

# Increasing countries' financial resilience through global catastrophe risk pooling

**Alessio Ciullo**

PostDoc Researcher, Institute for Environmental Decisions, ETH Zurich, Zurich, Switzerland  
Climate Risk Analyst, CLIMADA Technologies, Zurich, Switzerland

[alessio.ciullo@climada.tech](mailto:alessio.ciullo@climada.tech)

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Alessio Ciullo<sup>1,2</sup>✉, Eric Strobl<sup>3</sup>, Simona Meiler<sup>1,2</sup>, Olivia Martius<sup>4</sup> & David N. Bresch<sup>1,2</sup>

Extreme weather events can severely impact national economies, leading the recovery of low- to middle-income countries to become reliant on foreign financial aid. Foreign aid is, however, slow and uncertain. Therefore, the Sendai



# Introduction

- Extreme weather events can have **severe impacts** on countries' economies including:
  - ❖ a loss in annual growth, local income growth and total tax revenue
  - ❖ an increase in inflation and real exchange rates
- The recovery of many low- to -middle countries often relies on **Foreign Financial Aid, which is however notoriously slow and uncertain (ex-post)**
- The Sendai Framework and the Paris Agreement advocate for the adoption of **ex-ante** financial instruments, because they:
  - **reduce uncertainties** in when and how much money a country receives
  - **allow** countries to integrate disaster risk finance into **longer-term financial planning** activities
- The InsuResilience Global Partnership identified **sovereign catastrophe risk pools** as a promising *ex-ante* mechanism for disaster risk finance

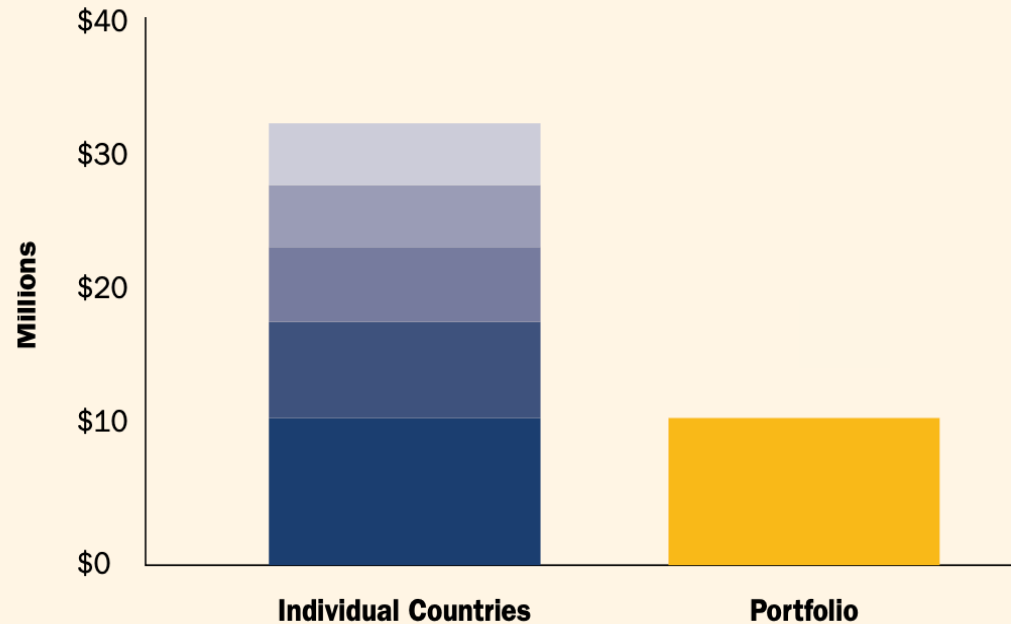
# Sovereign Catastrophe Risk Pools: What are they?

- They are financial mechanisms through which **countries pool their individual risk into a single portfolio**
- If effectively done, **risk pooling makes countries' risk share** within the portfolio **lower than their individual risk**
- This allows them to pay a **reduced premium** for the same coverage or to obtain a higher coverage for the same premium
- **Three catastrophe pools exist**, covering different regions and perils:
  - the Caribbean Catastrophe Risk Insurance Facility (CRIFF)
  - the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI)
  - the African Risk Capacity (ARC)

# Sovereign Catastrophe Risk Pools: Risk Diversification

The benefit of risk diversification via sovereign catastrophe pools (World Bank, 2017):

**FIGURE 7. DIVERSIFICATION BENEFITS MODELED FOR THE PCRAFI PROGRAM:  
SIMPLE AGGREGATES VERSUS POOLED RISK FOR 1-IN-250-YEAR RETURN PERIOD  
LOSSES**



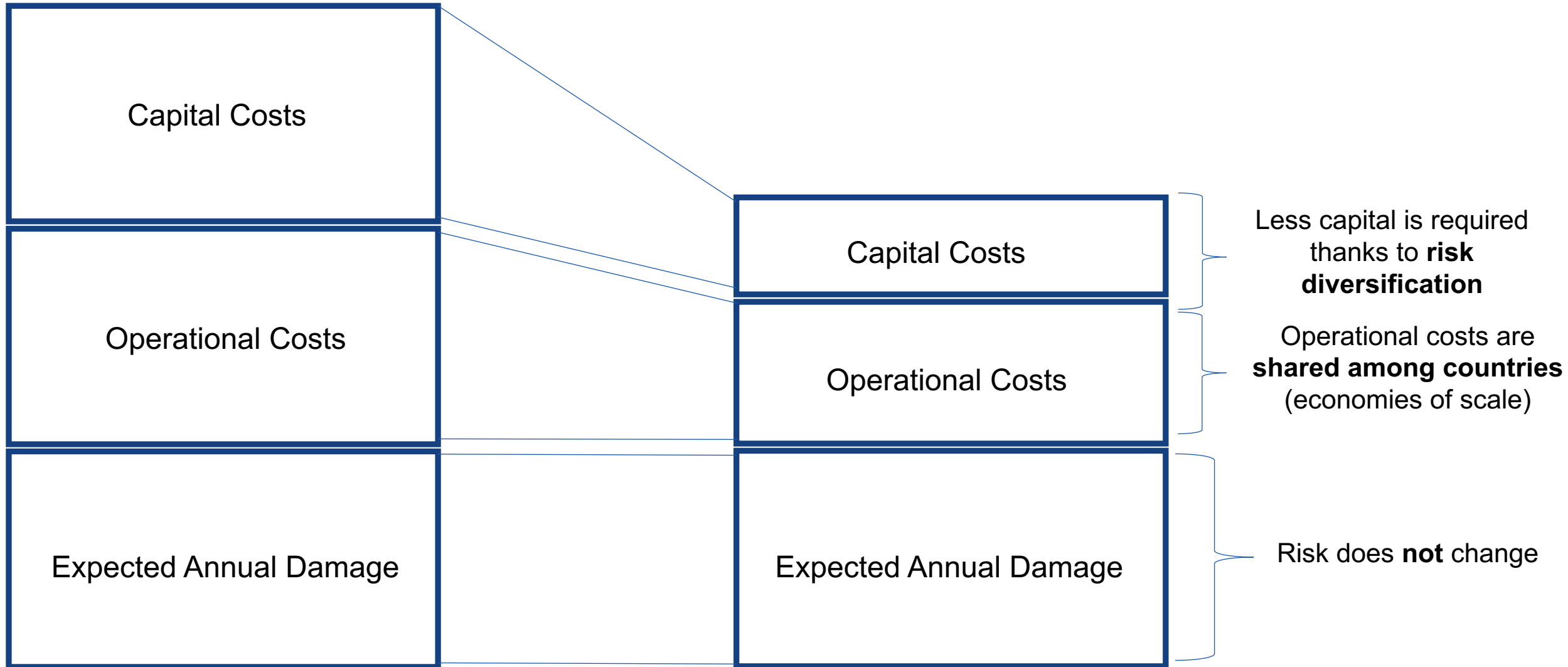
Source: World Bank and PCRAFI (2016).

Source: World Bank (2017): *Sovereign Climate And Disaster Risk Pooling*

# Sovereign Catastrophe Risk Pools: Premium Reduction

Premium without pooling

Premium with pooling



# The Problem

- Although **existing pools** like CRIFF, ARC and PCRAFI provide significant diversification benefits to their members, these benefits **may be limited** because:
  - The pools were simply **not designed** with the explicit scope of maximizing risk diversification
  - The pools are **regional** and may thus forego risk diversification potentials resulting from not including countries outside their own region

# The Goal

- Focusing on tropical cyclones risk of CRIFF and PCRAFI, the goal is to show whether, and to what extent, these limitations hold.
- To do so, we assess:
  - The current pools' risk diversification
  - The changes in risk diversification obtained by **optimally extending** the pools **regionally** and **globally**
  - The **contribution of the countries' risk to the pools' risk** (proxy for countries' 'fair' premium), and how this may change under **regional and global pooling**



# Method

1. A 10.000 years time series of tropical cyclones around the globe is constructed.

A synthetic event set for the historical time period of 1979-2019 is created using the model introduced by Emanuel et al. (2006, 2008) and then years are resampled using the procedure in Emanuel et al. (2012).

2. A 10.000 years time series of (wind-driven) losses,  $L$ , for 91 countries is generated.

This is achieved using the globally consistent open -source and -access CLIMADA modeling platform (<https://wcr.ethz.ch/research/climada.html>)

3. We find **the smallest set of countries** - out of all possible combinations - **to be added** to CCRIF and PCRAFI in order to achieve the **maximum** risk diversification.

This is an **optimization problem** where the goal is to find the **smallest set** of countries which **maximizes risk diversification**,  $RD$ , herein defined as:

$$RD = 1 - \frac{\sum_i E[L_i | L \geq VaR_\alpha]}{\sum_i E[L_i | L_i \geq VaR_{\alpha_i}]}$$

Sum of expected countries' losses when the pool undergoes large losses

Sum of expected countries' large losses

Then, one can also assess the share of a country's risk ending up in the pool's risk (proxy of countries' fair premium):

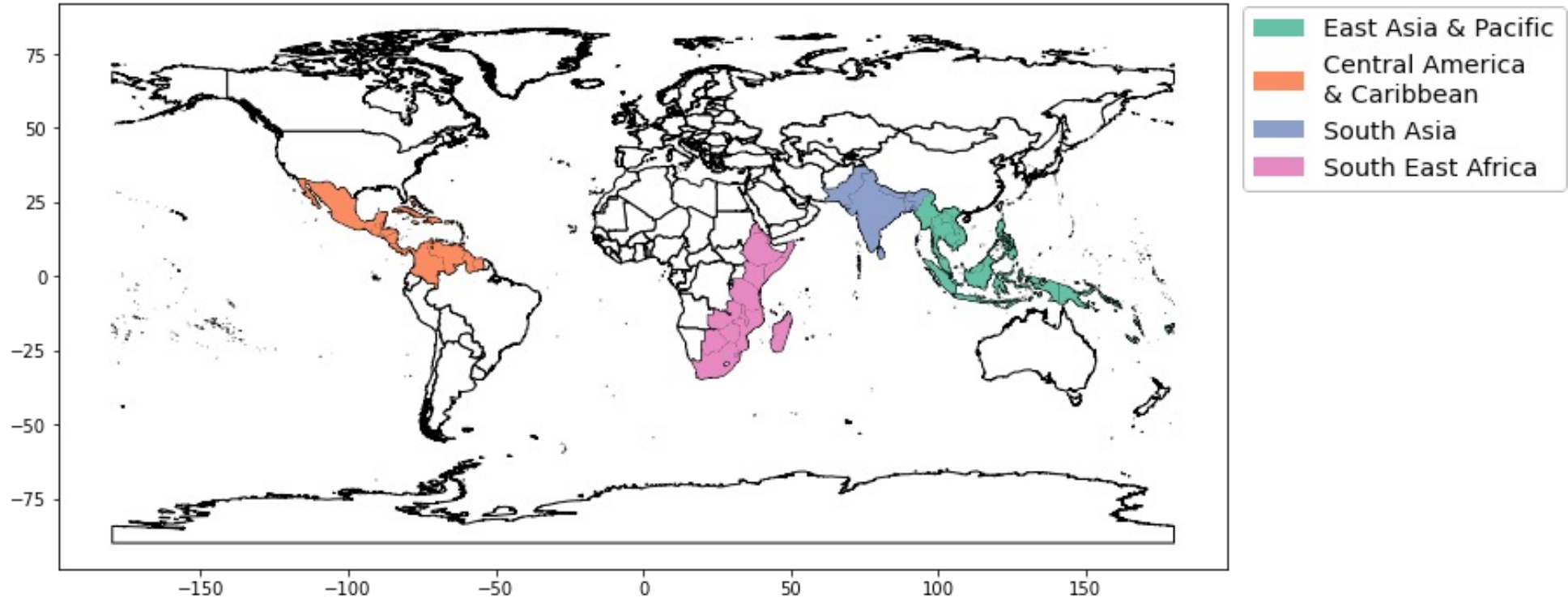
$$s_i = \frac{E[L_i | L \geq VaR_\alpha]}{E[L_i | L_i \geq VaR_{\alpha_i}]}$$

Expected losses for country,  $i$ , when the pool undergoes large losses

Expected large losses for country,  $i$

VaR with  $\alpha = 0.995$

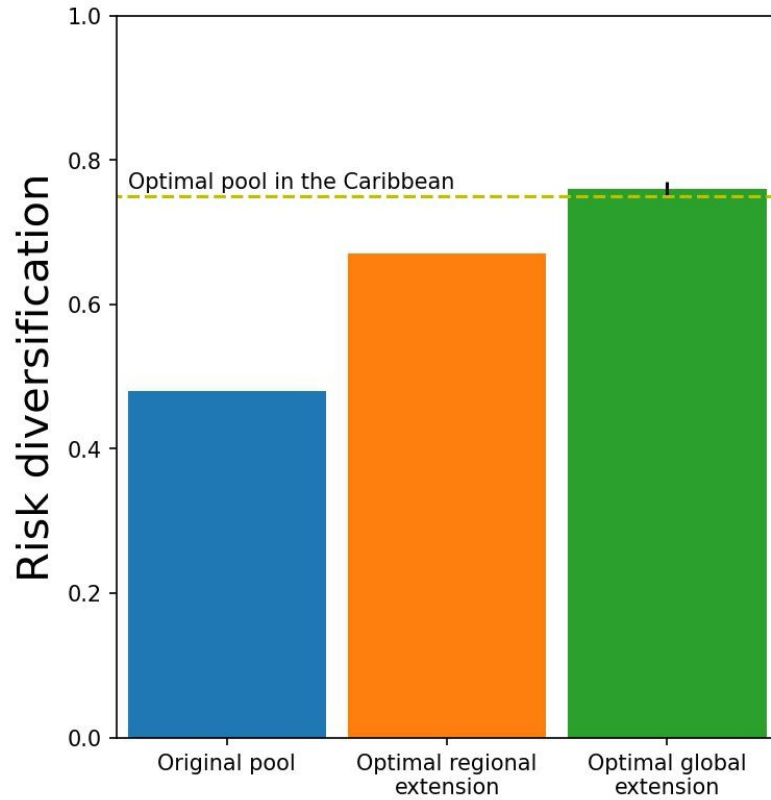
# The identified regions



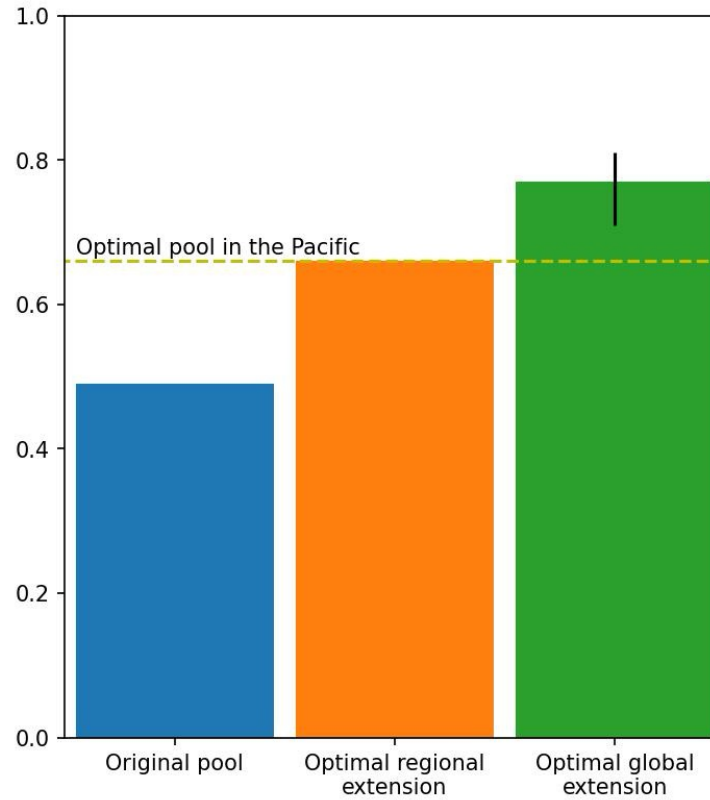
The 92 countries considered are divided into **four regions** based on the WB's regional definition and on the relevance of tropical cyclone risk. PCRAFI and CCRIF are extended by pooling additional countries:

- ❖ Regionally, i.e., from their respective region (East Asia & Pacific for PCRAFI and Central America & Caribbean for CCRIF)
- ❖ Globally, i.e., from any of the four regions

# Results : PCRAFI's and CCRIF's risk diversification



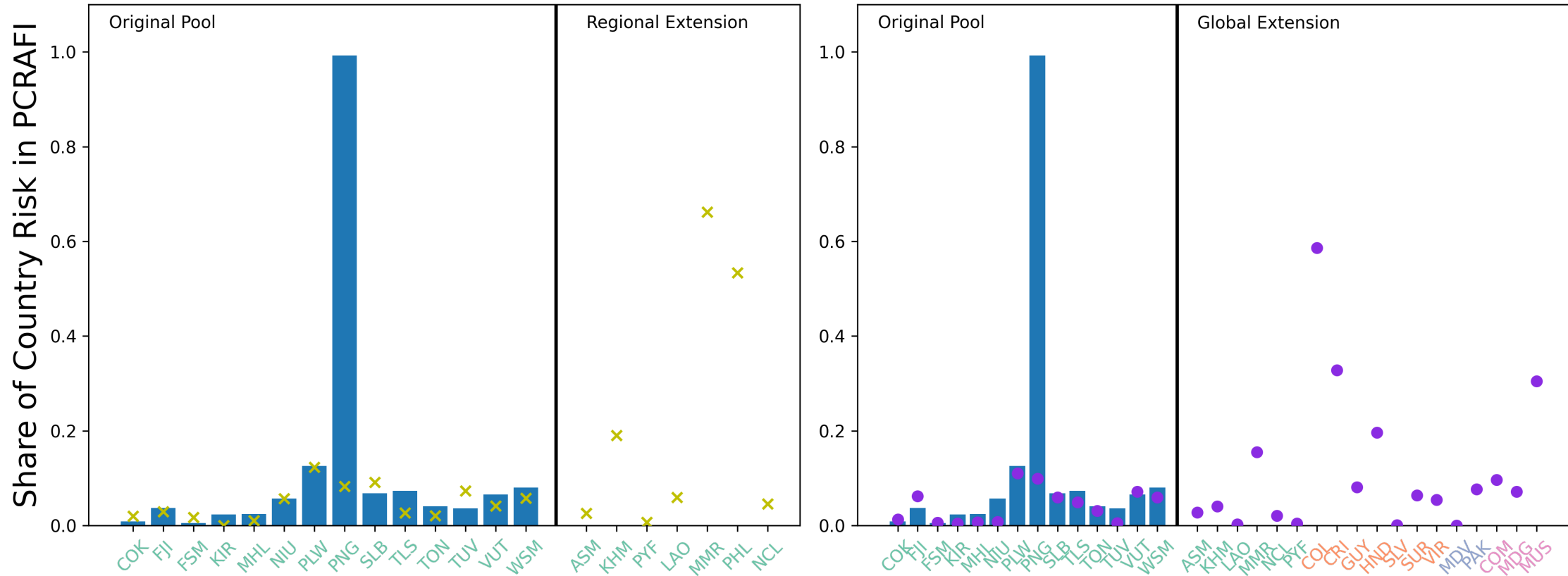
Caribbean Catastrophe Risk Insurance Facility (CCRIF)



Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI)

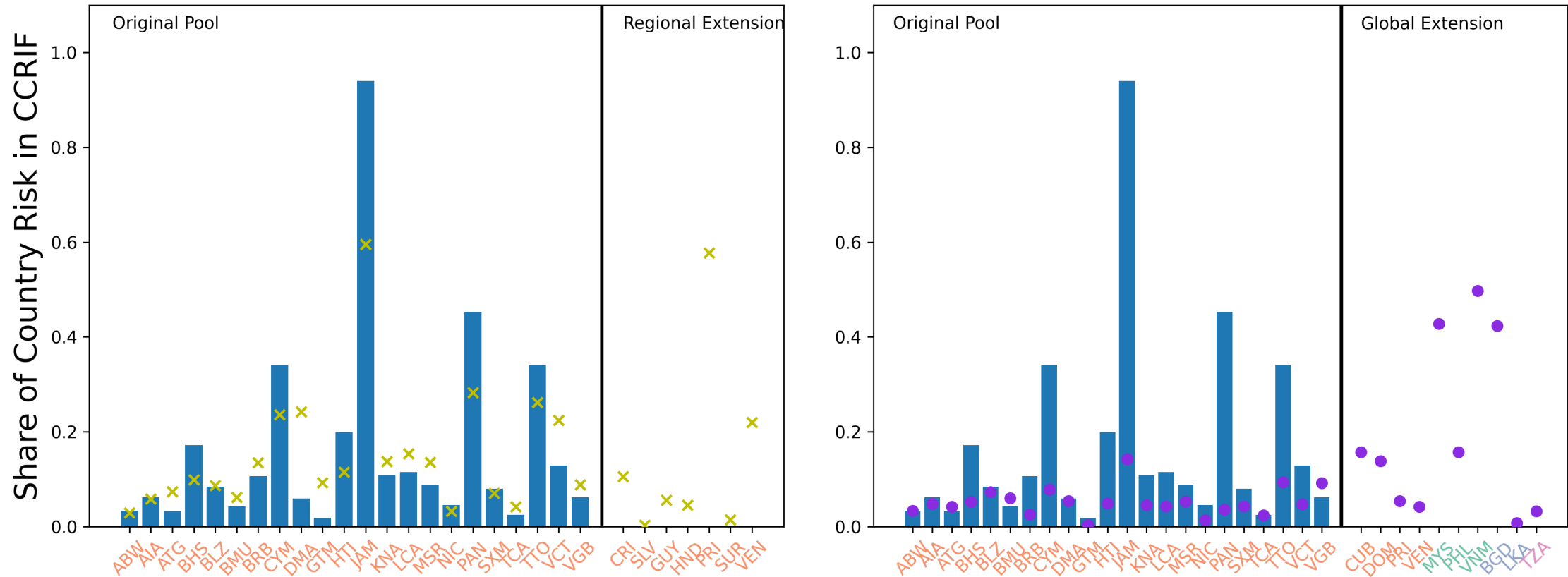
- **Currently** (blue bars), **risk diversification** of PCRAFI and CCRIF is of about **50 %** and it's **lower** than the **max** attainable **regional** values
- **Regional optimal pooling** (orange bars) would **close this gap** for **PCRAFI** but **not** for **CCRIF**
- **Global optimal pooling** (green bars) could **increase** risk diversification up to **over 80 %** for **PCRAFI** and **over 75 %** for **CCRIF**

# Results : Share of Countries' Risk in PCRAFI



- Currently (blue bars), virtually all Papua New Guinea's (PNG) tropical cyclone risk contributes to PCRAFI's risk.
- Regional pooling (yellow crosses) reduces this share. The highest shares (above 60%) would be retained by Myanmar (MMR).
- Global pooling (purple dots) also significantly reduces risk shares. Now the highest share would be of about 60% (retained by Colombia). Many more countries can join the pool, most of them from within the same region and the Caribbean & Central America, some also from South Asia and South East Africa.

# Results : Share of Countries' Risk in CCRIF



- Currently (blue bars), virtually all Jamaica's (JAM) tropical cyclone risk contributes to CCRIF's risk.
- Regional pooling (yellow crosses) reduces this share, bringing it to about 60% together with Puerto Rico (PRI).
- Global pooling (purple dots) reduces risk shares even more. Now the highest share would be of about 50% (retained by Vietnam, VNM). About the same number of countries join the pool, mostly from within the same region and East Asia and Pacific, some also from South Asia and South East Africa.

# Conclusions

- The current pools' risk diversification

The risk diversification of the current pools is of about 50 %.

- The changes in risk diversification obtained by **optimally extending** the pools **regionally** and **globally**

**Regional pooling** could **substantially increase risk diversification in both cases**. For CCRIF, however, the obtained value would still be lower than the attainable optimal value in the Caribbean.

**Global pooling** could **increase risk diversification even more** than regional pooling. For PCRAFI this would be way higher than the optimal regional diversification. For CCRIF this would be just about equal to the regional optimal diversification value.

- The **contribution of the countries' risk to the pools' risk** (proxy for countries' 'fair' premium), and how this may change under **regional and global pooling**

Currently, there seems to be a **single country** (Papua New Guinea for PCRAFI and Jamaica for CCRIF) which **transfers its full risk to the pool**.

**Both regional and global pooling reduce the share of countries' risk transferred to the pool** and make it more equal and balanced across countries in the pool.

Thank you!

Alessio Ciullo, [alessio.ciullo@climada.tech](mailto:alessio.ciullo@climada.tech)

## References

World Bank. Sovereign Climate And Disaster Risk *Pooling* (2017).

Emanuel, K., Ravela, S., Vivant, E. & Risi, C. A Statistical Deterministic Approach to Hurricane Risk Assessment. *Bull. Am. Meteorol. Soc.* **87**, 299–314 (2006).

Emanuel, K., Fondriest, F. & Kossin, J. Potential Economic Value of Seasonal Hurricane Forecasts. *Weather Clim. Soc.* **4**, 110–117 (2012).

Aznar-Siguan, G. & Bresch, D. N. CLIMADA v1: a global weather and climate risk assessment platform. *Geosci. Model Dev.* **12**, 3085–3097 (2019).

Bresch, D. N. & Aznar-Siguan, G. CLIMADA v1.4.1: towards a globally consistent adaptation options appraisal tool. *Geosci. Model Dev.* **14**, 351–363 (2021).