

Asset-level assessment of climate physical risk matters for adaptation finance

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Motivation and contribution

Motivation

- Main **knowledge gaps** remain in climate physical risk assessment
- Poor risk assessment hinders **capital reallocation** (Kreibiehl et al., 2022) and the **feasibility** of the transition (Battiston et al., 2021)
- **Delayed action** on adaptation and mitigation leads to higher climate risks and failure to close the **adaptation gap** (UNEP, 2021)

Contributions

- We provide a **methodology** for asset-level physical risk assessment to adjust the financial valuation of securities and portfolio risk
- Risk emerges from the **interplay** of acute and chronic shocks on assets, asset location and role in firm's revenues
- **Results:** neglecting asset-level dimension and tail risks can lead to underestimation of losses and non-coherent investment decisions

Literature and knowledge gaps

- **Asset-level data** (e.g. production plants): non standardized, proprietary; no consolidation (financial, climate, extrafin. info)
- **Plants' ownership** information: not standardized, difficult to reconstruct chain of ownership due to complexity of ownership networks (Garcia-Bernardo et al., 2017)
- **(Mis)pricing**: contrasting evidence, mostly for past disasters (Beirne et al., 2021, Giglio et al., 2021, Garbarino and Guin, 2021, Nguyen et al., 2022)
- Addressing these challenges is key to identify **policy responses** (Hallegatte et al., 2020), **financing needs** (GCA, 2021) and **instruments** (Mullan and Ranger, 2022) to fill the adaptation gap

Are physical risks priced? Examples from the literature

Several studies investigated **market pricing** of physical risks:

- (Acharya et al., 2022) find that **heath stress** is most relevant for municipal bonds, non-investment grade bonds, and equity starting 2013-2015 (physical risk data **427**¹ and **SEAGLAS**²)
- (Gostlow, 2021) finds that **hurricanes** command a positive risk premium and **heath stress** a negative risk premium (data: **427**)
- (Nguyen et al., 2022) document a positive sea-level risk premium for mortgages (data: **NOAA**³)

Disagreement due to data **limitations**: aggregate physical risk scores (eg. 427) diverge even within the same measurement method (Hain et al., 2022)!

Most studies are **backward looking** (past data) but the future climate will be much different: need to work with scenarios

¹<https://www.moodys.com/web/en/us/capabilities/esg.html>

²(Hsiang et al., 2017)

³<https://www.noaa.gov/>

Methodological framework

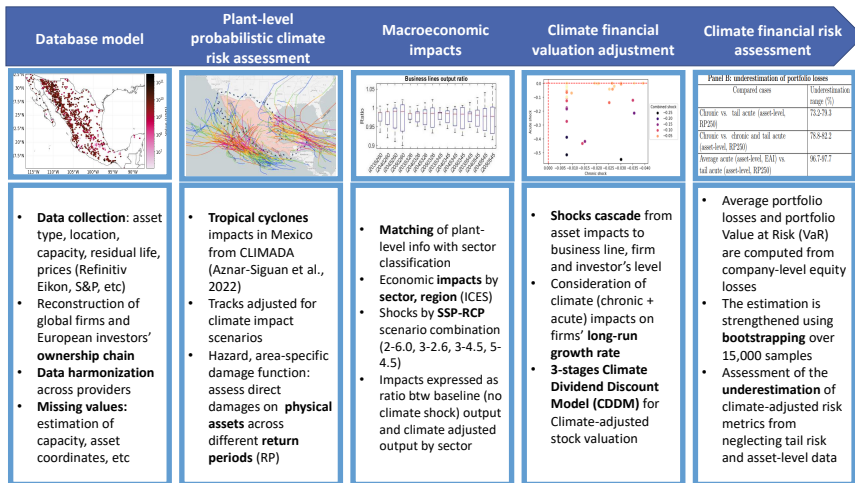


Figure: Methodological framework for asset-level climate physical risk assessment (Bressan et al., 2022)

Business-line data deep dive

Financial statements can be **manually reclassified** to extract companies' revenues by business line, a key input for assessment of climate risk – but this is **extremely time-consuming**.

| Name of the company: Teck Resources Ltd | | | | | |
|---|------------------|----------------|----------------|---------------|----------------|
| Industrial classification: NACE Rev 2 class 05.10 - 'Mining of lignite' | | | | | |
| Total revenue (FY2019): 8997.91 million USD | | | | | |
| millions USD | FY2019 | | | | |
| | Business units | | | | |
| Product types | Steelmaking Coal | Copper | Zinc | Energy | Total |
| Steelmaking Coal | 4163.44 | - | - | - | 4163.44 |
| Copper | - | 1627.07 | - | - | 1627.07 |
| Zinc | - | 122.90 | 1783.90 | - | 1906.80 |
| Blended Bitumen | - | - | - | 735.12 | 735.12 |
| Silver | - | 18.10 | 283.49 | - | 301.59 |
| Lead | - | 3.77 | 297.82 | - | 301.59 |
| Other | - | 89.72 | 263.89 | - | 353.61 |
| Intra-segment | - | - | -391.31 | - | -391.31 |
| Total | 4163.44 | 1861.56 | 2237.79 | 735.12 | 8997.91 |

| ICES sectors | Revenue by ICES sector (million USD) | Revenue shares by ICES sector |
|------------------|--------------------------------------|-------------------------------|
| Coal | 4163.44 | 46% |
| Oil | 735.12 | 8% |
| Other industries | 3785.01 | 42% |
| Other | 314.34 | 3% |

Company-level view

- One company
- One sector of economic activity/industry
- One revenue figure

Business lines view

- One company
- Multiple business lines
- Multiple revenue shares reflecting relative importance of business lines

Machine learning can bridge the gap and lift the weight of manual work, allowing for a **scaling up** of the proposed approach.

Estimating revenue shares by business lines reflects the combination of two tasks:

- A **multi-label classification** problem, combining NLP with:
 - Binary relevance, classifier chains, etc.
 - Deep learning.
- A **regression** problem, to assign the corresponding revenue share.

The two tasks, potentially, can be combined and performed in **one-go**

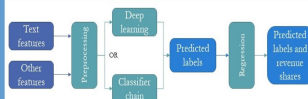
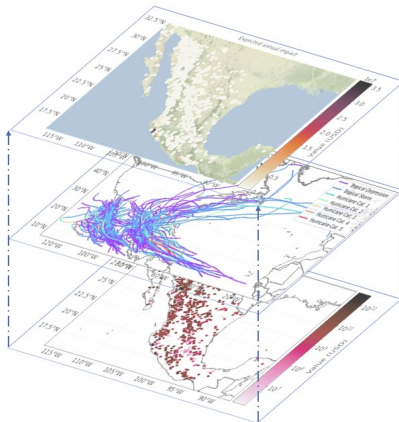


Figure: Business-lines view of a company and possible ML-based extension to automate the task (Bressan et al., 2022)

Asset-level probabilistic risk assessment - workflow



Impact

- **Direct damages** computed at different return periods and on average
- Info feeds into equity shocks and valuation adjustments

Hazards

- **Tropical cyclones** as computed in the CLIMADA model
- Other **acute** hazards shall be considered in further studies

Geolocalized assets

- Referenced by **latitude/longitude**
- Defined by asset type (e.g. power plant, mine, etc.)
- Non-financial variables (e.g. capacity, residual life)
- Financial variables (e.g. value)

Figure: Workflow for probabilistic disaster risk assessment for tropical cyclones in Mexico (Bressan et al., 2022).

Asset-level probabilistic risk assessment - historical

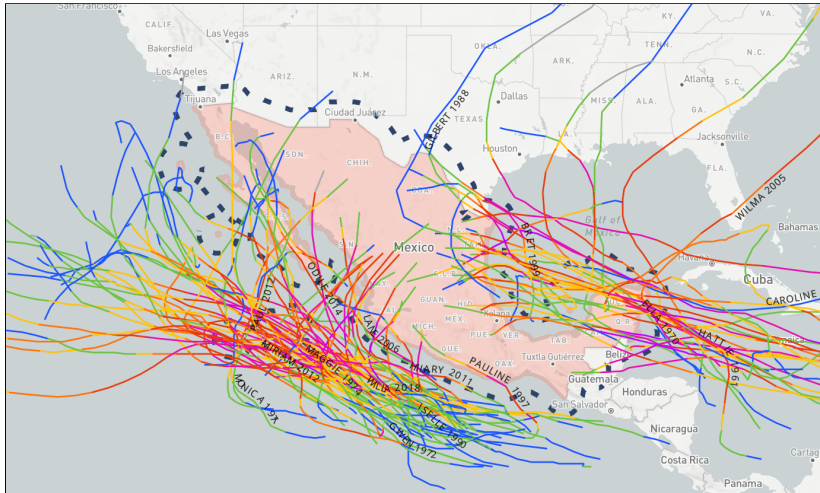


Figure: Historical data for tropical cyclones crossing Mexico. Source: NOAA.

Asset-level probabilistic risk assessment - hurricanes

- **Assets' geolocations** matched to wind-speed along tracks
- Assets are shocked with a damage function that translates wind speed in plant losses (monetary value):
 - $F_{index} = \frac{v^3}{(1+v^3)}$, $v = \frac{\max((W_{spd} - W_{tresh}), 0)}{(W_{half} - W_{tresh})}$
 - Where $W_{tresh} = 65\text{km/h}$ and $W_{half} = 253\text{km/h}$ (Dunz et al., 2021)
- Impact computed as **Expected Annual Impacts (EAI)**:

$$EAI_j = \sum_{i=1}^{N_{ev}} x_{ij} F(E_i), \quad (1)$$

- where X is the impact random variable, E_i an hurricane, F its annual frequency, N_{ev} are the independent events considered.
- Impact also computed for tail events (high **Return Periods (RP)**).

Climate-adjusted financial valuation

- We develop a three stages climate dividend discount model (CDDM)

$$V_0 = \sum_{t=1}^{t_1} \frac{D_t}{(1+r)^t} + \sum_{t=t_1+1}^{t_2} \frac{D_t}{(1+r)^t} + \frac{D_{t_2}(1+g_L)}{(1+r)^{t_2}(r-g_L)} \quad (2)$$

- D_t dividends, r discount rate, g_L long-run growth rate of dividends.
- Calibration:
 - Between $t = 1$ and t_1 firms' dividends provided by S&P
 - Between t_1 and t_2 Earnings Per Share are multiplied by payout ratio to describe the reversion of dividends
 - From t_2 onward the terminal value is computed.
- CDDM distinguishes short and long run impacts of physical risk.

Chronic and acute physical risks lead to adjustments in g_L

$$\tilde{g}_{L,(I,j)} = g_L \sum_{i=1}^{K_j} \left(\frac{O_{I,j,i}}{O_{B,j,i}} \frac{1}{\delta_{I,j,i}} s_{j,i} \right) \quad (3)$$

Adjustments from g_L to the climate risk-adjusted \tilde{g}_L depend on:

- **Chronic shocks** on sectors and business lines, described by $\frac{O_{I,j}}{O_{B,j}}$:
 - $O_{I,j,i}$ and $O_{B,j,i}$: output trajectories calculated for each business line i of owner j respectively under climate scenario I and baseline B
 - A ratio smaller than 1 implies a negative impact from chronic shock
- **Acute shocks** on assets described by $\frac{1}{\delta_{I,j,i}}$ for j :
 - δ : aggregation of acute shock on firms' assets by business lines
- The impact of both shocks is weighted by $s_{j,i}$, i.e. the **revenue share of the business line**, for all K_j firm's business lines.

Application to Mexico

- Mexico (MX) is relevant for cascading economic and financial losses: it is exposed to physical risks and has FDI and listed firms with global investors, it is also a main beneficiary of adaptation finance (UNEP, [2021](#)).
- 177 firms (MX + internationally owned) with 1,820 geolocalized assets in MX
- Exposure of European investors (banks, pension funds, etc) to MX firms via 17,147 equity holdings, 290.11 bn USD (June 30, 2020)
- Climate adjusted financial evaluation carried out at the year 2020
- Climate financial risk metrics computed with bootstrap

Acute shocks at the asset level

- Assets are heterogeneously distributed in MX, and differ by sector and productive capacity
- The impact of tropical cyclones increases significantly for higher Representative Concentration Pathway (RCP) scenarios and RP

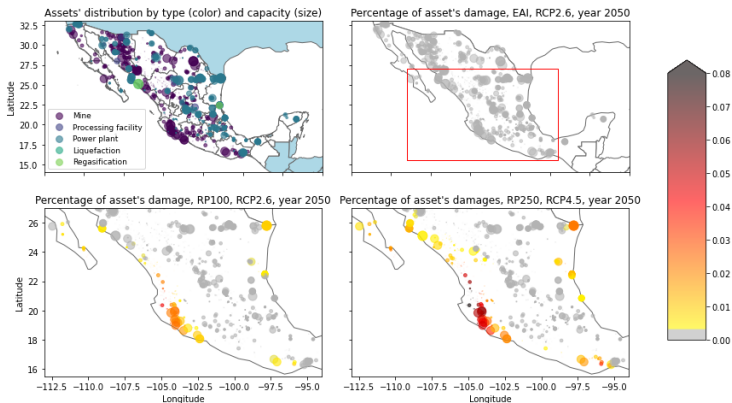


Figure: Assets' distribution and direct impact of hurricanes on assets (Bressan et al., 2022)

Acute vs chronic shocks on firms' stocks

1. Diversified companies (Company 1) have **both acute and chronic** shocks depending on share of revenues from assets and geolocations
2. Companies can have similar chronic shock (because same sector) but very **different acute shock** (due to geolocalization, Company 2 vs. Company 3)
3. Companies can have **large acute shocks** even if operating in different sectors (Company 3 vs. Company 4)
4. Companies can be affected by similar large acute shocks but **different chronic shock** (same pair as above)

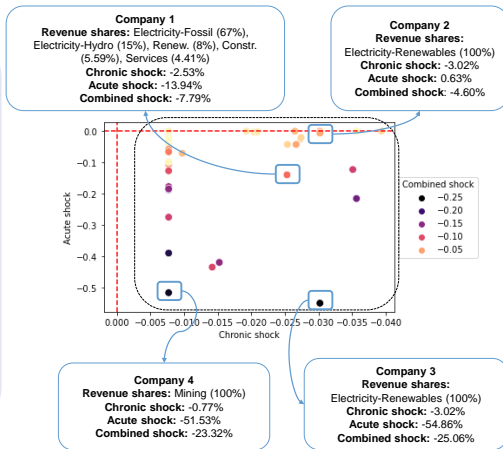


Figure: Scatter plot: for each firm (dot) shows acute, chronic and combined shocks. Scenarios combination SSP3, RCP4.5, year 2040. X-axis: chronic shock (relative change in stock value to no-shock), Y-axis: % of asset damages (Bressan et al., 2022).

Acute impacts lead to large losses on firms' stock value

- Black line: equal RP250 and average acute shocks on firms
- Firms below the black line: RP250 shocks are larger than EAI
- Histograms represent distribution of losses: RP250 has longer tail and larger support of distribution than EAI
- Ignoring acute shocks leads to underestimation of losses on stocks

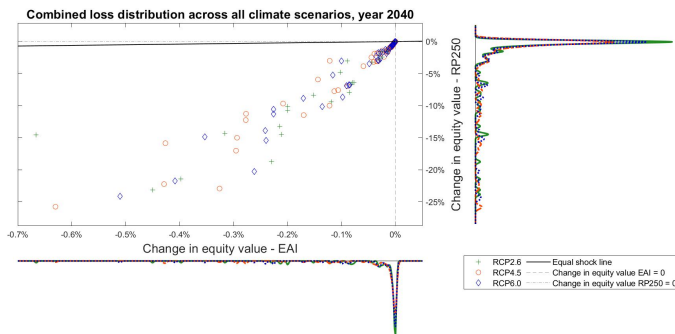


Figure: Scatter plot for the joint EAI and RP250 loss distributions for the year 2040, 86 companies with available asset-level data (Bressan et al., 2022).

Impact of discount rate and growth rate on equity value

- Higher (lower) **discount rate** r , lower (higher) equity losses
- Higher (lower) **growth rate** g_L , higher (lower) equity losses
- Higher (lower) **difference** $r - g_L$, lower (higher) equity losses

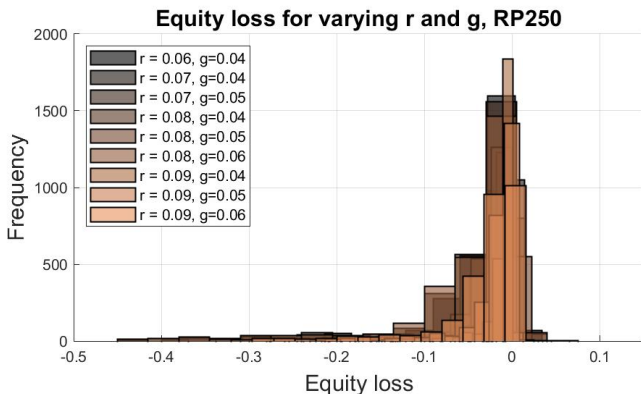


Figure: Sensitivity analysis of company-level losses from physical risk to different combinations of r and g_L (Bressan et al., 2022).

Tail acute risks and underestimation of losses

- How physical risks translate into portfolio losses for investors?
- We compare different futures of physical risks and quantify the underestimation of portfolio losses
- Neglecting acute risk leads to an underestimation of portfolio losses up to 82.2% Neglecting the tail component of acute risk (RP250) leads to an underestimation of portfolio losses up to 97.6%

| Compared physical risk futures | Underestimation range (%) |
|--|---------------------------|
| Chronic vs. tail acute (asset-level, RP250) | 73.2-79.3 |
| Chronic vs. chronic and tail acute (asset-level, RP250) | 78.8-82.2 |
| Average acute (asset-level, EAI) vs. tail acute (asset-level, RP250) | 96.7-97.4 |

Table: Underestimation of portfolio losses, scenario SSP3-RCP4.5, year 2040 (Bressan et al., 2022).

Asset-level data and underestimation of losses

- We compute results for the same firms as if asset information was not available, i.e. we measure physical risk at companies' MX HQ
- We quantify the underestimation of portfolio losses using firm-level instead of asset-level data
- Neglecting asset-level impacts leads to an underestimation of losses up to 70.8% for investors' portfolios

| Case | Underestimation range (%) firm-level vs. asset-level |
|--------------------------------|--|
| Acute RP250 (tail) | 67.4-92.3 |
| Chronic and acute RP250 (tail) | 58.0-70.8 |

Table: Underestimation of portfolio losses (cont'd), scenario SSP3-RCP4.5, year 2040 (Bressan et al., 2022).

Conclusions

- We introduce a **science-based methodology** to assess asset-level physical risks and loss cascades considering tail acute risk scenarios
- The methodology includes a CDDM model to integrate climate physical risk into **financial valuation adjustment** (stocks)
- We find that:
 - neglecting the **tail component** of acute risk can lead to up to 97% underestimation of portfolio losses
 - neglecting **asset-level data** can lead to up to 70% underestimation of portfolio losses
- Thus, considering tail risk and asset-level info is crucial for **climate financial risk management** and to inform **adaptation finance**

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Appendix

Cascading climate financial risks

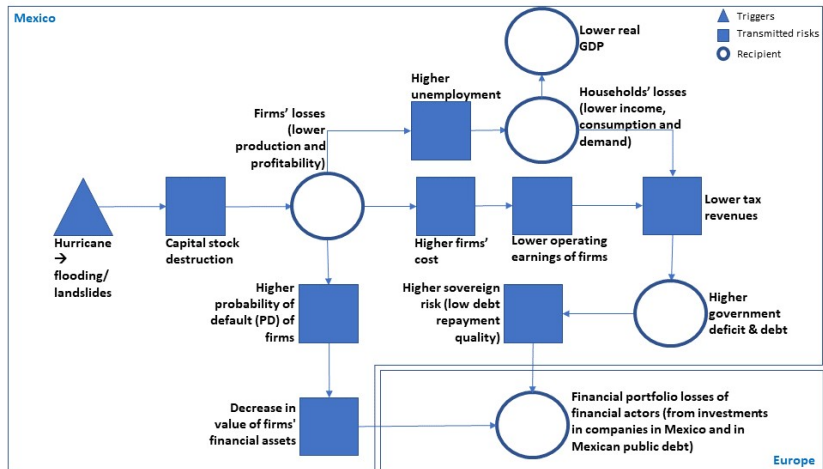


Figure: Cascading climate physical risk to the European financial system.

Cascading climate financial risks

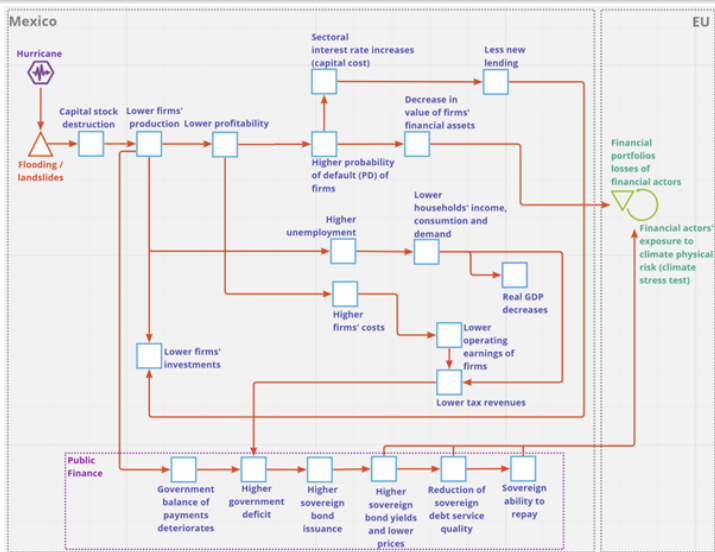


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