Quantifying Economic & Financial Impacts of Droughts

Small economies (e.g., island states) are highly exposed to hydrometeorological shocks. We propose a tractable model that links (i) a low-dimensional water-balance model, (ii) an input–output (IO) model for the propagation of water shortages across sectors, and (iii) macro–financial dynamics mapping GDP and fiscal responses into sovereign default risk. The goal is to generate drought stress scenarios suitable for policy analysis and climate stress testing).

Minimal water-balance

We adopt a parsimonious model in the spirit of **ABCD** [10, 8] or **GR2M** [7, 9] at the monthly frequency, driven by precipitation P_t and potential evapotranspiration PET_t (from climate scenarios or a stochastic generator [5]). Let S_t be national effective storage (surface + soil), E_t actual evapotranspiration, Q_t outflow, and W_t total withdrawals (agriculture+industry):

$$S_{t+1} = S_t + P_t - E_t - Q_t - W_t, \quad E_t = \mathrm{PET}_t \, \frac{S_t}{S_t + C_e}, \quad Q_t = k\, S_t, \quad 0 \le S_t \le C.$$

We define water available to the economy (post agricultural allocation) as $W_t = \alpha Q_t + \beta S_t$.

Coupling with an input–output economy

Let A be the IO matrix, $L = (I - A)^{-1}$ the Leontief inverse, $\bar{y}_t$ baseline final demand, and w sectoral water intensities (m^3 per unit output, calibrated from water footprint/MRIO datasets [6]). Unconstrained output $\bar{x}_t = L\bar{y}_t$ implies a baseline water requirement $\bar{R}_t = w^\top \bar{x}_t$. We enforce a monthly water cap via a scalar contraction:

$$\lambda_t = \min\left\{1,\ \frac{W_t}{\bar{R}_t + \varepsilon}\right\}, \qquad x_t = \lambda_t\, \bar{x}_t, \quad y_t = \lambda_t\, \bar{y}_t.$$

This mirrors hydro-economic practice [4] while remaining simple and easy to calibrate. To model longer-term impact of disruptions and recovery, one may replace scalar scaling with a dynamic inoperability IO model (DIIM) [3], but we keep the static mapping for parsimony.

Debt, GDP, and default risk.

Aggregate GDP is $Y_t = \mathbf{1}^\top x_t$. Let public debt evolve as

$$B_{t+1} = (1 + i_t)\, B_t - \mathrm{PB}_t, \qquad d_t = \frac{B_t}{Y_t},$$

where $i_t = r_t + s(d_t)$ and PB_t is the primary balance (from policy scenarios). Empirically, sovereign spreads $s(\cdot)$ and default probabilities rise with debt to

GDP ratio [1, 2]. We model default as in a reduced form model with hazard rate $\lambda_t = \ell(d_t, z_t)$ (with controls z_t for openness, reserves, terms of trade), yielding a default probability over horizon H,

$$\mathbb{P}(\text{default in } [t, t+H]) = 1 - \exp\Big(-\sum_{h=1}^{H} \lambda_{t+h}\Delta\Big).$$

This links *water shocks ⇒ IO output contraction ⇒ GDP and fiscal paths ⇒ spreads and default risk.*

Data & calibration

Hydrology: P_t, PET_t from reanalysis/RCP scenarios or a stochastic generator [5]; C, k, C_e by fitting runoff/storage anomalies (e.g., GRACE) to ABCD/GR2M [8, 9]. Economy: national IO table, sectoral water intensities [6]. Macro–finance: debt stocks/flows, spreads, and covariates to estimate $s(d)$ and λ_t (logit/probit or survival), following [1, 2]. Scenario design can align with climate-risk practice (e.g., NGFS-style drought years).

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