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Risk Layering - A Loss Classification Approach

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Motivation

- Natural hazards in the 21st century (World Economic Forum 2021)
- High-frequency, severe losses from climate-related disasters (Blöschl et al. 2019)
- Hazards' impact on political, social, and economic systems (Lamperti et al. 2019)
- Urgency of sound proactive risk management models for reducing climate disaster risks policies in 2023 (Kajwang 2022)
- Insurance acts as an enabler of solutions that drive social and environmental sustainability ("Paris Agreement" 2015; Garayeta, De la Peña, and Trigo 2022)
- Insufficient and gaps in insurance coverage for climate weather-related catastrophes
- Challenges of accurately categorizing and assessing the magnitude of diverse perils (OECD 2021)

Proposal

- To address this issue, we propose loss-layering approach with two intertwined steps.
- The idea of loss-layering, originates from the insurance sector and serves as a fundamental principle in effective risk management (Hochrainer-Stigler and Reiter 2021).
- Losses are divided into multiple well-defined layers (thresholds):
    1. Attachment threshold
    2. Exhaustion threshold
    3. Financial strain or bankruptcy

Goals

- We need to accomplish two goals:

1. **Classifying Losses**: Classifying regional losses into distinct categories, namely “near maximum” and “near minimum” loss values.
2. **Layer Allocation through Regression**: Utilizes a robust non-linear regression method and classified losses and its accompanying confidence interval to accurately allocate the layers.

- Benefits for the public (government) and private insurers such as (OECD 2016; Linnerooth-Bayer and Hochrainer-Stigler 2015; “Paris Agreement” 2015):
  - Evidence-based policy formulation
  - Higher levels of insurance coverage for climate perils
  - Informed decision-making, resource allocation and fiscal stability (public)
  - Improved loss reserving and pricing (private)

Data Summary

- The data is for this project is from **EM-DAT database** for total estimated damages and losses to North America region.
- The loss data are for years 1963-2022 (inclusive) (EM-DAT 2008).
- **Total estimated damages**: value of all damages and economic losses directly or indirectly related to the disaster.
- The total damages are in billions of 2021 USD.
- The meteorological events:



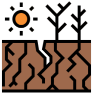
Data Summary

- The hydrological events:



- The climatological events:





Second-order Difference of Loss Space

- We have a time series of loss values, $\boldsymbol{x} = (x_t : t = 1, 2, \ldots, 60)$, at annual intervals of time.
- Consider 3 time indexes, namely indeces $t-1$, t, and $t+1$.
- The choice of discretization scheme follows from expanding the Taylor series at $t+1$ and $t-1$ according to

$$x_t'' = \frac{x_{t+1} - 2x_t + x_{t-1}}{h^2} + O(h^2) \tag{1}$$

- By setting $h = 1$, to represent annual loss values, then we can approximate x_t'' by $\hat{x}_t''$

$$\hat{x}_t'' \approx x_{t+1} - 2x_t + x_{t-1} \tag{2}$$

- At index $t = 1$ and $t = 60$, we assumed interpolated Neumann boundary condition, such that $\hat{x}_1'' = \hat{x}_2''$ and $\hat{x}_{60}'' = \hat{x}_{59}''$.

Classification of Loss - Approach I

- We can partition $\boldsymbol{x}$ into **concave segments** and **convex segments** using $\hat{\boldsymbol{x}}''$:

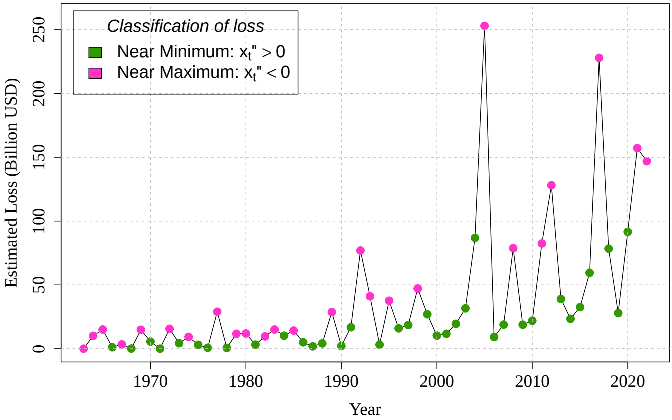


Figure 1: Classification of losses using loss space.

Loss Layers - Approach I

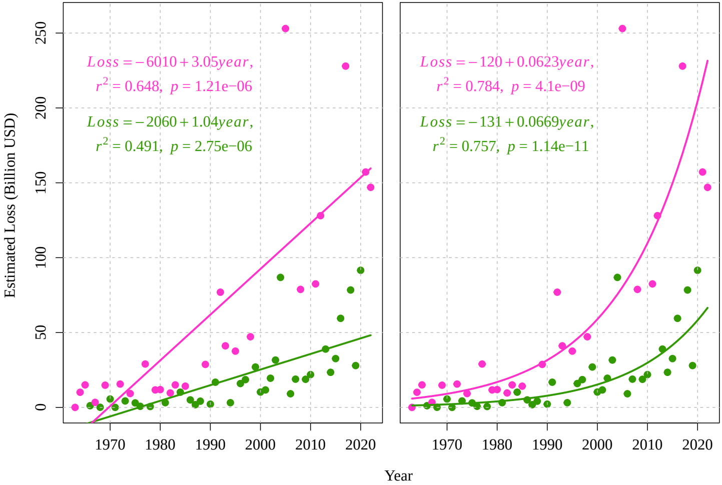
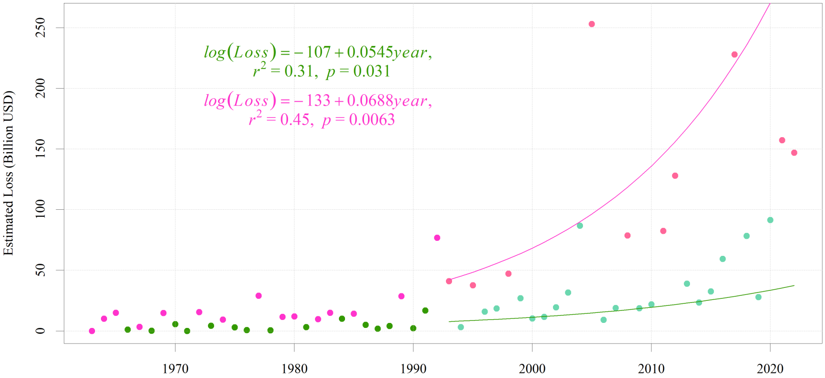


Figure 2: (Left) Linear loss layers using linear regression. (Right) Non-linear loss layers using log-transform of loss.

Loss Layers - Approach I

Classification by loss space



Prediction of losses for the low-medium and medium-high layers, for years: 1993-2022

Empirical Cumulative Distribution Function

- Let vector $\boldsymbol{x} = (x_1, x_2, \dots, x_t, \dots, x_{60})$ represent the aggregated (estimated) loss values for a region, for years 1963-2022.
- The empirical cumulative distribution function is given as

$$\hat{F}(x) = \frac{1}{60} \sum_{i=1}^{60} \mathbb{1}_{\{x_i \leq x\}}$$

- Cumulative distribution function is non-decreasing.

$$\text{If } x \geq y \text{ then } F(x) \geq F(y)$$

Loss to ECDF

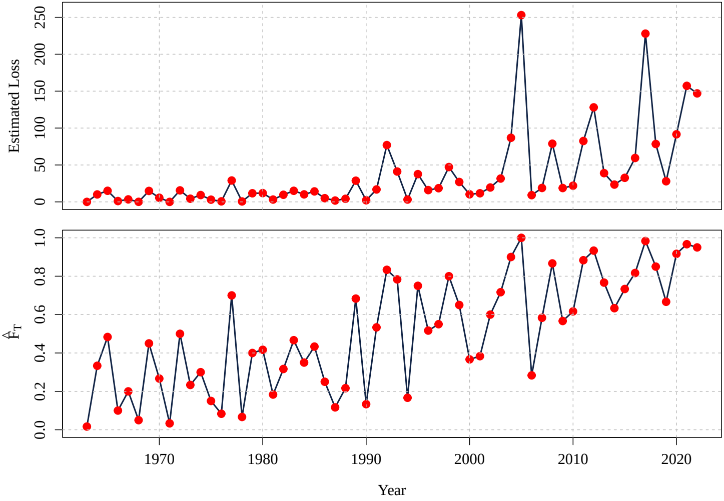


Figure 3: (Top) Estimated loss per year (Billion USD), (Bottom) Cumulative probabilities for all 60 years.

Classification of Loss - Approach II

- We can partition $\boldsymbol{p}$ into **concave segments** and **convex segments** using $\hat{\boldsymbol{p}}''$:

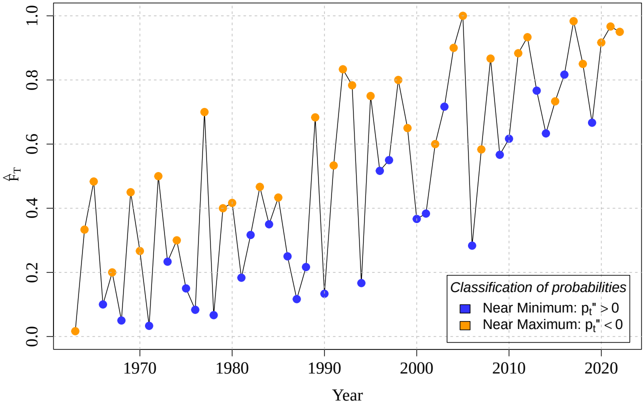


Figure 4: Classification of cumulative probabilities.

Loss Layers - Approach II

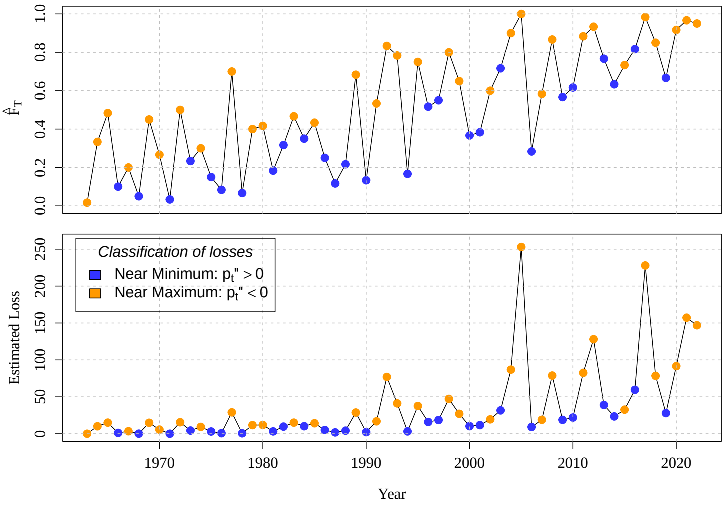
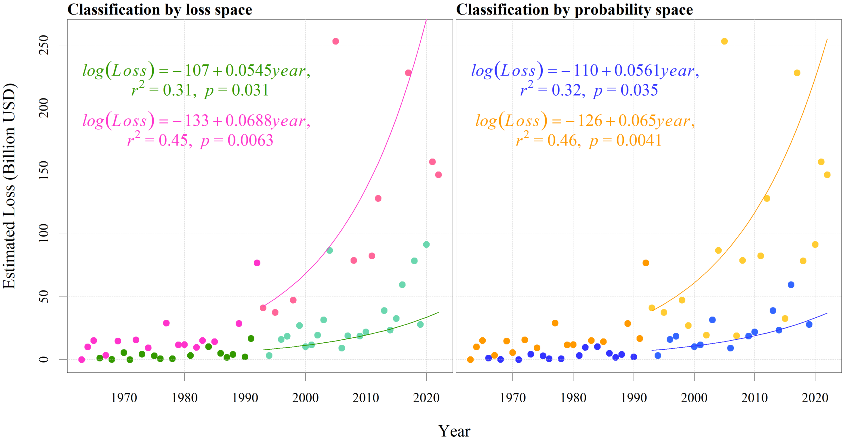


Figure 5: (Top) Classification of segments for cumulative probabilities, (Bottom) Classification of loss per year (Billion USD) based on the segments of cumulative probabilities.

Approach I vs. Approach II



Prediction of losses for the low-medium and medium-high layers, for years: 1993-2022

So what now?

- For the medium-high and high loss layers, insurers must explore options such as (Linnerooth-Bayer and Hochrainer-Stigler 2015):

1. Public donor support or publicly backed insurance (**solidarity**)
   a. Leverage emergency relief funds
   b. National insurance programs
   c. Engage in private-public partnerships
2. Risk transfer mechanisms (**reinsurance**)
   a. Traditional commercial reinsurance
   b. Financial reinsurance (Boffo, Patalano, and OECD Paris 2020)
   c. Catastrophe bonds

Recap

- We constructed a method for categorization of the losses based on their magnitudes.
- We established a robust approach for allocating loss layers, effectively determining attachment and exhaustion thresholds.
- We offered mechanisms to financial recovery for each layer.

Further Work

- Construct the model on different geographical regions.
- Construct the model for specific meteorological, climatological, and hydrological events.
- Take extra variables into consideration for the regression model.
- Extend the model to include a probabilistic model for each loss-layer.

Thank you for listening.

References I

Blöschl, Günter, Julia Hall, Alberto Viglione, Rui A P Perdigão, Juraj Parajka, Bruno Merz, David Lun, et al. 2019. "Changing Climate Both Increases and Decreases European River Floods." *Nature* 573: 108–11.

Boffo, R, R Patalano, and OECD Paris. 2020. "ESG Investing: Practices, Progress and Challenges."

EM-DAT. 2008. "EM-DAT: The International Disaster Database."

Garayeta, Asier, J Iñaki De la Peña, and Eduardo Trigo. 2022. "Towards a Global Solvency Model in the Insurance Market: A Qualitative Analysis." *Sustainability* 14 (11): 6465.

Hochrainer-Stigler, Stefan, and Karina Reiter. 2021. "Risk-Layering for Indirect Effects." *Int. J. Disaster Risk Sci.* 12 (5): 770–78.

Kajwang, Ben. 2022. "Role of the Insurance Sector in Supporting the Achievement of Vision 2030." *Journal of Poverty, Investment and Development* 7 (1): 33–43.

Lamperti, Francesco, Valentina Bosetti, Andrea Roventini, and Massimo Tavoni. 2019. "The Public Costs of Climate-Induced Financial Instability." Vol. 9. Nature Publishing Group.

Linnerooth-Bayer, Joanne, and Stefan Hochrainer-Stigler. 2015. "Financial Instruments for Disaster Risk Management and Climate Change Adaptation." *Clim. Change* 133 (1): 85–100.

OECD. 2016. "Disaster Risk Assessment and Risk Financing: A G20 / OECD METHODOLOGICAL FRAMEWORK."

———. 2021. "Enhancing Financial Protection Against Catastrophe Risks: The Role of Catastrophe Risk Insurance Programmes."

"Paris Agreement." 2015. *The Paris Outcome on Loss and Damage*.

World Economic Forum. 2021. "The Global Risks Report 2021, 16th Edition."