# IMF Working Paper

## Government Insurance Against Natural Disasters: An Application to the ECCU

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**Assessing Government Insurance Against Natural Disasters:**

**An Application to the ECCU[1]**

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**Abstract**

This paper estimates insurance requirements against natural disasters (NDs) in the Eastern Caribbean Currency Union (ECCU) using an insurance layering framework. The layers include a government saving fund, as well as market instruments. Each layer is calibrated to cover estimated fiscal cost of NDs according to intensity and expected damage. The results indicate that ECCU countries could target saving fund stocks for relatively smaller and more frequent events in the range of 6-12 percent of GDP, enough to cover 95 percent of NDs' fiscal costs. To ensure financially-sustainable saving funds with a low probability of depletion, this requires annual budget savings in the range os 0.5 to 1.9 percent of GDP per year. Additional coverage could be obtained with market instruments for large and less frequent events, albeit at a significant cost. The results are based on a Monte-Carlo experiment that simulates natural disaster shocks and their impact on output and government finances.

JEL Classification Numbers: C6; G18; H6.

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[1] The results were presented at a Eastern Caribbean central Bank seminar during the 2019 ECCU regional consultation of the International Monetary Fund, and at the International Monetary Fund. Country-specific results were also presented at the Ministry of Finance in Dominica, and in St. Lucia.

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**CONTENTS**

## I. INTRODUCTION

**1.     Tropical storms and other forms of natural disasters (ND) continue to affect the Easter Caribbean Currency Union (ECCU), resulting in human loss, destruction of infrastructure, and fiscal costs.** Natural disasters put pressure on government's finances in the near and long term. In the near term, pressures arise from unanticipated needs for immediate social protection and rehabilitation expenditures, at a time when revenues typically decline. In the long term, the costs of ND contribute to the ratcheting up of public debt (Acevedo, 2014). Barro (2006, 2009) shows that the occurrence of large economic disasters in advanced economies (wars, economic depressions, financial crises) implies large welfare costs equivalent to about 20 percent of annual GDP, which he estimates to be much larger than the costs of economic fluctuations of less amplitude. Cantelmo, Melina and Papageorgiou (2019) find that the welfare loss from natural disasters are equivalent to a permanent decline in consumption of 1.6 percent



Damage and frequency of natural disasters in the ECCU

of GDP. For developing small states such as in the ECCU, which are subject to larger and more frequent disasters than advanced economies, these events should have an even greater effect.
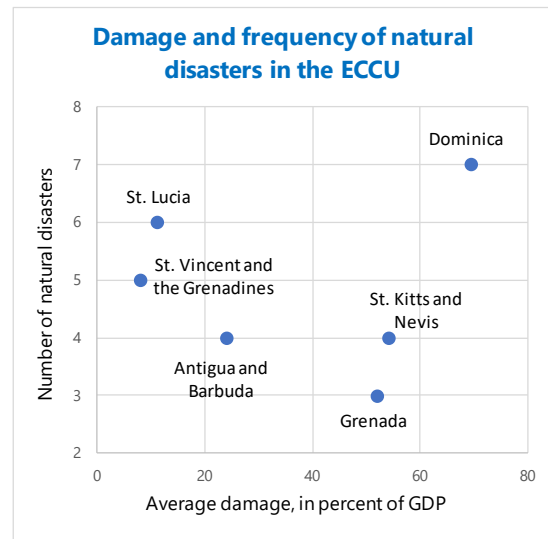
**2.     Despite the large impact of natural disasters, ex-ante buffers and insurance coverage in ECCU countries are insufficient.** Damages and losses of natural disasters can be very large in the ECCU countries (text chart). The private sector is in general uninsured or underinsured for ND, especially the most vulnerable segments of the population, typically the majority and most exposed. As a result of insufficient market-based insurance, governments become the de-facto ultimate insurer. This means that governments are typically called to cover not only the costs of destruction of public infrastructure, but also a significant share of private losses and to provide social support.

**3.     The Caribbean Catastrophe Risk Insurance Facility (CCRIF), to which all ECCU countries have access, have been a valuable instrument.** CCRIF ensures quick disbursement of amount related to parametric triggers, including wind and rain, within two weeks after a ND. However, payouts are insufficient relative to needs in extreme events[2]; it is intended for immediate liquidity needs; parametric triggers are imperfectly correlated with

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[2] CCRIF payout is limited to up to about $100 million per event, insufficient to cover fiscal costs.

NDs damages; and the cost is high, with expected payouts that are about half of insurance premia.[3]

4.      **Additional insurance layers with CCRIF and other market instruments such as CAT bonds support recovery, but they are costly.** These instruments can complement saving funds (SFs) coverage for high and extreme NDs intensity and damage, when self-insurance with SF is unlikely to be sufficient. Otherwise, unrealistically large SFs would be required, in light of opportunity cost in terms of competing developmental needs and subject to political economy constraints. These instruments, however, are very costly, with insurance multipliers (ratio of insurance premia to expected payout) in the range of about 1.5-2.0. This is important considering fiscal sustainability challenges in most ECCU countries. Also, their parametric nature with disbursements triggered according to weather conditions such as wind and rain intensity as opposed to estimated damage, results in imperfect correlation of damages and payouts. This imperfect correlation is less likely at less frequent but more intense disasters. High cost and imperfect correlation imply that these instruments worsen debt sustainability outlook in expected terms but help reduce debt volatility—less debt issuance is needed to cover costs of extreme NDs. As a result, and depending on "prudence" preferences of countries, these instruments could be considered with triggers specified at low frequency but high intensity NDs.

5.      **This paper quantifies NDs insurance coverage under a layering insurance framework.** It presents estimates of the size of SF and parametric insurance layers in each ECCU country, for specified coverage amounts of estimated fiscal costs of NDs. The results are based on a Monte Carlo experiment including simulations of output and fiscal revenues and expenditures as these are affected by ND shocks. Natural disasters identified as the tail of the distribution of fiscal deteriorations after other sources of large shocks have been controlled for in the model estimates, in line with observed frequency of natural disasters. The results provide estimates of size and annual saving flows needed to ensure the saving funds are sustainable, in the sense of having a sufficiently low probability of depletion. The methodology incorporates the recurrent and investment expenditure re-prioritization that typically takes place after NDs, as ongoing projects and allocations are postponed or discontinued to provide space for social relief, rehabilitation, and reconstruction needs.

6.      **The paper assumes that the start-up cost of SFs is financed with revenues from the Citizenship by Investment (CBI) programs.** In recent years, there has been a substantial surge in budget revenues from the CBI Programs in all ECCU countries with the only exception of St. Vincent and the Grenadines.[4] These are significant and thus relevant

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[3] CCRIF insurance multipliers, defined as the ratio of the cost of premia and expected payouts, are around 2, and higher for extreme events.

[4] In the case of St. Vincent and the Grenadines, where a CBI does not exist, it is assumed that the SFs is built gradually with additional annual saving of 1 percent of GDP. Alternatively, staring a SF for ND may require debt issuance.

from a macroeconomic perspective. If spent without regard to the general macroeconomic conditions, they can pose challenges to macroeconomic management and affect sector activities, including on financial stability, fiscal discipline, external competitiveness and growth (see Rasmussen 2004; Noy 2009; Cavallo and Noy 2011; Cavallo, Galiani, Noy and Pantano 2013; and Xin Xu, El-Ashram and Gold 2015). In addition, the uncertain and volatile nature of CBI revenues adds challenges to macroeconomic management, including the risk of a sudden stop given the increasing scrutiny from advanced economies, growing competition, or reputational spillovers to the CBI programs from other countries in the region.[5] These reasons support the case for the use of CBI financing to start-up and subsequently fund the SFs. In this way, the saved CBI flows would be allocated for reconstruction after NDs, reducing debt issuance after a ND shock, while reducing use of this unreliable source of revenue on current spending, supporting fiscal sustainability.

**7.     The paper is organized on four sections.** Section II explains the need for government insurance. Section III presents the methodology used in the simulation exercise. Section IV presents the calibration of the model parameters for each ECCU country. Section V presents the results and concludes.

## II.   WHY A SF FOR SELF-INSURANCE AGAINST ND AS THE FIRST INSURANCE LAYER?

**8.     Existing options to insure against ND are insufficient and costly.** The private sector is in general uninsured or underinsured for ND, especially the most vulnerable segments of the population, typically the majority and most exposed.[6] Also, NDs affect a significant share of the population and wealth in a single event, especially in a case of ECCU countries given small country size. The difficulties in assessing the probability distribution and wide range of potential damage of ND shocks (hurricanes with high wind; tropical storms with abnormally abundant rainfall; earthquakes) complicates the assessment of risk and the need for capital and liquidity by insurers[7], the actuarial assessment of expected losses, and the specification of insurance contracts. In addition, likely fat-tail probability distribution functions of natural disaster losses and damages makes this risk difficult to price (World Bank 2018). These factors result in high cost of insuring against NDs. General equilibrium analysis indicates that ensuring against ND by issuing CAT bonds would be beneficial only if the cost of issuing these bonds was significantly smaller than observed

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[5] The benefits of a CBI program are fully internalized by the country issuing a passport but the potential costs in the case of the granting of a passport to problematic beneficiaries could affect the reputation of the all CBI programs in the region. This reduces incentives for due-diligence effort, increasing risk of revenue erosion or outright loss.

[6] For example, low income households often settle in lands that are more exposed to flooding, and their income is also usually more affected by NDs.

[7] The largest insurance companies in the region have access to reliable international re-insurance, but this is not the case for in the majority of cases of relatively smaller insurance companies operating in the region.

(Borensztein, Cavallo and Jeanne 2015)[8]. Moreover, CAT bonds' triggers for payment are imperfectly correlated with the actual losses.[9]

**9.      As a result of insufficient market-based insurance, governments become the de-facto NDs insurer.** Governments are typically called to cover not only the costs of destruction of public infrastructure, but also a significant share of private losses and to provide social support. All ECCU members access the CCRIF, but its cost is high, as explained above, and the coverage purchased is typically limited. CCRIF also faces similar complications as related to insufficient development of market insurance and, as CAT bonds, its parametric triggers (i.e. rain volume or wind speeds), is imperfectly correlated with ND damages. CCRIF is more likely to payout in extreme NDs events (which would require inefficiently large savings under self-insurance), while also benefitting from regional diversification. This makes CCRIF a potential complement to government's self-insurance, but not a substitute.

**10.      A SF could provide public self-insurance for immediate expenditure needs, rehabilitation and reconstruction.** In principle, if access to financing was granted and immediate, a SF would not be necessary. A government could allocate the fiscal savings to debt reduction, of an amount commensurate to the expected cost of reconstruction, saving on interest expenditures, and then borrow when hit by a ND to cover the costs. However, this strategy is not realistic in practice. First, access to financing is typically not sufficiently rapid, especially for small countries with no access to international financial markets. Increasing official loans and changing the scope of existing official loans (i.e. to ND relief and rehabilitation) would typically involve a lengthy process. Furthermore, the disbursement of grants from bilateral donor countries also requires lengthy application and approval processes. Access to rapid domestic financing could also be limited, especially if the ND shock affects financial institutions' asset quality, and if deposits decline as the population copes with the shock.

**11.      A SF for NDs would support fiscal sustainability.** Government self-insurance can provide liquidity after a ND for immediate relief and rehabilitation needs and can complement other sources of insurance mentioned above. SFs can strengthen fiscal sustainability, which remains a challenge in several ECCU countries affected by high public debt. Acevedo (2014) finds that tropical storms and hurricanes have a negative effect on

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[8] CAT bonds are inherently risky, typically pay coupons of Libor plus a spread in the range of 3-20 percent, and have maturities of less than 3 years. See also Froot 2001; Cummins 2008 and 2012; and Cummins and Mahul 2009.

[9] CAT bonds are structured in four types of triggers for payment: (i) Indemnity (trigger by the actual losses in excess of a specific threshold0; (ii) modeled loss (based on catastrophe modeling run with the event parameters to measure if the modeled losses are above a specified threshold); (iii) indexed to industry loss (triggered when the insurance industry loss reached a specified threshold, as determined by a specified agency); (iv) parametric (trigger is indexed to the natural hazard caused by nature, such as wind speed in a specific location for a hurricane); and (v) parametric index (models used to compute an approximated loss, de-facto it is a hybrid parametric/modeled loss).

growth, and that these also have permanent effects on debt accumulation for a subsample of Caribbean countries. Establishment of SFs with recurrent budget savings for replenishment and sustainability imply that expected periodic cost of natural disasters are internalized in fiscal accounts, reducing need for debt issuance.

**12.     Some countries in the region already have SFs, but none is specifically targeting the financing of ND fiscal costs.** The Sugar Industry Diversification Fund in St. Kitts and Nevis is a national development fund that is also financed with CBI inflows, set up as a public fund. It was established in 2006 with the objective to support the financing of economic diversification away from the sugar industry through training and research. In 2011, its focus was expanded to maintain stability and the financing of industries. It provides budgetary support, undertakes direct social spending, and supports subsidized credit by banks. In 2014 Grenada launched a National Transformation Fund funded by CBI revenues. Set up as a Sovereign Wealth Fund (SWF), it is owned by the government but governed by an independent Board of Directors including both public and private representatives. It is regulated to make transfers to the government for the repayment of arrears and investment projects. Trinidad and Tobago has a SWF dedicated to the savings of oil revenues, which serves the purposes of cyclical stabilization and inter-generational equity. Turks and Caicos also has separate funds that serve different objectives, including a Development Fund, a Sinking Fund, and a Contingencies Fund. The experience with these funds in the region, however, has been mixed, in part due to political influence and capture affecting the allocation of resources. This underscores the importance of strong institutional design and oversight.

### III.  METHODOLOGY

**13.     The starting point is to estimate an empirical model for each economy that captures the effect of ND on output and government finances.** To this end, an unrestricted Vector Auto-regression Model (VAR) is estimated for each country including fiscal determinants of public debt dynamics, including vectors $Y_t$ and $X_t$ of endogenous and exogenous variables, respectively,

$$Y_t = \gamma_0 + \sum_{k=1}^{p} \gamma_k Y_{t-k} + \sum_{j=1}^{n} \beta_j X_j + \epsilon_t.$$

The endogenous variables in the VAR estimates include the cyclical components of GDP; government revenues excluding grants; grants; current primary expenditures; and capital expenditures. These are expressed as a share of each indicators' trend[10],

$$\hat{y}_{it} = y_{it}/y_{it}^{trend}; \hat{y}_{it} \in Y_t.$$

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[10] The cyclical components of GDP are estimated using the Hodrick-Prescott filter on 1990-2017 annual data. All variables expressed in real terms using the GDP deflator.

The exogenous control variables $X_j$ account for non-ND sources of major shocks in ECCU countries, and thus estimated residuals $\epsilon_t \sim N(0, \Omega)$ are orthogonal to these. The vector of control variables $X_j$ includes the U.S. real effective exchange (to capture competitiveness pressures given that the EC dollar is pegged to the U.S. dollar); the oil price (all countries are highly dependent on oil imports); the cyclical component of the U.S. output (the main source of tourist revenues); and a dummy for the September 11, 2001 terrorist attack in the United States that disrupted air travel and tourism exports. This allows the identification of ND shocks as the only potentially large shock remaining $-\epsilon_t$ thus includes ND and "small" shocks. The variance-covariance matrix $\Omega$ characterizes the joint statistical properties of the contemporaneous disturbances of the endogenous variables. $\gamma_k$ and $\beta_j$ are vectors of coefficients.

**14.     The second step is to run a Monte-Carlo experiment.** This involves generating a large number of simulations using the estimated model above. The simulations use a sequence of random vectors $\hat{\epsilon}_{t+1}, \ldots, \hat{\epsilon}_T$ such that $\forall\, \tau\, \in [t+1, T], \epsilon_\tau = W v_\tau$, where $v_\tau \sim N(0,1)$, and $W$ is such that $\Omega = W'W$ where $W$ is the Choleski factorization of $\Omega$. The estimated VAR is then used to generate 2000 forecasts $Y_t$ for each country with the randomly-generated shocks $\epsilon_\tau, \tau = t+1, \ldots, T$. In this way, the VAR produces joint dynamic responses of all variables in $Y_t$.[11]   Each simulation is a projection consisting of a sequence of the five endogenous variables in the model, each affected by a sequence of simulated random shocks. In this way, the simulations mimic historical patterns in terms of the volatility, persistence, and co-movement of the endogenous series, as observed in the sample data. The results are then used to compute probability density functions for each of the five endogenous variables in each year projected, for the period 2017-2030.

**15.     These simulations can then be used to calculate public debt dynamics for each random simulation with the debt accumulation identity**

$$D_{t+l+1} = (1 + i_{t+l+1})D_{t+l} - PB_{t+l} + (I_{t+l}^{SF} - O_{t+l}^{SF});\;\; D_{t+l} > 0;\;\; l = t+1, \ldots, T\,;$$

where $D_{t+l+l}$ is the stock of public debt in year $t+l+1$, and $PB_t$ is the primary balance obtained from the revenue and primary expenditure endogenous variables in the simulations. The implicit interest rate $i_t$ is calculated as the ratio of interest expenditures in year $t$ divided by public debt stock in $t-1$. $I_{t+l}^{SF} - O_{t+l}^{SF}$ are the below-the-line inflows and outflows from the SF for NDs. Depending on the sequence of events (occurrence or non-occurrence of a ND in any given year in the simulations), different debt paths are thus possible, as these flows vis-à-vis the budget replace debt issuance. Notice that the debt stock projections are not affected in

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[11] Notice that the results are not sensitive to the ordering of the variables in the VAR, as the stochastic simulation results are shaped per the variance-covariance matrix of reduced-form errors $\Omega$, which is unique.

expected terms, provided savings into the fund are utilized in the long-term and across simulations in a given period.[12]

**16.     Given that these projections are obtained as deviations from trend, they are then calculated as a percent of GDP.** To that end, a deterministic trend is projected for each variable, assuming each and all trends grow at the same constant rate starting from the end point of the estimated trend in the sample period, that is

$$y_{it+l} = \hat{y}_{it+l} y_{it+l}^{trend} \quad \text{with} \quad y_{it+l}^{trend} = y_{yt}(1+g)^{l-t}; l = t+1, \dots, T;$$

where $g$ is the potential growth rate assumption. After all endogenous variables are expressed in real-term levels, they can be expressed in percent of GDP by dividing each of the fiscal indicator projections by the GDP projection in each of the vector simulations. In order to ensure revenue and expenditure indicators as a percent of GDP are consistent with the data, the starting points of the trend projections are set at constant prices of the last year of the sample.[13]

**17.     The third step is to identify the occurrence of natural disasters in each simulation, as needed to inform the triggering of financing flows vis-à-vis the SFs.** To this end, the simulations include an algorithm that identifies as a ND the largest $d$ percent fiscal deteriorations. The fiscal deteriorations are computed as the sum of the year-on-year changes of (i) non-grant revenue $NG_t$ (with a negative sign as tax revenues decline along with output as affected by the ND); (ii) grant revenues $Gr_t$ (which typically increase after ND as donor partners increase their supports) (iii) current primary expenditure $G_t$ (as more social assistance and goods and services are needed after NDs); and (iv) capital expenditure $K_t$ (on account of additional expenditures for rehabilitation and reconstruction). The fiscal aggregate random variable $z_t \epsilon Z$ used to identify simulated NDs, can be written as

$$z_t = \triangle Gr_t - \triangle NG_t + \triangle GCE_t + \triangle GKE_t$$

**18.     Simulated NDs are identified as the largest random draw realizations of the random variable $z_t$.** The algorithm computes the distribution of this sum in every simulation year *t+l, l=t+1,...T,* across the 2000 simulations, and identifies as a ND all the random realizations that fall in the highest $d$ percent tail of the of the probability density function of this sum. In this way if, statistically in a given simulation, non-grant revenues decline significantly, and grant revenues, current primary expenditures, and capital expenditures increase significantly (a typical pattern after a ND), then that random simulation draw is labeled as a ND by the algorithm. As mentioned above, this identification rests on the

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[12] Forward iteration on the debt accumulation identity shows that, in expected terms, $I_{t+l}^{SF} - O_{t+l}^{SF} = 0$ if SF's inflows and outflows are calibrated to be zero in expected terms, as set in the simulations by construction.

[13] It is therefore implicitly assumed that the deflators of GDP and the remaining fiscal variables change at the same rate in the projections.

assumption that all other major sources of large shocks have been controlled for in the VARs, and thus every remaining negative large shock is a ND.

## A.   Saving Funds for Self-insurance

**19.     The next step is to specify SFs financing flows vis-à-vis the budget.** The simulations assume that in years with no ND (as identified by the algorithm explained above), the budget contributes savings to the SF.[14] These budget contributions to the SF are modeled as a fixed parameter $\theta$ as a percent of the previous' year GDP, with $\theta$ calibrated to achieve the financial sustainability of the Fund with a sufficiently low probability of depletion or, in other words, to ensure the SF stock is stable in expected terms[15].

**20.     In the event a ND occurs, as identified by the algorithm, a financing inflow to the budget from the SF takes place.** This budget financing is computed as the sum of four components:

+ *Gap of non-grant revenues below trend.* Captures the decline in tax and non-tax revenues that typically take place after NDs as a result of a typical decline in economic activity and tax compliance.

- *Gap of grant revenues above trend.* Grants tend to be higher after natural disasters as a result of an increase in donor support, reducing the need for financing flows from the Fund.

+ *Gap of current primary expenditure above trend.* Captures higher expenditures in social support and rehabilitation of infrastructure after natural disasters. An additional fixed amount as a percent of GDP is deducted to capture below-trend spending reprioritization. The reprioritization below trend is denoted $\rho^G\, G_{t+l}^{trend}$; $\rho^G \in (-1,1)$.

+ *Gap of capital expenditure above trend.* Captures the higher public investment that typically follows NDs with the reconstruction spending. An additional fixed amount as a percent of GDP is deducted to capture below-trend spending reprioritization. The reprioritization below trend is denoted $\rho^K\, K_{t+l}^{trend}$; $\rho^K \in (-1,1)$.

Denote the random variable obtained from the sum of the four components above as

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[14] If the simulations result in a fiscal deficit, then there would be a need to issue public debt to finance the required contribution to the Fund.

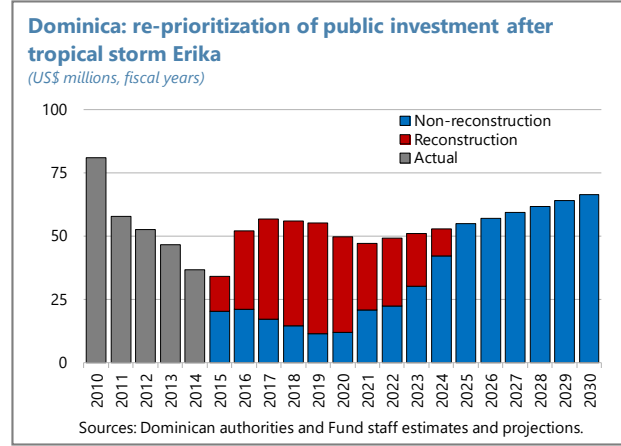[15] This ensures that the saving rate is of an amount commensurate with the fiscal costs of ND. If saving inflows into the SF are set too high, then the size of the SF would tend to increase in expected terms, accumulating excess assets inefficiently. If, on the other hand, the saving flow is set too low, the SF would unsustainably decline in expected terms towards depletion.

$$\sigma_t = -\left(NG_t - NG_t^{trend}\right) - \left(Gr_t - Gr_t^{trend}\right) + \left(G_t - G_t^{trend} - \rho^G\,G_t^{trend}\right) + (K_{t+l} - K_t^{trend} - \rho^K\,K_t^{trend}).$$

The contributions to the budget continue until the year in which each indicator returns to a level that is below the value in the year prior to the natural disaster –the $SF$ therefore finances the "hump".

**21.     Allowing for expenditure re-prioritization in the simulations is key for a realistic assessment of SFs' size.** In practice, a significant share of the fiscal space for social support and reconstruction after ND is obtained by way of reallocation and re-prioritization: some pre-ND allocations are postponed or cancelled. The text chart illustrates re-prioritization in the case of Dominica, after it was affected by Tropical storm Erika in August 2015. This implies that the reconstruction expenditures do not require an equivalent increase in public investment relative to the original investment levels without a ND. This is the reason for the reprioritization terms capturing expenditures that are postponed or cancelled, as explained above for current primary and capital spending.



Dominica: re-prioritization of public investment after tropical storm Erika
(US$ millions, fiscal years)

Sources: Dominican authorities and Fund staff estimates and projections.

**22.     The SF stock in each simulation evolves following the difference of saving inflows $I_{t+l}^{SF}$ and outflows $O_{t+l}^{SF}$ vis-à-vis the SF,**

$$SF_{t+1} = SF_t\,(1 + r_t) + I_{t+1}^{SF} - O_{t+1}^{SF} = SF_t\,(1 + r_t) + (1 - ND_t)\,\theta\,GDP_{t-1} - ND_t\,\sigma_t,$$

with $\theta\,GDP_{t+l-1} = 0$ in years in which the algorithm identifies a ND ($ND_t = 1$), with probability $P[d] = P[\sigma_t \geq \bar{\sigma}] = p$, and $\sigma_{t+l} = 0$ in year with no ND as identified by the algorithm, with probability 1-P[d] ($ND_t = 0$) . As explained above, $\bar{\sigma}$ is a parameter specified in the calibration when setting the annual probability $p$ of a ND, as per the frequency observed historically. For example, if a ND occurs every 5 years on average, then the calibration requires to set $p = 0.2$, which then informs the value of the threshold $\bar{\sigma}$ as per the estimated probability density function in the distribution of $\sigma_t$. $r_t$ is the rate of return of assets in the SF. If in a simulation the SF is depleted, $SF_t = 0$, the simulations assume that the remaining financing is covered with public debt issuance.

*23.*     **The modeling of the SF also includes an assumption for the initial stock value, the start-up cost.** This initial amount of assets $SF_0 > 0$ affects the probability of depletion over a time horizon. As the proposal assumes that the start-up cost of establishing a SF is funded with existing CBI assets, it has not been added to the debt stock at the beginning of the simulations.

**24.    The simulation parameters are calibrated consistent with macroeconomic frameworks for each ECCU country in the World Economic Outlook database.** The macroeconomic and fiscal parameters for calibration include potential GDP growth rate; the implicit interest rate on public debt; fiscal consolidation targets in percent of GDP. Appendix 1 shows the specific parametric calibrations used in the simulations for each country.

**25.    The parameters affecting the SF are calibrated to cover the full amount of fiscal deteriorations after NDs in 95 percent of the simulations.** In other words, SFs would be depleted in the largest 5 percent of simulated ND shocks. The calibration ensures the SF long-term financial sustainability with a low probability of depletion. For example, in the case of Dominica, the probability of a ND was set at P[$d$]=0.2, broadly consistent with the historical frequency of ND occurring every 5 years on average. The initial size of the Fund stock is set at 10 percent of GDP, as needed to obtain a probability of depletion within the next ten years of 0.08. Notice this probability of depletion determines insurance coverage, and it is to be chosen also consistent with risk tolerance of the authorities, although a sufficiently low probability of depletion is preferable to ensure the financial sustainability of the SF. In the simulations it is assumed that the probability of depletion is 5 percent –only in the most extreme 5 percent NDs' fiscal costs the SF savings are insufficient and is depleted. Budget saving flows into the SF in years without a ND of 1.5 percent of previous-year's GDP are needed to obtain a sustainable SF stock of assets in expected terms.

### B.    Parametric Insurance Instruments

**26.    CCRIF and state-contingent debt are then calibrated to cover fiscal deteriorations post natural disasters to top up SFs' self-insurance coverage.** These instruments are introduced as follows:

***CCRIF.*** It is assumed the CCRIF insurance premium $P^{CCRIF}$ is determined by the standard insurance formula

$$P^{CCRIF} = a\,AAL + b\,SD(AAL)$$

where $a$ and $b$ are fixed parameters calibrated to match observed premia, consistent with insurance multipliers in the range 1.5-2.0. $AAL$ and $SD(AAL)$ are NDs average annual losses and its standard deviation, respectively.

***State-contingent debt.*** Governments issue CAT bonds for debt service relief in case of a ND. As it is standard for CAT bonds, it is assumed the proceeds are invested in safe asset, with returns equivalent to Libor, and held in a Special Purpose Vehicle (SPV). Governments hold a call option on the principal of the SPV with triggers specified in the bond contract. If ND occurs, governments can withdraw funds from SPV to pay claims, and interest and principal payments are forgiven. If ND does not occur, investors receive principal and interest. It is

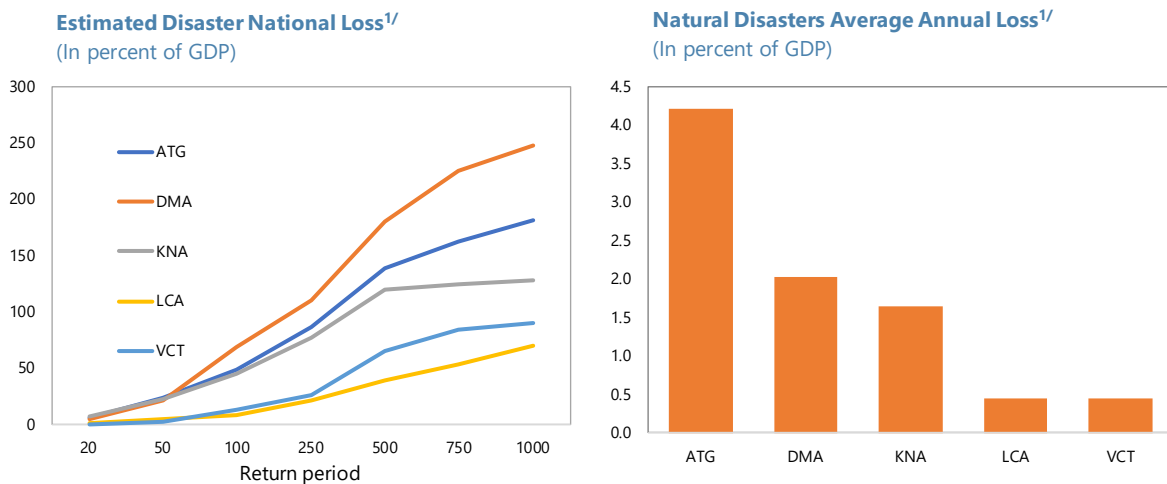assumed CAT bonds are issued with 3-year maturity and interest rate equivalent to Libor plus 500 basis points.

## IV. CALIBRATION

**27.    The simulation parameters are calibrated consistent with staff's macroeconomic frameworks for each ECCU country.** The macroeconomic and fiscal parameters for calibration include potential GDP growth rate; the implicit interest rate on public debt; fiscal consolidation targets in percent of GDP. Appendix 1 shows the specific parametric calibrations used in the simulations for each country.

**28.    The parameters affecting the SF are calibrated to achieve its long-term financial sustainability with a low probability of depletion.** For example, in the case of Dominica, the probability of a ND was set at P[$d$]=0.2, broadly consistent with the historical frequency of ND occurring every 5 years on average. The initial size of the Fund stock is set at 10 percent of GDP, as needed to obtain a probability of depletion within the next ten years of 0.08. Notice this probability of depletion is similar to insurance coverage, and it is to be chosen also consistent with risk tolerance of the authorities, although a sufficiently low probability of depletion is preferable to ensure the financial sustainability of the SF. Budget saving flows into the SF in years without a ND of 1.5 percent of previous-year's GDP are needed to obtain a sustainable SF stock of assets in expected terms. The rate of return on SF $r_t$ is set at 2 percent, broadly in line with international interest rates of long-term, risk-free and highly liquid instruments.

**29.    The remaining parameters for calibration specify the amount of SF financing to the budget after a ND, including for spending re-prioritization.** To this end, "base" levels of capital expenditures and current primary expenditures are calibrated, with "base" defined as the level of spending that would prevail in a year in which there is no spending associated with the occurrence of a ND. This is captured by the parameters $\rho^G$ and $\rho^K$, which need to be set to ensure realistic expenditure reprioritization.

**30.    The second insurance layer with CCRIF coverage is calibrated based on loss functions' damages for tropical cyclones and earthquakes as reported by CCRIF.** In each country's simulation the *attachment point* and *maximum coverage* are set according to the estimated damages along the expected loss function for 20 and 100 year estimated damages, respectively. Maximum coverage under CCRIF is thus the difference between maximum coverage and attachment point. CCRIF payouts in each simulation are triggered according with the ND algorithm explained above. The payout amount is determined in proportion of simulated losses. In addition, in light of imperfect correlation between parametric triggers under CCRIF and actual damages, it is assumed that CCRIF payouts are discounted by a factor of 0.5 for 1/20 year losses (that is, payouts turn out to be ½ of losses on average for the smaller NDs for which CCRIF is triggered). For larger and less frequent NDs, it is assumed that the correlation increases at a constant rate until convergence to a value of 1 for 1/100 year loss (the payout is proportional to the loss covered). These assumptions result in CCRIF disbursements that are increasing in the simulated intensity of NDs. The correlation between triggers and payouts of 0.5 is set according to CCRIF estimates of insurance multipliers near 1 for relatively smaller and more frequent NDs (used for 1/20 year NDs), and around 2 for large NDs (1/100 year NDs).



**Estimated Disaster National Loss[1]**
(In percent of GDP)

**Natural Disasters Average Annual Loss[1]**
(In percent of GDP)

Source: CCRIF.
1/ Includes flooding, tropical cyclones, and earthquakes. Estimates for Grenada not available.

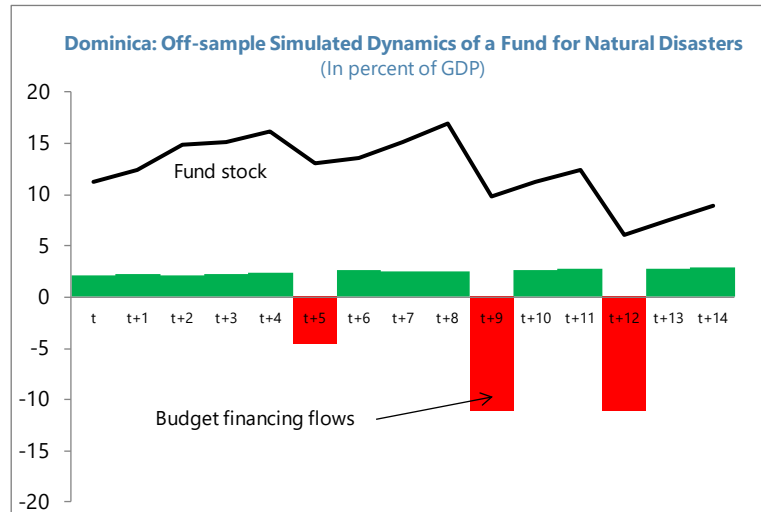**31.    The amount of CAT bond issuance is assumed to be determined by the residual coverage needed to top up self-insurance and maximum CCRIF coverage.** If the maximum insurance under CCRIF remains insufficient to reach 99 percent overall coverage of NDs' fiscal costs, the simulations assume that countries issue US$ 10 to 100 million in CAT bonds, as needed to reach the 99 percent target.

## V. RESULTS

### *Layer 1: Self-Insurance with SFs*

**32.     The methodology in this paper computes SFs to support the budget after NDs and are sustainable in expected terms.** The text chart shows one random off-sample simulation using the methodology in this paper for the case of Dominica, presented for illustrative purposes. In that particular random draw, the algorithm identifies the occurrence of three ND within a 15-year horizon in years t+5, t+9, and t+12. This is indicated by the negative red bars which represent SF financing flows to the budget in percent of GDP. Notice that the three random occurrences coincide with the expected number of NDs' frequency set in the calibration for Dominica for the 15-year horizon in the simulation. In other years, the SF receives saving contributions from the budget equivalent of 1.5 percent of previous years' GDP, as set in the calibration, indicated by the green bars. With a starting stock calibrated at 10 percent of GDP, the stock of assets in the SF increase in years with no NDs, and declines when NDs occur.

Dominica: Off-sample Simulated Dynamics of a Fund for Natural Disasters
(In percent of GDP)

Fund stock

Budget financing flows

**33.     Notice that the simulated size of each ND is random, determined by the realization $\sigma_{t+l}$.** In the particular simulation in the chart, there is a relatively smaller natural disaster in t+5, with budget contributions of near 5 percent of GDP, and two relatively larger NDs in t+9 and t+12 with financing flows to the budget of over 10 percent of GDP. In this particular draw, the SF is not depleted after the three NDs occurrences. However, it is possible that in the most extreme ND the SF becomes depleted if the specified budget financing flow was higher than the remaining assets. The chances of this occurrence remain a function of the chosen probability of depletion in the calibration, ultimately a parameter to be set according to a country's government or population risk tolerance. For example, if a government was more risk averse, then the probability of depletion could be set lower than in the illustrative simulation, and would require a commensurately higher stock of assets in the SF to ensure its financial sustainability.

34.     **Under plausible calibration assumptions, countries would need SF stocks in the range of 6-12 percent of GDP, and annual savings of 0.5-1.9 percent of GDP.** The annual savings are needed to achieve financial sustainability with a low probability of depletion (see text table). Figure 1 illustrates alternative assumptions and the rationale for the size and amount of annual saving proposed. For each ECCU country, Figure 1 shows the sensitivity of the size of a SF to changes in the calibrated frequency of natural disasters, as determined by the probability threshold. For example, if the probability of a ND was instead set one notch higher than in the proposed calibration shown in the text table, the annual budget saving needs would need to be higher from around 0.2 percent of GDP (Grenada; St. Lucia; St. Vincent and the Grenadines) to around 0.5 percent of GDP (Antigua and Barbuda; Dominica; St. Kitts and Nevis).

## Government Saving Funds for Natural Disasters (ND) in the ECCU
(In percent of GDP unless otherwise indicated)

|  | ATG | DMA | GRD | KNA | LCA | VCT |
|---|---|---|---|---|---|---|
| Fund size | 12.00 | 10.00 | 6.00 | 10.00 | 8.00 | 8.00 |
| Annual budget saving if no ND | 1.90 | 1.50 | 0.35 | 1.90 | 0.90 | 0.95 |
| Probability of fund depletion, units | 0.05 | 0.08 | 0.04 | 0.07 | 0.05 | 0.03 |
| Annual expected use of the fund if ND | 8.7 | 5.9 | 3.0 | 4.8 | 3.0 | 2.6 |
| Average fiscal cost of simulated ND [1/] | 57.9 | 29.3 | 29.7 | 19.3 | 15.0 | 12.9 |

Source: Staff calculations based on authorities' data.

1/ Includes the estimated average decline in revenues and increase in primary expenditures in the simulations, net of the expected increase in donor grants.

35.     **Under the parameter calibrations proposed, the SF of all countries would be financially sustainable with a low probability of depletion.** Figure 2 shows the probability of depletion of the SF when the ND probability is calibrated at the value used in the proposal, and shows the probability of depletion of the SF for different initial sizes of SF stock of assets within a ten-year horizon. According to Figure 2, lowering the proposed stock of assets in the SF by 2 percent of GDP would result in a probability of depletion of about 10 percent of more, which would undermine the long-term financial sustainability of the SFs.

### Layers 2 and 3: Parametric Insurance

36.     **Parametric insurance instruments complement SFs coverage for high and extreme intensity disasters.** Layers 2 and 3 are therefore presented to achieve coverage of 99 percent of the fiscal costs of NDs, with 95 percent of expected cost of damages covered with the SFs (layer 1), then maximum coverage under CCRIF (layer 2), and finally CAT bond issuance (layer 3) of maximum coverage under CCRIF remains insufficient to reach the 99 percent coverage target. Simulation results under these assumptions indicates that ECCU countries would require coverage of 13-31 percent of GDP. Under these illustrative coverage

assumptions, SFs would cover the initial 6-12 percent of GDP. All countries would require maximum CCRIF access, with coverage estimated in the range of 2-17 percent of GDP. As this remains insufficient reach 99 percent coverage of NDs fiscal costs targeted in the simulations, all countries need to issue CAT bonds in the range of 1.7-4.6 percent of GDP (text chart). These thresholds and coverage levels are illustrative, and countries could choose to modify coverage and instrument composition according to preferences towards risk aversion. Institutional capacity to safeguard SFs' integrity should also be taken into consideration.

**Natural Disaster Insurance Layering**
(percent of GDP)
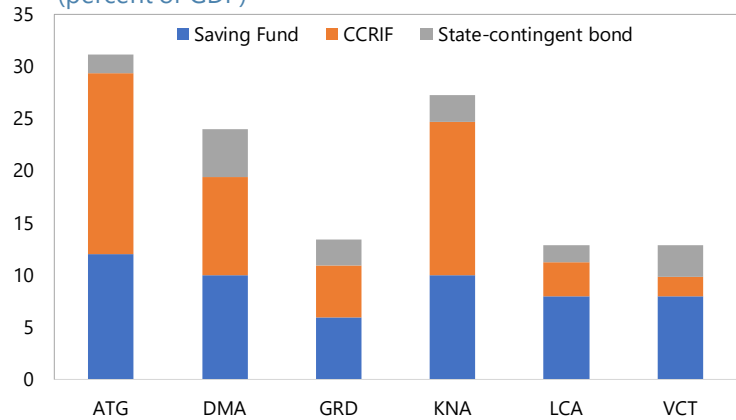


Source: IMF staff calculations based on CCRIF and authorities' data.

**37.     The insurance layering with 99 percent coverage implies annual fiscal costs in the range of 0.5-1.9 percent of GDP.** The simulations indicate higher costs for Dominica, Antigua and Barbuda and St. Kitts and Nevis, reflecting higher estimated Average Annual Losses of NDs in those countries. The cost composition also reflects the relatively expensive nature of parametric insurance, SFs are more cost effective relative to the significant level of coverage targeted (text chart). In the simulations, insurance costs are calibrated with multipliers of 1.5-2.0 (ratio of insurance premia to expected payouts). Notice that multipliers above 1 imply that insurance costs worsen fiscal sustainability in expected terms, albeit they reduce dispersion of expected debt outcomes by reducing need to issue debt after extreme NDs.

**Annual Fiscal Cost of Insurance**
(percent of GDP)
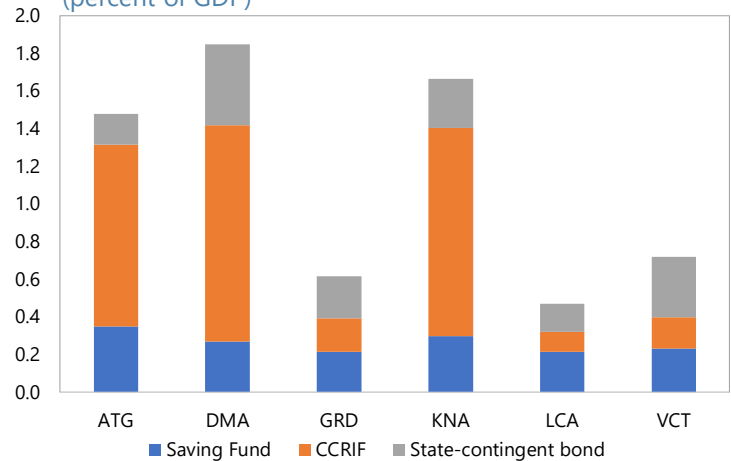


**38.     The high cost of parametric insurance could be difficult to accommodate given fiscal sustainability challenges in the ECCU.** Increasing the share of coverage with SFs could reduce costs, but it could prove challenging to maintain in practice given competing developmental needs and political pressures for spending. It is important to remark that targeting a lower coverage only implies no internalization of these costs and need for additional debt issuance ex-post.

**39.** **International donors could reduce incentives for underinsurance with grants subsidizing insurance costs, as part of a comprehensive ex-ante resilience strategy.** Grants for insurance payments could be designed to remove existing incentives for underinsurance due to high cost, while supporting fiscal sustainability by entrenching internalization of NDs fiscal costs. For example, donors could donors could provide an "insurance subsidy" grant to make insurance costs fiscally neutral, that is, of amount calibrated to equalize insurance costs paid by governments with expected average annual losses of disasters –effectively resulting in insurance multipliers of 1 from the country's perspective. This would imply an incentive-compatible strategy for governments and donors. From the governments' perspective, it incentivizes the purchase of appropriate levels of insurance coverage without worsening long-term fiscal sustainability. From the donors' perspective, it ensures the allocation of government resources in line with their fiduciary mandates –and could therefore result in an increase in donors grant flows. Under the simulation assumptions above, making insurance fiscally-neutral in expected terms would require grants in the range of 0.2-1.1 percent of GDP per year –equivalent to about US$ 40 million per year for all ECCU countries (text chart).
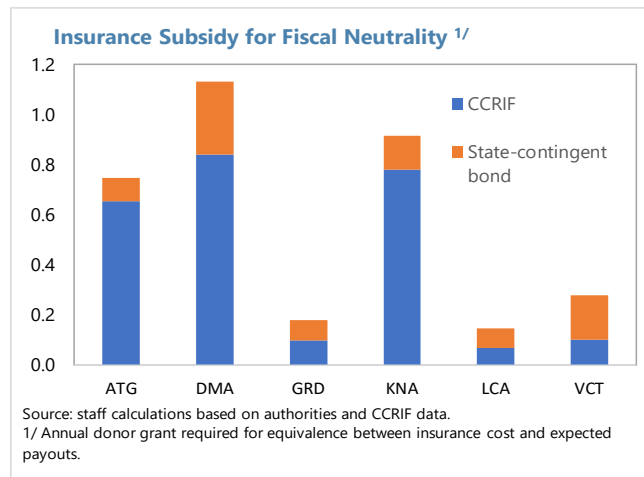


**Insurance Subsidy for Fiscal Neutrality** [1]

Source: staff calculations based on authorities and CCRIF data.
1/ Annual donor grant required for equivalence between insurance cost and expected payouts.

## VI. CONCLUDING REMARKS

**40.** **This paper presents estimates of government insurance needs for natural disasters in ECCU countries in an insurance layering framework.** It argues that self-insurance with a SF is needed given high cost of parametric insurance instruments. A layering framework including parametric instruments can be used to cover tail NDs risk for relatively low probability events of high intensity and damage.

**41.** **Saving funds and the parametric instruments would provide quick access to resources in the aftermath of NDs, important for immediate relief and rehabilitation.** Tax revenues typically decline after NDs, and debt issuance could be constrained by sustainability concerns, and can be slow disbursing relative to needs in the case of official financing or costly for market instruments with the uncertainty on the sovereign creditworthiness wrought by the NDs. The results in this paper indicate that countries would need SF stocks in the range of 6-12 percent of GDP and annual savings of 0.5-1.9 percent of GDP to achieve financial sustainability with a low probability of depletion. The results are based on a Monte Carlo experiments using VAR model estimates for each country that account for the impact of natural disasters on output and government finances.

**42.** **The insurance need estimated in this paper are a lower bound.** First, the fiscal space for re-prioritization may be lower than assumed in the simulations. Second, the

methodology focuses on cyclical fluctuations, thereby omitting long term increase in insurance coverage need as a result of increase in disaster intensity and/or frequency with climate change. Third, natural disasters can have permanent or structural effects on output (see for example Hsiang and Jina, 2014), which are not incorporated in the estimations in this paper. On the other hand, investment in infrastructure resilient to natural disasters which has commenced in several ECCU countries, if sustained in time, would reduce the extent of damage and the fiscal cost of natural disasters, reducing the coverage need and cost of insurance. Overall, these reasons imply the need to periodically reassess and recalibrate the insurance need of each country.

**43.     Strong institutional setup od SFs is critical to contain political pressures for spending or opportunistic appropriations.** A strong institutional design should include unambiguous budget contribution and disbursement rules, with triggers based on verifiable criteria, a clearly-stated objective, and strict information disclosure requirements to ensure the transparency of its operations.

**44.     CCRIF and other market catastrophe insurance can complement government self-insurance for medium and large disasters**. Parametric triggers are imperfectly correlated with damages for low and medium intensity NDs. However, for large and extreme NDs, parametric thresholds (i.e. relatively high rainfall, windspeed) are more likely to trigger, and could therefore top-up SFs coverage. Parametric triggers could be set at higher thresholds for large damage. High cost of parametric insurance makes the economic and welfare justification questionable. However, theoretically, risk aversion in social welfare criteria would justify some (non-negative) purchase of actuarially-unfair parametric options, and could be rationalized as a way to reduce the dispersion of debt outcomes, at a cost of worsening expected or average debt sustainability prospects.

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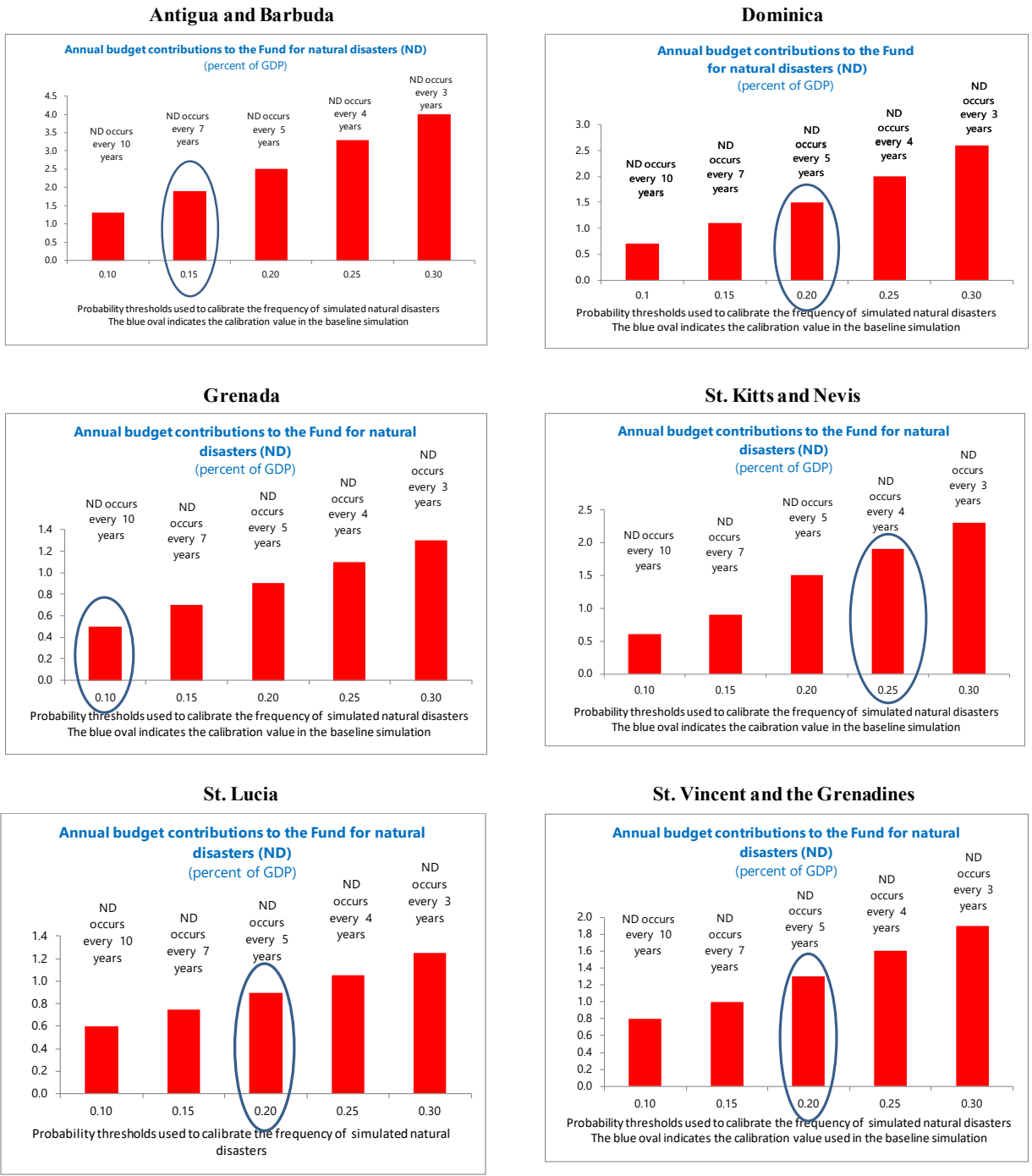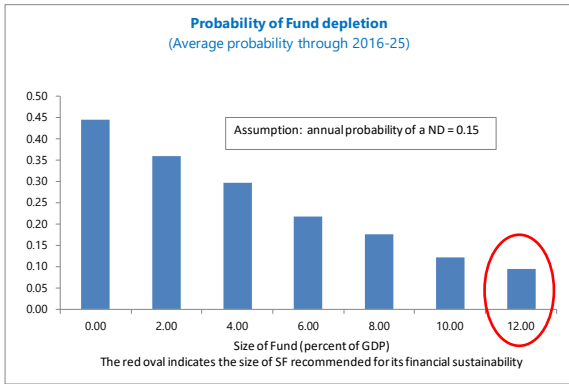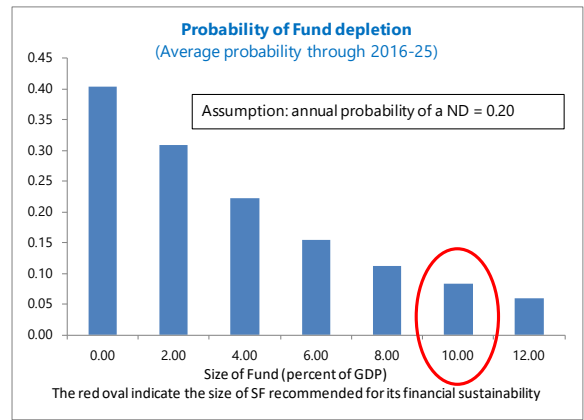# Figure 1: Annual budget savings required for the financial sustainability of the SFs

## Antigua and Barbuda



## Dominica



## Grenada



## St. Kitts and Nevis



## St. Lucia



## St. Vincent and the Grenadines
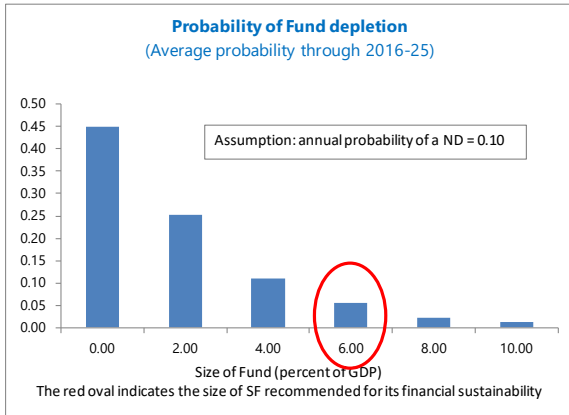
# Figure 2: Size of the SFs and probabilities of depletion
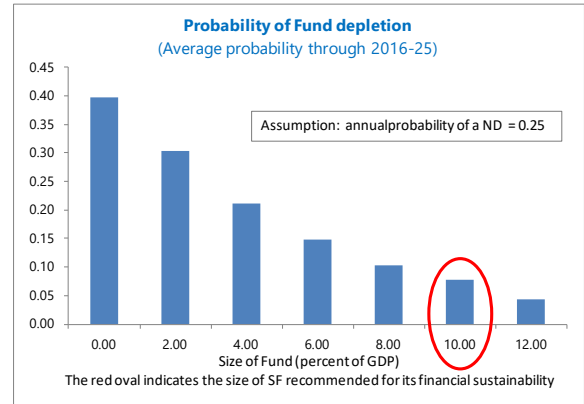
### Antigua and Barbuda

**Probability of Fund depletion**
(Average probability through 2016-25)

Assumption: annual probability of a ND = 0.15

Size of Fund (percent of GDP)
The red oval indicates the size of SF recommended for its financial sustainability

### Dominica

**Probability of Fund depletion**
(Average probability through 2016-25)

Assumption: annual probability of a ND = 0.20

Size of Fund (percent of GDP)
The red oval indicate the size of SF recommended for its financial sustainability

### Grenada

**Probability of Fund depletion**
(Average probability through 2016-25)

Assumption: annual probability of a ND = 0.10

Size of Fund (percent of GDP)
The red oval indicates the size of SF recommended for its financial sustainability

### St. Kitts and Nevis

**Probability of Fund depletion**
(Average probability through 2016-25)

Assumption: annualprobability of a ND = 0.25

Size of Fund (percent of GDP)
The red oval indicates the size of SF recommended for its financial sustainability

### St. Lucia

**Probability of Fund depletion**
(Average probability through 2016-25)

Assumption: annual probability of a ND = 0.2

Size of Fund (percent of GDP)
The red oval indicates the size of SF recommended for its financial sustainability

### St. Vincent and the Grenadines

**Probability of Fund depletion**
(Average probability through 2016-25)

Assumption: annual probability of a ND = 0.20

Size of Fund (percent of GDP)
The red oval indicates the size of SF recommended for its financial sustainability

## Appendix 1. Parameter Calibrations

| | Antigua and Barbuda | Dominica [2/] | Grenada | St. Lucia | St. Kitts & Nevis [3/] | St. Vincent & the Grenadines |
|---|---|---|---|---|---|---|
| GDP potential growth, percent | 2.70 | 1.70 | 2.70 | 1.50 | 2.50 | 3.00 |
| Implicit interest rate on public debt, percent | 3.30 | 2.54 | 3.57 | 5.07 | 3.47 | 3.27 |
| **Fiscal consolidation measures** [1/] | | | | | | |
| Primary Balance, percent of GDP | 2.88 | 5.00 | 1.80 | 0.80 | 1.08 | 3.70 |
| Non-grant revenue | 2.14 | 3.50 | 0.00 | 0.30 | -5.32 | 0.00 |
| Grant revenue | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 |
| Current primary expenditure | -0.74 | -3.00 | 0.00 | -0.50 | -6.40 | 0.00 |
| Capital expenditure | 0.00 | 1.50 | -1.80 | 0.00 | 0.00 | -3.20 |
| **Government Fund** | | | | | | |
| Initial Fund stock / GDP | 12.00 | 10.00 | 6.00 | 8.00 | 10.00 | 8.00 |
| Inflows into the Fund from the budget, percent of GDP | | | | | | |
| Non-grant revenue t-1 | 1.90 | 1.50 | 0.35 | 0.90 | 1.90 | 0.95 |
| Grant revenue t-1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Outflows of the Fund to the budget parameters | | | | | | |
| Storm probability threshold | 0.15 | 0.20 | 0.10 | 0.20 | 0.25 | 0.20 |
| Base capital expenditure level / GDP | 0.02 | 0.06 | 0.07 | 0.07 | 0.04 | 0.04 |
| Capital expenditure trend / GDP trend | 0.03 | 0.08 | 0.08 | 0.08 | 0.05 | 0.05 |
| Year average capital expenditure on reconstruction / GDP | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| Base current primary expenditure / GDP | 0.19 | 0.19 | 0.16 | 0.18 | 0.22 | 0.22 |
| Current primary expenditure trend / GDP trend | 0.20 | 0.23 | 0.17 | 0.19 | 0.23 | 0.23 |
| Year average current expenditure social transfers and rehabilitation / GDP | 0.01 | 0.04 | 0.01 | 0.01 | 0.01 | 0.01 |

Source: author's calculations based on authorities data.

1/ Include cumulative fiscal consolidation over five years starting from the first simulated year.

2/ Excludes the impact of hurricane Maria which hit Domimica in September 2017.

3/ The decline in non-grant revenue Includes a projected decline in CBI program revenues, consistent with Fund staff projections. The simulation assumes fiscal consolidation of current primary expenditures, as needeed for fiscal sustainability.