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Pricing of insurance-linked securities

led by

Actuarial Intelligence Triangle limited company

Open Floor

Polish Society of Actuaries

31 January 2024

Pricing of insurance-linked securities

Abstract

This seminar focuses on a brief market overview, valuation techniques and pricing theory of insurance-linked securities (catastrophe bonds, insurance loss warranties, etc.) as an alternative (and not limited to) catastrophe risk-transfer solution that can help to close identified protection gaps and increase personal and societal resilience.

Actuarial pricing techniques, including machine learning approach, are becoming more important in catastrophe modelling as the severity and frequency of natural events are getting ever more unpredictable with the acceleration of the climate change dynamics.

Presenters

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Agenda of the presentation

1. AI Triangle – short intro *[Grzegorz Kukla]*
2. What is the insurance-linked security *[Grzegorz Kukla]*
   - Popular ILS structure – how it works
   - Main ILS types
3. Introduction to ILS pricing *[Michał Suchan]*
   - Determining the price of a Catastrophic bond
   - The Sponsor and the Inwestor perspective
   - Components of price: risk-free rate, spread
   - Other considerations
4. Pricing of ILS [*Krzysztof Burnecki*]
   - Different pricing approaches
   - Machine learning approach

AI Triangle – short intro

Grzegorz Kukla

AI Triangle – short intro

ACTUARIAL INTELLIGENCE TRIANGLE

WHO ARE WE?

OUR COMPANY

- The newly established **Actuarial Center of Excellence in Poland** with actuarial services for (re)insurance companies wordwide
- The symbolism of our name - the three vertices of the triangle means our capabilities and skills: **actuarial, scientific, and IT**
- We want to combine them to provide our clients with c**omprehensive solutions**

OUR TEAM

Licensed actuaries with many years of experience in the insurance industry and consulting

People with educational **background in mathematics and computer science**

Scientists and research workers

IT specialists

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ACTUARIAL TEAM

Service or support of pricing and independent review (Local GAAP, IFRS including IFRS17, Solvency II, financial cash-flows, (re)insurance portfolio valuation, other actuarial tests, and analyses)

We are the real members of Polish Society of Actuaries (PSA). The PSA is a full member of the International Actuarial Association (IAA) and the Actuarial Association of Europe (AAE), and the qualifications of a Full Fellow of the PSA are equivalent to European and global actuarial requirements

Review or analyze/ development of internal control system, reinsurance program, insurance risk management, financial analysis, ESG risk identification/ analysis/reporting, support in M&A (business plan, capital valuation)

Actuarial practitioners with experience in both the insurance (non-life and life) and advisory industries

ACADEMIC TEAM

- Advanced Monte Carlo simulations (financial and insurance scenarios)
- Forecasting the mortality rates (including AI techniques)
- Pricing of financial instruments, reinsurance contracts and CAT bonds
- Analysis of financial and insurance risk
- Point and interval prediction with the use of time series models
- Data anomaly detection
- Statistical testing and validation fitted stochastic models
- Machine Learning / Artificial Intelligence approach deployment

Applied mathematicians with varied experience – assistant professors, Ph.D., and master's students

Bringing the latest scientific achievements to actuarial practice

Educating young adepts of actuarial science

IT TEAM

Thanks to the access to Wroclaw (Poland) fast-growing IT hub in the EU, we can provide your company with technologies like:

- Artificial Intelligence
- Intelligent automation
- Software development
- Anomaly measurement alerting
- Supply chain forecasting
- Big Data visualization
- Prediction models for finance
- SLA monitoring and identity verification

What is the insurance-linked security

Grzegorz Kukla

What is the insurance-linked security

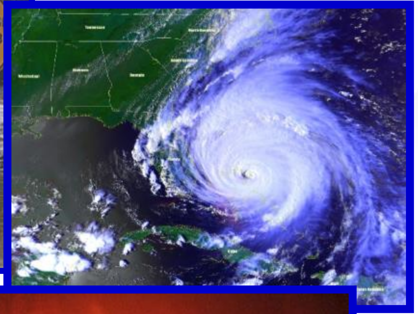
The fact is, that factors like:

- climate change,
- environmental devastation,
- global inflation (in claims and cost)
- people concentration in high-risk areas,

they have an undeniable impact on huge damage from natural catastrophes such as:

- earthquakes,
- floods,
- hurricanes,
- wildfires
- winter storms,

which have become more intense and frequent in recent years.
The large gap in (re)insurance protection (capacity) has been identified all around the world during last years.
It makes more difficult for businesses and people to recover from disasters. **The insurance-linked securities can help.**



What is the insurance-linked security

Definition

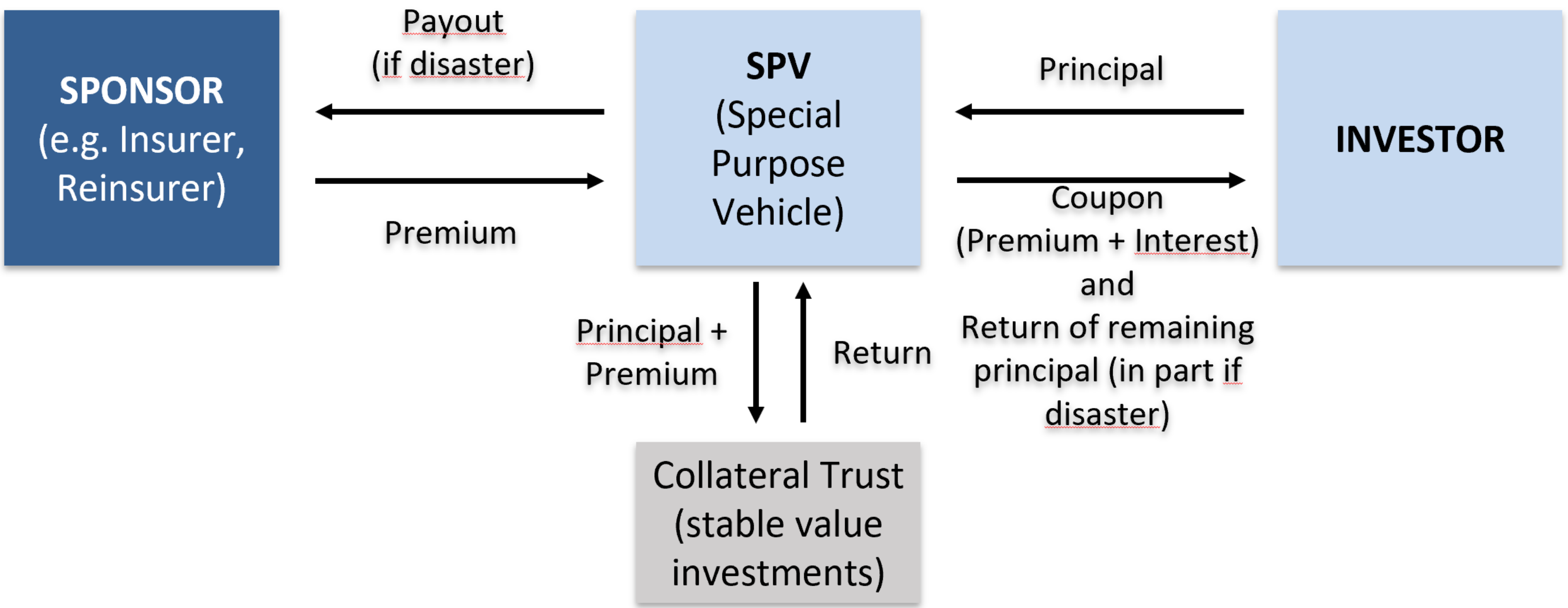
Insurance-linked securities, or ILS, are essentially financial instruments which are sold to investors whose value is affected by an insured loss event (www.artemis.bm definition).

Insurance-linked securities are an innovative type of financial product that connects the (re)insurance industry and capital market. The securitization market, existing since the mid-1990s, is mainly used by reinsurers and insurers who want to transfer risk to the capital market.

Note: ILS are investment assets linked to insurance-related, non-financial risks such as **natural disasters, life and health insurance risks including mortality or longevity**, but also newly present in other risks such as **mortgage, casualty and cyber**. They are generally thought to have little to no correlation with the wider financial markets (and that is why they enjoy great interest from investors).

What is the insurance-linked security

Popular ILS structure – how it works



What is the insurance-linked security

Main ILS types

Thera are main types of ILS:

- Catastrophe (Cat) Bonds
- Sidecars
- Industry-Loss Warranties (ILW)
- Collateralized Reinsurance and many other types

What is the insurance-linked security

Catastrophe bonds (CAT bonds)

- the most popular type of ILS
- used mainly by (re)insurers to transfer major risks on their books, such as for hurricanes, windstorms, and earthquakes to capital market multiple investors
- unlike traditional reinsurance where it is possible for the reinsurer to fail to pay out following a loss event, CAT bond is 100% collateralized and structured to eliminate counterparty risk; it is also **standardized paper** – this make it very popular among investors
- special-purpose vehicles (SPV) through which (re)insurer cede premiums associated with a book of business to multiple investors who place sufficient funds in this SPV to ensure claims are paid if they arise – for reduction the (re)insurers loss
- payment of interest or principal to the (re)insurer depends on the occurrence of a catastrophe event
- can be structured as **long-term instrument** covering a broad array of perils and geographies

What is the insurance-linked security

Catastrophe bonds (CAT bonds)

Four broad **types of catastrophe bond triggers** exist, with the first three being more traditional:

1. **indemnity triggers**, where the trigger is based on the actual losses of the issuer/sponsor – (re)insurer;
2. **parametric triggers**, where the trigger is based on the occurrence of pre-specified characteristics or criteria of a pre-specified natural disaster;
3. **industry index triggers**, where the trigger is based on insurance-industry catastrophe loss indices (e.g. Property Claim Services by Verisk)
4. **modelled loss triggers**, wherein a risk-modelling firm provides an evaluation of the catastrophe risk

What is the insurance-linked security

Sidecars

- Sidecars are deployed mainly by reinsurers following major catastrophes to add risk-bearing capacity in periods of increased market stress by sharing risk and risk-return according to a **fixed percentage** (like quota-share reinsurance contracts)
- typically used to spread catastrophe risk, like hurricanes, floods, or earthquakes
- in contrast to CAT bonds, **Sidecars are tactical instruments of limited duration, during a hard market** (they became popular after Hurricane Katrina event in 2005)

What is the insurance-linked security

Industry-Loss Warranties (ILW)

- popular hedging tools for reinsurance firms, enabling them to hedge their broad industry exposure to major catastrophe losses using a **contract that pays out based on the industry-wide loss experience from an event**
- the payment trigger - industry-wide loss – naturally involves **base risk** (reinsurer may receive some deviations in payment vs real loss because of different exposure to the event than wide market exposure
- like Sidecars - **tactical instruments of limited duration**, deployed mainly by reinsurers at the end of calendar year (during the renewal period) to close the remaining part of risk exposure in the portfolio

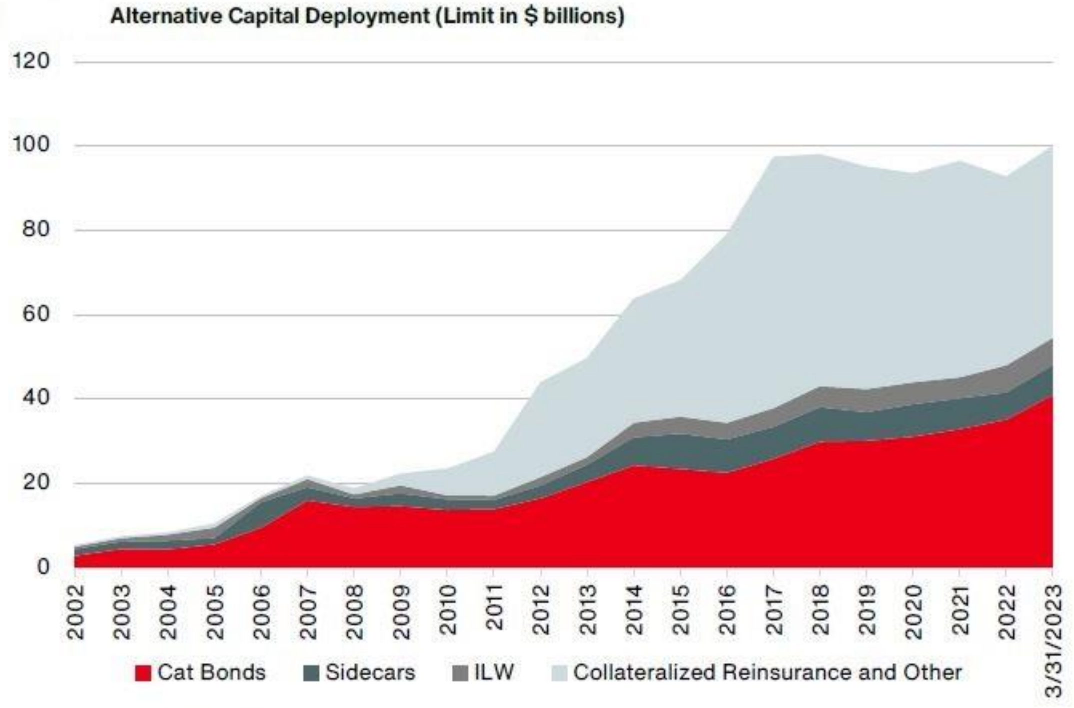
What is the insurance-linked security

Collateralized reinsurance

- The market in collateralized reinsurance enables these institutional investors to **directly participate in the reinsurance market** and provide a source of risk capital to cedents in the market
- The collateral is put up by investors to cover in full the **potential claims** that could arise **from the reinsurance contract**
- often created by taking reinsurance contracts and transforming them using an offshore entity into securities which are bought and so collateralized
- normally the collateral posted is equal to the full reinsurance contract limit, minus the net premiums charged for the protection
- **more customizable but less liquid investments than CAT bonds**
- they **became popular when interest rates dropped to near zero** and then collateralized reinsurance allows ILS funds, hedge funds, pension funds and unrated, third-party capitalised reinsurance vehicles to receive **better yield** by participation in major reinsurance programs as the contracts they wrote were **fully-collateralised**

What is the insurance-linked security

ILS market
(2002 - Q1 2023),
cumulative
values



Source: Aon Securities, LLC

Introduction to ILS pricing

Michał Suchan

Introduction to ILS pricing

Determining the price of a Catastrophic bond

We will focus here on the characteristics of a simple Catastrophic bond as an example of an ILS type product.

In general, the pricing of such product is made up of two components, a spread or margin over the risk free rate to cover the insurance risk and an underlying risk free rate, usually taken as government bond return, to compensate investors for loss of interest during the period in question.

This can be shown as an equation:

Return (yield %) = risk-free rate (%) + Spread (%, expected loss, margin, costs)

Introduction to ILS pricing

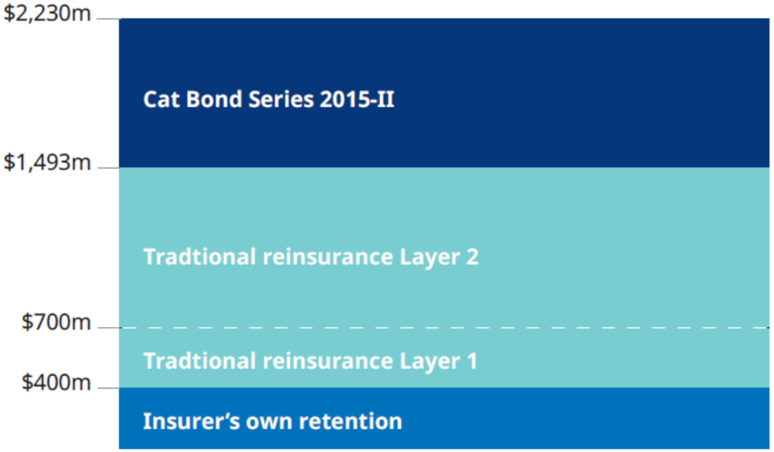
The Sponsor perspective

The following shows how the Sponsor would view such transaction, which simply put would look like a typical Cat excess of loss type of coverage.

This basically gives the Sponsor additional cover above a certain threshold (attachment, trigger) point and for a defined amount (limit).

Why do it?

- Sponsors gain a diversifying capital as compared to their shareholder capital or debt or traditional reinsurance
- additional capital allows the Sponsor to assume more risks
- diversified sources of capital support a more stable risk taking activity

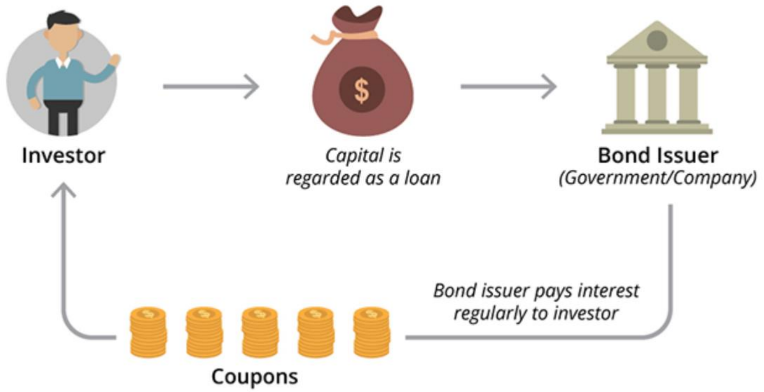


Source: Schroders, for illustration only.

Introduction to ILS pricing

The Investor perspective

The following shows how the Investor would view such transaction.
Taken at face value the loss characteristics of ILS are very similar to those of government or corporate bonds. An event triggers a loss that in turn results in a total or partial loss of capital. The only differences are then in what causes these events and then what determines how much of the capital is actually lost.



Why do it?
- main reason for Investors to invest in ILS products is the diversification effect compared to traditional asset classes
- ILS products are not sensitive to market volatility, triggers are based on natural events
- it is also an interesting way to invest in insurance risks, without assuming any business related risks (e.g. investing in stocks of (re)insurance companies)

Introduction to ILS pricing

Components of price: risk-free rate

The risk-free rate is usually the interest rate associated with government type bonds and investment products. This are usually very safe investments, where the underlying credit risk is a government entity (country), e.g. US Treasuries, UK, German, French government bonds. Also often money-market and liquidity funds are used, as they have a very low risk profile.

- The goal of this component is to compensate investors for the ordinary, risk-free interest, they would otherwise be able to achieve by simply putting their money into the investment market
- This component is often required to be very safe and only highly rated instruments are used
- For some transactions, this could also be a more risky portfolio (depending on investor preferences)
- Sometimes also a possibility is to use illiquid investments as collateral for such transactions (depends on investor and sponsor preferences and risk appetite).

Introduction to ILS pricing

Components of price: spread

The Spread component is equivalent, and directly comparable, to the traditional catastrophe reinsurance layer cost expressed as a Rate On Line (ROL). In other words, it expresses the expected loss (amount expressing the annual expected loss burden) divided by the limit of the transaction.
For example, if the Cat bond covers a limit of 100m USD and we expect a 5m USD loss each year, then the Spread of such transaction would be 5%.

- In practice the ROL or the Spread will include not only the expected loss
- Additional components could be the margin assumptions of the reinsurer, any additional costs (e.g. brokerage, legal fees) and taxes and fees.
- Climate change impact is often being taken into account, however has more impact on more frequent risks and not on risks with lower expected return periods.

Introduction to ILS pricing

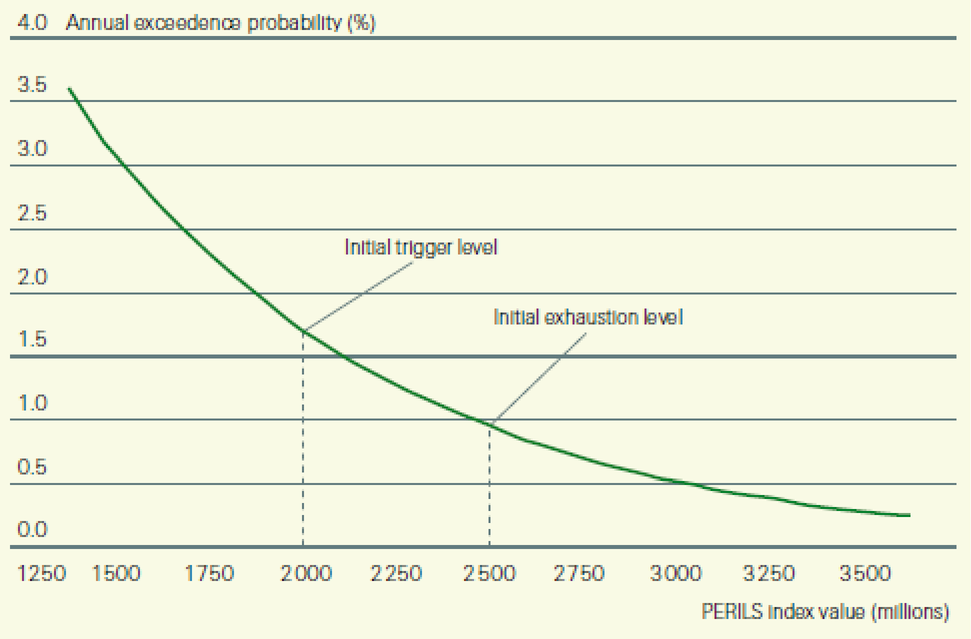
Components of price: spread

- **How to come up with the expected loss?**
  There is very little actual ILS loss experience to date (depends on the underlying risk/peril). However, compared to financial data, this is quite scarce experience one can work with and higher the loss there is less data available.
  This lack of actual, reliable data can be overcome to an extent by historic and scientific study of events stretching back hundreds of years as reflected in the continuing development and enhancement of the commercial catastrophe modelling tools.
  These models have powerful statistical simulation engines for generating events supplemented by sophisticated, engineering based, damage models that turn event severity characteristics at geographic locations into expected losses on a detailed property by property basis.
  Example of such models most widely used in the market are: RMS, AIR (Verisk) and Impact Forecasting (AON)

Introduction to ILS pricing

Components of price: spread

- **How to come up with the expected loss?**
  The use of catastrophe models has increased significantly over time and has expanded to many more perils. Initially, the only catastrophe models that existed were for hurricanes or earthquakes. Catastrophe models have now been built for most major catastrophe perils, including severe storms, floods, and wildfires.



Introduction to ILS pricing

Other considerations

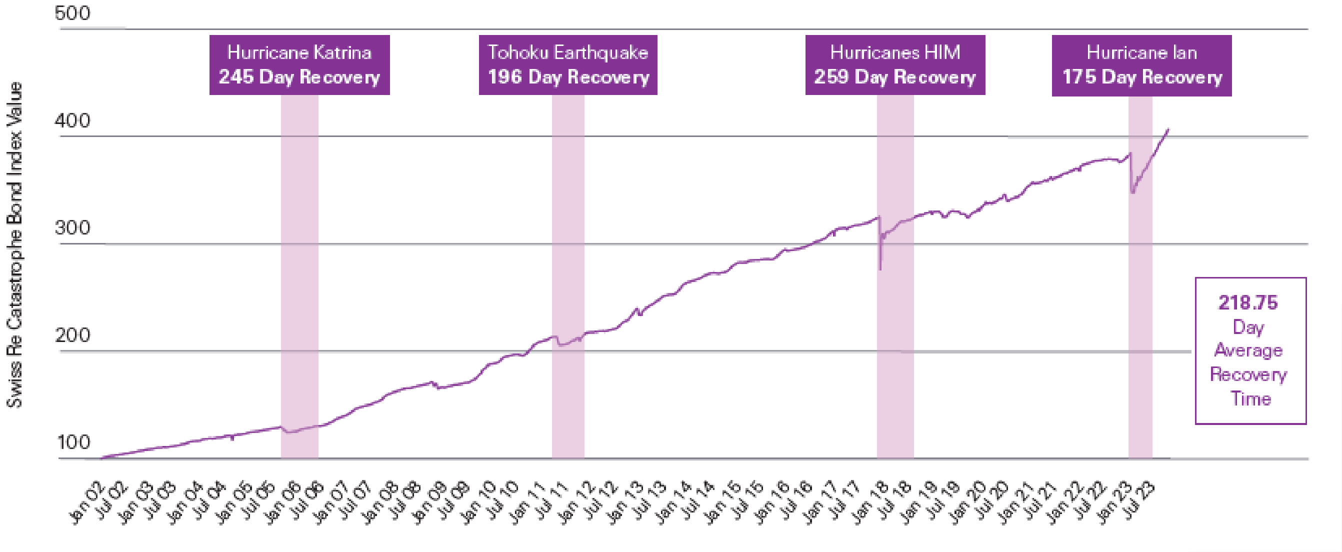
- The actual funds/money is held in a so called SPV (Special Purpose Vehicle) structure on a specifically created Trust account. This ensures that there is no credit risk (or at least very limited) in addition to the insurance risk assumed by the Investor.

- One of the biggest challenge in the market is that investors may be reluctant to invest the time and effort needed to understand the risks associated with these securities, hence need for educated investor – it might be difficult for the investor to evaluate the risk related to the bond (1 in 100 event – what does that mean? Is that reasonable?

Introduction to ILS pricing

Other considerations

- Market is often influenced by very large catastrophic events, which wipe out quite some capital and new capital requires improved returns to come back to the market.



Pricing of ILS

Krzysztof Burnecki

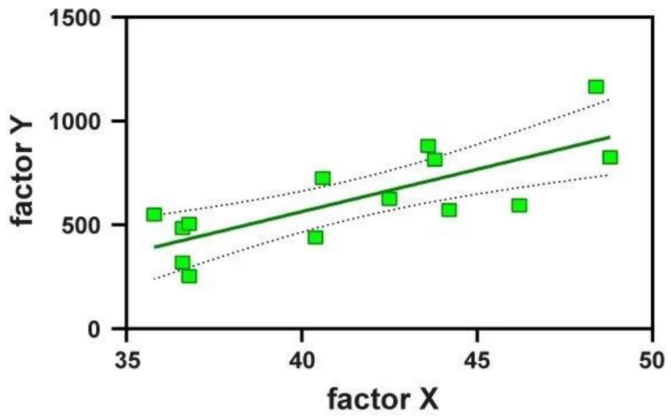
Pricing approaches

- Zero risk premium
- Arbitrage pricing theory
- Probability transform
- Econometric approach

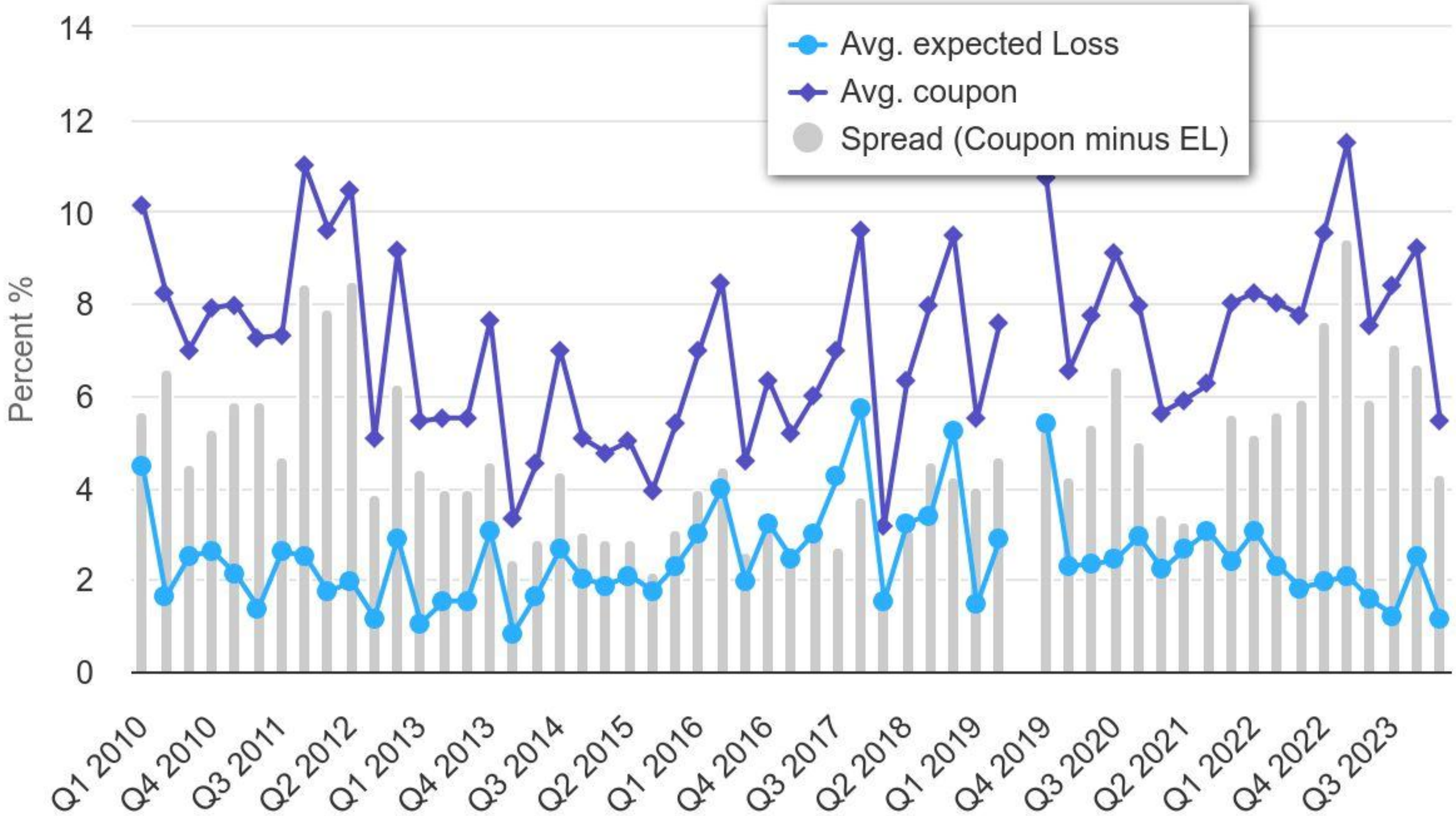
- Reinsurance rates for the same layer and exposure
- Ratings of fixed-income securities

Econometric approach

- Relationship between pricing spreads and EL and other factors
- Regression of premiums versus EL plus several independent variables
- Machine learning



Catastrophe bonds & ILS issuance average expected loss and coupon by quarter



Source: www.Artemis.bm Deal Directory

Pricing

$$Premium/Spread = EL + \gamma PFL^{\propto} CEL^{\beta},$$

where

- EL - expected loss,
- PFL - probability of first loss,
- CEL - conditional expected loss,
- $\alpha > 0, \beta > 0, \gamma > 0.$

(similar to the Cobb-Douglas production function)

Lane, *Pricing risk transfer transactions*, Astin Bulletin (2000)

Lane model

For 1999 transactions:

Expected Loss:	$= 0.0127$
Net Price: EER	$= 0.55x(0.047)^{(0.4946)}(0.2702)^{(0.5741)}$
	$= 0.0577$
Full Price:	$= \mathrm{EL} + \mathrm{EER}$
	$= 0.0704$
Adjusted for Day Count:	$= 0.0695$
And converted to basis points	
Final Price:	$= \mathrm{LIBOR} + 695$ bps

Lane, *Pricing risk transfer transactions*, Astin Bulletin (2000)

Regression approach

$$Premium = \propto + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon,$$

where

- α is an intercept,
- β_i are coefficients,
- X_i are explanatory variables (one being EL) and
- ε is a random error term.

Regression approach. Only EL variable

- Twenty years of data (2001-2020)
- 757 individual ILS
- **Results:**
  α = 3.65%, EL coefficient = 1.47, R^2 = 0.58.

Lane, *The Loss File - Natural Catastrophe ILS Issues 2001-2020* (Lane Financial LLC, 2021)

Regression approach, cont.

Linear function of three continuous variables:

1. Expected Loss
2. The competing financial environment (as represented by BB bonds)
3. The status of the competing cat market (as represented by an RoLX index)

Plus, contributions (+or-) from three binary indicator variables for

1. Whether the cover is for a “Peak Zone”
2. Whether the bond was issued by Swiss Re
3. Whether the bond is “Investment Grade”

Braun, *Pricing in the primary market for cat bonds—New empirical evidence,* Journal of Risk and Insurance (2016)

Regression approach, cont.

- Analysis covers the period **from 1997 to the end of 2012** and uses a data set, compiled from many sources, that contains **466 tranches** issued to the primary market during that period.
- **The adjusted R^2** for this model is **0.89** and the **SE** is **156 basis points**.

Braun, *Pricing in the primary market for cat bonds—New empirical evidence,* Journal of Risk and Insurance (2016)

Regression approach, cont.

- Broad data set of **secondary market CAT bond premiums** from 2002 to 2012.
- **Time dependent coefficients.**
- Positive relationship between **corporate spreads and CAT bond premiums**.
- Results indicate that **deal complexity, ratings, and the reinsurance cycle are significant drivers** of CAT bond premiums.

Gürtler, Hibbeln, Winkelvos, *The Impact of the Financial Crisis and Natural Catastrophes on CAT Bonds*, Journal of Risk and Insurance (2016)

Implied Poisson intensities

- Analyze **580 cat bonds**, covering the time period from December 2000 to May 2017.
- Extract **implied Poisson intensities** from regularly observed prices.
- Propose to exploit pricing information embedded in secondary market catastrophe bond quotes.

Beer and Braun, *Market-consistent valuation of natural catastrophe risk*, Journal of Banking and Finance (2022)

Machine learning approach

- Linear model, random forests model
- Introducing secondary market ILS data
- Result: a small improvement over Braun’s model

Lane and Murphy, *Pricing Cat Bonds: Regressions and Machine Learning - Some observations, some lessons* (Lane Financial **LLC**, 2018)

Testing the Fit and the Forecasts of Various Machine Learning models

	Training Period 3/2004 - 3/2014		ONE YEAR TEST 3/2014 -3/2015		THREE YEAR TEST 3/2014 - 12/2017	
	Accuracy	RMSE	Accuracy	RMSE	Accuracy	RMSE
Braun (actual 1/97 - 12/12)	0.89	1.56	0.95#	2.41#	0.96#	3.44#
2014S (original,i.e. w.Outliers)	0.94	2.51	0.95	0.99	0.94	1.82
Machine Learned	In-Sample CV Model		Out of Sample Test		Out of Sample Test	
	Train on Primary Only		Testing on Post 2014 Primary Issuance ONLY			
	Accuracy	RMSE	Accuracy	RMSE	Accuracy	RMSE
Linear Model (KS)*	0.90	2.09	0.96	2.01	0.96	4.54
Linear Model (AS)**	0.86	2.47	0.96	2.44	0.96	4.45
Randon Forest	0.92	2.10	0.98	1.30	0.92	2.74
Randon Forest (AS)	0.89	2.22	0.97	1.80	0.94	3.86
	Train on Primary and Secondary Mkt Qrtly Data		Testing on Post 2014 Primary Issuance ONLY			
Linear Model (KS)	0.91	1.89	0.96	2.02	0.97	3.53
Linear Model (AS)	0.89	2.04	0.95	3.03	0.96	4.76
Randon Forest	0.99	0.57	0.97	1.98	0.91	3.09
Randon Forest (AS)	0.99	0.48	0.98	2.19	0.94	4.23

indicated that these numbers were construct using synthetic data. It NOT the work of the original author and therefore may be in error.

* KS =Kitchen Sink, **AS= Attribute Selected

Lane and Murphy, *Pricing Cat Bonds: Regressions and Machine Learning - Some observations, some lessons* (Lane Financial **LLC**, 2018)

Machine learning approach, cont.

- Enhanced machine learning methods
- Variable selection methods, penalization methods, random forests method, neural networks

Results:

- **Random forests** provide stable and significant performance improvements for a relatively small asset class.
- They **exhibit the highest forecasting performance, followed by linear regression models and neural networks**.

Götze, Gürtler, Witowski, *Improving CAT bond pricing models via machine learning*, Journal of Asset Management (2020)

Q/A session

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Thank you for participating in the webinar!

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