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Panit Wattanakoon and Wanissa Suanin

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Panit Wattanakoon and Wanissa Suanin*

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Abstract

This study explores the potential of catastrophe bonds (CAT bonds) as a financial instrument to mitigate the macroeconomic impacts of flooding in emerging economies, using Thailand as a case study. We embed indemnity-loss and parametric-trigger CAT bonds in a calibrated dynamic small-open-economy model featuring sovereign default risk, and capital inflow dynamics. Our analysis demonstrates that both CAT bonds lessen the immediate drops in capital, output, consumption and public net worth relative to a no-insurance benchmark. Indemnity cover yields only marginal gains, but the parametric design is superior: its instant, fixed payout narrows sovereign spreads and trims lifetime welfare losses across the wealth distribution. Both instruments modestly raise ex-ante public debt and crowd out capital inflows. The findings support implementing a stratified disaster financing framework whereby parametric CAT bond tranches complement fiscal reserves, optimally balancing liquidity provision, basis risk exposure, and borrowing costs. This layered approach offers emerging economies an effective mechanism for enhancing financial resilience against climate-related natural disasters while maintaining fiscal sustainability.

Keywords: Catastrophe Bond, Flood, Climate Change, Sovereign Default
JEL Classification: E44, G22, H12, H63, Q54

*Center for International Competitiveness and Development (ICDS), Faculty of Economics, Thammasat University; corresponding author: wanissa@econ.tu.ac.th. We thank participants at PIER Research Workshop 2025 for comments and suggestions.

1 Introduction

Climate change is amplifying the frequency and severity of extreme weather events, particularly in developing economies with limited capacity to adapt. Among the most destructive of these events are floods, which have become increasingly common and damaging. The IPCC Sixth Assessment Report emphasizes that under high-emissions scenarios, the probability of intense precipitation and large-scale flood events will rise significantly (Intergovernmental Panel on Climate Change (IPCC), 2022). These developments pose serious macroeconomic risks to emerging economies, where exposure to natural hazards is compounded by structural vulnerabilities such as dense urbanization, inadequate infrastructure, and constrained fiscal space.

Floods inflict a multifaceted burden on economies. Beyond their immediate humanitarian costs, floods destroy productive capital, reduce output, and impair both household and corporate balance sheets. At the sovereign level, governments are often forced to mobilize emergency spending for reconstruction, leading to increased borrowing. As a result, debt levels surge and bond spreads widen, reflecting investor concerns over default risk. These effects are mutually reinforcing, damaged capital reduces productivity, diminished household wealth curtails consumption, and financial fragility discourages private investment and invites capital flight. In the absence of effective pre-arranged financing, these dynamics can spiral into a broader economic crisis.

In this context, disaster risk financing tools that can buffer economies from post-disaster fiscal shocks are increasingly vital. This study explores one such instrument: catastrophe bonds (CAT bonds). CAT bonds are insurance-linked securities that provide governments with contingent financing in the event of a disaster, transferring risk to international capital markets in exchange for yield-bearing premiums. Upon the occurrence of a predefined event, measured either by actual losses (indemnity triggers) or objective metrics such as rainfall or flooded area (parametric triggers), the bond's principal may be partially or fully forgiven, delivering liquidity precisely when it is most needed. As such, CAT bonds can help smooth fiscal volatility, reduce the need for ad hoc borrowing, and stabilize investor expectations.

The objective of this study is to evaluate the macroeconomic implications of adopting CAT bonds in flood-prone developing economies, using Thailand as a case study. Specifically, it assesses the extent to which CAT bond issuance can mitigate welfare losses following exogenous flood shocks by alleviating the collapses in capital stocks and output. This analysis provides a general equilibrium perspective on CAT bond adoption by tracing its effects across key macroeconomic variables: the capital-to-output ratio, household net worth and consumption, the debt-to-output ratio, sovereign bond spreads, and capital account dynamics.

Thailand offers a compelling case for this analysis for several reasons. *First*, the country faces chronic exposure to flood events that are severe enough to cause economic disruptions but typically fall short of triggering large-scale humanitarian crises. The 2011 floods, however, stand as an exception, resulting in economic losses of approximately USD 46.5 billion and revealing deep weaknesses in flood defenses and fiscal preparedness. *Second*, the paper distinguishes between indemnity and parametric bond triggers, offering insight into the trade-offs between responsiveness and basis risk in disaster financing. *Third*, Thailand's financial system is sufficiently developed to issue CAT bonds on the international market, and its integration with global capital flows means that sovereign risk perceptions can quickly translate into macroeconomic consequences.

Despite these attributes, Thailand has not yet adopted CAT bonds as a formal instrument in its disaster risk management strategy. While mechanisms such as budgetary reserves and post-disaster borrowing are in place, these tools lack the speed, scale, and risk-sharing potential that CAT bonds offer. The limited uptake of CAT bonds in similar emerging economies may reflect uncertainties around their macroeconomic policy effectiveness, a gap this paper aims to address. Indeed, while prior study has emphasized the public debt dynamics after the issuance of CAT bonds in stabilizing government spending post-disaster (Suanin and Wattanakoon, 2023), their broader macroeconomic implications have yet to be systematically explored.

Moreover, the existing literature tends to focus on infrequent high-impact events in regions such as Latin America or the Caribbean. For example, Phan and Schwartzman (2024) examine the macroeconomic impact of CAT bonds in Mexico in the context of cyclones, but flood risk, arguably a more pervasive and frequent threat in many emerging economies, has not been similarly analyzed. This study therefore shifts the focus to a more prevalent disaster type and asks whether the stylized benefits of CAT bonds extend to economies facing chronic, moderate-scale natural hazards.

The contribution of this study is threefold. First, it incorporates CAT bonds into a small open economy model that captures the interlinkages between flood shocks, sovereign borrowing, private consumption, and capital flows. This integrated framework allows for an assessment of how CAT bonds affect welfare through multiple transmission channels. Second, the paper distinguishes between indemnity and parametric bond triggers, offering insight into the trade-offs between responsiveness and basis risk in disaster financing. Third, it generates quantitative estimates of the welfare gains associated with CAT bond adoption, calibrated to the economic and climatic conditions of Thailand, thereby offering practical implications for policymaking.

By addressing these questions, the paper seeks to inform both domestic and international stakeholders engaged in disaster risk finance and climate resilience. For Thailand, the findings could guide the design of an adaptive financing strategy that complements existing fiscal tools and infrastructure investments. For other middle-income economies with similar flood exposure and institutional constraints, the Thai case provides a policy blueprint for integrating market-based instruments into national adaptation plans. This study responds to the growing need for innovative financing solutions that can help developing economies weather the macroeconomic shocks associated with climate change. In doing so, it adds to the limited but growing body of research on the intersection of sovereign finance, climate risk, and macroeconomic stability.

The paper is organized as follows: Section 2 provides the model set-up, equilibrium characterization and the implications of catastrophe bond adoption, while section 3 illustrates the quantitive analysis with relevant calibrated parameters for a small open economy like Thailand. Section 4 concludes.

2 Model

2.1 Baseline Set-up

The small open economy with a representative sovereign government is modeled in the same fashion as Phan and Schwartzman (2024). Only a single consumption good from capital (K_t) and labor, which is supplied inelastically, is produced following a Cobb-Douglas production function:

$$Y_t = (e^{-x_t d_t} K_t)^{\alpha} (A_t)^{1-\alpha}, \text{ where capital share } \alpha \in (0,1)$$

where A_t is total factor productivity assumed to follow a random walk with the identically and independently distributed (i.i.d.) growth shock g_t: $\log \frac{A_{t+1}}{A_t}$ from a distribution Φ_g.

Weather shocks: Flood is modeled as exogenous shocks x_t and d_t, which are the extensive and intensive margins of a stochastic process of disaster. The dummy variable, x_t, appears as 1 if there is a bad weather shock or a flood hits the economy, and 0 otherwise. The continuous variable, $d_t \geq 0$, represents the level of damage of flood toward the capital stock. The probability of a bad weather shock is a constant $\Pr(x_t = 1) = p$ and the damage d_t follows i.i.d. distribution Φ_d with support over $[0, \infty]$

Preferences: The representative government maximizes Epstein and Zin (1989) recursive preferences as follows:

$$V_t = \left(C_t^{1-\iota} + \beta E_t (V_{t+1}^{1-\gamma})^{\frac{1-\iota}{1-\gamma}} \right)^{\frac{1}{1-\iota}},$$

where ι, γ, β are the inverse intertemporal elasticity of substitution, the relative risk aversion coefficient and the discount factor, respectively, while C_t is treated as government consumption in the current period. Following macrofinance literatures i.e. Bansal and Yaron (2004) and Cai and Lontzek (2019), only a relevant range of ι is bounded within 1.

Sovereign borrowing: The government has access to one-period non-contingent bonds issued by risk-neutral international lenders with a promise to repay one unit of consumption good in the subsequent period. The country can decide either to repay the debt or default. If the country decides to default, it needs to bear deadweight loss of a fraction ℓ_t of the country's output in the same version as Aguiar et al. (2016). Following Adam and Grill (2017), we assume that it can regain access to the international credit market immediately after default in the sense that next period bond issuance is possible after mispayment. The government has tendency to default in a low-growth state. The specification of a procyclical fractional loss $\ell_t = \ell(g_t)$ is defined as:

$$\ell(g') = \bar{\ell} e^{\psi g'}, \psi \geq 0, \bar{\ell} > 0, \tag{2.1}$$

where g' and ψ are next period growth shock and the responsiveness of the default to the loss fraction.

Optimization Problem: After the growth and weather shocks are realized in period t, the government chooses (i) to repay or to default on its outstanding debt, (ii) the value of new bonds issued (b_n), and (iii) new capital investment (k_n). All variables are detrended by the productivity A_t and detrended variables were written in lowercases (i.e. $\nu_t = \frac{V_t}{A_t}$, $k_t = \frac{K_t}{A_t}$). The government has the following optimization problem with one state variable:

the country's net worth, m:

$$\nu(m)^{1-\iota} = \max_{k_n \geq 0, b_n} c^{1-\iota} + \beta E\Big[\nu(\max\{m'_R, m'_D\})^{1-\gamma} e^{(1-\gamma)g'}\Big]^{\frac{1-\iota}{1-\gamma}} \tag{2.2}$$

subject to budget constraint:

$$c = m - k_n + q(b_n, k_n)b_n$$

where b_n and k_n are the value of new bond issued and capital investment, and $q(b_n, k_n)$ represents the bond price schedule. The budget constraint reflects that government consumption must not exceed the sum of the country's net worth m and the value of newly issued bond $q(b_n, k_n)b_n$ net new capital investment. The detrended next-period debt (b') and capital stocks (k') after the realized subsequent-period shocks are as follows:

$$\begin{aligned} b' &= \ e^{-g'} b_n \\ k' &= \ e^{-x'd'-g'} k_n \end{aligned}$$

The country's net worth in the next period is defined as $m' = \max\{m'_R, m'_D\}$, which is equal to m'_R if the government repays the debt, while m'_D if the government decides to default, is given by:

$$m'_R = (k')^\alpha + (1-\delta)k' - b' \tag{2.3}$$

$$m'_D = (1-\ell(g'))(k')^\alpha + (1-\delta)k', \tag{2.4}$$

where δ is depreciation rate.

The decision to default comes when its debt over GDP is greater than the output lost fraction $\ell(g')$:

$$m'_R < m'_D \Leftrightarrow \underbrace{\frac{b'}{k'^\alpha}}_{\text{debt to GDP}} > \ell(g') \Leftrightarrow \underbrace{g' - \frac{\alpha}{1-\alpha+\psi} x'd'}_{\tilde{g}'} < \underbrace{\frac{\alpha}{1-\alpha+\psi} \ln \frac{b_n}{\bar{\ell} k_n^\alpha}}_{\bar{g}(b_n, k_n)} \tag{2.5}$$

With a fractional loss of default from equation 2.1 substituted into the above default condition, we find that the country decides to default when the weather-adjusted growth term $\tilde{g}' = g' - \frac{\alpha}{1-\alpha+\psi} x'd'$, which expresses the damage toward capital stock, is less than an endogenous default threshold $\bar{g}(b_n, k_n) = \frac{\alpha}{1-\alpha+\psi} \ln \frac{b_n}{\bar{\ell} k_n^\alpha}$.

Phan and Schwartzman (2024) found that the difference between $\bar{g}$ and $\tilde{g}'$ is the distance to default. Equation 2.5 indicates the default threshold $\bar{g}$ rises with higher debt level (b_n) and falls with next-period capital stock (k_n), implying that default risk rises with greater debt and falls with higher future capital. The expression also underscores the importance of cyclical default costs. As the parameter ψ increases, amplifying the responsiveness of default costs to the growth shock g', the sensitivity of the default threshold $\bar{g}$ to changes in debt and capital stock diminishes.

Bond: The equilibrium bond price schedule defines the price per unit of sovereign debt as a function of the country's borrowing decisions. In a competitive credit market with risk-neutral lenders who account for the possibility of default, this schedule is determined by:

$$q(b_n, k_n) = \frac{1 - s(b_n, k_n)}{1 + r}, \forall b_n, k_n, \tag{2.6}$$

where r is the world risk-free interest rate assumed to be constant and taken for a small open economy, and s is the sovereign default spread defined as the probability of default with repayment and default net worth (m'_R and m'_D from equations 2.3 and 2.4) as follows:

$$\begin{aligned} s(b_n, k_n) &= \Pr[m'_R < m'_D] \\ &= \Pr[\tilde{g}' < \bar{g}(b_n, k_n)] \\ &= (1-p)\Phi_g(\bar{g}) + pE_{d'}\Big[\Phi_g\Big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}d'\Big)\Big] \end{aligned} \tag{2.7}$$

The function s is the spread between the price of a risk-free bond and the price of a bond issued by the country. Equation 2.7 illustrates how disaster risk influences the bond spread schedule. Conceptually, default is a tail event that occurs when economic conditions deteriorate to the point where the cost of repayment exceeds the output loss from default. The introduction of disaster risk effectively alters the distribution of the growth shock from g' to $\tilde{g}'$. Since the distribution of $\tilde{g}'$ exhibits a fatter left tail compared to that of g', the presence of disaster risk increases the likelihood of adverse economic realizations. Consequently, this raises the probability of default for any given level of debt b_n and future capital k_n.

The shape of the spread schedule s determines how sensitive the economy's borrowing cost is to disaster risk. Phan and Schwartzman (2024) established that equilibrium spreads increase with higher levels of debt issuance and declines with higher next-period capital. This result directly follows from the observation that the default threshold ($\bar{b}$) is decreasing in new capital investment (k_n) hereby reducing the size of the default region as characterized in equation 2.5. Therefore, the interaction between capital, debt, and sovereign spreads generates a vicious feedback loop. A decline in the capital stock from disaster leads to higher spreads, which in turn raise the cost of borrowing and constrain further capital accumulation. This self-reinforcing mechanism amplifies economic vulnerability and plays a critical role in the transmission of weather shocks, as explored in the quantitative analysis presented in Section 3.

2.2 Catastrophe Bond Adoption

We explore the use of catastrophe (CAT) bonds, which function similarly to traditional bonds but include an important contingency feature: their face value is automatically reduced if a predefined trigger event occurs, typically when a natural disaster surpasses a specified intensity threshold. We consider two different trigger types for CAT bond: indemnity loss and parametric triggers. An indemnity loss trigger pays out based on the actual damages (d') if such loss is above the threshold ($\bar{d}$). The issuer then obtains the compensation equal to the excess damages incurred by the issuer ($d' - \bar{d}$). In contrast, a parametric trigger releases payouts when pre-defined physical measures, such as flood depth or rainfall intensity (ω), exceed a set threshold ($\bar{\omega}$), despite of the actual monetary losses. The issuer will then receive a fixed compensation (μ_p).

Regardless of CAT bond triggers, we set the country's optimization problem as follows: The representative government decides the composition of debt issuance between regular and CAT bonds. Denote $\theta \in [0, 1]$ as a fraction of CAT bond in total debt portfolio. The optimization problem for the country is given by:

$$\nu(m)^{1-\iota} = \max_{k_n \geq 0, b_n, \theta} c^{1-\iota} + \beta E\Big[\nu(\max\{m'_R, m'_D\})^{1-\gamma} e^{(1-\gamma)g'}\Big]^{\frac{1-\iota}{1-\gamma}} \tag{2.8}$$

subject to

$$c = m - k_n + q(b_n, k_n, \theta) b_n \tag{2.9}$$

$$b' = (1 - T'\theta) e^{-g'} b_n \tag{2.10}$$

$$k' = e^{-x'd' - g'} k_n \tag{2.11}$$

$$m'_R = k'^{\alpha} + (1 - \delta) k' - b' \tag{2.12}$$

$$m'_D = (1 - \ell(g')) k'^{\alpha} + (1 - \delta) k' \tag{2.13}$$

Next period bond issuance equation (2.10) is modified to include CAT bond. If T' is equal to 1, it means that the condition for CAT bond to pay out is met and the issued CAT bond will default, which result in a lower level of new bond issuance in the next period. The rest of the set-up is similar to the baseline case.

Note that q now represents the price of the entire bond portfolio. This price depends on θ, not only because lenders demand an insurance premium for disaster coverage, but also because the use of CAT bonds affects the country's default incentives as follows.

$$q(b_n, k_n) = \frac{1 - s(\bar{g}(b_n, k_n), \theta)}{1 + r} \tag{2.14}$$

Next, we consider two different triggers i.e. indemnity loss and parametric ones and their subsequent results on spread functions.

2.2.1 Indemnity Loss Trigger

We define T'_d as the dummy for the indemnity loss trigger for CAT bond. T'_d is 1 when the disaster hit ($x' = 1$), the damage is big enough ($d' > \bar{d}$), and there are newly bond issued ($b_n > 0$).

$$T'_d = x' \mathbf{1}_{d' > \bar{d}} \mathbf{1}_{b^n \geq 0} \tag{2.15}$$

Then, s denotes the spread for the entire bond portfolio issued by the sovereign government, expressed as a function of the endogenous default threshold $\bar{g}$ defined in equation (2.5) and the CAT bond fraction θ. If $\bar{d} > 0$, s takes the following form:

$$\begin{aligned} s\big(\bar{g}, \theta, \bar{d}\big) &= (1-p)\,\Phi_g(\bar{g}) \\ &\quad + p \int_0^{\bar{d}} \Phi_g\big(\bar{g} + \tfrac{\alpha}{1-\alpha+\psi}\, d'\big)\, f_{d'}(d')\, \mathrm{d}d' \\ &\quad + p(1-\theta) \int_{\bar{d}}^{\infty} \Phi_g\Big(\bar{g} + \tfrac{\alpha}{1-\alpha+\psi}\, d' + \underbrace{\tfrac{1}{1-\alpha+\psi}\, \ln\big(1-\theta\big)}_{<0,\text{ reduced default risks.}}\Big)\, f_{d'}(d')\, \mathrm{d}d' \\ &\quad + \underbrace{p\,\theta \Big[1 - \int_{\bar{d}}^{\infty} \Phi_g\Big(\bar{g} + \tfrac{\alpha}{1-\alpha+\psi}\, d' + \tfrac{1}{1-\alpha+\psi}\, \ln\big(1-\theta\big)\Big)\, f_{d'}(d')\, \mathrm{d}d'\Big]}_{>0,\text{ CAT bond premium}}. \end{aligned} \tag{2.16}$$

The spread $s(\bar{g}, \theta, \bar{d})$ in equation 2.16 is the risk-neutral expected loss per unit of face value that lenders suffer next period, so it equals the bond's price discount relative to a risk-free bond. It has four additive parts. The first term represents the probability of sovereign default when no disaster occurs. The second part captures default risk in disaster states whose loss (d') is below the indemnity trigger ($\bar{d}$), so the debt is not written down and the face value remains 1. The third term measures default risk in disasters above the trigger, but now the country's repayment obligation has been reduced to $(1-\theta)$ which lowers the default threshold by the constant $\frac{1}{1-\alpha+\psi}\ln(1-\theta) < 0$. The final term is CAT bond or insurance premium: even if the country repays after a severe disaster, creditors still lose the fraction θ that is automatically written off, which results in higher spread.

Intuitively, when a trigger $\bar{d}$ is raised, a slice of disaster states that previously qualified for the automatic write-down ($d' > \bar{d}$). In those states lenders stop paying the insurance premium since they no longer forfeit the fraction θ of face value. Nevertheless, they simultaneously lose the default-risk cushion the CAT bond had provided. Without the write-down the sovereign must repay the full unit, so the default probability jumps from the lower level $\Phi_g\big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d} + \frac{1}{1-\alpha+\psi}\ln(1-\theta)\big)$ (with relief) to the higher $\Phi_g\big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d}\big)$ (no relief), and because $\frac{1}{1-\alpha+\psi}\ln(1-\theta) < 0$ this jump is strictly positive. The increase in expected losses from the higher chance of outright default outweighs the premium that lenders save, so under risk-neutral pricing the net expected loss per dollar of face value, i.e. the spread, rises when the trigger is set tougher. The result is summarized in first part of proposition 1.

Proposition 1. *The equilibrium spread schedule s is positively related to $\bar{d}$:*

$$\frac{\partial s}{\partial \bar{d}} = p f_{d'}(\bar{d})\left[\Phi_g\Big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d}\Big) - (1-2\theta)\Phi_g\Big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d} + \frac{1}{1-\alpha+\psi}\ln(1-\theta)\Big)\right] > 0 \tag{2.17}$$

and there exists θ^* that determine the relationship between spread and θ such that $\frac{\partial s}{\partial \theta} < 0$ for $\theta < \theta^*$, while $\frac{\partial s}{\partial \theta} > 0$ for $\theta > \theta^*$
where

$$\begin{aligned}\frac{\partial s}{\partial \theta} =& p\Bigg[1 - 2\int_{\bar{d}}^{\infty} \Phi_g\Big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d} + \frac{1}{1-\alpha+\psi}\ln(1-\theta)\Big) f_{d'}(d')dd' + \\ & \frac{2\theta-1}{1-\theta}\frac{1}{1-\alpha+\psi}\int_{\bar{d}}^{\infty} \phi\Big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d} + \frac{1}{1-\alpha+\psi}\ln(1-\theta)\Big) f_{d'}(d')dd'\Bigg]\end{aligned} \tag{2.18}$$

Proof: *Appendix A*

The second part of proposition 1 is similar to Phan and Schwartzman (2024) regarding $\frac{\partial s}{\partial \theta}$. When the share of CAT bond is smaller than the threshold ($\theta < \theta^*$), raising θ shifts the repayment threshold left, cuts the probability of outright default, and therefore reduces the spread. In contrast, when the share exceeds such threshold ($\theta > \theta^*$), a larger θ enlarges the insurance premium lenders must forfeit whenever the CAT bond is triggered, and that premium grows faster than the incremental fall in default risk, so the sovereign spread widens.

In sum, for indemnity-triggered CAT bonds, payouts are based on the actual damages incurred by the insured party. This ensures accuracy and alignment with realized damages, but it often requires a lengthy claims assessment process, which can delay the release of funds. In contrast, parametric triggers rely on predefined physical indicators such as rainfall exceeding a threshold, flood depth at a given location, or even flooded area to activate payouts. These triggers allow for faster disbursement and greater transparency but may result in a basis risk where payouts do not perfectly match the actual economic losses experienced. We then model parametric trigger CAT bond in the following section.

2.2.2 Parametric Trigger

Consider T_p' as the dummy for the parametric-triggers CAT bond as follows

$$T_p' = x' \mathbf{1}_{\omega' > \bar{\omega}} \mathbf{1}_{b^n \geq 0} \tag{2.19}$$

Given $d' = \omega' \times \mu_p$, we denote ω' represents the cumulative intensity of flood events (measured in square kilometers of area-weighted intensity) in the next period, and $\mu_p > 0$ denotes the contract payout which is given to the issuers if the trigger is met. We can derive the spread of the entire bond portfolio with parametric-trigger CAT bond as follows:

$$\begin{aligned} s\big(\bar{g}, \theta, \bar{\omega}\big) &= (1-p)\, \Phi_g(\bar{g}) \\ &\quad + p \int_0^{\bar{\omega}} \Phi_g\Big(\bar{g} + \tfrac{\alpha}{1-\alpha+\psi}\, \mu_p\, \omega'\Big)\, f_{\omega'}(\omega')\, \mathrm{d}\omega' \\ &\quad + p(1-\theta) \int_{\bar{\omega}}^{\infty} \Phi_g\Big(\bar{g} + \tfrac{\alpha}{1-\alpha+\psi}\, \mu_p\, \omega' + \tfrac{1}{1-\alpha+\psi}\, \ln\big(1-\theta\big)\Big)\, f_{\omega'}(\omega')\, \mathrm{d}\omega' \\ &\quad + p\,\theta \Big[1 - \int_{\bar{\omega}}^{\infty} \Phi_g\Big(\bar{g} + \tfrac{\alpha}{1-\alpha+\psi}\, \mu_p\, \omega' + \tfrac{1}{1-\alpha+\psi}\, \ln\big(1-\theta\big)\Big)\, f_{\omega'}(\omega')\, \mathrm{d}\omega'\Big]. \end{aligned} \tag{2.20}$$

Equation 2.20 is similar to 2.16. Replacing the indemnity loss d' with $d' = \omega' \mu_p$ rescales the default threshold by a constant factor μ_p. All occurrences of $\frac{\alpha}{1-\alpha+\psi} d'$ in the equation 2.16 become $\frac{\alpha}{1-\alpha+\psi} \mu_p \omega'$, and the trigger shifts from a loss $\bar{d}$ to an intensity threshold $\bar{\omega}$. For

$\omega' \leq \bar{\omega}$, CAT bond remains inactive, so the sovereign must repay the full unit and decide to default when $g' < \bar{g} + \frac{\alpha}{1-\alpha+\psi}\mu_p\omega'$. For $\omega' > \bar{\omega}$, the bond writes down the face value to $1-\theta$, lowering the default cutoff to $\bar{g} + \frac{\alpha}{1-\alpha+\psi}\mu_p\omega' + \frac{1}{1-\alpha+\psi}\ln\big(1-\theta\big)$ with $\frac{1}{1-\alpha+\psi}\ln\big(1-\theta\big) < 0$. The spread therefore equals the risk-neutral expectation of creditor losses over these two regions integrated with respect to the probability density function of ω' plus the parametric-trigger CAT bond premium term.

3 Quantitative Result

We perform a quantitative simulation of the impact of the exogenous shock. The disaster risk under consideration is that of flood, an important and recurrent source of climate-related shocks for emerging economy. For our calibration, we focus on Thailand, an emerging market economy that faces significant exposure to flooding risk.

3.1 Calibration

We set each period to five years, which is well-suited to our focus on recovery dynamics following major disasters. Using five-year periods enhances the model's tractability, as capital adjustment costs are less likely to play a significant role over such horizons. Additionally, the implied five-year maturity of the model's one-period debt aligns more closely with the average maturity of sovereign bonds in emerging markets compared to models calibrated at quarterly or annual frequencies. This choice also allows us to abstract from the autocorrelation typically observed in TFP growth rates, further simplifying the state space.

In our baseline analysis, we follow Phan and Schwartzman (2024) except capital share and flooding-related parameters. Bank of Thailand reported that labor income share is around 44-47% from 2003 to 2021 and thus we employ capital share $\alpha = 1/2$ to reflex the state of the Thai economy. For weather shock parameter, we need to calibrate flood probability, marginal output damage, and the distribution of flood.

On the extensive margin, we interpret the model's weather shock dummy x_t as indicating whether a country experiences a flood within a given period. We calibrate the strike probability p which governs the Poisson arrival rate of rain, to match the observed average annual probability of 30% (Worawiwat et al., 2021).

On the intensive margin, we interpret the damage parameter d_t as representing the country's cumulative economic damage from flood events over a five-year period. This captures the aggregate impact of flood intensity and frequency within each model period. We assume that $d = \omega * \mu$ where ω represents the cumulative intensity of flood events (measured in square kilometers of area-weighted intensity) within a given period, and μ denotes the marginal damage to the capital stock per additional flooded area[1]. We set the marginal damage for output as 4.81%, following the estimated economic loss found in Tanoue et al. (2020)

We assume that maximum flood depth follows a Gamma distribution, which has been shown to provide a good empirical fit for modeling hydrological events (Khooriphan et al., 2022). The shape and scale parameters of Gamma distribution are set to 0.3391 and 148.7617, following Suanin and Wattanakoon (2023). Table 1 shows the parameter used in our analysis.

Table 1: Calibrated parameters.

	Parameter	**Value**	**Source**
	period length	5 years	
α	capital share	1/2	Bank of Thailand
β	discount factor	0.96^5	Standard RBC values
δ	depreciation	$1 - 0.9^5$	
r	world interest rate	$1.01^5 - 1$	
ℓ	inverse elasticity of substitution	0.5	Gourio (2012)
γ	risk aversion	4	
μ_g	mean TFP growth	$1.006^{20} - 1$	Aguiar and Gopinath (2007)
σ_g	std of TFP growth	$0.0213\sqrt{20}$	
ℓ	default cost constant	0.07	Aguiar et al. (2016)
ψ	default cost curvature	7	
p	flood probability	0.30	Worawiwat et al. (2021)
μ	marginal output damage	0.0481	Tanoue et al. (2020)
Φ_d	shape of Gamma distribution	0.3391	Suanin and Wattanakoon (2023)
	scale of Gamma distribution	148.7617	
$\bar{d}$	Indemnity Loss Trigger	90th percentile of d	Standard CAT Bond Contract
$\bar{\omega}$	Parametric Trigger	90th percentile of ω	

Note: Most of the basic parameters are similar to Phan and Schwartzman (2024)

[1]For indemnity-loss-trigger CAT bond, we apply damage $\bar{d}$ as a trigger and thus the compensation for the flooded victims is calculated from the actual damage and the trigger $d' - \bar{d}$, while parametric-trigger one uses $\bar{\omega}$ as a trigger, and therefore a constant fixed payout μ_p is compensated to the victim. We set μ_p = CAT Bond Coverage $\times$ Trigger Threshold $\times$ (1 $-$ basis risk), which is set as follows: coverage = 70%, trigger threshold at 90th percentile of expected damage, and basis risk at 30%. The expected compensation parametric-trigger CAT bond issuers is $\mu_p \times \mathbf{1}_{\omega > \bar{\omega}}$

3.2 Numerical Analysis

3.2.1 Propagation of flood shock

We examine the impulse responses of the economy to a one-time, one-standard-deviation shock to flood. The responses are generated by averaging across one million simulated paths, where in each path the economy is simulated until it reaches its ergodic steady state. Then, in period $t = 0$, we introduce an unanticipated shock that raises the period's cumulative area-weighted flood intensity from its ergodic steady-state average value of 13,000 to 27,000 square kilometers[2], representing a one-standard-deviation increase. We interpret this shock as capturing the impact of an exceptionally severe flood event occurring in period $t = 0$.

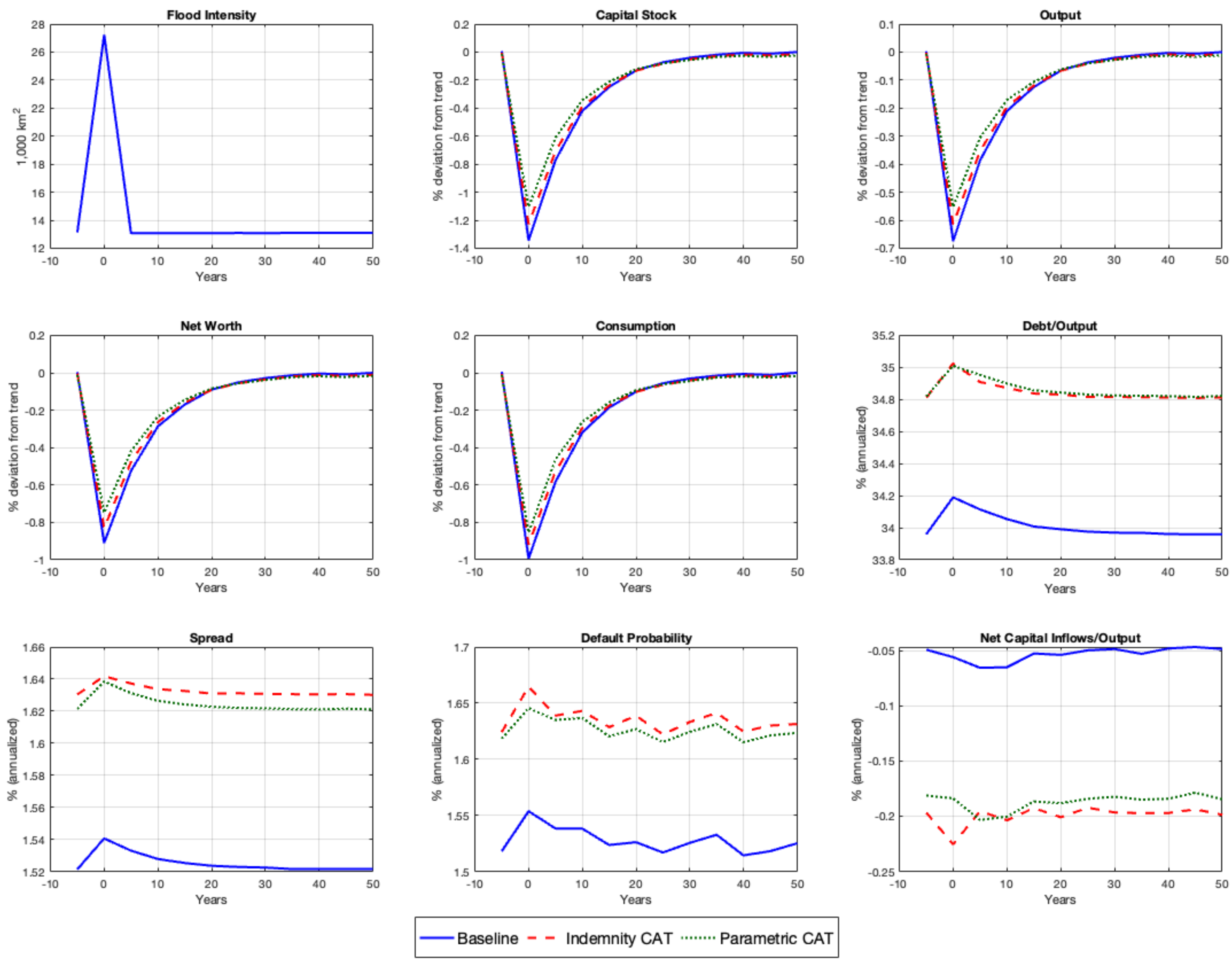
Figure 1 illustrates the impulse in the first panel and the responses of aggregate detrended variables in the subsequent panels under three policy regimes: (i) a Baseline without disaster insurance (solid blue), (ii) an Indemnity CAT bond (dashed red), and (iii) a Parametric CAT bond (dotted green). To aid interpretation, we adjust the reported values to annual terms by dividing the spread and default frequency by five and multiplying the debt-to-output ratio by five, reflecting the fact that each model period represents five years.

The second and third panels of the first row confirm that the flood shock still inflicts a sharp, one-period loss of productive capacity: capital stock falls by about -1.35 percent in the uninsured economy (blue), -1.25 percent under an indemnity CAT bond (red), and only -1.15 percent when a parametric bond (green) releases its full notional immediately. The same ranking carries over to output, and the gap persists for roughly a decade; faster capital deepening under the parametric scheme pulls output back to trend some five years sooner than in the baseline, underscoring the macro-stabilization dividend of rapid liquidity.

The second row traces government's balance sheets. Net worth and consumption contract most without insurance around -0.90 percent and -1.0 percent, respectively, while losses are noticeably milder with CAT coverage, again favoring the parametric trigger. Consumption recovers faster than wealth in both insured cases, illustrating how external transfers smooth inter-temporal allocations when domestic assets are impaired. By construction, however, both CAT bonds raise the debt-to-output ratio on impact to just about one percentage point higher than the baseline because the bonds are booked as public debt whereas the contingent transfer is recorded below the line.

[2]The ergodic steady-state average flooded area is simulated from the Gamma distribution calibrated from Suanin and Wattanakoon (2023) over one million simulated samples

Figure 1: Impulse responses of detrended variables to an unanticipated one-standard-deviation shock of flood



Note: Impulse responses are drawn from one-million simulated samples.

Higher gross debt feeds directly into the bottom-row financial indicators. Sovereign spreads widen by roughly 9 basis points under the indemnity bond and about 8 basis points under the parametric bond from the baseline scenario, reflecting investors's compensation for the larger debt stock and, in the indemnity case, for the possibility that verified losses will be too small to trigger a full payout. The default-probability panel mirrors this ordering: the hazard rate hovers near 1.65 percent with indemnity cover, slips to 1.63 percent with parametric cover, and remains around 1.53 percent in the baseline. Consequently, net capital inflows[3] fall slightly under the indemnity design (around -0.20 percent of output), somewhat less under the parametric bond, and hardly at all without insurance, reinforcing the tightening of external finance.

Taken together, the figure highlights a fundamental trade-off. CAT bonds, especially parametric ones, deliver swift macro-stabilization by curbing flood damage and accelerating the rebound of production and welfare. Yet, the ex-ante increase in gross debt, coupled with higher required spreads, raises sovereign risk metrics and crowds out capital inflows. Optimal contract design must therefore weigh the short-run benefits of faster recovery against the medium-term costs of a heavier debt burden and tighter external financing.

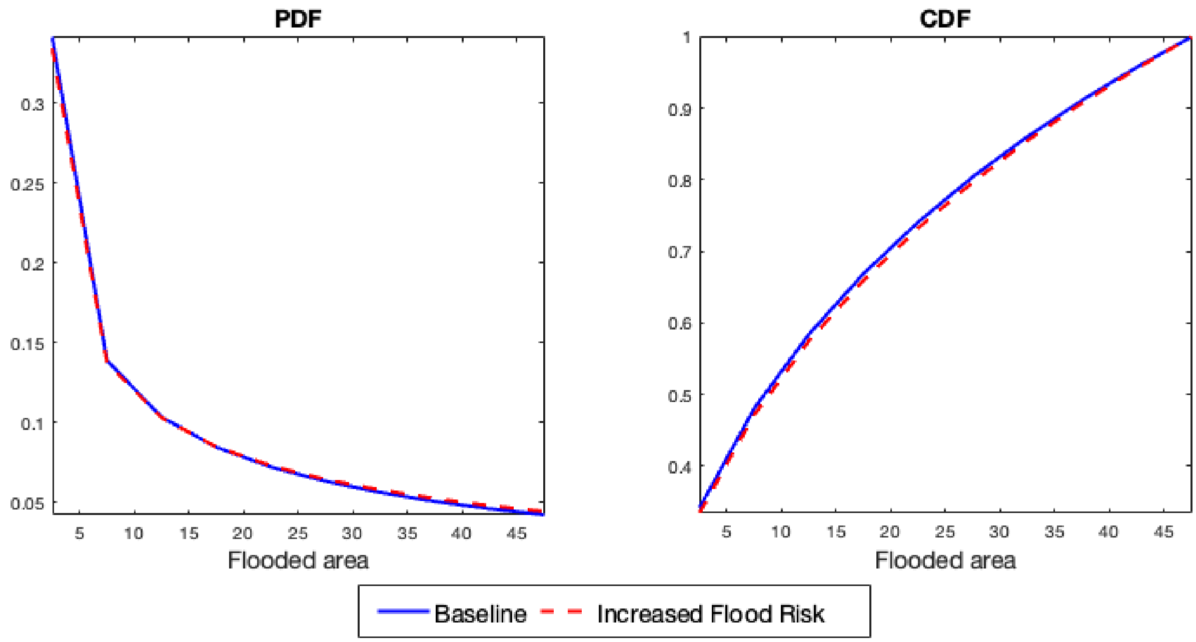
3.2.2 Welfare Analysis with Climate Change

We investigate the welfare implications of a shift in the distribution of flood intensity due to climate change. According to projections based on Intergovernmental Panel on Climate Change (IPCC) (2022), flood intensity in regions such as Southeast Asia including Thailand is expected to increase by an average of 30% in the next ten years. We model this shift by increasing the scale parameter of the Gamma distribution governing flood intensity by 30% from the baseline set-up and plot the probability and cumulative density functions in figure 2.

We compute a change in welfare after the effect of climate change using the equation 3.1 Denote $E[v(m)]$ and $E_+[v_+(m)]$ as the lifetime utility for a given net worth level m and those under the increased flood risk scenario. By evaluating welfare over the ergodic distribution of the state variable m, the metric Δw captures long-run welfare effects, appropriately reflecting the persistent rise in flood risk that unfolds gradually with climate change. Under Epstein-Zin preferences, this same Δw coincides with the standard macroeconomic consumption-equivalent welfare measures (Lucas, 1987; Barro, 2009). In other words, Δw tells us a fraction of lifetime consumption the representative household would be willing to forego permanently, across all dates and all states to avert the projected escalation in flood intensity.

[3] Net capital inflows are computed from the following equation: $q_t b_t^n - b_t$

Figure 2: Change in the distribution after an increase in 30% of flood risk



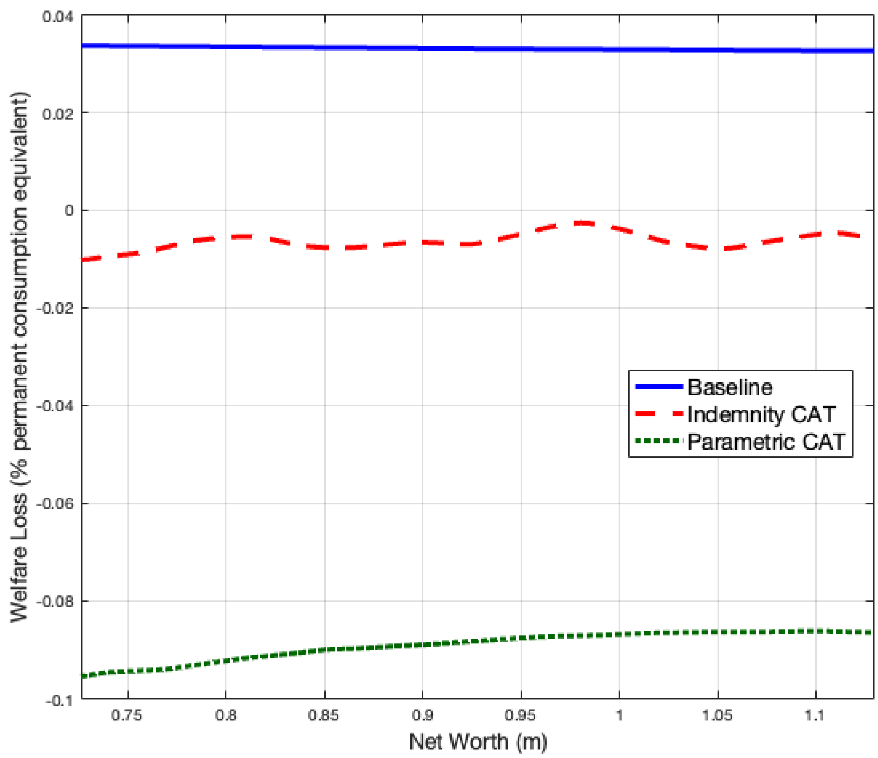
Note: Authors' computation

$$\Delta w = 1 - \frac{E_+[v_+(m)]}{E[v(m)]} \tag{3.1}$$

Figure 3 plots lifetime welfare losses expressed as permanent-consumption-equivalent percentages against the pre-disaster distribution of government net worth. In the baseline (solid blue) an intensification of flood risk uniformly reduces welfare by a little more than 0.03 percent, because government cannot diversify aggregate climate risk and the government must finance reconstruction through distortionary taxation and expensive external borrowing. Tax smoothing in this environment imposes classic deadweight losses: higher current and future tax wedges depress investment in every state of the world, so the marginal welfare cost of the climate shock is essentially state-invariant and pinned to the average loss in output and consumption that follows.

Issuing sovereign CAT bonds fundamentally alters these welfare dynamics by changing the timing and source of post-disaster liquidity. A parametric CAT bond (dotted green) delivers an immediate, rule-based payout once the flood index crosses the trigger, averting the need for short-term debt. The cash injection blunts the initial falls in capital and output (Figure 1). As a result, welfare improves by roughly 0.09 percent for the relevant range of m.

Figure 3: Welfare Losses from CAT Bond Adoption



Note: Authors' computation

In contrast, an indemnity CAT bond pays only for the verified portion of damage above the attachment point, and thus its expected transfer might be smaller than the fixed payout released by a parametric trigger. Although capital and output are cushioned relative to the baseline, confirmed in figure 1, the weaker transfer combined with the same coupon burden yields a minimal welfare gain around 0.01 percent across the relevant range of m. Thus, while both instruments mitigate the welfare impact of climate shocks, the parametric design dominates by providing larger, faster liquidity and therefore the greatest reduction in lifetime welfare losses.

4 Conclusion

This study gauges how sovereign CAT bonds can shield flood-prone emerging economies exemplified by Thailand from macroeconomic fallout. Using a calibrated dynamic small open economy model, we embed both indemnity- and parametric-trigger CAT bonds and trace their general-equilibrium effects on capital-to-output ratios, government net worth and consumption, public debt, sovereign spreads, and capital inflows after an exogenous flood shock. Thailand is an apt case because its recurrent and disruptive floods expose fiscal vulnerabilities, yet its financial depth allows international CAT issuance. By contrasting indemnity payouts (accurate but slow) with parametric triggers (rapid but basis-risky), the analysis quantifies how trigger design influences the speed of liquidity provision and, in turn, the mitigation of welfare losses from capital and output collapses.

Our simulations show that pre-arranged disaster risk finance can materially soften the macroeconomic and welfare costs of severe floods. Relative to a no-insurance benchmark, both CAT-bond designs cushion the initial fall in capital, output, consumption, and the government's net worth, but the parametric trigger dominates because it releases its full notional immediately. That speed advantage trims sovereign spreads, and cuts lifetime welfare losses in permanent consumption across the ergodic distribution of wealth. The flip-side is a slight increase in public debt for both types of CAT bonds, which temporarily crowds out capital inflows; hence CAT bonds shift, rather than eliminate, fiscal pressure.

For middle-income and flood-exposed economies similar to Thailand, our results point to a layered strategy that places a parametric CAT bond at the top of the financing stack. A tranche sized to cover the tail of losses would deliver rapid liquidity when conventional debt markets are most stressed, while budgetary buffers could handle moderate events and reduce basis risk. To contain coupon costs, governments should link issuance to credible adaptation plans, thereby lowering default risk, and seek partial donor support for premiums, as pioneered by the Pacific CAT Facility. Domestic regulatory changes that recognize CAT-bond proceeds as a counter-cyclical fiscal buffer, and efforts to deepen the regional investor base, would further enhance their stabilization power.

This paper provides a solid launch pad for deeper inquiry. Future extensions can enhance its realism by layering in multi-period climate trends, household- and firm-level heterogeneity, and the political-economy considerations that influence contract design and payout deployment. Incorporating payout delays, endogenous adaptation investment, and a sequence of correlated disaster shocks, while tracking distributional impacts and global financial cycles would yield an even richer picture of CAT-bond effectiveness. On the empirical side, the expanding record of sovereign CAT transactions offers a valuable opportunity to fine-tune model parameters and rigorously test the predicted interactions between CAT bond issuance and capital inflows, paving the way for the suitable disaster-risk-financing instruments.

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A Proofs

Proof of Proposition 1:
Part 1: $\frac{\partial s}{\partial \bar{d}} > 0$

$$\frac{\partial s}{\partial \bar{d}} = p f_{d'}(\bar{d}) \left[\Phi_g\Big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d}\Big) - (1-2\theta)\Phi_g\Big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d} + \underbrace{\frac{1}{1-\alpha+\psi}\ln(1-\theta)}_{<0}\Big)\right]$$

Since $\frac{1}{1-\alpha+\psi}\ln(1-\theta) < 0$, then $\Phi_g\Big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d}\Big) > \Phi_g\Big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d} + \frac{1}{1-\alpha+\psi}\ln(1-\theta)\Big)$. Therefore, for any $0 < \theta < 1$, $\frac{\partial s}{\partial \bar{d}} > 0$

Part 2: For $\theta > \frac{1}{2}$, then $\frac{\partial s}{\partial \theta} > 0$, while for $\theta < \frac{1}{2}$ then $\frac{\partial s}{\partial \theta} < 0$

$$\begin{aligned}\frac{\partial s}{\partial \theta} =& p\Bigg[1 - 2\int_{\bar{d}}^{\infty} \Phi_g\Big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d} + \frac{1}{1-\alpha+\psi}\ln(1-\theta)\Big) f_{d'}(d')\mathrm{d}d' + \\ & \frac{2\theta-1}{1-\theta}\frac{1}{1-\alpha+\psi}\int_{\bar{d}}^{\infty}\phi\Big(\bar{g} + \frac{\alpha}{1-\alpha+\psi}\bar{d} + \frac{1}{1-\alpha+\psi}\ln(1-\theta)\Big) f_{d'}(d')\mathrm{d}d'\Bigg] \gtrless 0\end{aligned}$$

Let

$$\frac{\partial s}{\partial \theta} = p\Big[1 - 2\,I(\theta) + \frac{\lambda(2\theta-1)}{1-\theta}\,J(\theta)\Big],$$

with

$$I(\theta) = \int_{\bar{d}}^{\infty} \Phi_g\big(\bar{g} + kd' + C(\theta)\big) f_{d'}(d')\,\mathrm{d}d' \tag{A.1}$$

$$J(\theta) = \int_{\bar{d}}^{\infty} \phi_g\big(\bar{g} + kd' + C(\theta)\big) f_{d'}(d')\,\mathrm{d}d' \tag{A.2}$$

$$C(\theta) = \lambda\ln(1-\theta) \tag{A.3}$$

$$\lambda = \frac{1}{1-\alpha+\psi} > 0 \tag{A.4}$$

1. Strict monotonicity: Using the chain rule, one obtains

$$I'(\theta) = -\frac{\lambda}{(1-\theta)}J(\theta), \qquad J'(\theta) < 0 \tag{A.5}$$

2. Uniqueness of the zero: Define $F(\theta) = \frac{1}{p}\partial s/\partial\theta$. From A.5, then

$$F'(\theta) = \frac{2\lambda}{1-\theta}J(\theta) - \frac{\lambda(1-2\theta)}{1-\theta}J'(\theta) - \frac{\lambda}{(1-\theta)^2}J(\theta) > 0$$

3. End-point signs

$$\lim_{\theta\to 0} F(\theta) < 0, \qquad \lim_{\theta\to 1} F(\theta) > 0 \tag{A.6}$$

The first is true because at $\theta = 0$ the premium term vanishes while default risk is still high, the second is also true because both $I(\theta)$ and $J(\theta)$ fall to 0 but the insurance premium grows without bound.

Because $F(\theta)$ is continuous and strictly increasing and its sign flips from negative to positive between 0 and 1, there must exist a single point where it crosses zero (by A.5 and A.6 and the intermediate-value theorem)

$$\exists! \theta^* \in (0,1), \text{ such that } F(\theta^*) = 0$$

4. Closed-form condition for θ^*: Set $\frac{\partial s}{\partial \theta} = 0$, we obtain

$$(1-2\theta^\star)J(\theta^\star) = \frac{1-\theta^\star}{\lambda}\left[1 - 2I(\theta^\star)\right]$$

Because $I(\theta)$ and $J(\theta)$ are strictly decreasing, the left-hand side is strictly increasing and crosses the positive right-hand side exactly once.

5. Sign of $\partial s/\partial\theta$ around θ^*: Since $F'(\theta^*) > 0$ then

If $\theta < \theta^*$ then $F(\theta) < 0 \Rightarrow \partial s/\partial\theta < 0$: Default-risk relief dominates the premium: a bigger write-down cuts the spread.

If $\theta > \theta^*$ then $F(\theta) > 0 \Rightarrow \partial s/\partial\theta < 0$: Insurance premium dominates: a bigger write-down now widens the spread.