and Motivation

2.1 The Fiscal Paradox of Small States

The fiscal vulnerability of small island states is geographical before it is fiscal. SIDS sit on hurricane tracks, face accelerating sea level rise, depend on coral reef ecosystems for food security and coastal protection, and have no continental buffer to absorb what climate delivers. When a storm makes landfall in Dominica or Vanuatu, there is nowhere for the damage to go except onto the public balance sheet. Hurricane Maria cost Dominica an estimated 226% of GDP in 2017 Government of Dominica (2017).

Debt has followed, persistently. Across the 27 SIDS in this paper's sample, mean external debt-to-GNI over 2000–2023 exceeds 60%, with Antigua and Barbuda averaging 88%, Barbados 97%, and Sao Tome and Principe 154%. This preceded the pandemic, survived it, and worsened through it.

[2] Now is a good point to clarify that *structural vulnerability* corresponds to the *systemic* risk, not the *actualized* disasters. Results from measures such as the MVI, ND-GAIN, and beyond, assign different levels of vulnerability to different states, and reacting to that vulnerability induces changes in financial reality.

The international finance system, meanwhile, is calibrated to income; not to the kind of structural exposure described above. Concessional finance is allocated primarily by GNI per capita, and many SIDS sit above the threshold for the most favorable terms, despite carrying debt levels and climate costs that dwarf comparable middle-income mainland economies. A country's average output per person tells you something about its capacity to service debt under normal conditions. It tells you nothing about how often those conditions are interrupted by a storm that costs two years of GDP. International climate finance flows to SIDS bear no significant correlation with measured vulnerability: the ten best-funded SIDS receive 67% of tracked adaptation finance Climate Policy Initiative (2025), while the most exposed countries receive neither the transfers nor the borrowing terms their risk profiles would warrant.

Structural exposure, in other words, goes unpriced, and the countries bearing it are left to absorb the cost through debt.

2.2 Literature Gap and Contribution

The academic literature has, to a significant degree, made the same mistake as the finance system: it has looked at the wrong horizon.

The sovereign debt literature is mature and rigorous. Edwards (1984) established the canonical macro determinants of LDC borrowing costs: growth, inflation, fiscal balances, external debt ratios. This framework has held up well across four decades of refinement. Eichengreen and Mody (1999) extended it to spread dynamics in emerging markets, and Uribe and Yue (2006) added the role of global push factors, showing that a significant share of emerging market spread variation is driven by external conditions rather than domestic fundamentals. These papers define the standard controls this paper uses. However, climate does not appear in any of them. I want note that this is not an oversight, but rather simply due to climate not yet being a fiscal variable of first-order importance for the countries they studied.

That began to change. Buhr et al. (2018) and Kling et al. (2021) introduced climate vulnerability as a determinant of borrowing costs in developing countries, finding that more exposed countries face higher costs of capital. These are the closest antecedents to this paper, and the distinction between them and what follows here is worth being precise about. Both of these papers study borrowing costs—spreads, cost of capital—not the stock of debt. Moreover, they both rely on cross-sectional variation or short-run responses to discrete events. Neither tests for a long-run cointegrating relationship between structural vulnerability and debt accumulation. And neither is built around SIDS: both use broader developing country samples in which small island states appear, if at all, as a handful of observations rather than the analytical focus. As mentioned in the Introduction, this group of countries faces particular risks and challenges; the inclusion of SIDS-specific vulnerabilities is a conscious effort that must be made to close this gap, both in literature and policy.

The SIDS exclusion is not incidental. Most SIDS do not issue dollar-denominated bonds at the scale required for inclusion in the JP Morgan EMBI, which requires a minimum of $500 million in outstanding face value. This means that the countries most acutely exposed to climate risk, and thus most directly relevant to the MVI reform, are the ones empirical finance work most consistently cannot see. The systemic exclusion of SIDS-specific vulnerabilities reinforces their inability to face these constraints: if the current structures systemically exclude SIDS countries.

By reorienting the dependent variable from market-based spread data to debt-to-GDP sourced from the World Bank International Debt Statistics and the IMF World Economic Outlook, this paper constructs a panel built around SIDS rather than one from which they fall out by construction.

The short-run/long-run distinction matters for a second reason. The existing climate-finance literature studies what happens after a disaster: spreads spike, borrowing costs rise, then they normalize. A market that reacts to Hurricane Maria when it arrives but ignores the underlying structural exposure of Caribbean islands in quiet periods is not pricing *systemic* climate risk in any meaningful sense. The cointegration framework tests a different question: whether two persistent series share a stable long-run equilibrium, independent of short-run fluctuations. That is the right framework for structural vulnerability, which is slow-moving, persistent, and present in the data whether or not a storm has recently made landfall.

To my knowledge, no paper has tested panel cointegration between structural climate vulnerability and sovereign debt in a sample built around SIDS, controlled for income directly in the cointegrating vector, and examined whether the error-correction mechanism is asymmetric. The first two of these are methodological contributions. The third is theoretical: a prediction about the nature of the adjustment process that follows directly from the structural features of small island economies. That prediction is developed in the next section.

3 The Ratchet Hypothesis

Standard cointegration implies that deviations from a long-run equilibrium are corrected over time; that when two persistent series drift apart, forces pull them back together. The adjustment coefficient in a VECM captures this: a negative coefficient on debt means that when debt is above its long-run vulnerability-implied level, it subsequently falls back. This mechanism is called *mean-reversion*, and it is the standard assumption underlying cointegration analysis.

For small island states, that assumption does not hold symmetrically. Three structural features of SIDS economies make it implausible. First, growth constraints: SIDS cannot grow their way out of elevated debt quickly, because their economies are small, open, and heavily dependent on tourism and commodity revenues that are themselves sensitive to climate conditions. Second, capital market access: most SIDS cannot refinance cheaply after a shock. They are excluded from major bond indices, lack deep domestic debt markets, and face borrowing terms that deteriorate precisely when they need to borrow most. Third, vulnerability persistence: the structural exposure that generated the debt does not diminish once the reconstruction is done. The hurricane track does not move. Sea levels do not fall. The island is still there, in the same place, when the next storm arrives.

The consequence is a ratchet. When vulnerability increases, whether through a discrete disaster or through the slow-moving deterioration of underlying exposure, debt rises to absorb the fiscal cost. The correction that would otherwise bring debt back down operates slowly and incompletely. But there is a second channel that the standard framework misses: the debt accumulated to absorb the last shock has itself reduced the country's adaptive capacity, which is one of the three components of structural vulnerability in the ND-GAIN methodology framework, alongside exposure and sensitivity Notre Dame Global Adaptation Initiative (2024). Consequently, fiscal space narrows, infrastructure investment is deferred, and institutional capacity is stretched. The country enters the next cycle more exposed than it was before, from a higher debt baseline. Figure 1 illustrates this mechanism.

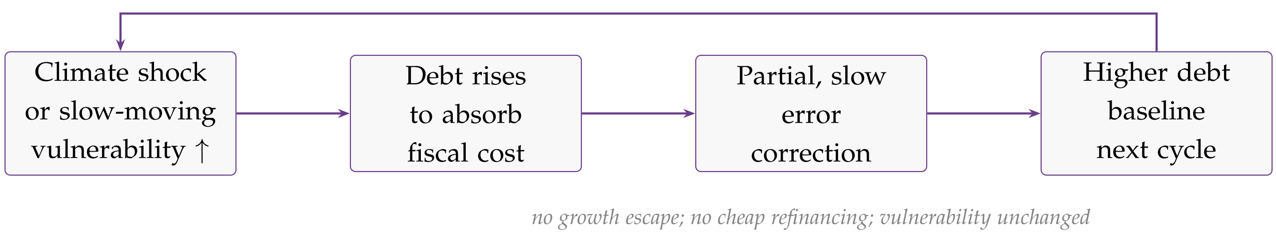

Figure 1: The ratchet mechanism: asymmetric error correction in SIDS

> The critical implication of the ratchet is that the long-run equilibrium level of debt is itself drifting upward as structural vulnerability increases with climate change. Mean-reversion in the residuals does not mean debt reverts to a fixed level, but rather that debt tracks vulnerability, and if vulnerability trends upward, debt inherits that trend. Concessional finance needs are not static; they are systematically increasing.

The implication for the long-run equilibrium is non-trivial. Standard cointegration assumes mean-reversion around a fixed equilibrium level. The ratchet implies something different: mean-reversion around a drifting equilibrium. Debt tracks vulnerability, and if vulnerability trends upward as climate change progresses—which the physical science literature strongly suggests Mycoo, Wairiu et al. (2022)—then the long-run debt level implied by the cointegrating relationship is itself rising over time. The financing gap between what SIDS need and what the international system provides is not a static problem. It is a worsening one.

This produces two observable signatures in the VECM. The adjustment coefficient on debt should be negative and significant: debt error-corrects toward its vulnerability-implied level when it deviates above it. The adjustment coefficient on vulnerability should be positive: vulnerability adjusts upward in response to disequilibrium, not downward. If both signatures are present in the data, the ratchet mechanism is operating. If only the first is present, the cointegrating relationship holds but the adjustment is symmetric. The empirical strategy is designed to distinguish between these cases.

4 Data

4.1 Sample

The panel covers 27 Small Island Developing States over 2000–2023, yielding 648 country-year observations at annual frequency. The sample is drawn from the 39 countries formally recognized as SIDS by the United Nations UN Office of the High Representative for LDCs, LLDCs and SIDS (2024), spanning three subregions: 14 Caribbean, 6 Pacific, and 7 Atlantic-Indian Ocean-South China Sea (AIS). Twelve SIDS are excluded due to insufficient data coverage: St. Kitts and Nevis is absent from the ND-GAIN vulnerability dataset; six Pacific microstates (Kiribati, Marshall Islands, Micronesia, Nauru, Palau, and Tuvalu) do not report to the World Bank Debtor Reporting System; and the remaining four lack the minimum time-series depth required for cointegration analysis. The full country list, with ISO3 codes, subregion classification, and debt data source, is provided in Appendix A.

The sample design allows for a specific focus on SIDS. Rather than treating SIDS as a subgroup within a broader emerging-market panel, this paper constructs a panel built around them. The 27 countries here are not an afterthought, but rather the analytical focus.

4.2 Variables

Table 1 summarizes all variables, their sources, and their roles in the empirical strategy. A few warrant additional comment.

The dependent variable is sovereign debt, sourced from two databases depending on country reporting status. For 21 SIDS that report to the World Bank Debtor Reporting System, external debt stocks as a percentage of GNI are drawn from the International Debt Statistics World Bank (2024a). For six higher-income SIDS—Antigua and Barbuda, Bahamas, Barbados, Seychelles, Suriname, and Trinidad and Tobago—that do not report to the DRS, general government gross debt as a percentage of GDP is sourced from the IMF World Economic Outlook International Monetary Fund (2024). The two measures are conceptually distinct: external debt captures obligations to foreign creditors, while general government gross debt captures total public sector liabilities. This difference is documented in the crosswalk in Appendix A and acknowledged where relevant in the robustness analysis.

Table 1: Core variables and data sources

Variable	Source	Role
Debt (% GNI / GDP)	WB IDS World Bank (2024a); IMF WEO International Monetary Fund (2024)	Primary dependent variable
ND-GAIN vulnerability	Notre Dame ND-GAIN Notre Dame Global Adaptation Initiative (2026)	Primary climate variable; I(1)
GDP per capita (PPP)	World Bank WDI World Bank (2024b)	Development-level control; I(1)
GDP growth	World Bank WDI World Bank (2024b)	Exogenous control; I(0)
Current account / GDP	World Bank WDI World Bank (2024b)	Exogenous control; I(0)
Inflation	World Bank WDI World Bank (2024b)	Exogenous control; I(0)
Fiscal balance / GDP	IMF WEO International Monetary Fund (2024)	Exogenous control; I(0)
Remittances / GDP	World Bank WDI World Bank (2024b)	Exogenous control; I(0)

Note: IDS covers 21 SIDS reporting to the World Bank Debtor Reporting System. WEO covers 6 higher-income SIDS (ATG, BHS, BRB, SUR, SYC, TTO) that do not report to the DRS. Integration order confirmed by Im-Pesaran-Shin panel unit root tests. I(0) variables enter the VECM as exogenous regressors. Robustness specifications additionally use ND-GAIN exposure and sensitivity sub-scores, EM-DAT disaster damage normalized by GDP Centre for Research on the Epidemiology of Disasters (2024), and UNCTAD trade openness United Nations Conference on Trade and Development (2024); these are described in Section 6 and listed in Appendix B.

The primary climate variable is the ND-GAIN Country Index vulnerability sub-score Notre Dame Global Adaptation Initiative (2026), which measures a country's exposure, sensitivity, and adaptive capacity across six life-supporting sectors: food, water, health, ecosystems, human habitat, and infrastructure. Scores range from 0 to 1, with higher values indicating greater vulnerability. Exposure indicators are time-invariant by design: they capture projected future biophysical impacts and do not vary year to year, while sensitivity and adaptive capacity vary annually. The full composite vulnerability score is used in the baseline specification; a decomposed specification using exposure and sensitivity only is estimated as a robustness check and discussed in Section 6.

Realized disaster shocks are measured using total inflation-adjusted damage as a percentage of nominal GDP, constructed from the EM-DAT International Disaster Database Centre for Research on the Epidemiology of Disasters (2024), maintained by the Centre for Research on the Epidemiology of Disasters at the Université catholique de Louvain. EM-DAT records are at the event level; they are aggregated to country-year totals and normalized by nominal GDP from the World Bank World Development Indicators World Bank (2024b).

Macroeconomic controls—GDP growth, inflation, current account balance, remittances, and GDP per capita PPP—are sourced from the World Bank WDI World Bank (2024b). Fiscal balance is sourced from the IMF WEO International Monetary Fund (2024). Trade openness is constructed from UNCTAD goods and services data United Nations Conference on Trade and Development (2024), available from 2005, and normalized by nominal GDP; it enters as a robustness control rather than a core specification variable.

4.3 Descriptive Patterns

Table 2 reports summary statistics for all variables. Two patterns are worth noting before the formal analysis. First, the SIDS in this sample are systematically more vulnerable than the global ND-GAIN average. Across the full sample period, the mean vulnerability gap between SIDS and non-SIDS countries is approximately 0.047 score units. This difference is consistent across years and does not narrow over the 2000-2023 window. The countries in this panel are not marginally more exposed than the rest of the world. They are structurally more exposed.

Second, there is substantial within-sample variation in both vulnerability and debt, which is what the VECM identifies on. Vulnerability ranges from approximately 0.38 for Mauritius to 0.55 for Guinea-Bissau. Debt ranges from under 20% of GNI for Guyana in the early 2000s to over 430% for Sao Tome and Principe in 2000, reflecting a debt relief episode that substantially reduced its stock over the sample period.

Figure 2 presents two descriptive cuts of the data that together motivate the empirical strategy. Panel A plots median debt trajectories for high- and low-vulnerability SIDS over 2000-2023. The higher median debt of the low-vulnerability group reflects deeper capital market access, a consequence of higher income and adaptive capacity, rather than lower fiscal stress. Both groups track broadly parallel long-run trends, but the high-vulnerability group shows greater sensitivity to discrete shock episodes, with a more pronounced mid-2000s decline driven by debt relief initiatives in Pacific and AIS states and a more muted COVID-19 response reflecting constrained

Table 2: Summary Statistics for Model Core Variables

	N	Mean	SD	Min	Median	Max
Debt (% GNI/GDP)	648.0	61.8	48.2	6.5	51.1	435.8
ND-GAIN vulnerability	648.0	0.5	0.1	0.3	0.5	0.7
ND-GAIN exposure	648.0	0.5	0.1	0.4	0.5	0.7
ND-GAIN sensitivity	648.0	0.4	0.1	0.2	0.3	0.6
Disaster damage (% GDP)	648.0	2486.0	18469.1	0.0	0.0	330749.9
GDP per capita PPP	648.0	13615.8	9470.3	1960.4	12037.0	49312.4
GDP growth (%)	648.0	2.8	6.2	-32.9	2.9	63.3
Current account (% GDP)	648.0	-8.0	10.8	-57.1	-7.0	38.8
Inflation (%)	642.0	5.2	7.3	-7.1	3.4	59.4
Fiscal balance (% GDP)	648.0	-2.4	7.3	-25.1	-2.6	125.1
Remittances (% GDP)	622.0	6.7	7.4	0.0	4.3	42.6

market access rather than lower impact. Panel B plots each country's mean vulnerability score against its mean debt level over the sample period. The near-flat cross-sectional relationship is itself informative: income and market access dominate the between-country comparison, obscuring the within-country dynamic that is the object of interest. This motivates the panel cointegration framework in Section 5, which identifies the vulnerability-debt relationship from variation over time within each country, controlling for income directly in the cointegrating vector.

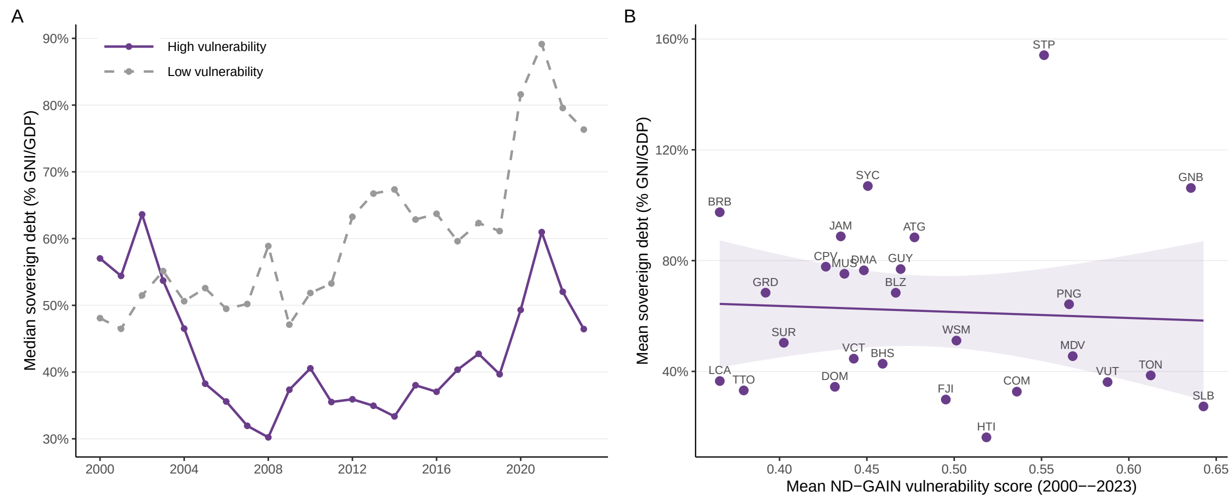

Figure 2: Descriptive evidence on vulnerability and debt in SIDS

Note: Panel A: Median sovereign debt by vulnerability group, 2000–2023. High- and low-vulnerability groups are defined by whether a country's mean ND-GAIN vulnerability score over 2000–2023 lies above or below the cross-country sample median. *Panel B:* Mean ND-GAIN vulnerability score against mean sovereign debt by country, 2000–2023. The near-flat regression line reflects a cross-sectional identification problem—higher vulnerability correlates with lower income and reduced capital market access, constraining debt accumulation independently of fiscal need.

5 Strategy

5.1 Why Cointegration?

A standard panel regression of debt on vulnerability would be misspecified. Both series are non-stationary: shocks to debt and to structural vulnerability are permanent rather than transitory, meaning the series do not revert to fixed means over time. Regressing one integrated series on another without accounting for this property risks spurious regression: finding a statistically significant relationship that reflects shared trends rather than a genuine equilibrium Granger and Newbold (1974). The solution is cointegration. If a linear combination of debt and vulnerability is stationary: if the two series move together over time in a way that keeps their long-run relationship bounded, then the relationship is genuine and can be estimated consistently Engle and Granger (1987). The Vector Error Correction Model extends this by modeling both the long-run equilibrium and the short-run adjustment dynamics in a single system, which is precisely the framework needed to test the ratchet prediction derived in Section 3.

5.2 Long-Run Specification and Integration Order

The long-run relationship of interest is:

$$\text{Debt}_{it} = \alpha_i + \beta_1 \, \text{Vulnerability}_{it} + \beta_2 \, \text{GDPpc}_{it} + \varepsilon_{it} \tag{1}$$

where β_1 is the coefficient of interest: a significant positive estimate means vulnerability drives debt accumulation beyond what income can explain. GDP per capita enters the cointegrating vector directly to ensure that β_1 captures a climate effect rather than a development-level story.[3]

Integration order is confirmed by Im–Pesaran–Shin panel unit root tests Im, Pesaran, and Shin (2003), which allow for heterogeneous autoregressive coefficients across countries. Table 3 reports results. Debt, vulnerability, and GDP per capita are non-stationary in levels and stationary in first differences—confirmed I(1). All remaining macro controls (GDP growth, current account balance, inflation, fiscal balance, remittances) are stationary in levels—confirmed I(0). The I(1) variables enter the cointegrating system as endogenous variables; the I(0) variables enter as exogenous regressors in the short-run dynamics.

[3] This is a point developed further in Section 6

Table 3: Im–Pesaran–Shin Panel Unit Root Tests

Variable	**W-bar**	**p-value**	**Order**
Panel A: Levels			
Debt	-1.078	0.141	I(1)
ND-GAIN vulnerability	-5.334	<0.001	I(0)
GDP per capita (PPP)	-1.95	0.026	I(0)
GDP growth	-13.998	<0.001	I(0)
Current account	-5.817	<0.001	I(0)
Inflation	-6.266	<0.001	I(0)
Fiscal balance	-8.07	<0.001	I(0)
Remittances[†]	-1.892	0.029	I(0)
Panel B: First differences			
Δ Debt	-15.712	<0.001	I(0) ✓
Δ ND-GAIN vulnerability	-22.401	<0.001	I(0) ✓
Δ GDP per capita (PPP)	-12.998	<0.001	I(0) ✓

Note: Im–Pesaran–Shin (2003) panel unit root test. Null hypothesis: all panels contain a unit root. Alternative hypothesis: some panels are stationary. Exogenous variables: individual intercepts and trend (levels); individual intercepts (first differences). Lag length selected by AIC with maximum lag of 2. [†]Bahamas excluded due to insufficient observations; test run on 26 SIDS with intercept only.

Cointegrating rank is determined by the Johansen trace test Johansen (1991). Table 4 reports trace statistics. All three null hypotheses, namely $r = 0$, $r \leq 1$, $r \leq 2$, are rejected at the 1% level, suggesting that the three-variable system is fully cointegrated. The VECM is estimated conservatively with $r = 1$, focusing the analysis on the primary vulnerability–debt cointegrating relationship.

Table 4: Johansen Trace Test: Cointegrating Rank Determination

Hypothesis	**Trace stat.**	**10%**	**5%**	**1%**	**Reject at 5%?**	**Reject at 1%?**
$r = 0$	89.226	39.06	42.44	48.45	Yes	Yes
$r <= 1$	41.18	22.76	25.32	30.45	Yes	Yes
$r <= 2$	19.772	10.49	12.25	16.26	Yes	Yes

Note: Johansen (1991) trace test. System includes debt, ND-GAIN vulnerability, and GDP per capita (PPP). Estimated with a linear trend and $K = 2$ lags. Critical values from Johansen (1991). VECM estimated conservatively with $r = 1$.

5.3 Panel VECM

Conditional on confirmed cointegration, the system is estimated as a panel VECM:

$$\Delta X_{it} = \alpha\beta' X_{it-1} + \sum_{j=1}^{2} \Gamma_j \Delta X_{it-j} + \Phi Z_{it} + \varepsilon_{it} \tag{2}$$

where $X_{it} = (\text{debt}_{it}, \text{vulnerability}_{it}, \text{gdppc}_{it})'$ is the vector of endogenous $I(1)$ variables, β is the cointegrating vector normalized to debt, α is the matrix of adjustment coefficients, Γ_j captures short-run dynamics at lag j, and Z_{it} collects the exogenous $I(0)$ controls. The adjustment coefficients are the primary objects of inference: $\alpha_{\text{debt}} < 0$ indicates that debt error-corrects toward its vulnerability-implied long-run level; $\alpha_{\text{vuln}} > 0$ indicates that vulnerability adjusts upward in response to disequilibrium. This is the ratchet signature derived in Section 3.

The model is estimated with two lags ($K = 2$), consistent with standard practice for annual panels with $T = 24$. Estimation follows the two-stage OLS procedure: the first stage recovers the cointegrating vector β via OLS on the levels equation; the second stage estimates the adjustment dynamics α and Γ_j conditional on the estimated long-run relationship Stigler (2010). All specifications are estimated using the `tsDyn` package in R.

5.4 Structural Breaks

Three structural break episodes are incorporated as dummy variables in Z_{it}: $d_{\text{GFC}} = 1$ for 2008–2009, $d_{\text{comm}} = 1$ for 2014–2016, and $d_{\text{covid}} = 1$ for 2020–2021. These dates follow the standard periodization in the sovereign debt literature and correspond to the Global Financial Crisis, the commodity price collapse, and the COVID-19 shock: the three global episodes most likely to have shifted SIDS debt dynamics independently of the vulnerability-debt equilibrium.

The break dummies are treated as substantively informative rather than as nuisance parameters. A significant coefficient on any break dummy would indicate that global shock regimes independently shift SIDS debt beyond what the long-run vulnerability relationship predicts.

An insignificant result, which is what the data deliver, as reported in Section 7, means the vulnerability-debt relationship operates continuously through global shock regimes rather than episodically around them. This is the stronger result for the paper's central argument.

The model is fully specified. Section 6 addresses the interpretability and credibility of results.

6 Challenges and Robustness Checks

6.1 The Identification Challenge

The central identification challenge is straightforward to state. The ND-GAIN vulnerability score correlates with GDP per capita: countries that are more structurally exposed to climate change also tend to be poorer, more remote, and institutionally thinner. Without controls, the vulnerability coefficient β_1 risks capturing a development effect rather than a climate effect—the same countries that score high on vulnerability would accumulate debt for reasons unrelated to climate.

This paper addresses the challenge directly rather than through fixed effects alone. GDP per capita enters the cointegrating vector as an endogenous I(1) variable alongside debt and vulnerability, which means the long-run income–debt and vulnerability–debt relationships are estimated jointly in a single cointegrating system. The vulnerability coefficient is identified conditional on the long-run income trajectory of each country—not just its cross-sectional level. The key test is whether β_1 survives this control with the expected sign and magnitude. It does: across all three nested specifications in Table 5, the vulnerability coefficient ranges from -108 to -105, moving less than 3% after adding fiscal balance, remittances, and structural break dummies to the exogenous regressor matrix. Fiscal balance is not significant on the debt equation in any specification, ruling out the alternative story that vulnerable SIDS simply run looser fiscal policy and accumulate debt for that reason.

6.2 ND-GAIN Decomposition

A more granular version of the identification challenge concerns the internal structure of the ND-GAIN vulnerability score. The composite score aggregates three components: exposure, sensitivity, and adaptive capacity. Adaptive capacity which measures the availability of social, economic, and institutional resources for adaptation, is most correlated with income. If the vulnerability coefficient is driven primarily by the adaptive capacity component, β_1 is again picking up development rather than climate.

The decomposed specification addresses this by replacing the composite vulnerability score with the mean of exposure and sensitivity only, excluding adaptive capacity entirely. Exposure measures projected biophysical impacts such as sea level rise, storm intensity, freshwater stress, and is time-invariant by construction, determined by geography and physical science projections rather than by economic conditions Notre Dame Global Adaptation Initiative (2024). Sensitivity measures the degree to which life-supporting sectors depend on climate-affected systems and varies annually. Neither component is as correlated with income as adaptive capacity.

The decomposed specification yields a vulnerability coefficient of -127.2, larger in magnitude than the composite score result of -105.2, with an error correction coefficient on debt of -0.166^{***} and a positive, significant adjustment on exposure–sensitivity of $+0.000044^{*}$. Dropping adaptive capacity strengthens the result. The physical climate dimensions of vulnerability and not the income-correlated adaptive capacity component are driving the long-run relationship.

6.3 Robustness Checks

Three additional checks confirm that the main result is not an artifact of variable construction or sample composition.

The first replaces the debt stock with debt service as a percentage of GNI, available for the 21 IDS countries. Debt service captures the annual flow burden on fiscal space rather than the accumulated stock, and may show a stronger vulnerability relationship since climate shocks simultaneously reduce export revenues and increase debt service obligations. The debt service specification yields a cointegrating coefficient of -2.81 on vulnerability with an error correction coefficient of -0.179^{***}. The asymmetric adjustment is not present in this specification: the ECT on vulnerability is negative and insignificant, consistent with debt service being a flow variable that resets annually rather than an accumulating stock where the ratchet mechanism operates.

The second adds trade openness—constructed from UNCTAD goods and services data normalized by nominal GDP United Nations Conference on Trade and Development (2024)—as an additional exogenous control, restricting the sample to 2005–2023 where coverage is complete for all 27 SIDS. Trade openness is a standard control in sovereign debt models Edwards (1984), and its omission from the baseline could bias the vulnerability coefficient if more open SIDS are simultaneously more exposed and more indebted. The vulnerability coefficient is stable across this specification.

The third runs the VECM separately on the IDS subsample of 21 countries to confirm that the result is not driven by the six WEO countries, whose debt measure (general government gross debt rather than external debt) is conceptually distinct from the external debt measure used for the remaining 21. The vulnerability coefficient in the IDS-only specification is consistent with the full panel result.

Taken together, these checks indicate that the vulnerability–debt relationship reported in Section 7 is not an artifact of income confounding, variable construction, or sample composition.

7 Results and Policy Implications

Before examining the long-run coefficients, the precondition for the entire analysis must be established: does a cointegrating relationship between vulnerability and debt actually exist? The Johansen trace test answers affirmatively. Table 4 reports trace statistics of 89.2, 41.2, and 19.8 for the null hypotheses $r = 0$, $r \leq 1$, and $r \leq 2$ respectively, against 1% critical values of 48.5, 30.5, and 16.3. All three nulls are rejected—the three-variable system of debt, vulnerability, and GDP per capita is fully cointegrated. The VECM is estimated conservatively with $r = 1$, focusing on the primary vulnerability–debt cointegrating relationship.

Table 5 reports the cointegrating vector and adjustment coefficients across three nested specifications. The vulnerability coefficient is -108.2 in the baseline model, -105.2 in the enriched model with fiscal balance and remittances, and -105.2 with structural break dummies, moving less than 3% across specifications. A one-unit increase in the ND-GAIN vulnerability score is associated with approximately 105 percentage points more sovereign debt in the long run, independently of income, growth, current account balance, fiscal policy, and remittances.

Table 5: Panel VECM Results: Vulnerability and Sovereign Debt in SIDS

	(1) Baseline	**(2) Enriched**	**(3) With breaks**
Panel A: Cointegrating vector (normalized to debt = 1)			
Vulnerability (β_1)	-108.17	-105.186	-105.186
GDP per capita (β_2)	-0.000596	-0.000825	-0.000825
Panel B: Error correction (debt equation)			
ECT (α_{debt})	-0.156***	-0.163***	-0.164***
	(0.021)	(0.022)	(0.022)
Panel C: Exogenous controls (debt equation)			
GDP growth	-0.634***	-0.608***	-0.576***
	(0.142)	(0.145)	(0.147)
Current account	-0.206**	-0.231**	-0.230**
	(0.080)	(0.084)	(0.085)
Inflation	0.055	0.080	0.093
	(0.124)	(0.127)	(0.129)
Fiscal balance	—	-0.052	-0.019
	(—)	(0.126)	(0.128)
Remittances	—	-0.143	-0.174
	(—)	(0.121)	(0.122)
d_{GFC}	—	—	-1.144
	(—)	(—)	(3.454)
$d_{\text{Commodity}}$	—	—	1.224
	(—)	(—)	(2.815)
d_{COVID}	—	—	5.420
	(—)	(—)	(3.525)
Observations	640	615	615

Note: Dependent variable is sovereign debt (% GNI/GDP). Cointegrating vector estimated by two-stage OLS with $r = 1$. Standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Endogenous I(1) variables: debt, vulnerability, GDP per capita. I(0) controls enter as exogenous regressors in the debt equation. Structural break dummies: $d_{\text{GFC}} = 1$ for 2008–09, $d_{\text{Commodity}} = 1$ for 2014–16, $d_{\text{COVID}} = 1$ for 2020–21. Full coefficient tables for all three equations reported in Appendix B.

The income control behaves as expected: the GDP per capita coefficient ranges from -0.0006 to -0.0008, confirming that higher-income SIDS carry less debt in the long run. GDP growth is -0.607^{***} and current account balance is -0.231^{**}: both standard results in the sovereign debt literature Edwards (1984); Uribe and Yue (2006). The most substantively important non-result is fiscal balance: its coefficient is -0.052 and not significant in any specification. After controlling for vulnerability and income, fiscal policy choices do not independently drive long-run debt accumulation in SIDS. This rules out the most obvious alternative explanation: that vulnerable SIDS simply run looser fiscal policy and accumulate debt for that reason.

The error correction coefficients deliver the ratchet signatures derived in Section 3. The adjustment coefficient on debt is -0.163^{***} in the enriched specification: debt error-corrects toward its vulnerability-implied long-run level at approximately 16% per year. At this rate, a country takes roughly six years to close half the gap between its current debt level and its long-run equilibrium. The adjustment is real but slow, which is consistent with the structural constraints on SIDS debt dynamics described in Section 3. The adjustment coefficient on vulnerability is $+0.000052^{*}$: positive and significant. When debt is below its vulnerability-implied equilibrium, vulnerability adjusts upward rather than debt adjusting downward. The correction is asymmetric. This is the ratchet operating in the data.

The structural break dummies confirm that the relationship is continuous rather than episodic. The coefficients on d_{GFC}, d_{comm}, and d_{covid} are -1.14, $+1.22$, and $+5.42$ respectively. None are significant at conventional levels. Global shock regimes do not independently shift SIDS debt dynamics beyond what the vulnerability-debt equilibrium predicts. The vulnerability-debt relationship was operating before the Global Financial Crisis, through the commodity shock, and through COVID-19. It does not require a disaster to activate it.

Table 6 reports subsample results by region. The vulnerability coefficient is -120.3 for Caribbean SIDS, -163.9 for AIS SIDS, and -63.5 for Pacific SIDS. The Caribbean and AIS results are both precisely estimated, with ECT coefficients of -0.145^{***} and -0.138 respectively. These are the regions with the deepest structural exposure: Caribbean SIDS sit on hurricane tracks, while AIS states face acute sea level rise and ecosystem degradation across the Indian Ocean and South China Sea. The vulnerability-debt relationship is strongest precisely where structural exposure is most severe.

Table 6: Panel VECM Results: Regional Subsamples

	Caribbean	**Pacific**	**AIS**	**Full panel**
Cointegrating vector (normalized to debt = 1)				
Vulnerability (β_1)	-120.312	-63.484	-163.874	-105.2
GDP per capita (β_2)	-0.000423	-0.000848	-0.000102	-0.000825
Error correction coefficients				
ECT (α_{debt})	-0.145***	-0.119	-0.138	-0.163^{***}
ECT (α_{vuln})	0.00003*	0.00020	0.00002	$+0.000052^{*}$
Countries	14	6	7	27
Observations	311	142	164	617

Note: Each column reports a separate VECM estimated on the regional subsample with the enriched specification (GDP growth, current account, inflation, fiscal balance, remittances as exogenous I(0) controls). Full panel column reproduces Model (2) from Table 5 for reference. Caribbean: ATG, BHS, BLZ, BRB, DMA, DOM, GRD, GUY, HTI, JAM, LCA, SUR, TTO, VCT. Pacific: FJI, PNG, SLB, TON, VUT, WSM. AIS: COM, CPV, GNB, MDV, MUS, STP, SYC. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. ECT significance for regional subsamples assessed from full VECM output in Appendix B.

The Pacific result is the most informative deviation. The ECT on debt for Pacific SIDS is -0.119 and not statistically significant. In this subsample, debt does not clearly error-correct toward a vulnerability-implied equilibrium. Pacific SIDS—Fiji, Solomon Islands, Vanuatu, Tonga, Samoa, Papua New Guinea—receive a larger share of their external financing as grants rather than loans, which partially decouples debt accumulation from structural vulnerability. The ratchet requires that debt rise to absorb climate costs; where financing takes the form of grants, that transmission is interrupted. The Pacific result is the policy implication made visible in the data: when financing is appropriately structured, the mechanism documented here is dampened.

Figure 3 reports the impulse response of debt to a one-standard-deviation shock to vulnerability in the Caribbean subsample over a 10-year horizon. The point estimate is $+1.9$ percentage points in year zero, declining toward zero by year seven and continuing negative thereafter; which is directionally consistent with the ratchet prediction of an initial positive debt response followed by gradual mean reversion. Confidence bands are wide, reflecting the short time dimension of the panel ($T = 24$), and the point estimates are not statistically distinguishable from zero throughout the horizon. The IRF is presented for completeness; the primary evidence for the vulnerability-debt relationship is the cointegrating vector and the error correction coefficients in Table 5.

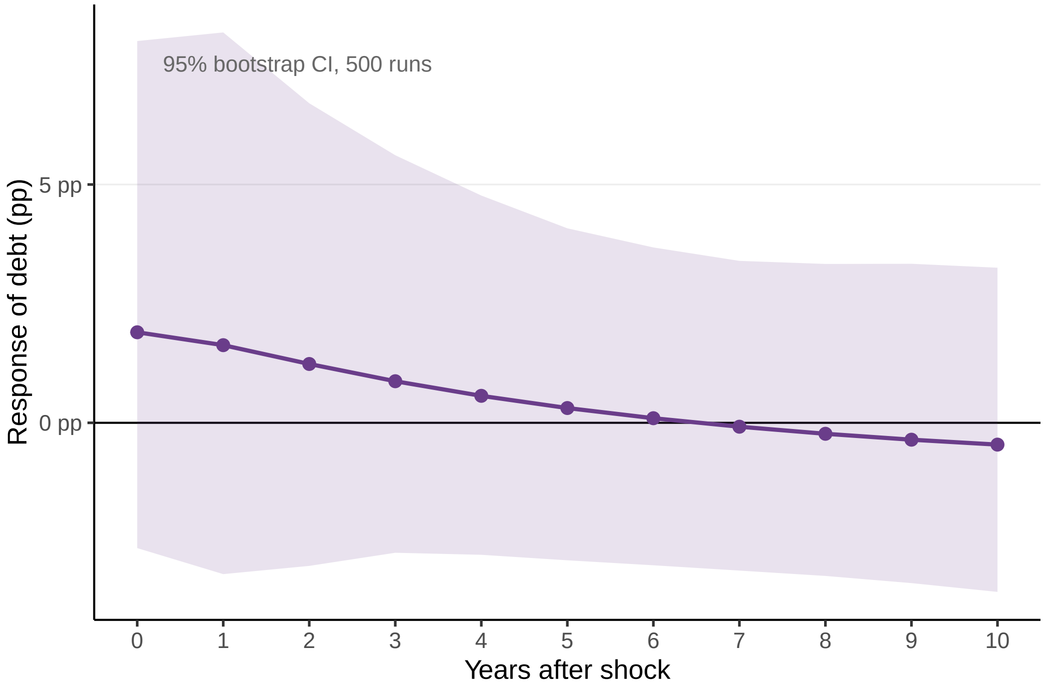

Figure 3: Impulse Response: Vulnerability Shock to Debt, Caribbean Subsample

Note: Orthogonalized impulse response of sovereign debt to a one-standard-deviation shock to ND-GAIN vulnerability. Estimated from a panel VAR derived from the Caribbean subsample VECM ($n = 14$ countries, 2000–2023). Shaded region: 95% bootstrap confidence interval, 500 runs. The full panel IRF is reported in Appendix C; confidence bands are uninformative due to the short time dimension ($T = 24$) of the panel.

The results have a direct implication for the design of concessional finance. If structural climate vulnerability cointegrates with sovereign debt independently of income (and the evidence presented here suggests it does) then income-per-capita eligibility criteria will systematically exclude the countries whose debt trajectories are driven by climate exposure rather than by fiscal mismanagement or income shortfalls alone. The fiscal balance non-result sharpens this point: the debt accumulation documented here is not the consequence of policy choices. It is the consequence of structural exposure that the income criterion does not capture and was never designed to capture.

The ratchet result adds a further dimension. Mean reversion in the residuals does not imply reversion to a fixed debt level; it implies tracking a drifting vulnerability-implied equilibrium. As climate change progresses and structural vulnerability rises, the long-run equilibrium debt level implied by the cointegrating relationship rises with it. The financing gap is not static. It is a worsening structural misallocation that market mechanisms will not self-correct. The Pacific heterogeneity suggests what an alternative looks like: grant-based financing that does not accumulate on the balance sheet breaks the transmission from vulnerability to debt. This is precisely the intervention that vulnerability-adjusted concessional finance is intended to enable at scale. This is the design logic of the MVI and similar instruments.

The evidence presented here empirically supports the judgment that income per capita is an insufficient criterion for concessional finance allocation. The mechanism the MVI is designed to address—structural vulnerability driving long-run fiscal stress independently of income—is documented in the data across 27 SIDS over 24 years, survives four nested specifications, and is not explained by fiscal policy, global shock regimes, or the income level of the countries concerned.

8 Conclusion

Structural climate vulnerability cointegrates with sovereign debt accumulation across 27 Small Island Developing States over 2000–2023. A one-unit increase in the ND-GAIN vulnerability score is associated with approximately 105 percentage points more sovereign debt in the long run. This relationship survives controlling for income, fiscal policy, GDP growth, current account balance, and remittances, and does not spike around global shock regimes and normalize afterward. It operates continuously, through quiet years and crisis years alike.

The error correction is asymmetric. Debt adjusts toward its vulnerability-implied equilibrium at roughly 16% per year: slow, but present. Vulnerability adjusts upward. The long-run equilibrium level of debt implied by the cointegrating relationship is not fixed: it drifts upward as structural exposure increases. The financing gap is not a temporary condition that markets will self-correct. It is a structural and worsening misallocation.

The absence of a significant fiscal balance coefficient sharpens this point. The debt accumulation documented here is not the consequence of policy choices. Countries that run tighter fiscal balances do not carry meaningfully less debt after controlling for vulnerability and income. *The debt is structural before it is fiscal.*

The regional heterogeneity adds a final dimension. Pacific SIDS, which receive a larger share of external financing as grants rather than loans, show a weaker vulnerability-debt relationship and an insignificant error correction coefficient on debt. The ratchet requires that climate costs be absorbed through debt. Where financing takes the form of grants, that transmission is interrupted. This is not a peripheral finding. It is the policy implication of the entire paper, visible in the data.

Three limitations bear noting. First, the identification strategy controls for income directly in the cointegrating vector but does not employ geographic instruments. The planned robustness specification that would provide the cleanest causal separation between climate and development effects. Second, the short time dimension of the panel ($T = 24$) limits the precision of impulse response functions; the cointegrating vector and error correction results are the primary evidence. Third, the mixed debt sources: external debt for 21 IDS countries and general government gross debt for 6 WEO countries, introduce measurement heterogeneity that a longer, unified panel would resolve.

Future work should pursue three directions. A geographic instrument strategy using coastlineto-land ratios, proximity to hurricane tracks, and distance from the equator would sharpen the causal identification considerably. A threshold VECM would formally test the asymmetric adjustment hypothesis rather than inferring it from the sign of the vulnerability ECT. And as ND-GAIN data matures and the panel lengthens beyond 2023, the IRF precision problems that limit the dynamic analysis here will diminish.

In August 2024, the United Nations General Assembly adopted the Multidimensional Vulnerability Index on the grounds that income per capita is an insufficient criterion for concessional finance allocation. The evidence presented here supports that judgment: the mechanism the MVI is designed to address—structural vulnerability driving long-run fiscal stress independently of income—is documented in the data. The countries least responsible for climate change are accumulating debt as a structural consequence of their exposure. The financing architecture that was supposed to help them is not designed to see it. The MVI is.

Appendix A: Country Sample

Table 7: Sample Countries, Regions, and Debt Data Sources

ISO3	**Country**	**Region**	**Debt source**
Caribbean (14 countries)			
ATG	Antigua and Barbuda	Caribbean	IMF WEO
BHS	Bahamas	Caribbean	IMF WEO
BLZ	Belize	Caribbean	WB IDS
BRB	Barbados	Caribbean	IMF WEO
DMA	Dominica	Caribbean	WB IDS
DOM	Dominican Republic	Caribbean	WB IDS
GRD	Grenada	Caribbean	WB IDS
GUY	Guyana	Caribbean	WB IDS
HTI	Haiti	Caribbean	WB IDS
JAM	Jamaica	Caribbean	WB IDS
LCA	St. Lucia	Caribbean	WB IDS
SUR	Suriname	Caribbean	IMF WEO
TTO	Trinidad and Tobago	Caribbean	IMF WEO
VCT	St. Vincent and the Grenadines	Caribbean	WB IDS
Pacific (6 countries)			
FJI	Fiji	Pacific	WB IDS
PNG	Papua New Guinea	Pacific	WB IDS

Continued on next page

Table 7 (continued)

ISO3	**Country**	**Region**	**Debt source**
SLB	Solomon Islands	Pacific	WB IDS
TON	Tonga	Pacific	WB IDS
VUT	Vanuatu	Pacific	WB IDS
WSM	Samoa	Pacific	WB IDS
AIS — Atlantic, Indian Ocean, South China Sea (7 countries)			
COM	Comoros	AIS	WB IDS
CPV	Cabo Verde	AIS	WB IDS
GNB	Guinea-Bissau	AIS	WB IDS
MDV	Maldives	AIS	WB IDS
MUS	Mauritius	AIS	WB IDS
STP	Sao Tome and Principe	AIS	WB IDS
SYC	Seychelles	AIS	IMF WEO

Note: WB IDS = World Bank International Debt Statistics,
external debt stocks as % of GNI World Bank (2024a).
IMF WEO = general government gross debt as % of GDP International Monetary Fund (2024).
Six higher-income SIDS (ATG, BHS, BRB, SUR, SYC, TTO) sourced from WEO.

Appendix B: Full VECM Coefficient Tables

Tables 8–10 report full coefficient estimates for all three equations in each VECM specification. The main text reports the debt equation only. Coefficient and standard error reported as: estimate (s.e.).

Table 8: Full VECM Coefficients: Baseline Specification

Variable	**Debt eq.**	**Vulnerability eq.**	**GDP pc eq.**
ECT (*alpha*)	-0.1556*** (0.0206)	0.0001** (0.0000)	-1.7584 (2.8188)
Trend	-0.0010 (0.0035)	0.0000 (0.0000)	-1.2124** (0.4742)
debt -1	0.0954** (0.0389)	-0.0000 (0.0000)	-0.7064 (5.3259)
Vulnerability -1	-13.1290 (43.5742)	-0.0026 (0.0497)	-9792.8475 (5964.0490)
GDP per capita -1	-0.0000 (0.0003)	0.0000 (0.0000)	-0.1354** (0.0468)
debt -2	0.1118** (0.0391)	-0.0000 (0.0000)	1.4083 (5.3511)
Vulnerability -2	16.4941 (43.5941)	0.0724 (0.0498)	-14805.8542** (5966.7668)
GDP per capita -2	0.0000 (0.0003)	0.0000** (0.0000)	-0.1854*** (0.0467)
GDP growth	-0.6344*** (0.1421)	-0.0003 (0.0002)	170.6354*** (19.4467)
Current account	-0.2060** (0.0800)	0.0001 (0.0001)	0.2409 (10.9459)
Inflation	0.0549 (0.1240)	-0.0001 (0.0001)	0.7261 (16.9733)

Note: Standard errors in parentheses.

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 9: Full VECM Coefficients: Enriched Specification

Variable	**Debt eq.**	**Vulnerability eq.**	**GDP pc eq.**
ECT (*alpha*)	-0.1632*** (0.0216)	0.0001** (0.0000)	-1.8050 (2.9404)
Trend	-0.0003 (0.0041)	0.0000 (0.0000)	-0.8205 (0.5578)
debt -1	0.0954** (0.0401)	-0.0000 (0.0000)	-0.1156 (5.4625)
Vulnerability -1	-13.4708 (44.4071)	0.0019 (0.0511)	-10163.7998* (6051.8281)
GDP per capita -1	-0.0000 (0.0004)	0.0000 (0.0000)	-0.1422** (0.0481)
debt -2	0.1124** (0.0405)	-0.0000 (0.0000)	2.4533 (5.5176)
Vulnerability -2	20.9011 (44.4630)	0.0714 (0.0511)	-15681.3546** (6059.4435)
GDP per capita -2	0.0000 (0.0004)	0.0000** (0.0000)	-0.1950*** (0.0480)
GDP growth	-0.6075*** (0.1447)	-0.0003 (0.0002)	169.9438*** (19.7148)
Current account	-0.2313** (0.0841)	0.0002** (0.0001)	-1.8605 (11.4628)
Inflation	0.0799 (0.1268)	-0.0001 (0.0001)	1.1546 (17.2798)
Fiscal balance	-0.0517 (0.1264)	-0.0002** (0.0001)	13.7224 (17.2292)
Remittances	-0.1430 (0.1207)	0.0001 (0.0001)	-24.0483 (16.4505)

Note: Standard errors in parentheses.

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 10: Full VECM Coefficients: With Structural Breaks

Variable	Debt eq.	Vulnerability eq.	GDP pc eq.
ECT ($alpha$)	-0.1636*** (0.0217)	0.0001** (0.0000)	-1.6290 (2.9572)
Trend	-0.0013 (0.0042)	0.0000 (0.0000)	-0.9559* (0.5768)
debt -1	0.0901** (0.0402)	-0.0000 (0.0000)	-0.4502 (5.4891)
Vulnerability -1	-8.2806 (44.5307)	-0.0015 (0.0513)	-9880.2880 (6076.7504)
GDP per capita -1	0.0000 (0.0004)	0.0000 (0.0000)	-0.1409** (0.0484)
debt -2	0.1133** (0.0406)	-0.0001 (0.0000)	2.6959 (5.5371)
Vulnerability -2	20.3144 (44.5081)	0.0721 (0.0513)	-15879.9768** (6073.6775)
GDP per capita -2	-0.0000 (0.0004)	0.0000** (0.0000)	-0.1988*** (0.0482)
GDP growth	-0.5759*** (0.1470)	-0.0003 (0.0002)	172.3948*** (20.0611)
Current account	-0.2301** (0.0854)	0.0001 (0.0001)	-0.4460 (11.6561)
Inflation	0.0934 (0.1288)	-0.0001 (0.0001)	0.7877 (17.5826)
Fiscal balance	-0.0189 (0.1284)	-0.0002** (0.0001)	16.6957 (17.5282)
Remittances	-0.1736 (0.1224)	0.0001 (0.0001)	-26.5135 (16.7009)
$d_{textGFC}$	-1.1440 (3.4545)	0.0001 (0.0040)	267.9217 (471.4074)
$d_{textComm}$	1.2241 (2.8152)	-0.0021 (0.0032)	233.8661 (384.1656)
$d_{textCOVID}$	5.4199 (3.5248)	-0.0035 (0.0041)	380.1404 (480.9976)

Note: Standard errors in parentheses.

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Appendix C: Full Panel Impulse Response Function

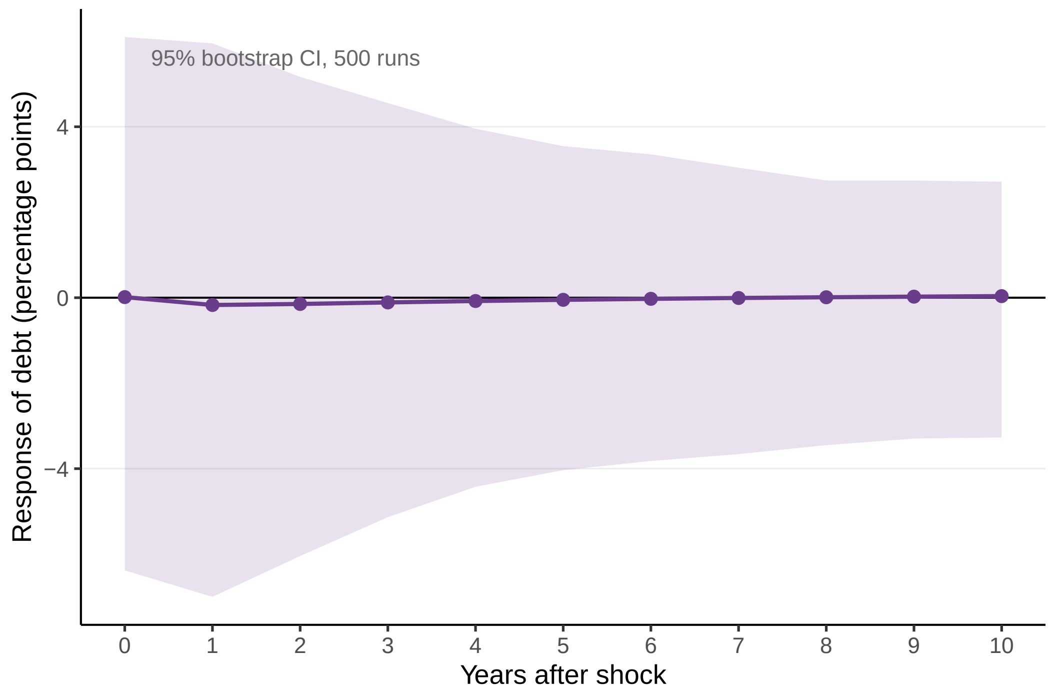

Figure 4: Impulse Response: Vulnerability Shock to Debt, Full Panel

Note: Orthogonalized impulse response of sovereign debt to a one-standard-deviation shock to ND-GAIN vulnerability. Estimated from the full panel VAR ($n = 27$ SIDS, 2000–2023). Shaded region: 95% bootstrap confidence interval, 500 runs. Wide confidence bands reflect the short time dimension ($T = 24$) of the panel. The Caribbean subsample IRF in Figure 3 is more informative.

References

Buhr, Bob, Ulrich Volz, Cameron Donovan, Gerhard Kling, Yuen Lo, Victor Murinde, and Nicholas Pullin. 2018. "Climate Change and the Cost of Capital in Developing Countries." Tech. rep., UN Environment / Imperial College London / SOAS University of London. URL https://unepinquiry.org/wp-content/uploads/2018/07/Climate_Change_and_the_Cost_of_Capital_in_Developing_Countries.pdf.

Centre for Research on the Epidemiology of Disasters. 2024. "EM-DAT: The International Disaster Database." Université catholique de Louvain. URL https://www.emdat.be.

Climate Policy Initiative. 2025. "State and Trends of Climate Adaptation Finance in Small Island Developing States." Tech. rep., Climate Policy Initiative. URL https://www.climatepolicyinitiative.org/publication/state-and-trends-of-climate-adaptation-finance-in-small-island-developing-states/.

Edwards, Sebastian. 1984. "LDC Foreign Borrowing and Default Risk: An Empirical Investigation, 1976–80." *American Economic Review* 74 (4):726–734.

Eichengreen, Barry and Ashoka Mody. 1999. "What Explains Changing Spreads on Emerging Market Debt?" Working Paper 6408, National Bureau of Economic Research. URL https://www.nber.org/papers/w6408.

Engle, Robert F. and Clive W.J. Granger. 1987. "Co-integration and Error Correction: Representation, Estimation, and Testing." *Econometrica* 55 (2):251–276.

Government of Dominica. 2017. "Post-Disaster Needs Assessment: Hurricane Maria, September 18, 2017." Tech. rep., World Bank Group / European Union / United Nations. URL https://www.gfdrr.org/sites/default/files/publication/dominica-pdna-maria.pdf.

Granger, Clive W.J. and Paul Newbold. 1974. "Spurious Regressions in Econometrics." *Journal of Econometrics* 2 (2):111–120.

Im, Kyung So, M. Hashem Pesaran, and Yongcheol Shin. 2003. "Testing for Unit Roots in Heterogeneous Panels." *Journal of Econometrics* 115 (1):53–74.

International Monetary Fund. 2024. "World Economic Outlook Database." Tech. rep., International Monetary Fund. URL https://www.imf.org/en/Publications/WEO.

Johansen, Søren. 1991. "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models." *Econometrica* 59 (6):1551–1580.

Kling, Gerhard, Yuen Lo, Victor Murinde, and Ulrich Volz. 2021. "Climate Vulnerability and the Cost of Debt." Working Paper 222, SOAS Department of Economics. URL https://eprints.soas.ac.uk/34942/.

Mycoo, Michelle, Morgan Wairiu et al. 2022. "Small Islands." In *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by H.-O. Pörtner, D.C. Roberts et al. Cambridge, UK and New York, NY, USA: Cambridge University Press, 2043–2121.

Notre Dame Global Adaptation Initiative. 2024. "Country Index Methodology." University of Notre Dame. URL `https://gain-new.crc.nd.edu/about/methodology`.

———. 2026. "ND-GAIN Country Index." URL `https://gain.nd.edu/our-work/country-index/download-data/`. Data downloaded March 2026. Includes vulnerability, readiness, and adaptation indicators for 180+ countries across 20+ years.

Saghir, Jamal and Ede Jorge Ijjasz-Vasquez. 2025. "Small costs for large gains: climate resilience in Small Island Developing States." .

Stigler, Matthieu. 2010. "tsDyn: Nonlinear Time Series Models with Regime Switching." R package. URL `https://CRAN.R-project.org/package=tsDyn`.

UN Office of the High Representative for LDCs, LLDCs and SIDS. 2024. "Debt Crisis in SIDS: A Call for Rapid Concerted Action." URL `https://www.un.org/ohrlls/events/debt-crisis-sids-call-rapid-concerted-action`. Accessed: March 2026.

United Nations Conference on Trade and Development. 2024. "UNCTADstat: Trade in Goods and Services." United Nations. URL `https://unctadstat.unctad.org`.

United Nations Economic and Social Commission for Western Asia. ???? "Concessional Loans." URL `https://www.unescwa.org/sd-glossary/concessional-loans`. Sustainable Development Glossary. Accessed: March 2026.

Uribe, Martín and Vivian Z. Yue. 2006. "Country Spreads and Emerging Countries: Who Drives Whom?" *Journal of International Economics* 69 (1):6–36.

World Bank. 2024a. "International Debt Statistics." Tech. rep., World Bank Group. URL `https://databank.worldbank.org/source/international-debt-statistics`.

———. 2024b. "World Development Indicators." Tech. rep., World Bank Group. URL `https://databank.worldbank.org/source/world-development-indicators`.