Thailand and The World Economy
P-ISSN: 2630-0931
E-ISSN: 2651-0529
Homepage : *https://www.tci-thaijo.org/index.php/TER*
Vol. 41, No.3, September - December 202 **Page [22-39]**

Catastrophe Bond and Sovereign Debt: Flooding Risk Transfer for Thailand

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Received 7 October 2022, Received in revised form 24 December 2022,
Accepted 12 January 2023, Available online 4 September 2023

Abstract

The dangers posed by natural disasters are a source of concern for policymakers. Severe occurrences caused by the devastation may contribute to the economic collapse and increase in sovereign debt. A catastrophe bond (CAT bond) can be utilized to transfer catastrophe risk to the financial market. This article examines how policymakers can use a CAT bond as an ex-ante financial instrument to raise funding. By using Thailand as a case study, this research replicates the loss caused by floods using three potential catastrophe bond packages based on the coverage size of the simulated loss. We find that all packages can slow the rising trend of the debt-to-GDP ratio under catastrophic flooding. Even if it cannot, on average, reduce the debt-to-GDP ratio, the greatest coverage bond provides the government with the highest level of utility since it can help mitigate the economic collapse during disaster seasons.

Keywords: Thailand, flooding, catastrophe bond, debt dynamics

JEL Classifications: E44, E47, E62, H12, H63

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This paper is a selected paper from Asia Pacific Economic Integration Forum (A-PAC EIF 2022), organized by Faculty of Economics, Thammasat University; Thammasat Business School, Thammasat University; Maharaja Agrasen Institute of Management Studies (MAIMS); The University of Danang - University of Economics and Faculty of Economics & Business Administration, Dalat University; and Entrepreneurship Development Institute of India.

1. Introduction

The dangers posed by natural disasters are a source of concern for policymakers. The catastrophe destroys the existing infrastructure, properties, and lives. It disrupts businesses and the means of subsistence for the impacted citizens. The economic impact of the devastation could be a fiscal burden for both local and central governments. The public expenditures for infrastructure reconstruction and the compensations for disaster victims tend to raise the public debt-to-GDP ratio. The government can resort to ex-post public finance management by issuing new short- or long-term government bonds as well as obtaining domestic or foreign aid for a full economic recovery. Nonetheless, those approaches might not be able to finance the required government disbursement in a timely manner since all necessary procedures for transparency and investors' protection must be met, and thus it takes time for the capital to be raised.

There are also ex-ante public finance management tools. The government can incentivize the private sector to buy insurance for their own protection using tax privileges or subsidies. Such a method helps transfer the catastrophe risks to an insurance company, which can also face bankruptcy if the incident poses a huge economic cost. A catastrophe bond (CAT bond) is another option innovated to solve such problems (Adena et al., 2009; Cummins, 2008; Cummins, 2012; Litzenberger, 1996). It is also a tool for ex-ante public finance management that can transfer natural disaster risks to the financial markets. Investors who purchase CAT bonds will bear the risk and receive a higher coupon than those who purchase risk-free government bonds.

This paper investigates the effect of issuing CAT bonds on public debt dynamics. Apart from a direct fall in GDP after the disaster interrupts production, the government's disbursements on disaster mitigation and victim relief can contribute to the heightened level of public debt. A CAT bond can be an ex-ante tool to raise the required funds for the economic recovery even before the meltdown. The government can effectively manage the disaster relief process if it has a sufficient amount of capital. However, there is a trade-off in CAT bond applications.

A natural disaster with a huge economic cost is a rare occurrence. Apart from the benefit of raising fund for emergencies, issuing CAT bonds obligates the bond issuers and the sponsor (the government for public finance management) to pay a higher coupon to the bearers of the bonds. These premiums must be paid to the investors; otherwise, no one wants to share the catastrophe risks. Additional fiscal burden is then accumulated each year when a CAT bond is issued. To successfully realize the benefit of a CAT bond, policymakers then need to balance the cost and the benefit. These tools are appropriately implemented for public finance management in developed countries but not so much in developing ones.

Ando et al. (2022) reported that the amount of CAT bonds issued is on the rise. The largest CAT bond public issuer is the US. Other countries, such as Mexico, Chile, and Turkey, have also participated in the sovereign CAT bond market. In 2019, the Philippines, with support from the World Bank, insured their natural disaster-prone provinces with a CAT bond. When Typhoon Rai hit the islands, such CAT bonds were successfully triggered and paid US$52.5 million to the Bureau of the Treasury of the Philippines. To the best of our knowledge, there were no study of the effect of CAT bonds on public debt dynamics in developing countries. Even if Cebotari & Youssef (2020) studied the disaster risk in public finance, insurance is the main instrument of their choice, not the CAT bond.

This paper uses flooding in Thailand as a case study. There is no such financial instrument in Thailand, and the natural disaster can affect both the Thai economy and the global supply chain[1]. Flooding is selected as the catastrophe of interest for Thailand due to its largest share of disaster relief. A successful case study can serve as inspiration for other developing countries to better prepare for unpredictable natural disasters.

In this paper, we begin our analysis of the fiscal burden from flooding in Thailand to point out the importance of the risks from flooding. We then discuss the theoretical framework for how CAT bonds work and how they will affect public debt dynamics in Section 3. After that, we outline all the steps taken to simulate the probability distributions of flooding, coupon payments, and their effect on public debt dynamics. Section 5 illustrates the results of CAT bonds on public debt dynamics, and Section 6 concludes.

2. Fiscal burden from flooding in Thailand

Thailand is vulnerable to floods due to its tropical position, the impact of the seasonal monsoon rains, and the local topography. Thailand has a monsoonal climate, with the southwest monsoon typically bringing heavy rains to the nation between mid-May and mid-October (Thai Meteorological Department, 2022). Rivers can overflow during the rainy months of August and September due to high runoff, which can cause floods. When there has been a very heavy downpour, Thailand's primary waterway, the Chao Phraya River basin, may flood. About 20 million people (or 30% of the total population) reside along the Chao Phraya River basin (DHI, 2012), along with the number of Thailand's manufacturing companies (Swiss Re, 2012). Because of the basin's low gradient (only 1.5 meters per 100 kilometers), floodwaters drain away slowly, and floods last a long time (DHI, 2012). Also, Thailand experiences the leftovers of tropical cyclones from the northwest Pacific because of its tropical location; these cyclones bring additional heavy rain, which can start or aggravate floods during the monsoon season.

According to Ministry of Finance Regulations Regarding Contingency Fund Advances for Emergency Relief Assistance (B.E. 2564), the government has the power to spend money on emergency situations to defend against and avoid flooding as well as mitigate its impacts. This budget can be broadly divided into six categories, including livelihood, social work, medical and public health, agriculture, disaster mitigation, and the operation of help and assistance to disaster victims.

Considering the actual loss of flooding through the data on government expenditure for flooding victim relief in Table 1, we can see that the fiscal expenditure on this task fluctuated and was uncertain over the past two decades. Furthermore, flooding is Thailand's most significant disaster, and the government needs a substantial budget to lessen its negative effects. More specifically, the flooding disasters that occurred between 2003 and 2021 are responsible for more than half of this type of spending. In particular, flooding cases accounted for practically all of the government's spending on disaster victim aid in the fiscal years 2017 and 2018[2].

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[1] Thailand encountered a huge flood in 2011 that created a shortage of personal computer hard disk drives in the global markets for months.

[2] Thailand's fiscal annual budget starts in October. For instance, the 2017 fiscal budget begins on October 1st, 2016 and ends on September 30th, 2017

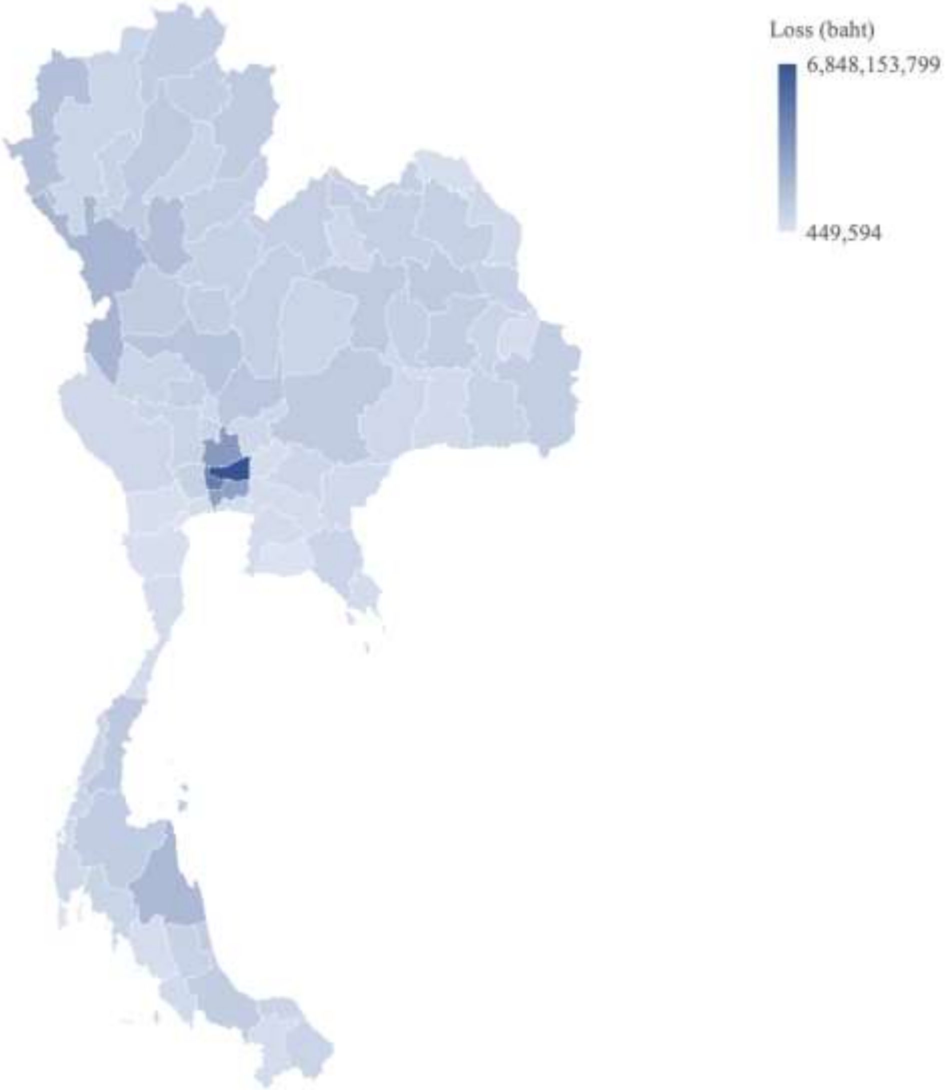
Table 1: The Government Expenditure for Flooding Victim Relief, the Fiscal Year 2003-2021

Fiscal year	**Flooding** (million baht)	**Share of total fiscal disaster expenditure** (%)
2003	854	72.17
2004	1,063	65.34
2005	1,517	29.99
2006	4,360	67.36
2007	5,204	65.60
2008	5,783	62.39
2009	4,923	58.25
2010	3,999	47.40
2011	8,416	55.76
2012	28,138	81.37
2013	318	8.82
2014	1,323	57.90
2015	557	n.a.
2016	297	25.92
2017	2,847	96.14
2018	1,833	94.63
2019	819	73.32
2020	540	30.68
2021	580	82.72

Source: Disaster Victim Relief Division, Ministry of Interior

The central section of Thailand has experienced the majority of Thailand's significant flooding over the past few decades. As shown in Figure 1, the more intense the color, the greater the relative loss of floods in over 77 Thai provinces from the fiscal years 2003 to 2021. In general, the intensity of the floods varied by province, although the majority of the damage occurred in the middle of Thailand, specifically in Pathum Thani (9.3%), Nonthaburi (6.5%), Ayutthaya (4.7%), and Bangkok (4.2%). About 18 billion baht, or close to a quarter of the total government expenditure for disaster victim relief, was exhausted in these four provinces.

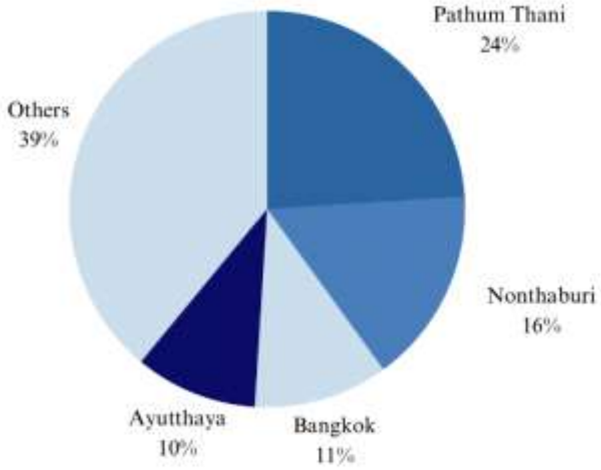
Figure 1: The Government Expenditure for Flooding Victim Relief by Province, the Fiscal Year 2003-2021



Source: Disaster Victim Relief Division, Ministry of Interior

In 2011, Thailand had record rainfall in March and April because of the early onset of the southwest monsoon (Swiss Re, 2012). Throughout the six-month monsoon season, rainfall was above average. This, along with severe rainfall from four tropical storm remnants passing the country's north, caused rivers to break their banks. Inadequate management of Thailand's main reservoirs resulted in overtopping and the release of even more water, intensifying the floods and causing considerable damage to residences, historical monuments, and industrial estates controlled by huge multi- national corporations such as Sony, Honda, and Toyota (Aon Benfield., 2012). As a result of the severe flooding in 2011, the actual loss from floods in the fiscal year 2012 peaked at 28 billion baht, or around 81 percent of the entire expenditure for fiscal disasters. Pathum Thani, in particular, had the most severe impact, accounting for around 24 percent of the entire fiscal spending on flooding victim assistance during that fiscal year (Figure 2).

Figure 2: The Share of Government Expenditure for Flooding Victim Relief by Province, the Fiscal Year 2012



Source: Disaster Victim Relief Division, Ministry of Interior

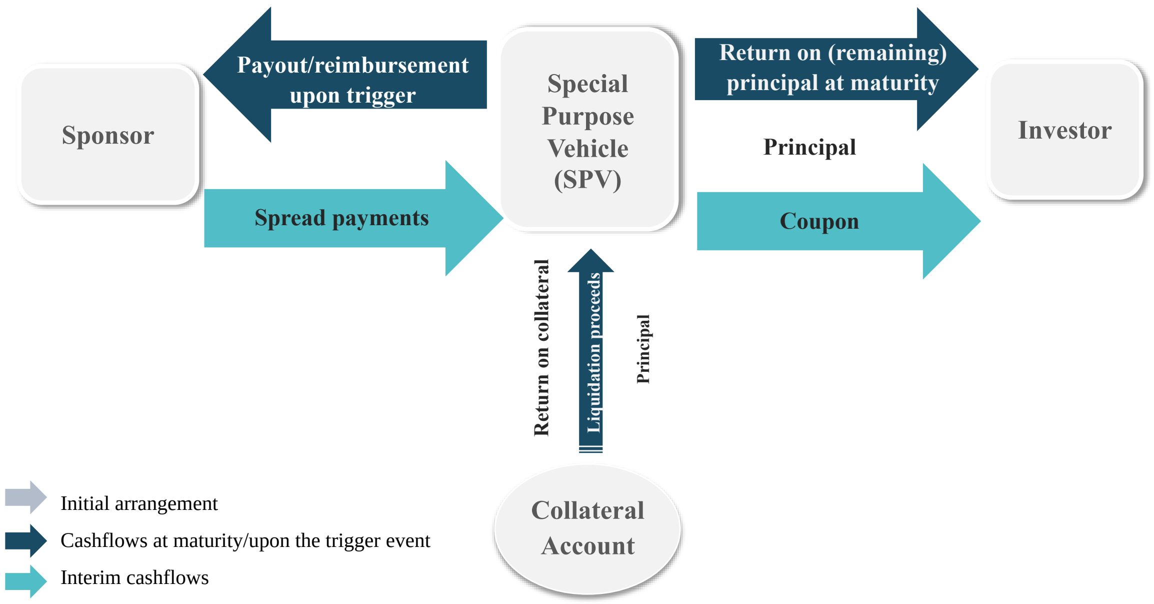
3. Theoretical Framework

3.1 Catastrophe Bond

A catastrophe bond (CAT bond) is an ex-ante financial instrument that can raise funds for an organization before the disaster occurs. The default of the CAT bond depends on the likelihood and magnitude of the catastrophe. If no disaster occurs and the level of its intensity is not up to the threshold, the bond will continue paying coupons (and potentially the principal at bond maturity) to the bearer of the CAT bond. Nevertheless, if the disaster strikes and its level of magnitude exceeds the threshold described in the bond, the investors in the CAT bond can lose a portion or all of their principal.

Figure 3 illustrates how the CAT bond works. Sponsors (in this case, the Thai government) can establish a special-purpose vehicle to issue and administer CAT bonds. Its role is to receive spread payments from the sponsor, sell CAT bonds at par value, and pay coupons to investors. All the funds raised will be deposited and invested in a collateral account. In the event of a triggered event, the collateral account will be liquidated and reimbursed to the sponsor. Otherwise, the return on the collateral account will be paid back to investors as a coupon and the principal at maturity. These CAT bonds can also be traded in the secondary market.

Figure 3: How Catastrophe Bond Functions



Source: Authors’ Compilation

One of the most important features of a CAT bond is the trigger. It indicates the condition that the bond will be reimbursed to the sponsors rather than investors. From investors’ perspectives, this condition indicates the probability of default on this investment. There are at least 5 types of triggers for CAT bonds (Hagedorn et al., 2012):

1. Indemnity loss trigger: The condition of the payout is determined by the victim's actual loss.
2. Parametric trigger: The reimbursement relies on scientific indicators such as the level of rainfall in a certain area.
3. Index trigger: The threshold is measured through industrial indicators. If the loss of industry exceeds a particular level, the investor will lose a portion or all of the principal.
4. Modeled loss index trigger: Sponsors will get paid back if the level of modelled loss calculated by the independent and trusted organization is higher than the agreed value.
5. Hybrid trigger: Bond issuers could put together more than one of the above triggers as a condition for paying out.

The choice of trigger as well as the area that CAT bonds covers are critical for the optimal design of CAT bonds since its conditions for getting or not getting reimbursed entirely depend on them. There might be a disaster that causes severe economic loss, but its center is outside the area specified in the CAT bond. To focus only on the potential benefit of CAT bonds on public debt dynamics, we select an indemnity loss trigger to demonstrate the application of CAT bonds to the issuers and decide to cover the entire area of Thailand.

To design a CAT bond for Thailand, we chose flooding as a case study and considered two important aspects of the CAT bonds: the trigger and coupon payment. The computational details are as follows:

3.1.1 Trigger

The indemnity trigger follows equation (1). When the actual loss realized by the sponsor (E) exceeds the initial threshold (E_1), the bond will be enforced to reimburse the sponsor with *E*-E_1 Thai baht but not exceed E_2. Nonetheless, no reimbursement is made if the actual loss E is less than E_1.

$$L = \text{Min}\ [\text{Max}(E - E_1, 0), E_2] \tag{1}$$

where L is the amount of payout/reimbursement to the sponsor,
E is the actual loss incurred to the sponsor,
E_1 is the initial threshold that the bond will trigger to reimburse sponsor,
E_2 is the limit threshold that the bond will no longer reimburse,
Min and Max are the minimum and maximum functions, respectively.

For example, given a CAT bond with an initial threshold of 5,000 million Thai baht, during the coverage period, the disaster causes an actual loss of 5,500 million Thai baht. The sponsor will be reimbursed by 500 million Thai baht in that particular year; however, if the actual loss is 3,000 million Thai baht instead, the bond will not trigger. This paper will use the government advance for natural disaster relief collected by Thailand's Ministry of Interior as the actual loss to simulate and compute the level of reimbursement.

3.1.2 Coupon payment

The value of the coupon paid to investors is based on insurance premiums as determined by actuarial science. We collect historical data on past flooding, such as the actual loss incurred and frequency of flooding, to compute the probability distribution of the flooding by applying maximum likelihood estimation (MSE) and simulate the reimbursement of CAT bonds.

After obtaining the simulated data, we calculate the coupon using equation (2). The expected value of the payout is combined with the Value-at-Risk (VaR) to take the investors' risk tolerance into account. This VaR term captures the additional premium investors are willing to accept at the alpha-*th* percentiles (i.e., the 90-*th*, 95-*th*, and 99-*th* percentiles) of expected loss (L). The higher the risk, the higher the required insurance premium or coupon paid to investors.

$$Coupon = E(L) + b \cdot [VaR(L, alpha)] \tag{2}$$

where $Coupon$ is the payment to investor by bond issuers
$E(L)$ is the expected value of payout/reimbursement (L)
b is the Value-at-Risk coefficient reflecting the investors' risk tolerance; if high, investors are more risk averse and need higher coupon to compensate
$VaR(L, alpha)$ is the value of alpha-*th* percentiles of L

3.2 Debt dynamics

The ability of the government to service its debt is a critical condition for fiscal sustainability. At any time, *t*, government spending cannot exceed receipts and new debt. The government must be able to repay the preceding period's debt stock (D_{t-1}) at the end of that time with real interest (r_t). The government's budgetary constraints are as follows (Ghosh et al., 2013; Ostry et al., 2010):

$$G_t + (1 + r_t)D_{t-1} = T_t + D_t \tag{3}$$

where G_t is primary expenditure, not including debt services. T_t denotes the government's revenues. In other words, the current public debt, D_t, is equal to the stock of public debt in the preceding period, D_{t-1}, with the debt service, $r_t D_{t-1}$, deducted by the primary balance, $PB_t \equiv T_t - G_t$, as follows:

$$D_t = (1 + r_t)D_{t-1} - PB_t \tag{4}$$

The debt dynamics in equation (4) may be reformulated in proportion to economic size as measured by GDP. Suppose that the percentage of economic growth is θ_t, the equation (4) becomes

$$d_t = \left(\frac{1+r_t}{1+\theta_t}\right) d_{t-1} - pb_t \tag{5}$$

where the small latter indicates the variable in terms of GDP ratio.

The previous equation shows that the current public debt to GDP ratio depends on two main factors*:*

*(*i*)* Interest rate-growth differential (IRGD). If the interest rate exceeds the growth rate ($r_t > \theta_t$), the government must utilize a budget surplus strategy to repay the principal and interest to maintain a sustainable level of public debt in the long term. On the other hand, if instead $r_t < \theta_t$, the government can run a budget deficit to stimulate the economy to some extent without worrying about the impact on public debt.

(ii) Primary balance. If the government pursues an expansionary fiscal policy with a budgetary deficit, it may compensate for the deficit by issuing more debt. Fiscal surplus policy, thus, has the opposite effect.

Suppose that the government issues CAT bonds. Once the catastrophe occurs, the primary balance will become

$$pb_t = p^* - premium_i - \min\left[Loss_t - payout_{i,t}, borrowing_{i,t}\right] \tag{6}$$

where p^* is the steady-state (baseline) primary balance, $premium_i$ is the cost of the CAT bond package i, $payout_{i,t}$ is the reimbursement from the CAT bond if it triggers, and the minimum function of $[Loss_t - payout_{i,t}, borrowing_{i,t}]$ indicates the minimum of net disaster-related government expenditure between getting reimbursed by the CAT bond or direct borrowing for the post-catastrophe recovery. We also assume that the flooding losses affect only the current primary balance without being divided across time. By adding the premium, payouts, and disaster-related expenditures to the baseline primary balance, we can quantify the effects of CAT bonds and flooding disasters on debt dynamics.

To identify which CAT bonds are more appealing than others, we apply packages that maximize the government's utility function (U_i), expressed in equation *(7)*. Following Cebotari & Youssef (2020), we assume that the government is risk averse in terms of economic growth but risk neutral in terms of debt sustainability, and we employ an additive constant risk aversion government utility function from the CAT bond package, i.

$$U_i = (1 - z)\frac{\Delta\theta_i^{(1-\rho)}}{(1-\rho)} - z\Delta d_i \tag{7}$$

where ρ is the coefficient of constant risk aversion, and z is the weight in the utility function assigned to debt sustainability considerations. $\Delta\theta_i$ denotes the growth outcomes under CAT bond package i in comparison to a no-CAT bond scenario, expressed as a difference averaged over all simulations. Δd_i is the result of the debt-to-GDP ratio under the CAT bond package i compared to a no-CAT bond scenario.

4. Research Results

4.1 Variable measurement and data sources

As mentioned before, the loss from flooding is measured by the data on government expenditure on flooding victim relief, provided by the Disaster Victim Relief Division, Ministry of Interior. This expenditure is available by province on a yearly basis from 2003 to 2021.

For the debt dynamics study, all variables are measured as a ratio of GDP, and the data comes from several sources. Thailand’s public debt to GDP ratio is collected from the Public Debt Management Office of Thailand. The primary balance data is obtained from the Fiscal Policy Office. GDP and real GDP growth rates are from the National Economic and Social Development Council's Office. The potential growth prediction is based on the IMF's World Economic Outlook for 2022. The interest rate, measured as the 10-year government bond yield, is collected from the Thai Bond Market Association (ThaiBMA). It should be noted that the nominal variables are deflated by an inflation rate based on the Ministry of Commerce's Consumer Price Index.

4.2 Simulation

Step 1: Estimate the loss distribution

We use the historical data on government expenditure on flooding victim relief as a proxy for actual loss to the sponsor and apply the Kolmogorov-Smirnov goodness of fit test for Gamma distribution to verify the fitness of actual loss. The result of its fitness is shown in Table 2. After we confirm that the data follows a gamma distribution with a coefficient of 0.7850 for alpha and 4919.0497 for beta, we use these coefficients to simulate the loss distribution 10,000 times. It yields the simulated loss distribution with a mean of 3,882.7 and a standard deviation of 4366.8 and its cumulative distribution as illustrated in Figures 4 and 5, respectively.

From the simulation, we observe that the value of loss lower than 10,000 million Thai baht occurs around 9,000 out of 10,000 simulated times. The rest of the 1,000 cases comprise losses of over 10,000 million Thai baht, and there are a few incidences of losses exceeding 30,000 million Thai baht.

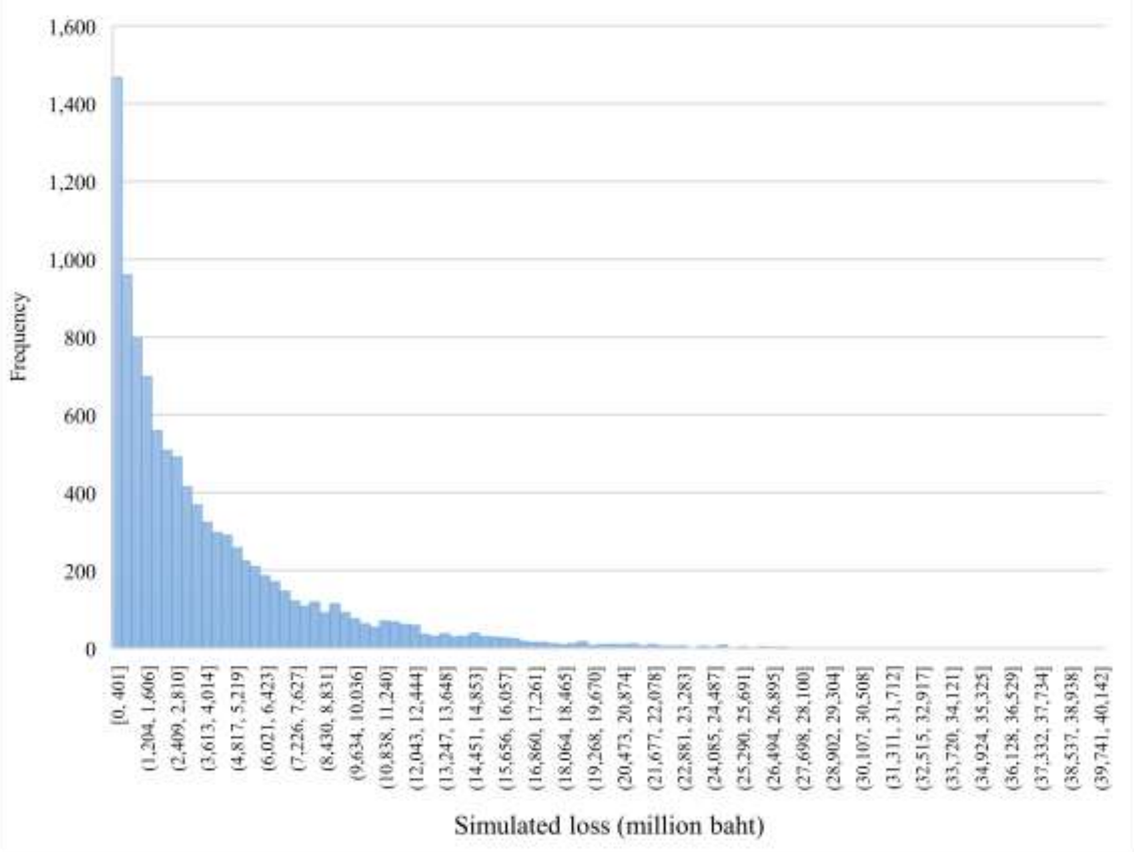
Table 2: Kolmogorov-Smirnov Goodness of Fit Test for Gamma distribution

Gamma Distribution: $\boldsymbol{\Gamma(x, \alpha = 0.7850, \beta = 4919.0497)}$	**Statistics**
Mean	3861.632
Standard Deviation	4358.389
Significant is:	False
Kolmogorov-Smirnov Test	0.155
P-value:	0.697

Note: The null hypothesis is that the government advance for disaster relief follows a gamma distribution, while the alternative hypothesis is otherwise; since the p-value is 0.697, we cannot reject the null hypothesis at the 0.05 level of significance and therefore conclude that the government advance follows gamma distribution.

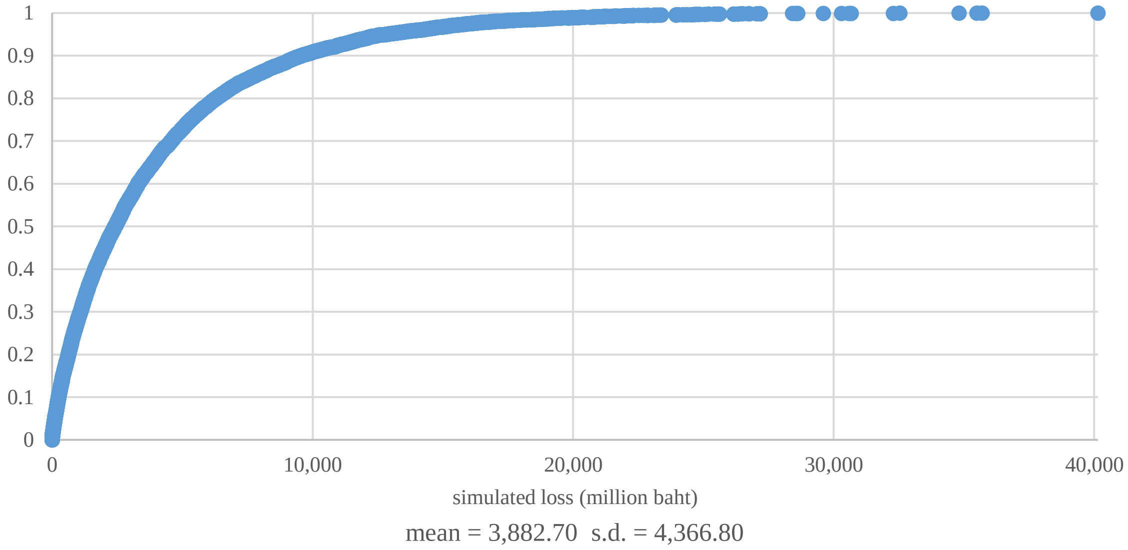
Source: Authors’ Computation

Figure 4: Simulated Loss Distribution



Source: Authors' Computation

Figure 5: Cumulative Distribution



Source: Authors' Computation

Step 2: Compute expected value of payout or E(L)

After obtaining the loss distribution, we use equation (1) as a criterion to filter out which events (out of 10,000 simulated cases) trigger the CAT bond and reimburse the sponsor. If the simulated loss does exceed the initial threshold, the payout is the difference between the simulated loss and the initial threshold (E-E_1) but does not exceed the limit threshold (E_2); otherwise, the payout is zero. Then we can compute the expected value of payouts out of 10,000 simulated events.

We assign the value of the initial threshold (E_1) of 4,000 million Thai baht in our simulation because this is the average value of government expenditure on flood relief in the past decades. As long as the loss from flooding exceeds the historical record, the flooding CAT bond will trigger and reimburse the government. For the limit threshold (E_2), we consider three packages of CAT bonds with different limit thresholds: $E_2 = \{10000, 20000, 30000\}$ million Thai baht. The maximum loss from floods to the Thai government in 2012 was 28,000 million Thai baht; therefore, 30,000 million Thai baht of principal sold to investors should be sufficient to reimburse the government relief fund. The extreme event is a rare occurrence, so we lower the limit threshold to 20,000 and 10,000 to examine the potential benefit of issuing a CAT bond at different levels of principal.

Step 3: Compute coupon payment

With the expected loss computed from step 2, we can use equation (2) to derive the required coupon paid for each package of CAT bonds. We assign the Value-at-Risk coefficient (b) for an investor's risk tolerance as 0.05 and use the 99-*th* percentiles of loss to calculate value at risk. We find that the 99-*th* percentiles of Value at Risk from simulated loss are 16,376.87 million Thai baht.

For all packages, there are 34.2% of first losses, i.e., out of 10,000 scenarios, the CAT bond will be triggered 3,420 times. On average, the expected payout for each package is 1,541.96, 1,528.27, and 1,369 million Thai baht. The higher principal means the limit threshold is higher, which allows for higher losses to be covered and makes the average payout higher.

When we compare the average payout to the level of principal (% expected loss to principal) for each package, they are 13.69%, 7.64%, and 5.14% for packages 10k, 20k, and 30k, respectively. Given the higher value of principal or coverage size, we observe that the % expected loss to principal is the lowest for package 30k. Table 3 concludes all the information about the CAT bond for each package.

Table 3: Summary of CAT Bond Packages

Details	Package 10k	Package 20k	Package 30k
Bond issuers	Special purpose vehicle ABC	Special purpose vehicle ABC	Special purpose vehicle ABC
Sponsor	Thai Government	Thai Government	Thai Government
Area	Thailand	Thailand	Thailand
Trigger: Indemnity	Reimburse if actual loss is realized from 4,000 – 10,000 million THB	Reimburse if actual loss is realized from 4,000 – 20,000 million THB	Reimburse if actual loss is realized from 4,000 – 30,000 million THB
Time to maturity	1 year	1 year	1 year
Principal (Coverage size)	10,000 million THB	20,000 million THB	30,000 million THB
% Expected loss to principal	13.69%	7.64%	5.14%
Coupon	Fixed at 18.69%	Fixed at 11.74%	Fixed at 7.87%

Source: Authors' Computation

Step 4: Simulate debt dynamics

To simulate the debt dynamic in equation (5), we simulate the parameters: r, θ, and the variable pb 10,000 times randomly under the normal distribution assumption with an average and standard error of the relevant data shown in Table 4.

Table 4: The Statistics of Real Interest, Growth, and Primary Balance

		mean	Standard error	Time period
r	averaged real interest rate of 10-year government bonds	0.02	0.02	1999-2019
θ	real economic growth	0.03	0.04	1994-2020
pb	primary balance to GDP	-0.02	0.01	2003-2020

Source: Authors' Compilation

According to the estimates by Von Peter et al. in 2012 regarding the impact of insured and uninsured damages caused by natural catastrophes on economic growth, we assume that growth is affected by losses that are not covered by insurance payouts. The growth dynamics are as follows:

$$\theta_{i,t} = \theta_{i,t}^{*} + \alpha_0 \left(\frac{Loss_t - payout_{i,t}}{GDP_t}\right) + \alpha_1 \left(\frac{Loss_{t-1} - payout_{i,t-1}}{GDP_{t-1}}\right) \tag{8}$$

where $\theta_{i,t}^{*}$ is the country's potential growth under the CAT bond package, i. $Loss_i$ and $payout_i$ are the government loss derived from the disaster simulation in *Step 1*, and the payout by package i for the realization of the disaster at time t as derived from *Step 2*, respectively. The coefficient α_0 is assumed to be -0.3, negative contemporaneous effects due to disruptions in production, and α_1 is equal to 0.1, positive lagged effects due to a transitory pickup in reconstruction activities. These estimates for the short-run effects are based on Von Peter et al. (2012).

However, natural disasters, in turn, might have an impact on potential growth if damages are not compensated to recoup lost capital. As a result, potential growth is expected to fall somewhat, following equation (9), if the payouts and ex-post borrowing do not completely cover disaster losses[3]:

$$\theta^{*}_{i,t} = \theta^{f} - 0.1\left(\frac{Loss_t - payout_{i,t} - borrowing_t}{GDP_t}\right) \tag{9}$$

where θ^{f} is the potential growth projection based on the IMF's WEO projection as of 2022. We assume that the government can easily pay the baseline (pre-disaster) overall balance and the CAT bond premium, but it will have challenges covering natural disaster losses, which may exceed the sovereign's borrowing capacity. We set the post-disaster loss borrowing cap ($borrowing_t$) at 5% of GDP.[4]

To simulate the debt dynamics equation (5), we assume that large increases in debt have the following effects on the real interest rate[5]:

$$r_{i,t} = r_{i,t-1} + 0.04(d_{i,t-1} - d_{i,t-2}) \tag{10}$$

We repeat this step 10,000 times to find the distribution of debt and growth under various scenarios and obtain the debt and output dynamics.

Step 5: Simulate the government utility function

In this step, the simulated growth and debt-to-GDP ratios are employed to compute the government utility function in equation (7). This is done to determine which packages of CAT bonds generate the greatest government utility.

5. The effect of CAT bonds to debt dynamics

To examine the role of CAT bonds on debt dynamics, we start by considering the situation in which Thailand experiences floods but does not transfer the risk through CAT bonds. Figure 6 depicts the potential debt dynamics. In the worst-case scenario, the severe damage from floods could drive the debt-to-GDP ratio to 62.63 percent in 2022, up from the current level of 60.58 percent when there is no substantial flooding. The difference between the two scenarios is approximately 2 percent.

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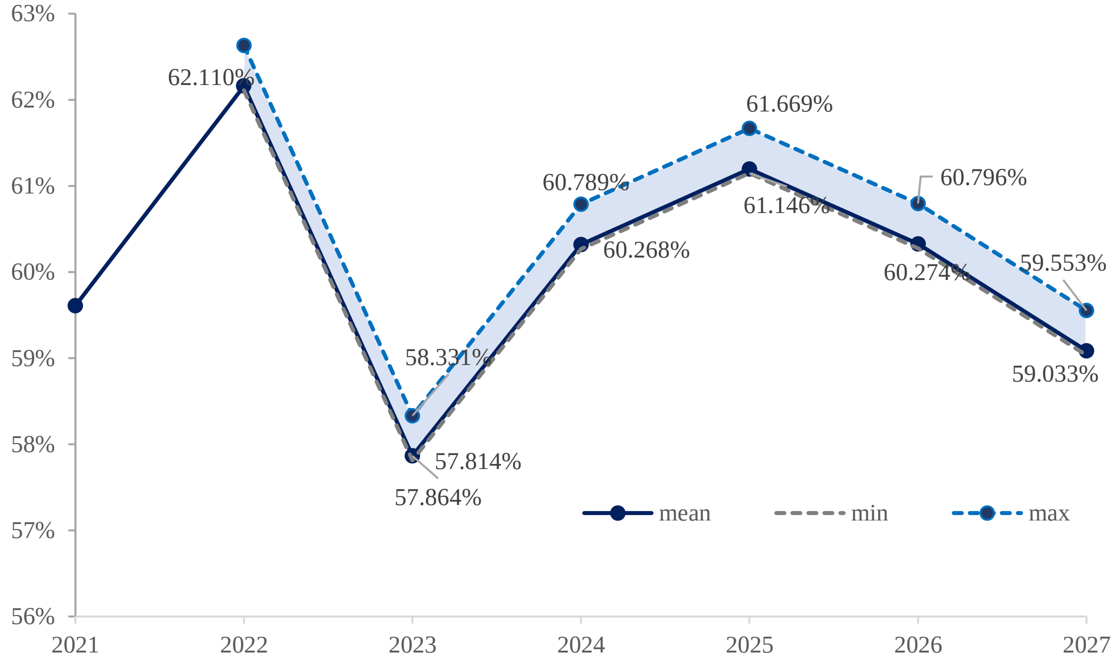
[3] Even if Thailand has never encountered a decline in potential output growth due to insufficient ex-post borrowing, there is still a small probability that such a never-before-seen situation occurs.

[4] To ensure that Thailand's public debt to GDP does not exceed the debt limit of 70%.

[5] The parameter is based on Cebotari & Youssef (2020).

Figure 6: Public Debt to GDP with Flooding without CAT Bonds



Source: Authors' Computation

In the event of flooding, Table 5 shows the debt-to-GDP deference level against any CAT bond packages. We found that catastrophe bonds are only effective at reducing the debt-to-GDP ratio in the event of severe flooding. However, the probability of encountering a severe flood with losses exceeding 30,000 is extremely low, at only 0.1%. Therefore, when flood damages are not severe, issuing larger CAT bonds places a strain on the government's budget. Furthermore, in the case of minimal and normal (or average) flooding, issuing CAT bond packages could result in payment burdens for governments, raising the debt-to-GDP ratio. More clearly, Figure 7 illustrates the difference in the debt-to-GDP ratio between any CAT bond package and a no-CAT bond scenario. It demonstrates that a 30K CAT bond package can reduce the country's debt to GDP level when the country suffers sizable losses as a result of flooding.[6]

To determine the optimal risk transfer of CAT bonds, we report the government utility level estimated from equation (7) with average Δd and $\Delta\theta$ over the 10,000 simulated outcomes for each CAT bond package, *i*. Under this government utility, the government faces a trade-off between protection (economic growth) and the premium expenses of CAT bond coverage. Figure 8 illustrates that the 30k package provides the highest utility level to the government as the payout may be used to foster recovery from the collapse due to flooding, even if it comes at a higher premium that must be paid for with more borrowing.

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[6] The findings are based on a one-year study. For future research, when the data are available, the long-term analysis will reveal a more accurate result.

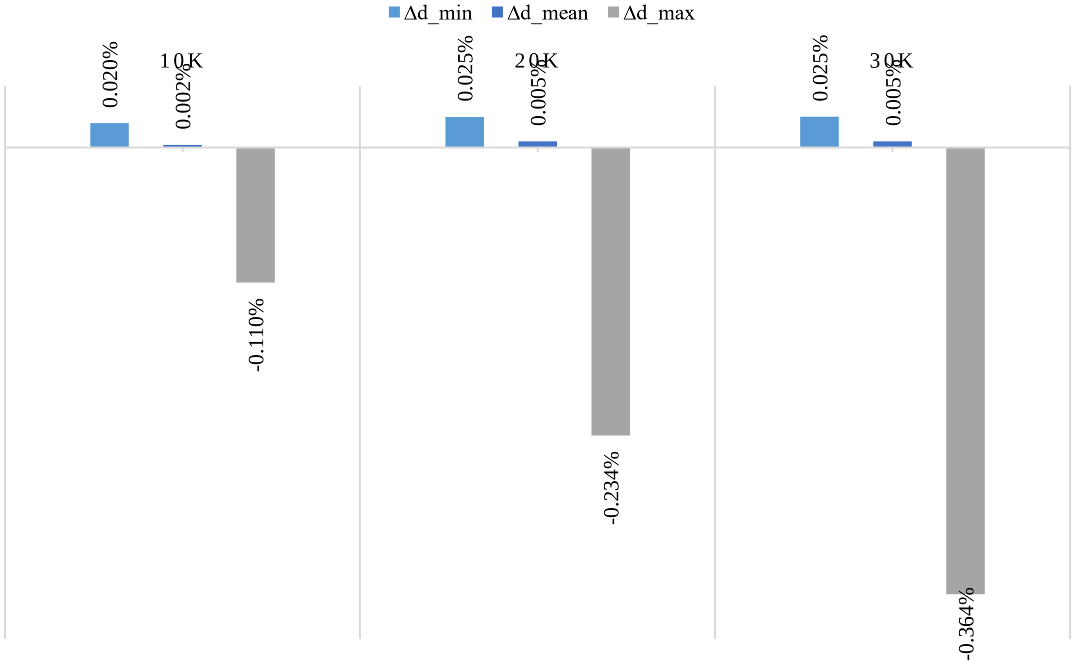
Table 5: Public Debt to GDP with Flooding by CAT Bond Packages

CAT bond packages	**possible debt to GDP (%)**		
(principal)	min	mean	max
0	62.10956	62.15985	62.62962
10K	62.12935	62.16191	62.51982
20K	62.13441	62.16491	62.39532
30K	62.13456	62.16487	62.26592

Note: the benchmark is: $r = 0.000448$, $\theta^f = 0.02839$, $p^* = -0.044$, *borrowing = 0.05%, GDP = 9.4459 trillion baht, and* $d_{t-1} = 0.5961$ *.*

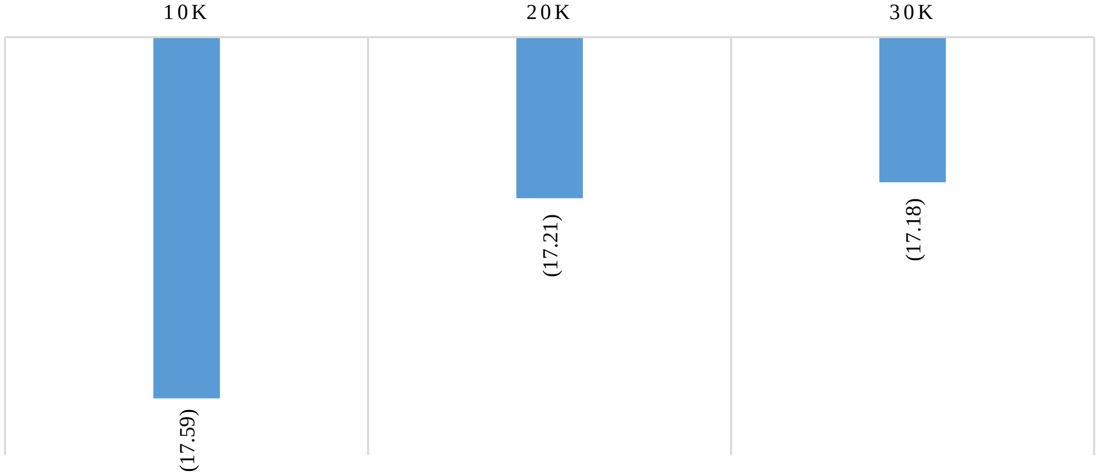
Source: Authors' Computation

Figure 7: The Difference between Debt to GDP with CAT Bonds and without CAT Bond, by CAT Bond Packages



Source: Authors' Computation

Figure 8: Government Utility Level, by CAT Bond Packages



Source: Authors' Computation

6. Concluding remarks

Natural disasters are potential risks to the fiscal burden of any country if there is no suitable risk management in place. To alleviate the victims' suffering and rebuild the economy after the devastation, the government can rely on new public debt issued after the disaster or on donations both domestically and internationally. There are, however, several other approaches to tackling and managing fiscal risk from catastrophes, one of which is a financial instrument called a catastrophe bond.

A catastrophe bond can be used as an ex-ante fiscal risk management tool to mitigate against risks from natural disasters. By transferring possible losses from disasters to investors in the financial market, the government can raise funds before the disaster occurs. In turn, investors benefit from higher coupon rates, which correspond to the higher risks they must bear. In developed countries, both the public and private sectors prevalently use CAT bonds, but that is rarely the case in developing countries, especially Thailand, where flooding is one of the natural disasters that hit the economy hard.

This paper studies the effect of CAT bonds on public debt dynamics. We consider three different packages of CAT bonds based on the coverage size of the simulated loss. We find that all packages can decelerate the rising trend of the debt-to-GDP ratio when there is a severe economic loss from flooding. The largest coverage bond gives the highest utility level to the government as it can help tone down the economic collapse during the disastrous season, even if it cannot, on average, lessen the debt to GDP ratio.

There are still certain limitations to our study. First, the parameters used in this study are derived from previous research on developing countries. Country-specific parametrization should be conducted for an accurate estimation of debt dynamics. Second, a CAT bond for flooding can be considered an alternative financial instrument to administer the disaster-relief expenditures. Introducing CAT bonds to other large catastrophe losses, such as COVID-19 pandemics and tsunamis, is crucially relevant to disaster-risk management. Third, CAT bonds associated with the entire area of a country are not well diversified in the eyes of investors. With flooding in any place in Thailand, investors’ principal will be deducted. A collaboration among ASEAN countries to issue CAT bonds could be a solution. Countries pooling resources to finance the premium for CAT bonds should theoretically lower the fiscal burden for all the countries. A serious dialogue on fiscal collaboration towards disaster relief is needed.

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