Trapped by Climate Stress: Vulnerability Dynamics and Sovereign Credit Risk

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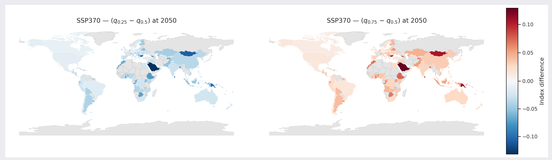
Introduction

- **Research Objective:** To quantify the full intertemporal feedback cycle in climate risk — climate shocks weaken fundamentals, macro-financial stress raises the probability of shifting into a more vulnerable regime, and increased vulnerability amplifies the impact of subsequent shocks — providing a unified perspective absent from existing models.
- **Methodological Contribution:** The framework models the dynamics of vulnerability feedback rather than simply incorporating vulnerability levels into sovereign risk projections.
- **Policy Implication:** Marginal improvements in adaptation are insufficient to offset rising climate stress; meaningful credit improvements require structural changes that reduce macro-fiscal stress enough to alter regime transitions and strengthen the resilient regime.

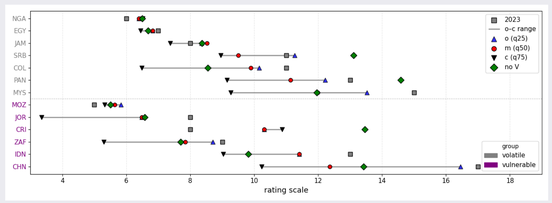
Additional Results

Scenario	Quantile	2030	2040	2050	2100
SSP1	q75	−0.3	−0.7	−1.3	−2.2
	q50	−0.2	−0.2	−0.3	−0.5
	q25	−0.2	−0.2	−0.2	−0.2
SSP2	q75	−0.4	−1.2	−1.8	−2.9
	q50	−0.2	−0.3	−0.4	−1.1
	q25	−0.2	−0.2	−0.2	−0.3
SSP3	q75	−0.6	−1.8	−2.4	−4.2
	q50	−0.3	−0.6	−1.3	−2.1
	q25	−0.2	−0.2	−0.3	−0.5
SSP5	q75	−0.7	−2.2	−2.6	−4.3
	q50	−0.3	−1.3	−1.9	−3.1
	q25	−0.2	−0.3	−0.6	−1.8

NOTES: Rating deviations relative to 2023 baseline.



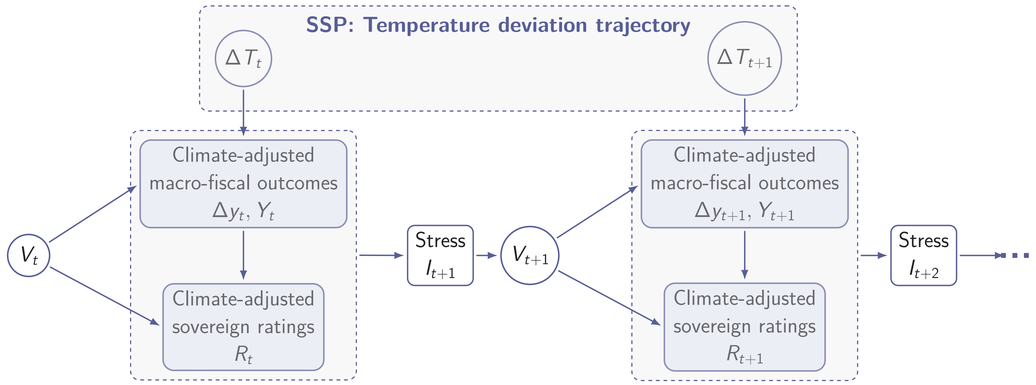
NOTES: Global vulnerability levels under SSP3-7.0 by 2050 under the pessimistic (right) and optimistic (left) path relative to the median level.



NOTES: Selected vulnerable and volatile countries: rating outcomes in 2050 under SSP3–7.0.

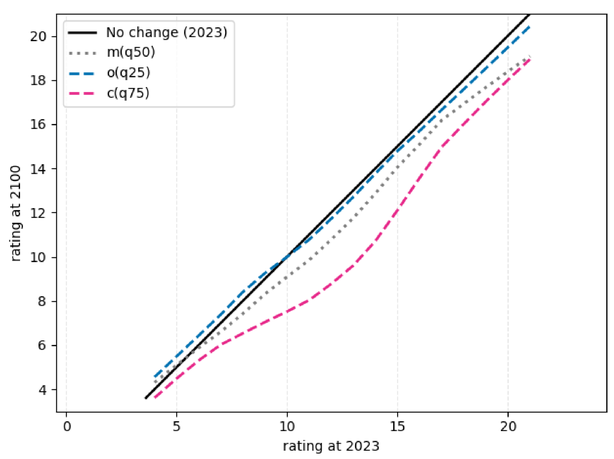
When climate shocks hit, vulnerability evolves — and sovereign risk follows.

Mechanism of the Framework

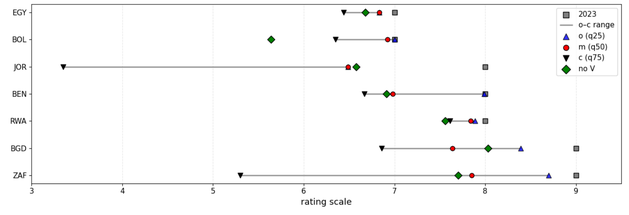


NOTES: Dynamic simulation of climate vulnerability V_t, macro–fiscal outcomes Δy_t, Y_t, sovereign ratings R_t and latent stress indicator I_t under temperature deviation ΔT_t trajectories corresponding to Shared Socioeconomic Pathway (SSP) scenarios.

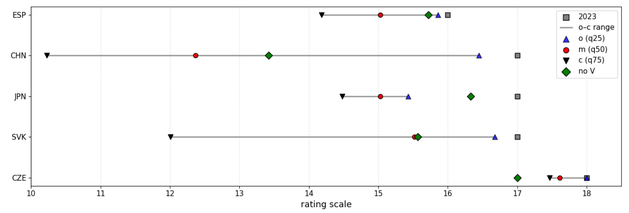
Country-Level Results



Projected rating paths in 2100 under SSP3 for optimistic, median, and pessimistic vulnerability trajectories.



Projected rating paths under SSP3 for the low-rating countries.



Projected rating paths under SSP3 for the high-rating countries.

NOTES: In the left panel, the pessimistic vulnerability profile leads to additional downgrades relative to the median path, whereas the optimistic profile produces only limited rating improvements. The right panels show ISO-level projected sovereign ratings for low- and high-rating countries under SSP3–7.0. Gray squares denote the 2023 baseline; green diamonds indicate projections from the benchmark model without vulnerability.

Main Messages:

- **Including climate vulnerability changes projected sovereign ratings.**
- **The effects are asymmetric: small vulnerability improvements help, but worsening it hurts much more.**

Methods

- **Climate-Adjusted Macro-Fiscal Outcomes**

$$\Delta y_{i,t} = \delta_i + \sum_{k=1}^{p} \varphi_k \Delta y_{i,t-k} + \sum_{l=0}^{q} \theta_l^T \Delta T_{i,t-l}(k) + \sum_{l=0}^{q} \theta_l^V \Delta V_{i,t-l} + \epsilon_{i,t}.$$

- **Climate-Adjusted Sovereign Ratings**

$$\bar{R}_{i,t} = f(X_{i,t}, D_{i,t}, V_{i,t})$$

- **Latent Stress Indicator**

We introduce a latent stress indicator $I_{i,t}$ using SHAP values:

$$I_{i,t} = \sum_{j=1}^{K} \max\{-\phi_{i,t-1}^{(j)}, 0\}$$

where $\bar{R}_{i,t} - \mathbb{E}[\bar{R}] = \sum_{j=1}^{K-1} \phi_{i,t}^{(j)}$.

- **Climate Vulnerability as an Endogenous Stochastic Process**

Two-state Gaussian HMM on pooled standardized $\Delta V_{it}^{(z)}$:

$$\Delta V_{i,t}^{(z)} \mid S_{i,t} = s \sim \mathcal{N}(\mu_s, \sigma_s^2), \quad s \in \{0, 1\}$$

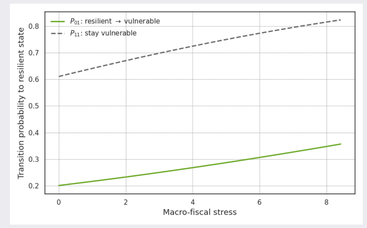
Stress-dependent transitions via WGLM with logit link:

$$\pi_{i,t}^{s1} = \Lambda(\alpha_{s1} + \beta_{s1}^{\top} I_{i,t})$$

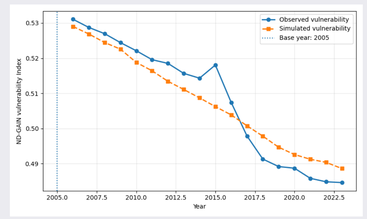
- **Integrated System and Forward Dynamics**

Scenario analysis under SSP climate pathways; vulnerability summarized at optimistic ($q = 0.25$), median ($q = 0.50$), and pessimistic ($q = 0.75$) quantiles.

Endogenous Evolution of the Vulnerability Index



NOTES: Stress-dependent transition probabilities from logit models for the 0→1 and 1→1 transitions.



NOTES: Historical hindcast of vulnerability paths, base year 2005.

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