Investigating the links between CAT bond and capital markets with European natural catastrophes

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About the speaker

- **Fernando MIERZEJEWSKI –** *Consultant,* **Milliman Benelux**. *Risk expert with 20+ years of practical and academic experience implementing quantitative risk methodologies for the banking and insurance industries. Performs academic research within the fields of financial economics and actuarial risk theory.*

- Milliman is one of the world's largest independent consulting, analytics & actuarial firms. Currently advises over 80% of the world's leading insurers, with a **strong European base** spread across 14 offices in the continent. Milliman's unique approach offers **global expertise** and **market-leading technical skills** combined with local market presence, leveraging **in-depth knowledge of markets and regulations**.

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Executive Summary

- As climate change continues increasing the frequency and severity of **extreme natural catastrophe events** (re)insurance coverage is becoming less accessible and more expensive
- Relevant players in the European insurance sector have addressed the need for **promoting synergies between reinsurance and financial markets** as a means to expanding reinsurance capacity by leveraging capital from investors [IMF 2022; EIOPA 2024]
- Structured products such as **catastrophe (CAT) bonds** have been developed in financial markets offering protection against low-probability and high-severity climate-related events

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- We **investigate the links** between market spreads, and observed CAT Bond spreads, CAT Bond attachment probabilities & attachment points – under a **CAT Bond modelling framework** grounded in actuarial risk theory
- Market prices of financial transactions are primarily determined by market forces rather than any stylised pricing formula
- We aim to identify potential **misalignments** in CAT Bond, reinsurance and capital markets – linked to **frictions** in CAT Bond markets

What are CAT Bonds?

- Catastrophe bonds (**CAT Bonds**) are a type of insurance-linked-security (ILS) whereby investors receive periodic principal and interest payments compensating for potential losses due to a certain **natural catastrophe peril**
  - We say a contract defaults when losses exceed a pre-determined threshold, named **attachment point**
  - More precisely, the attachment point is the threshold that triggers a payout from investors to sponsors :
    - Below the threshold : investors keep their principal and pay standard coupons;
    - Above the threshold : capital is used to cover the sponsor's losses

- Pricing of CAT Bonds is made up of two components:
  - A **risk-free interest rate** to compensate investors for the loss of interest
  - A **spread over the risk-free interest rate** to cover for the underlying catastrophe risk

- When rated, CAT Bonds are comparable to **Medium to High-Yield Grades** of Corporate Bonds

Implemented approach – Agenda

I. Market Benchmark

Time series of market CAT Bond spreads, reinsurance indexes and corporate yields as a benchmark for catastrophe risk premiums

II. CAT Bond Markets

Apply regression analysis to evaluate the **log-linear relationship** between CAT Bond spreads & Expected Loss (EL)

III. Natural Catastrophe

Evaluate the **log-linear relationship** between CAT Bond spreads & Exceedance Probability (EP);

Estimate the **Pareto tail probability** for the pairs of attach.prob. & attach.point of observed CAT Bond transactions

IV. CAT Bond links to Natural Catastrophe

Investigate the links between CAT Bond markets with **implicit patterns** of natural catastrophe

V. CAT Bond Spread Sensitivity & Frictional Costs

CAT Bond spreads sensitivity & **Frictional Costs** – due to spreads, taxes, fees, and commissions – as determined by investors attitude towards risk

I. Market Benchmark

Study cases

REGION	PERIL	PERIOD	NR. OBS.	MODEL
Europe	European Windstorm	Sept. 2012 to Nov. 2025	16	CAT Bond Spread vs Expected Loss
USA	US Named Storm	June 2018 to Nov. 2025	32	CAT Bond Spread vs Expected Loss
Europe	European Windstorm	Sept. 2012 to Nov. 2025	14	CAT Bond Spread vs Default Probability
USA	US Named Storm	June 2018 to Nov. 2025	21	CAT Bond Spread vs Default Probability
Europe	European Windstorm	Sept. 2012 to Nov. 2025	12	Default Probability vs Attachment Threshold
USA	US Named Storm	June 2018 to Nov. 2025	12	Default Probability vs Attachment Threshold

- DATA – CAT Bond prices are retrieved from the platform ARTEMIS
  - ARTEMIS *covers CAT bonds, insurance-linked securities (ILS), alternative reinsurance capital, risk transfer, investments, longevity and weather risk markets.*

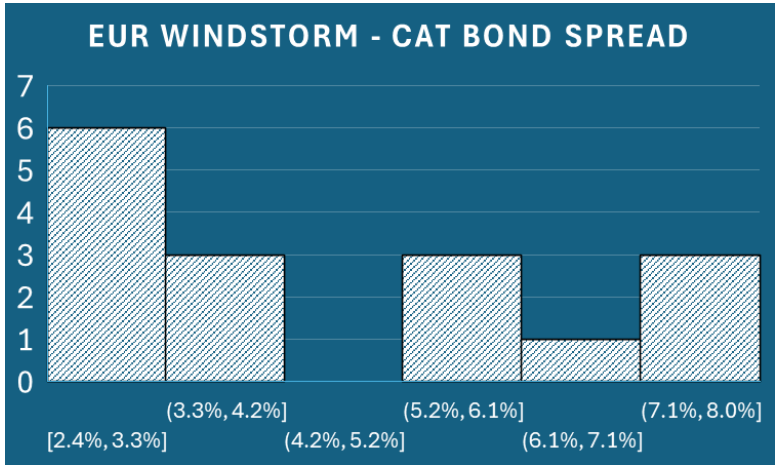
https://www.artemis.bm/deal-directory/?_sft_perils=european-windstorm

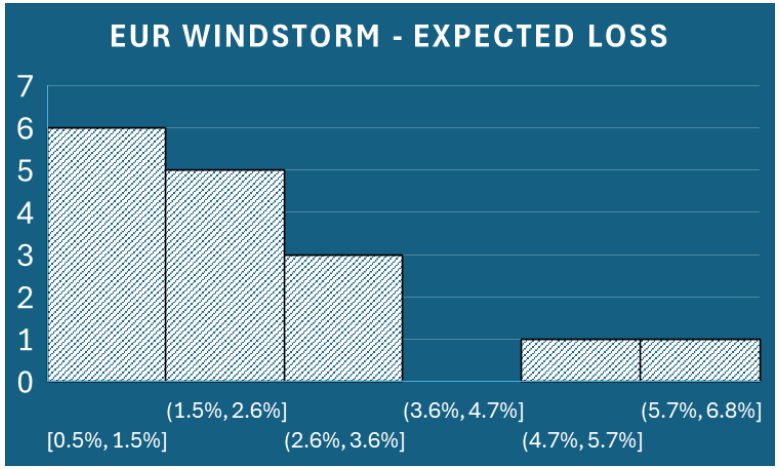
https://www.artemis.bm/deal-directory?_sft_perils=u-s-named-storm-and-hurricane-risks

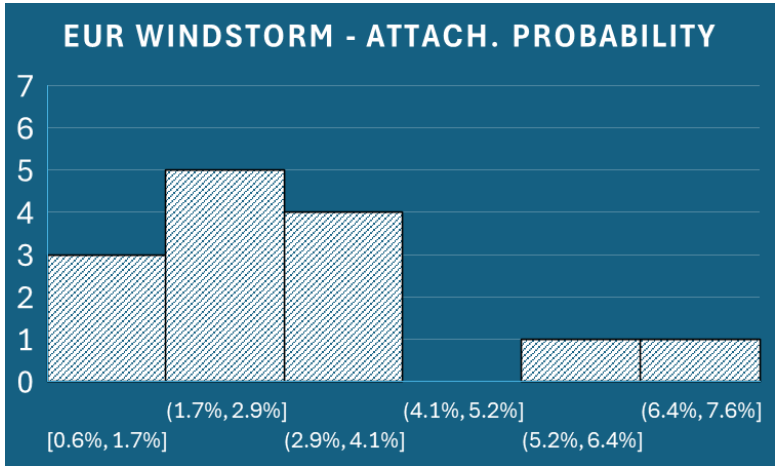
- The peril **European Windstorm (EUR.WS)** comprises the perils:
  - European windstorm [11 obs.]
  - European windstorm and severe thunderstorm [3 obs.]
  - European windstorm (France only) [2 obs.]
- The peril **US Named Storm (US.NS)** is a combined peril.
  - *The term "**named storm**" means any organised weather system with a defined surface circulation and maximum sustained winds of not less than 39 miles per hour which the **National Hurricane Centre of the United States National Weather Service** names as a tropical storm or a hurricane.*

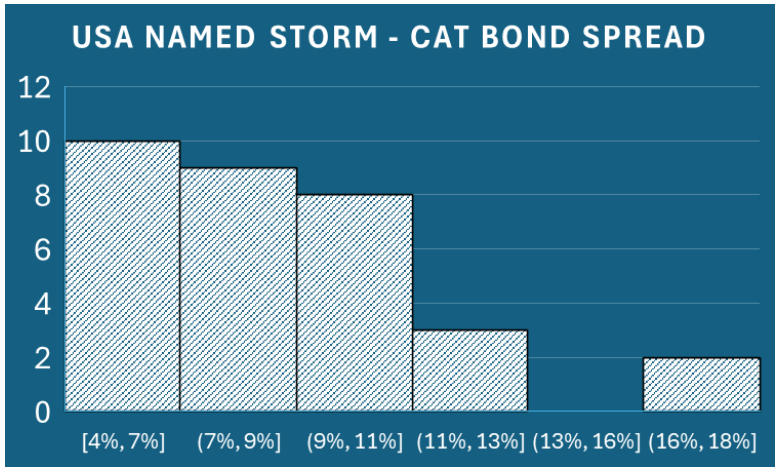
https://www.law.cornell.edu/uscode/text/42/4057#a_5

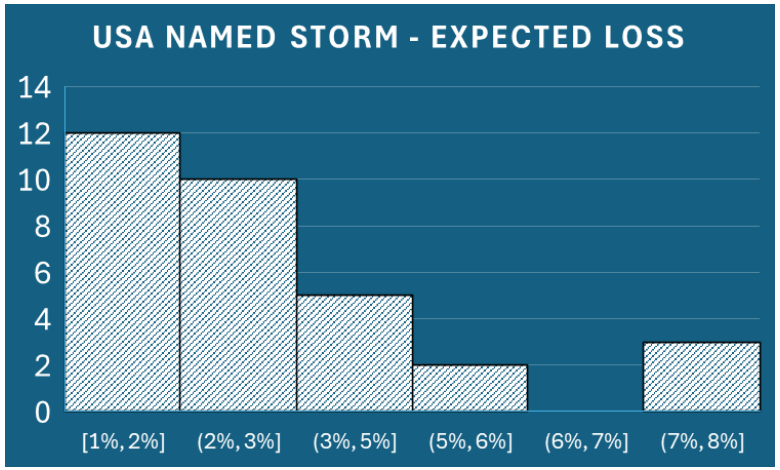
ARTEMIS CAT Bond Data

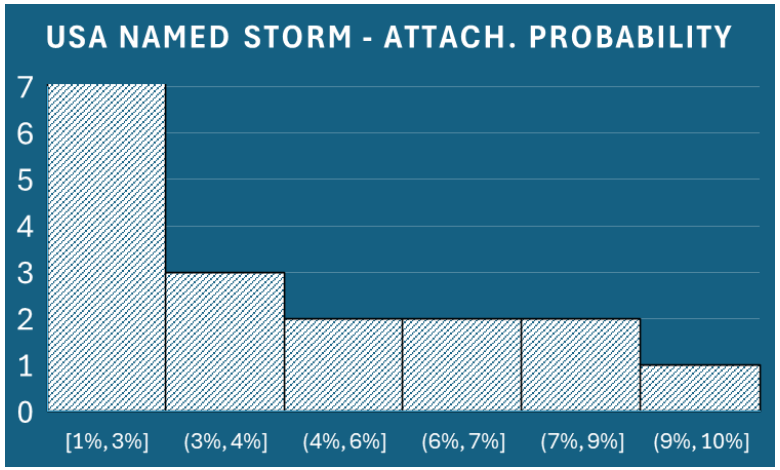




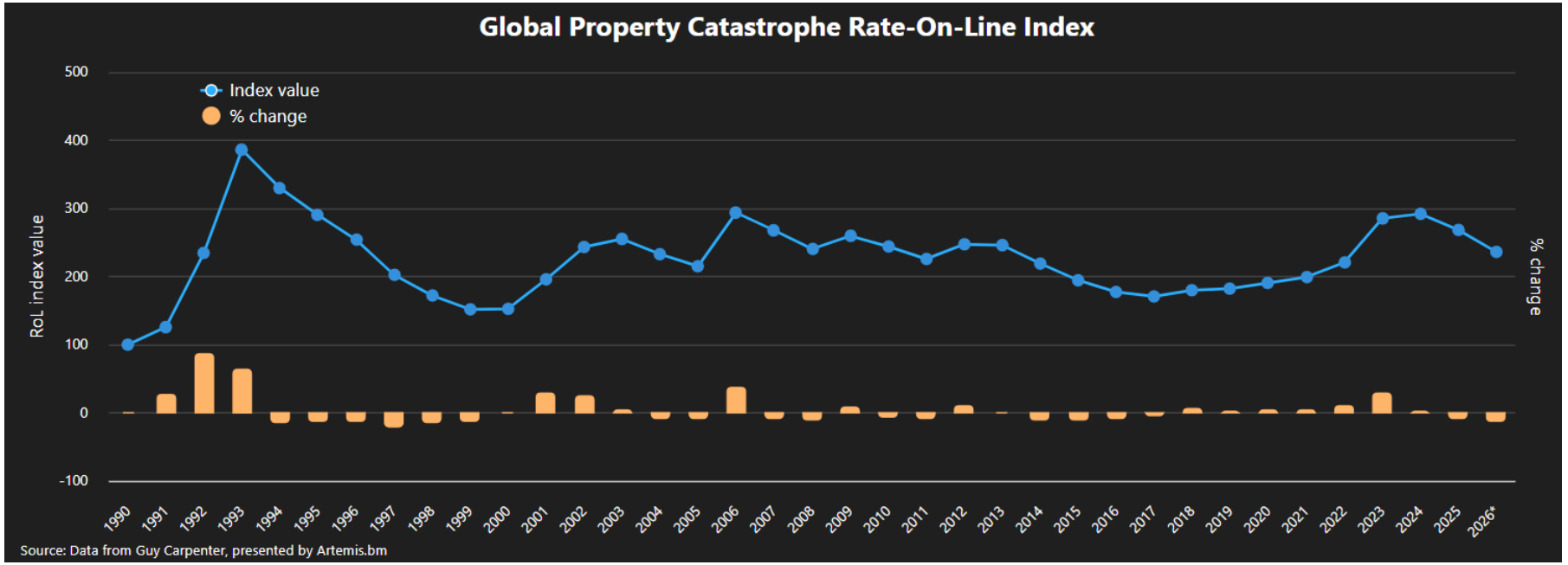


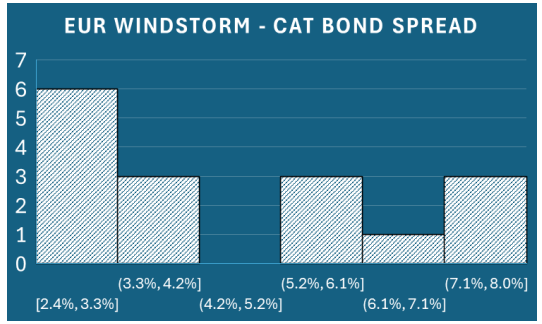


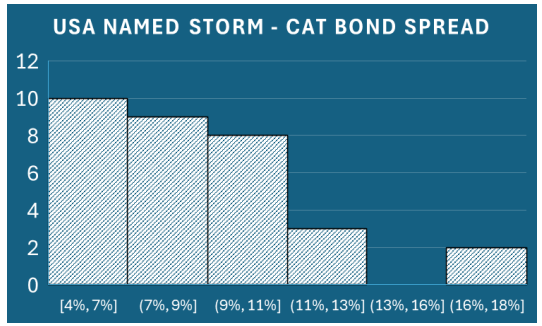




Guy Carpenter Property CAT ROL Index



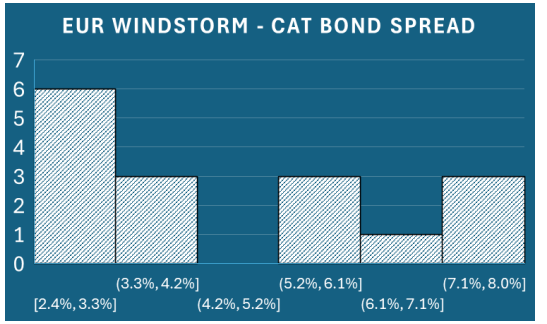


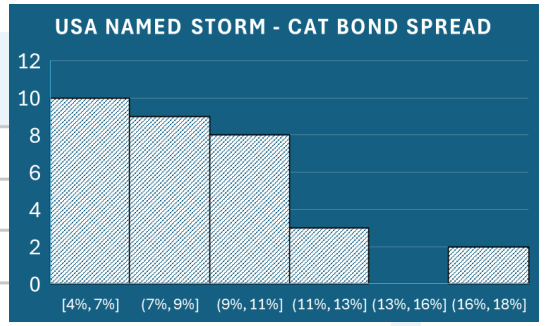


Guy Carpenter Global Property Rate-on-Line (ROL) Index – proprietary index of global property catastrophe reinsurance Rate-on-Line movements, on brokered excess of loss placements, maintained by Guy Carpenter since 1990. The index covers all major global catastrophe reinsurance markets. It is updated following January 1st renewals each year by calculating the change in ROL year on year across the same renewal base.

ARTEMIS | https://www.artemis.bm/global-property-cat-rate-on-line-index/

Euro & US High-Yield Spreads





FRED: Federal Reserve Bank St. Louis | https://fred.stlouisfed.org/series/BAMLHE00EHYIOAS

CAT Bond vs High-Yield Corporate Spreads

- ARTEMIS CAT BOND SPREADS :
  - **EUR Windstorm CAT Bond** spreads are distributed across the range [2.4% , 8.0%]
  - **US Named Storm CAT Bond** spreads are distributed across the range [4.0% , 18.0%]

- GUY CARPENTER CAT ROL IDX :
  - **GUY CAT ROL IDX** is distributed across the range [100bp , 400bp] ⇔ [1.0% , 4.0%]
  - The GUY CAT ROL IDX tends to show lower levels than CAT Bond spreads due to different **market dynamics** and **appetite for risk** between traditional reinsurance and CAT Bond markets.

    ARTEMIS | https://www.artemis.bm/news/cat-bond-market-yield-hits-9-3-as-spreads-rise-4-5-on-seasonal-widening-in-april-plenum/

- CORPORATE YIELDS :
  - **Euro & US High-Yield Spreads** are distributed across the range [2.0% , 11.0%]
  - CAT Bond spreads are comparable to High-Yield corporate spreads.

II. Implemented approach to CAT Bond Markets

- MODEL :
  - **CAT Bond spreads** are expressed as a function of the **Expected Loss (EL)** at the inception of the contract

- STUDY CASES :
  - EUR.WS : European Windstorm
  - US.NS : USA Names Storm

- DATA :
  - Artemis platform

Katsushika Hokusai. The Great Wave ca. 1830–32. Public Domain | https://www.metmuseum.org/art/collection/search/45434

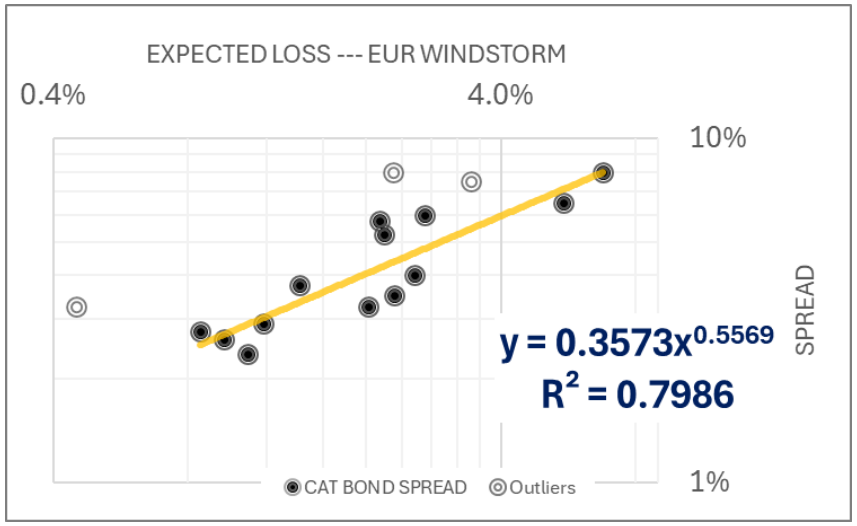
CAT Bond Spreads as determined by the Expected Loss (EL)

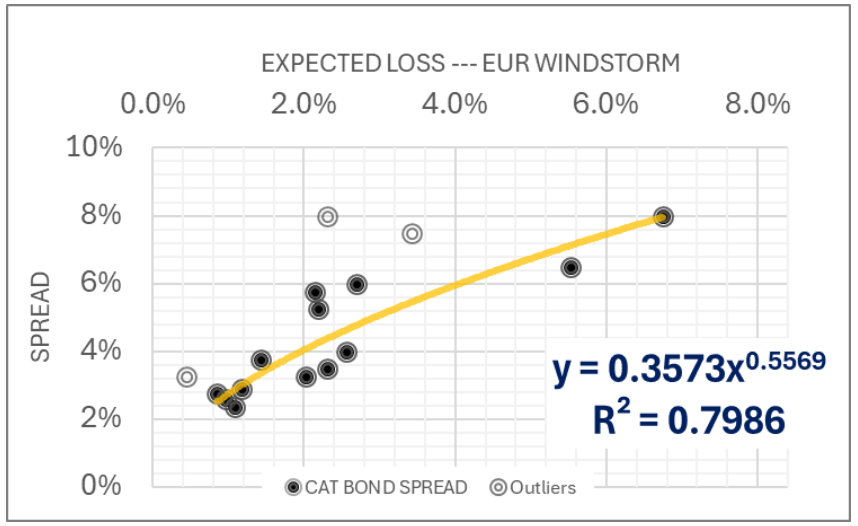
- MODEL – CAT Bond spreads are expressed as a function of the **Expected Loss** (**EL**) [ASTIN 2004] :

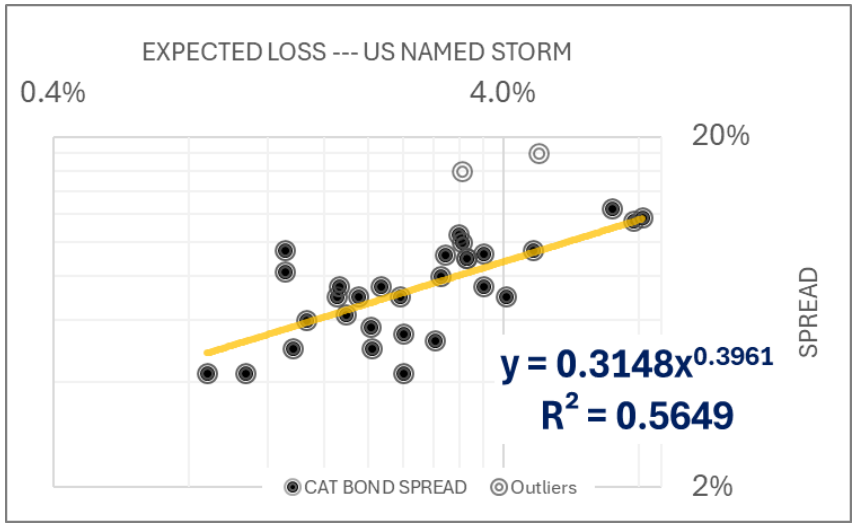
$$\textbf{CAT Spread} = \mathbf{C} \cdot \mathbf{EL}^{1/\theta}$$

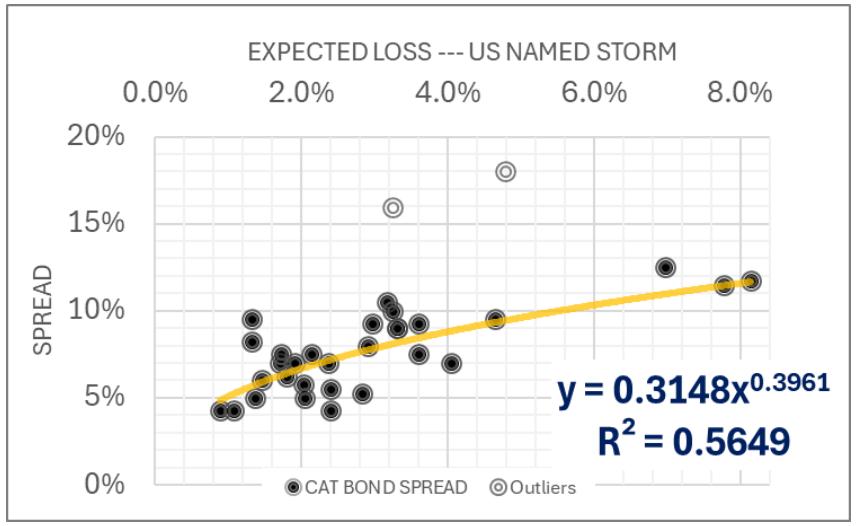
- **C** : ***peril-specific*** loss multiplier
- **θ** : ***market-specific*** attitude towards risk
- The formula is obtained under the assumption that the **tail-probability** of underlying CAT losses can be approximated by an **exponential decay function**

CAT Bond Spreads as determined by the Expected Loss (EL)









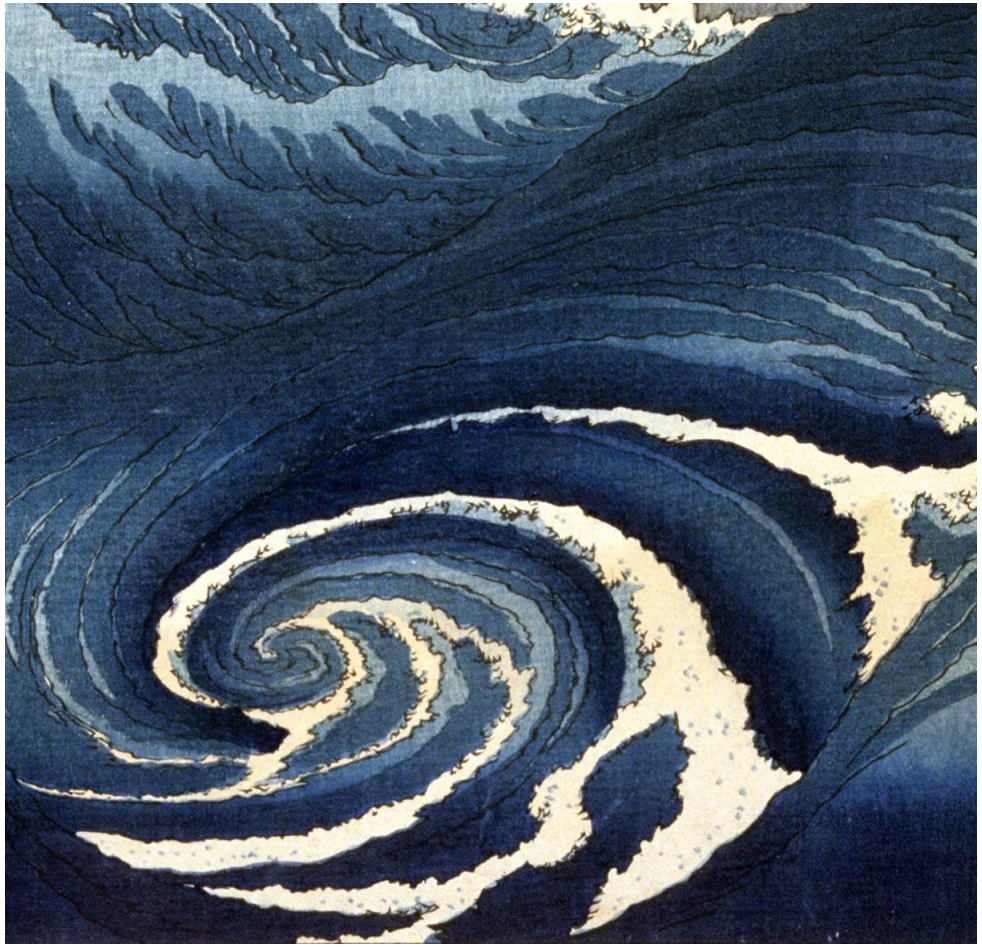
CAT Bond Modelling interpretation

- Investors in both markets show **aversion to risk** :
  - $\theta_{EUR.WS} = \frac{1}{0.5569} = 1.7957 > 1$ & $\theta_{US.NS} = \frac{1}{0.3961} = 2.5246 > 1$
  - $\theta > 1$ ➔ investors overestimate the price of NAT CAT risk ➔ investors are **averse-to-risk**
  - $\theta_{EUR.WS} < \theta_{US.NS}$ ➔ investors in the **EUR.WS market show more risk-tolerance than in US.NS**

- The **estimated peril-specific multiplier** is slightly higher for the EUR.WS peril than for the US.NS peril :
  - $C_{EUR.WS} = 0.3573$ & $C_{US.NS} = 0.3148$

- For the same expected return, the peril US.NS offers higher spreads than EUR.WS
  - This means that **US.NS is perceived by the market to be riskier, or harder to model, than EUR.WS** – which forces the sponsor to pay a higher premium to attract investors
  - Some evidence supporting that US.NS is harder to model : $R^2_{EUR.WS} = 0.7986 > R^2_{US.NS} = 0.5649$

III. Implemented approach to Natural Catastrophe



- MODEL :
  - **CAT Bond spreads** are expressed as a function of the **Exceedance Probability (EP)** i.e. the probability of default at the attachment point
- STUDY CASES :
  - EUR.WS : European Windstorm
  - US.NS : USA Names Storm
- DATA :
  - Artemis platform

Utagawa Hiroshige. Naruto Whirlpool ca. 1853. Public Domain | https://www.metmuseum.org/art/collection/search/53783

CAT Bond Spreads determined by the Exceedance Probability (EP)

- MODEL – CAT Bond spreads are expressed as a function of the **Exceedance Probability (EP)** – probability of default at the attachment point [IMA 2011; SAJ 2013] :

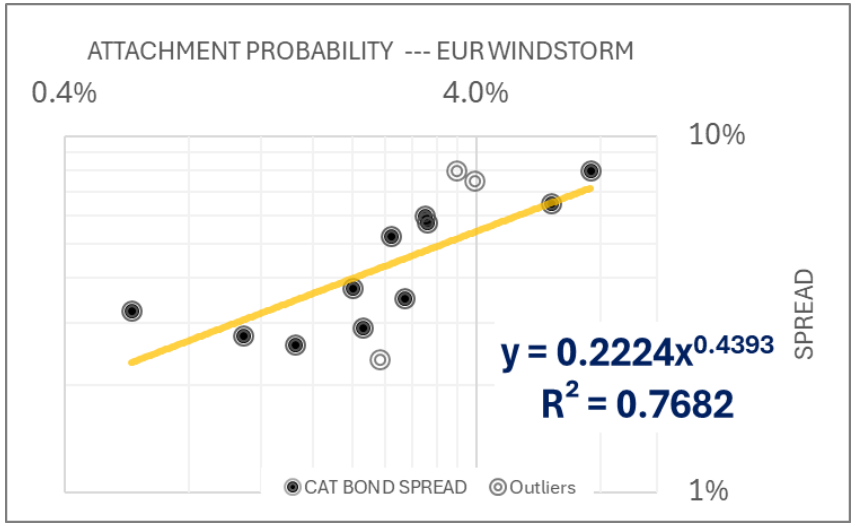
$$\textbf{CAT Spread} = \mathbf{C} \cdot \mathbf{EP}^{1/\theta}$$

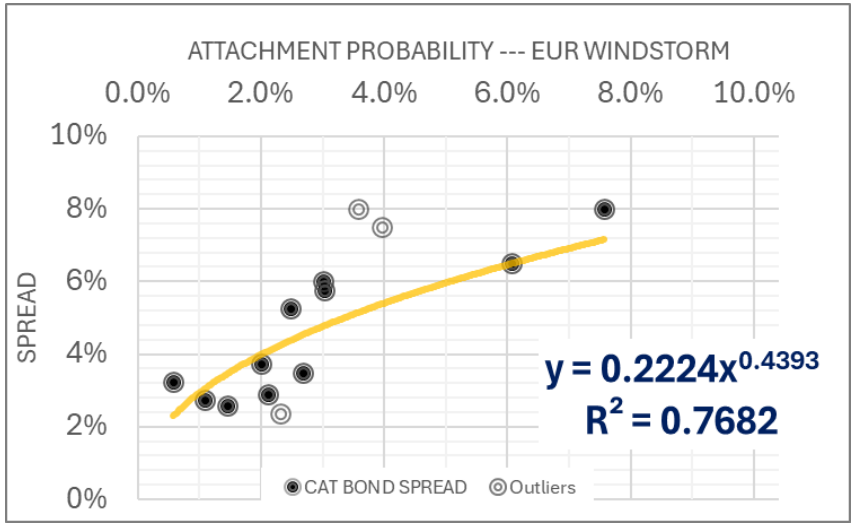
  - **C** : ***peril-specific*** loss multiplier
  - **θ** : ***market-specific*** attitude towards risk
  - The formula is obtained under conditions of equilibrium in CAT Bond markets, and under the assumption that the **exceedance probability** can be approximated by a **power-law (Pareto) decay function**

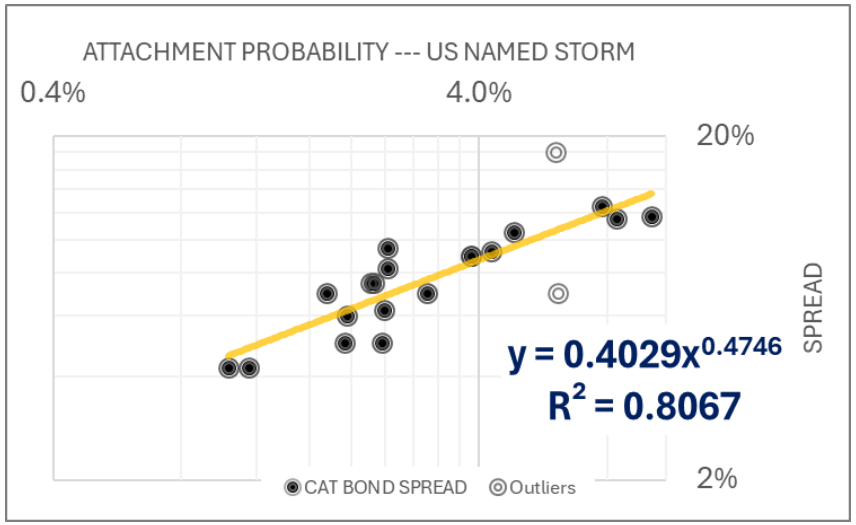
  - **Exceedance Probability** (**EP**): *key metric* in catastrophe modelling defined as the probability that the maximum loss from a given peril exceeds a pre-determined threshold – **used for assessing the risk quality of insurance and reinsurance contracts**

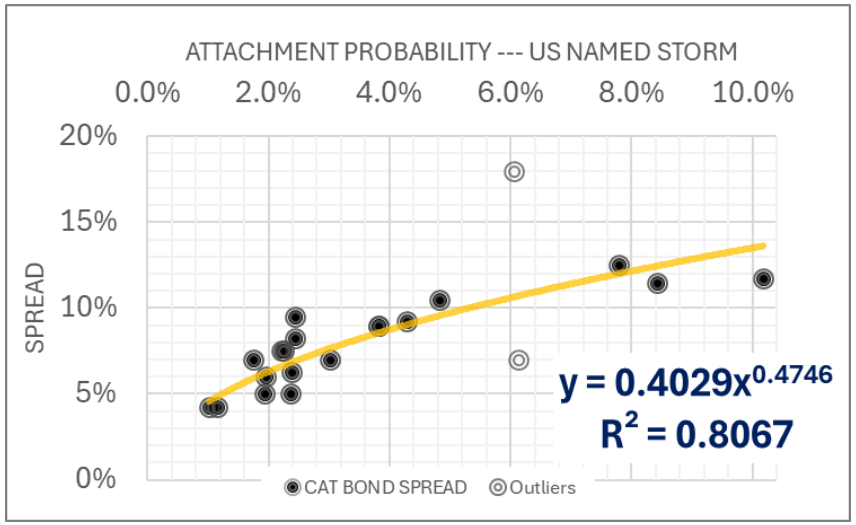
$$\mathbf{EP} = \varphi(Loss.Thr) \leftrightarrow Loss.Thr = F(Return.Period) = F\left(\frac{1}{EP}\right)$$

CAT Bond Spreads determined by the Exceedance Probability (EP)









CAT Bond Modelling interpretation

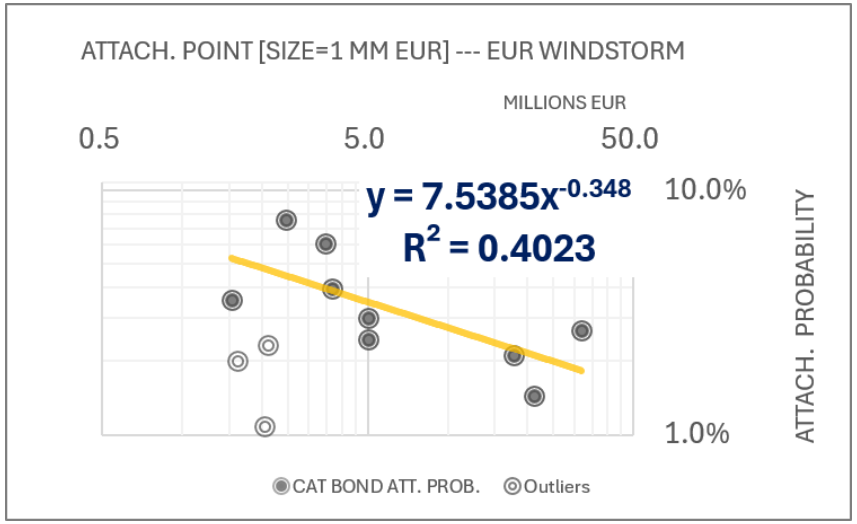
- Investors in both markets show **aversion to risk** :
  - $\theta_{EUR.WS} = \frac{1}{0.4393} = 2.2763 > 1$ & $\theta_{US.NS} = \frac{1}{0.4746} = 2.1070 > 1$
  - $\theta_{EUR.WS} > \theta_{US.NS}$ ➔ investors in the **EUR.WS market show slightly less risk-tolerance than in US.NS**

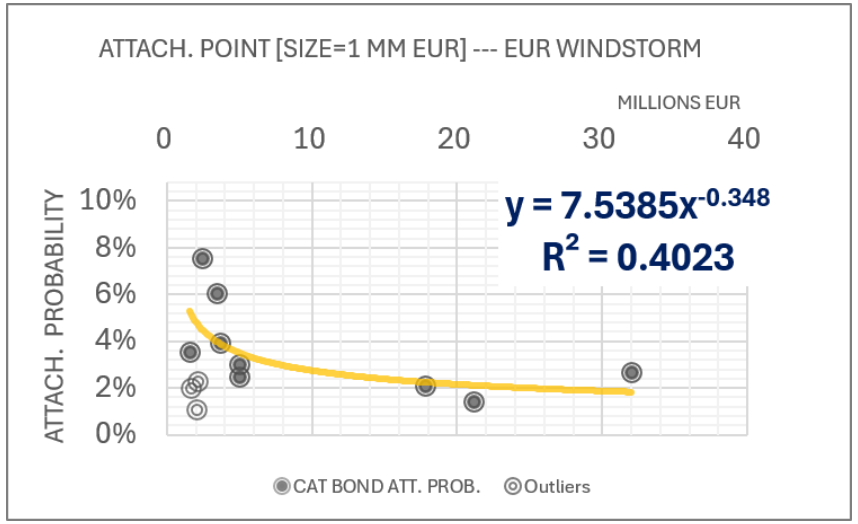
- The **estimated peril-specific multiplier** is slightly higher for the US.NS peril than for the EUR.WS peril :
  - $C_{EUR.WS} = 0.2224$ & $C_{US.NS} = 0.4029$

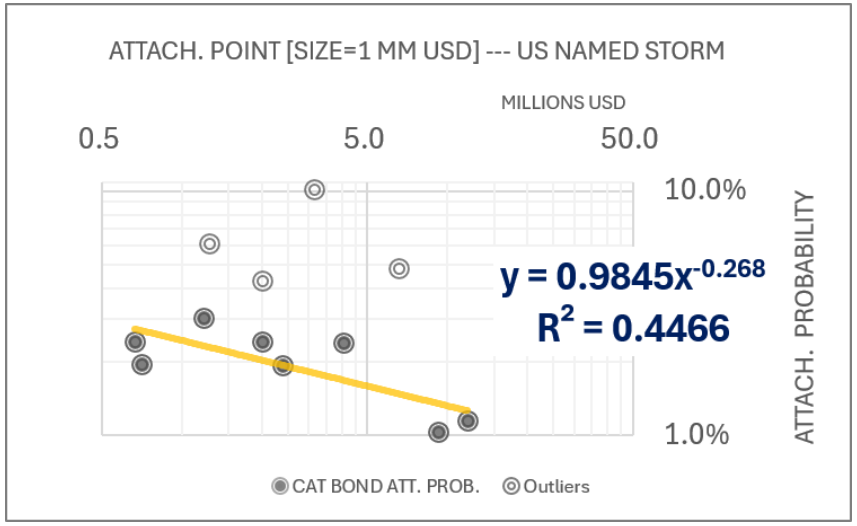
- For the same attachment probability, the US.NS peril offers higher spreads than EUR.WS – i.e. **US.NS is perceived to be riskier, or harder to model, than EUR.WS**

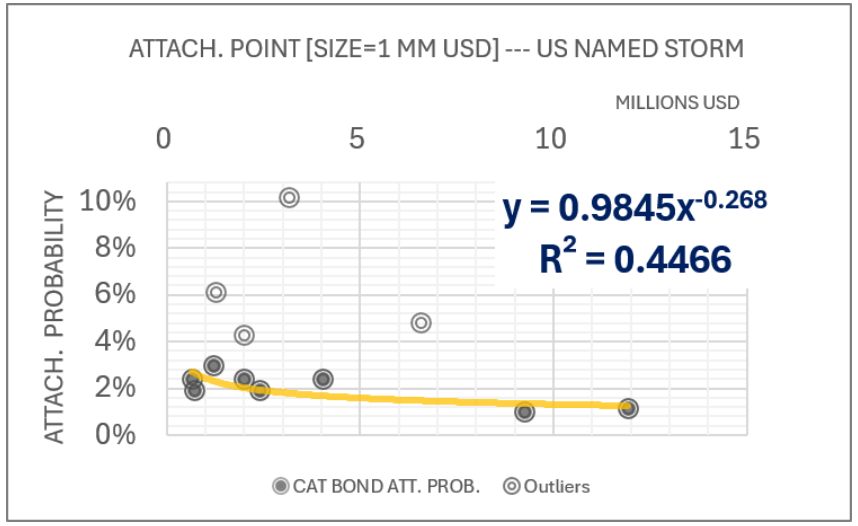
- Compare the **R-Squared measure** of the fitted EP model vs the fitted EL model :
  - Slightly decreases for the EUR.WS peril, from 0.7986 to 0.7682
  - Yet it notoriously increases for the US.NS peril, from 0.5649 to 0.8067

Exceedance Probability (approx. Pareto distribution)

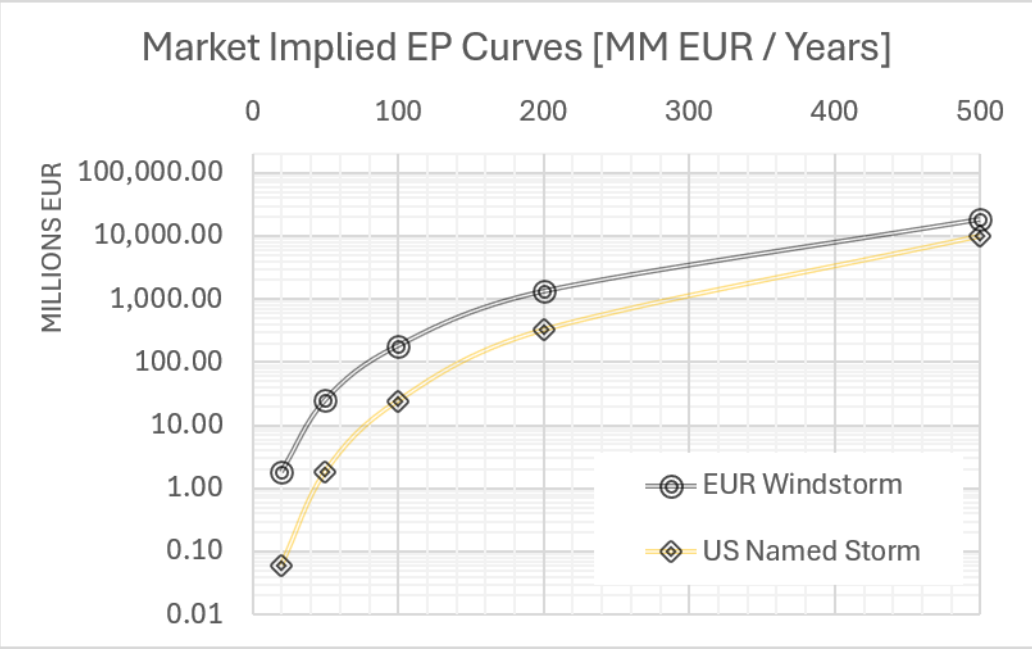


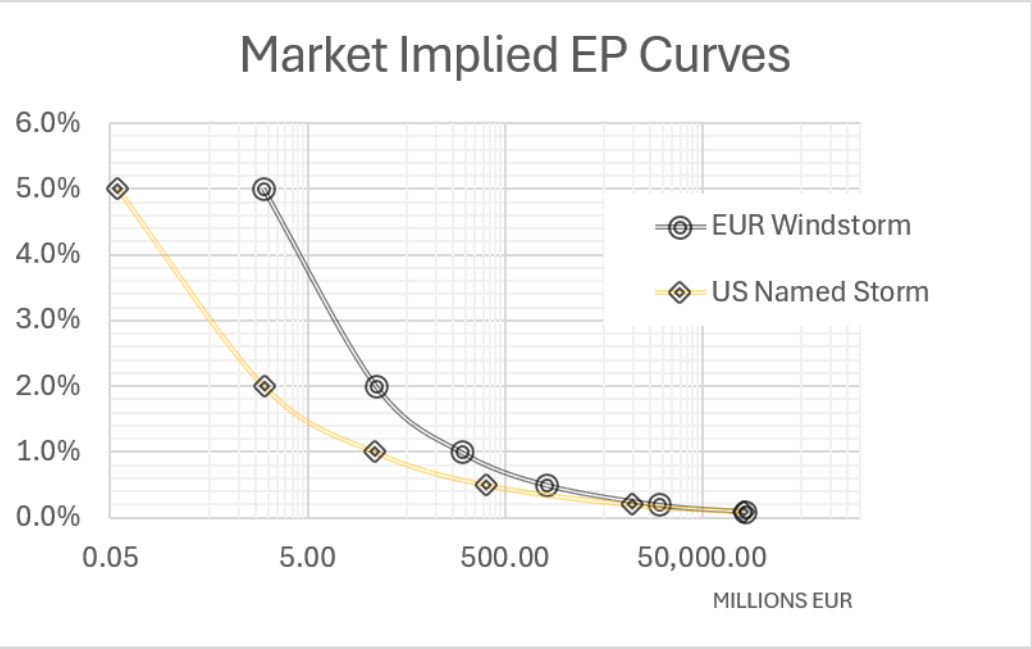






Exceedance Probability (EP) Curves





- The US.NS OEP curve represents a parallel upwards shift of the EUR.WS OEP curve consistently with the calibrated models :
  - EUR.WS investors show **more risk tolerance** than US.NS investors (higher aversion-to-risk parameter)
  - EUR.WS shows a higher **loss multiplier** than US.NS

Implied CAT Bond Tranches

CLASS SIZE (EXPOSURE) = 1 Million EUR	ATTACH. PROB.	SII CONF. LEVEL	RETURN PERIOD	ATTACH.POINT EUR Windstorm [Million EUR]	ATTACH.POINT US Named Storm [Million EUR]
Investment Grade	*0.10%*	**99.90%**	**1000**	**135.1914**	**131.9784**
Medium Investment Grade	*0.20%*	**99.80%**	**500**	**18.4820**	**9.8972**
Lower Investment Grade	*0.50%*	**99.50%**	**200**	**1.3315**	**0.3224**
Non-investment Grade	*1.00%*	**99.00%**	**100**	**0.1820**	**0.0242**
Somehow Speculative	*2.00%*	**98.00%**	**50**	**0.0249**	**0.0018**
Speculative	*5.00%*	**95.00%**	**20**	**0.0018**	**0.0001**

- The market regards EUR.WS tranches of lower quality than US.NS tranches :
  - Given any investment grade, a **higher attachment point** compensates for the perceived **lower quality** of the corresponding CAT Bond tranche
- EUR.WS and US.ND qualify as non-investment grade :
  - For a non-investment-grade (high-yield) bond exposure of one million EUR, investors would normally retain a loss between 400K and 600K EUR in the event of default

CAT Bond Links to Natural Catastrophe

- ❑ IV. CAT Bond Links to Natural Catastrophe
- ❑ V. CAT Bond Spread Sensitivity & Frictional Costs

- ❑ Conclusions
- ❑ Bibliographical references

Ogata Kōrin. Rough Waves ca. 1704–09. Public Domain | https://www.metmuseum.org/art/collection/search/44918

IV. CAT Bond Market links to Natural Catastrophe

- EVIDENCE FROM MARKET CAT BOND SPREADS :
  - For the same level of expected return, US.NS offers higher CAT Bond spreads than EUR.WS
  - For the same level of attachment probability, US.NS offers higher CAT Bond spreads than EUR.WS
  - The market regards **the peril US.NS as riskier, or harder to model, than the EUR.WS peril**

- EVIDENCE FROM MARKET-IMPLIED EXCEEDANCE PROBABILITY :
  - For the same investment grade, EUR.WS tranches receive higher attachment points than US.NS tranches
  - The market regards **EUR.WS tranches of lower quality than US.NS tranches**

- From a strictly risk-assessment perspective, the CAT Bond market seems to **inconsistently designate the risk quality of the EU WS and US.NS perils** :
  - Market data on CAT Bond spreads ➔ US.NS is perceived as riskier than EUR.WS
  - Market data on attach. probabilities & attach. Points ➔ EUR.WS is perceived as riskier than US.NS

V. CAT Bond Spread Sensitivity & Frictional Costs

- The market-specific **parameter $1/\theta$** denotes the slope in the line of CAT Bond spreads in the regression model, and thus represents the **model-derived sensitivity** :
  - CAT Bond spreads are more sensitive to the Expected Loss for the EUR.WS than for the US.NS market
  - The CAT Bond spread sensitivity with respect to the Excedaance Probability is similar for both markets

- Market-specific **risk-attitude θ** determines the **incurred frictional costs** [ASTIN 2004] :
  - Explicit plus hidden cost of executing transactions – expressed as bid-ask spreads, taxes, commissions, as well as application, origination and broker fees
  - $\lambda = 1 - \frac{1}{\theta}$ therefore : $\theta \uparrow \rightarrow \lambda \uparrow$ for $\theta \geq 1$ & $\theta \uparrow \rightarrow \lambda \downarrow$ for $0 \leq \theta < 1$
  - Comparatively **less risk-tolerant investors** ($\theta \uparrow$) require an additional premium to bear risk, which leads to comparatively **higher frictional costs** ($\lambda \uparrow$)

- CAT Bond Spread vs Expected Loss regression model [ASTIN 2004] :
  - $\theta_{US.NS} > \theta_{EUR.WS} \rightarrow \lambda_{US.NS} > \lambda_{EUR.WS}$
  - Sponsors in the US.NS market must bear **higher frictional costs** than in the EUR.WS market

Conclusions

- Observed CAT Bond spreads are generally higher than similarly rated corporate bonds
  - The gap reflects business opportunities missed due to **frictional costs** [ASTIN 2004]

- Loglinear regression model of CAT Bond spread vs of EL or EP :
  - The market regards the peril **US.NS as riskier, or harder to model, than EUR.WS**
- Loglinear regression model of attach. probability vs attach. threshold :
  - The market regards **EUR.WS tranches of lower quality than US.NS tranches**
- Link between CAT Bond frictional costs & general attitude-towards-risk :
  - Model-derived **frictional costs** are **higher** in markets where investors show **less tolerance** towards risk

- US.NS CAT Bond spreads can be higher than EUR.WS CAT Bond spreads while EUR.WS tranches are regarded of lower quality than US.NS tranches :
  - The excess of US.NS spread over EUR.WS spread is partially caused by outstanding **frictions within CAT Bond markets** which are more pronounced in US.NS than in EUR.WS markets
  - The gap is explained on the grounds of **liquidity** rather than risk-modelling factors

References

- [ASTIN 2004] Christofides, S. (2004). “Pricing of Catastrophe Linked Securities”. ASTIN Colloquium International Actuarial Association, Brussels, Belgium, 2004.
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Thank you

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