Projekt inovace předmětů – Teorie a praxe dluhopisů
Část I

Transferring of insurance loss risk to capital markets

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-- Brief summary --

EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

Transferring of insurance loss risk to capital markets – course outline

- ILS instruments introduction
- Securitization of life insurance assets and liabilities
- Longevity risk transfers
- Longevity risk pricing and optimal security design
- The EIB longevity bond
- Mortality catastrophe bonds
- Recent trends in mortality-linked securities
- Mortality indices
- Mortality swaps and forwards
- Mortality/longevity futures and options
- CAT bonds design, trigger problematics
- CAT bonds valuation
- ILS market characteristics

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ILS instruments introduction

- ILS - Insurance linked Securities
- Both life and non-life
- “Briefly” defined as a group of financial instruments whose values are driven by insurance loss events
- Alternative Risk Transfer (ART) through the securitization of life and non-life insurance products
- More appropriate in today’s world than the classical cession of insurance risks as, for example, in classical reinsurance.
- Simplifying the problem, many of the ART methods are motivated by the effort to cede huge insurance risks to capital markets, which have many times the capacity of insurance markets.

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ILS instruments introduction

Mortality-linked securities and its derivatives
(ILS for life insurance and pension plans)

Terminology:

- Such terminology does not distinguish between mortality-linked and longevity-linked securities

Types:

- Longevity (survivor) bonds
- Mortality catastrophe bonds (CATM/MCBs bonds), extreme mortality bonds
- Mortality swaps, futures/forwards, options

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ILS instruments introduction

Catastrophe bonds, also known as CAT bonds

Typical ILS for non-life insurance

Types, linked to:

- Hurricane and tropical storm
- Earthquake
- Floods, hailstorms

ILS instruments introduction, features

- Embedded options
- Floating coupon
- Risk management on ILS, using for hedging and diversification
- Investment restrictions, for example catastrophe bonds are sold only to QIB's (qualified institutional buyers), which are generally pension/hedge/ILS funds with over $100 million AUM. The theory is that qualified institutional buyers should be provided a safe harbor to certain securities restrictions, since they are more experienced in handling financial instruments than the average person
- Insurance event probability valuation based on ILS market price, the probability of catastrophe priced by the bond market

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Basic concepts of population mathematics

$\mathrm{m}(t,x)$	**Mortality rate**
$D(t,x)$	number of deaths, during calendar year *t* aged *x*
$E(t,x)$	Mid-population during calendar year *t* aged *x*
$\mathrm{q}(t,x)$	is the probability that a person aged *x* at time *t* will die within one year
$\mathrm{p}(t,x)$	corresponding survival probability
$\mathrm{p}(t,x)_n$	generalized over *n* years by chain relation

$$\mathrm{m}(t,x) = \frac{D(t,x)}{E(t,x)}$$

$$\mathrm{q}(t,x) = 1 - e^{\mathrm{m}(t,x)}$$

$$\mathrm{p}(t,x) = 1 - \mathrm{q}(t,x)$$

$$\mathrm{p}(t,x)_n = \mathrm{p}(t,x) \cdot \mathrm{p}(t+1,x+1) \cdot \ \dots \ \cdot \mathrm{p}(t+n-1,x+n-1)$$

Source: B. Stádník

Basic concepts of population mathematics

S(t)	Surviving rate
t	*1,2,...25*

$$S(0) = 1$$

$$S(1) = S(0)(1-\mathrm{m}(2003,65))$$

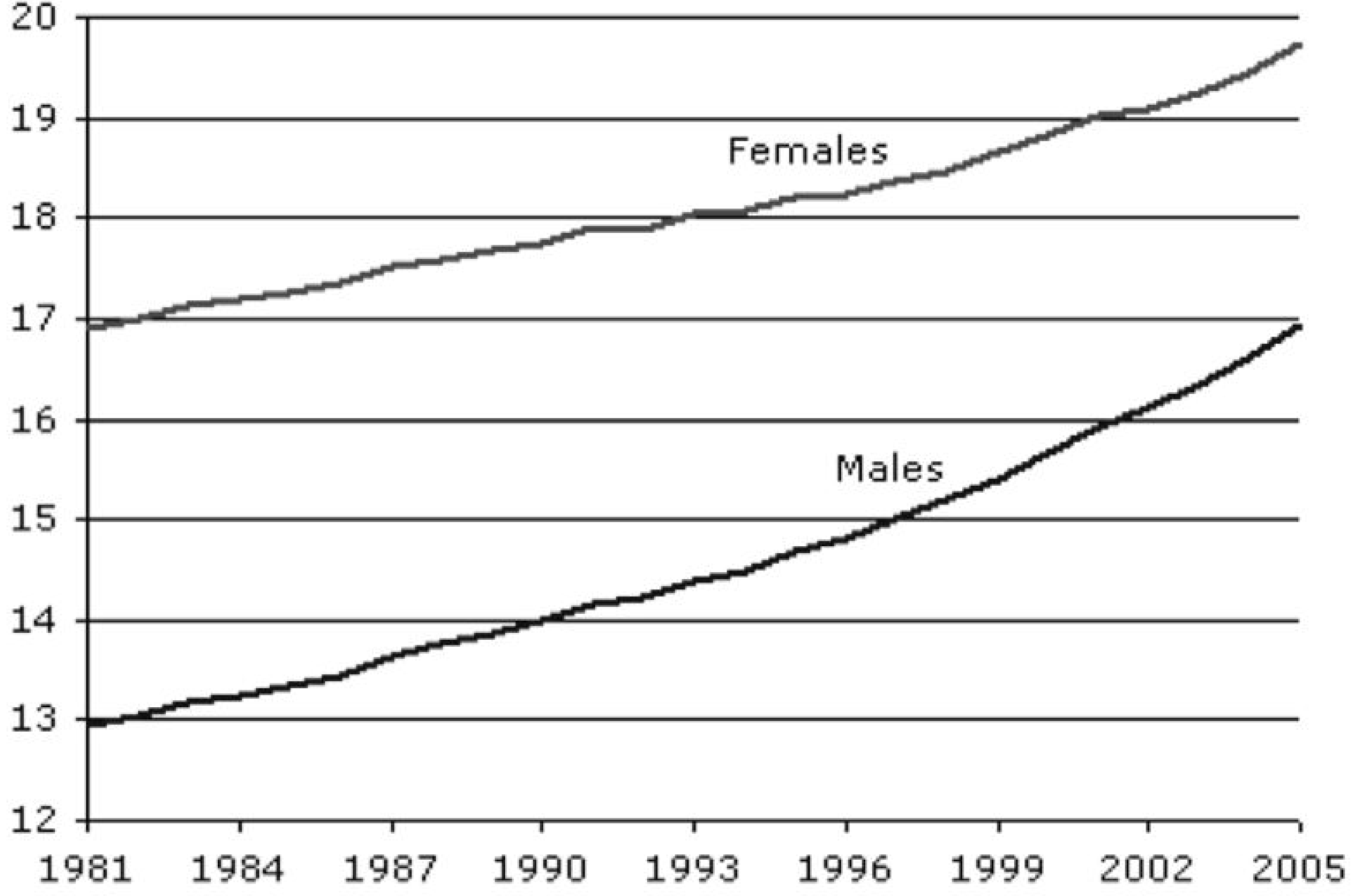
$$S(t) = S(0)(1-\mathrm{m}(2003,65)) \cdot (1-\mathrm{m}(2004,66)) \cdot \ldots \cdot (1-\mathrm{m}(2002+\mathrm{t},64+\mathrm{t}))$$

Source: B. Stádník

Mortality-linked securities and derivatives, the process

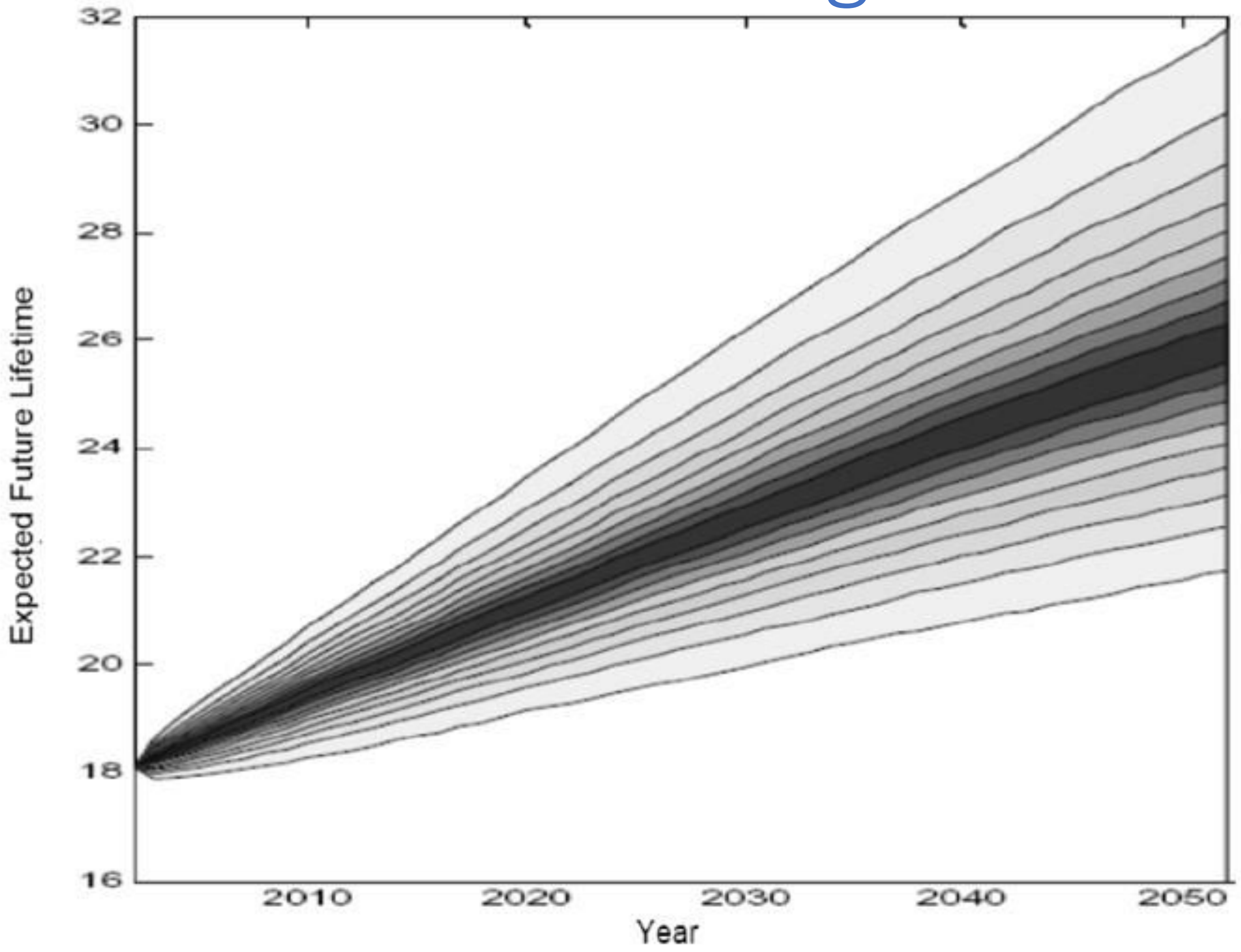
- The volatility of mortality rates – fairly low
- The uncertainty surrounding changes in mortality trends – high
- Forecasting mortality trends is a challenging exercise that concerns investors willing to take on exposures to longevity risk.
- The role played by trends and volatility in mortality rates in determining equilibrium risk premium in longevity risk transfers.

Mortality-linked securities and derivatives, historical data



Life expectancy at age 65 in the UK, from 1981 to 2005. Source: ONS

Mortality-linked securities and derivatives, forecasting



Longevity fan chart for 65-year-old English and Welsh males. Source: Dowd *et al.* (2007).

Longevity risk transfers

- Pension buyouts
- Securitization of life insurance assets and liabilities

Longevity Bonds

LBs can be divided into several categories:

- standard LBs, i.e., coupon-bearing bonds whose coupon payments fall over time proportionally to a survivor index, i.e., $f_t(\cdot) = k \cdot S_t$ for a positive constant k;
- inverse LBs, i.e., bonds whose coupons are inversely related to a survivor index, i.e., rising over time instead of falling with $f_t(\cdot) = k \cdot (1 - S_t)$;
- longevity zero bonds, i.e., zero-coupon bonds where the principal is a function of a survivor index
- principal-at-risk LBs, i.e., bonds whose principal, not coupons (fixed or floating), is linked to a survivor index;
- survivor bonds, which, unlike standard LBs, have no specified maturity but continue to pay coupons as long as the last member of the reference population is alive (in particular, they have no principal payment).

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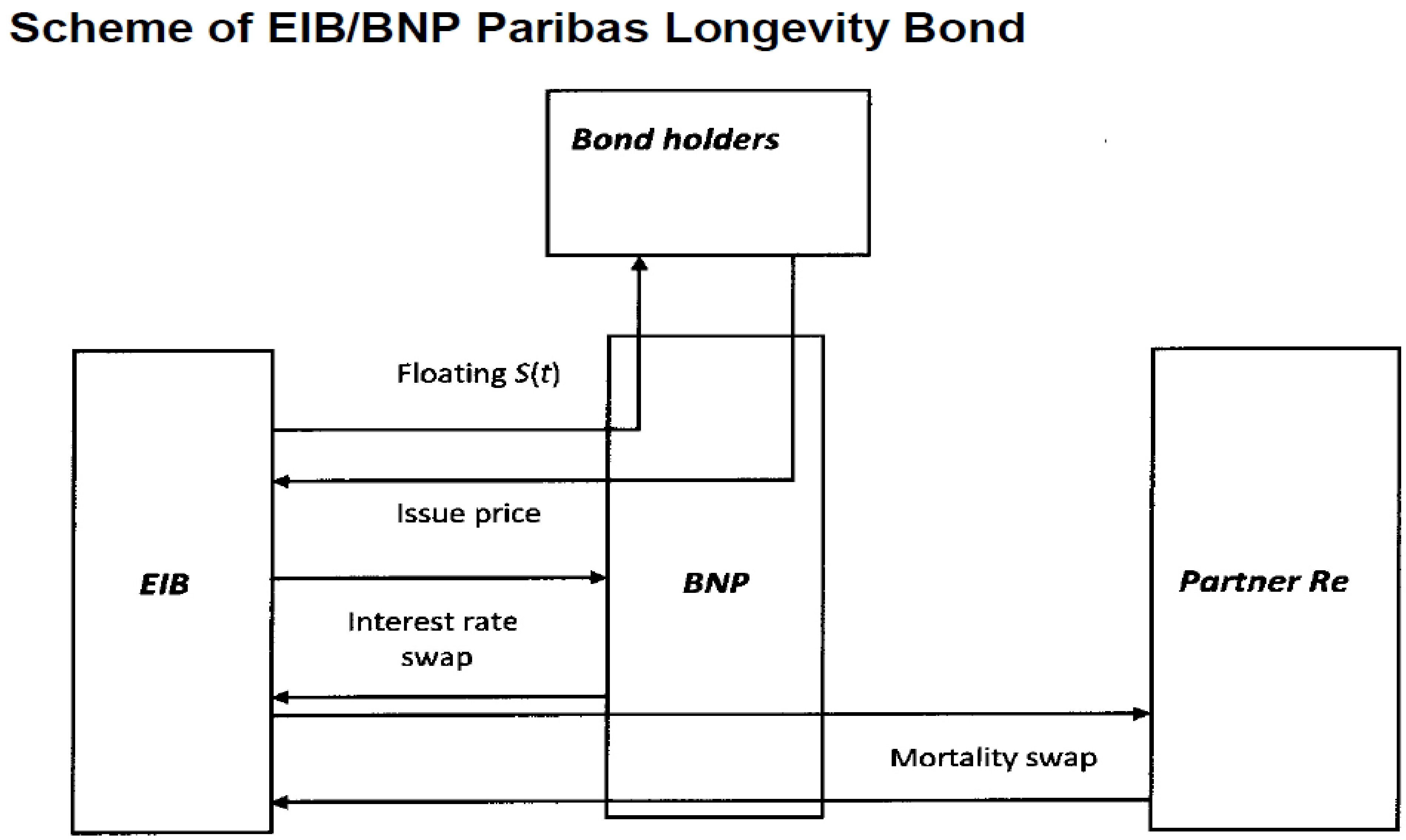
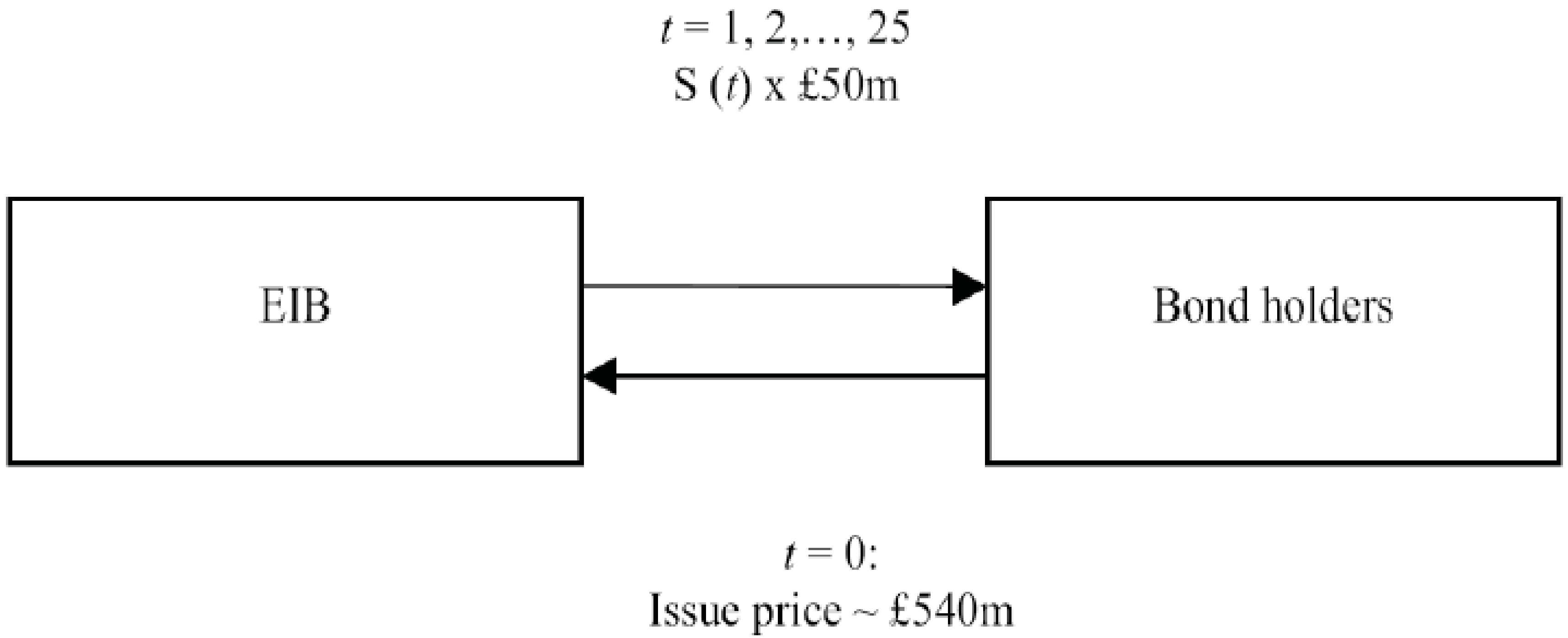
EIB (European Investment Bank) Longevity bond



Source: B. Stádník

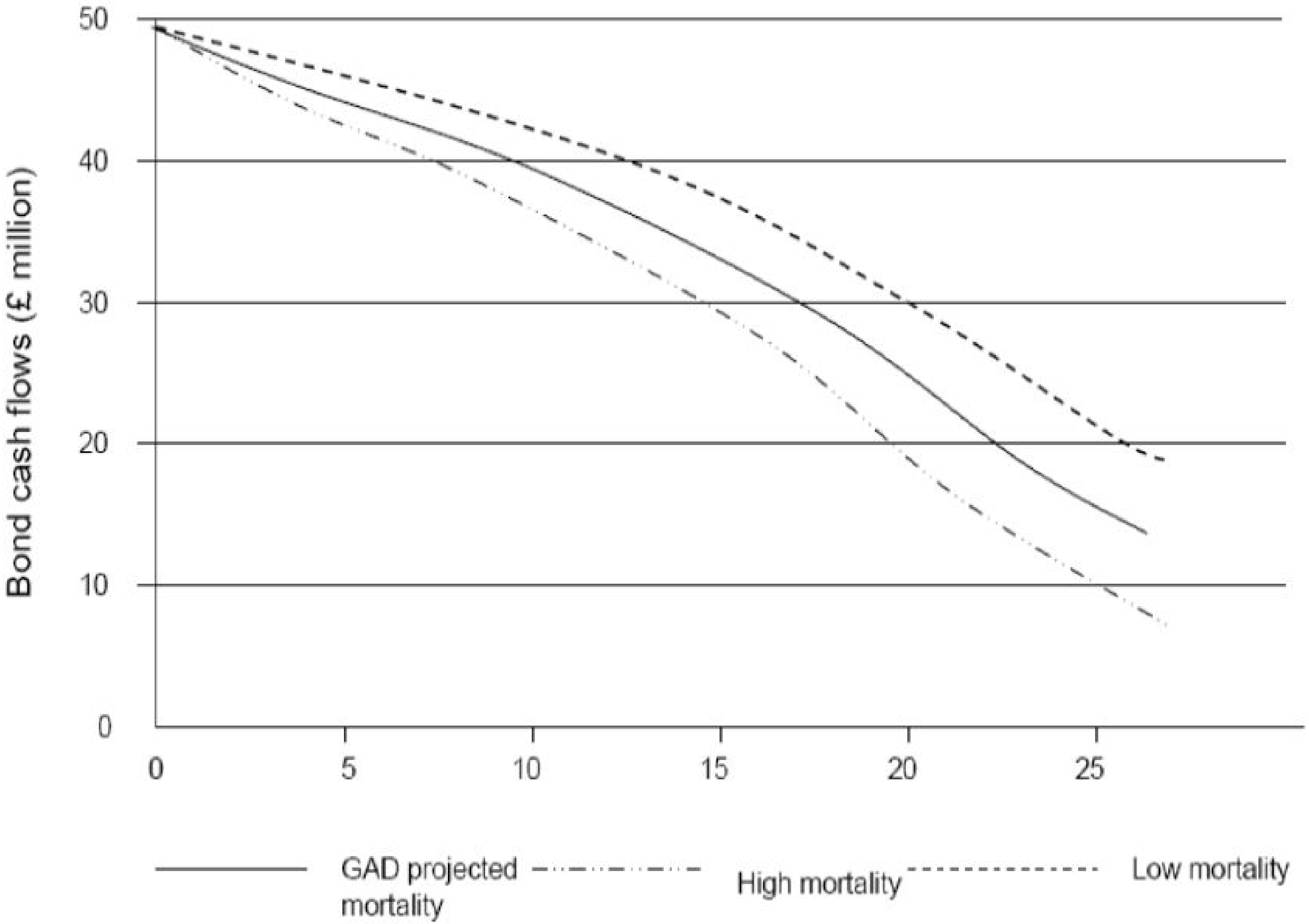
Securitization of life insurance assets and liabilities, the EIB longevity bond



Cash flows from the EIB bond, as viewed by investors. $S(t)$ denotes the survivor index at the end of year t. Source: Blake *et al.* (2006).

Source: B. Stádník

The EIB longevity bond

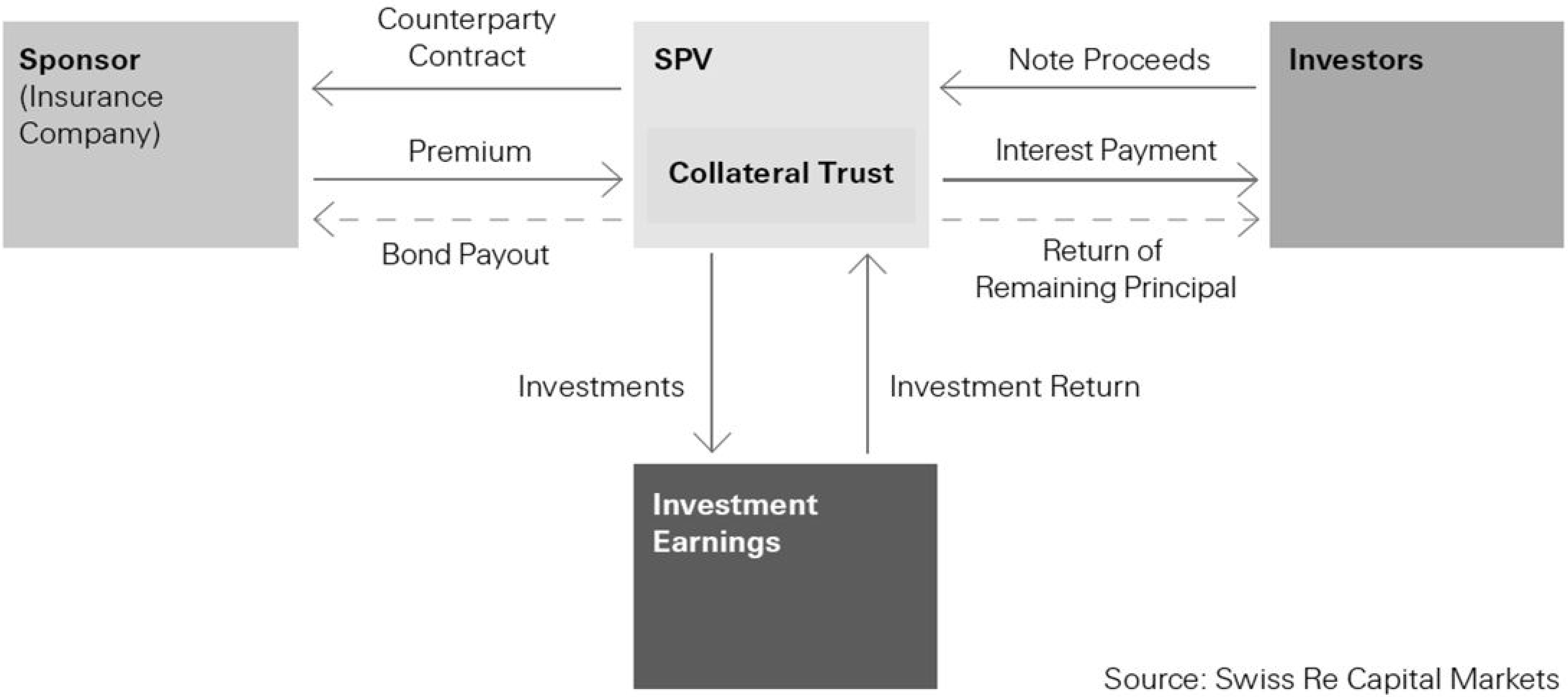


Source: B. Stádník

SPV

A Special-Purpose Vehicle, or SPV is a subsidiary of a company which is bankruptcy remote from the main organization (i.e. protected even if the parent organization goes bankrupt). The actions of a SPV are usually very tightly controlled and they are only allowed to finance, buy and sell assets.

Securitization of life insurance assets and liabilities, optimal security design



Source: Swiss Re Capital Markets

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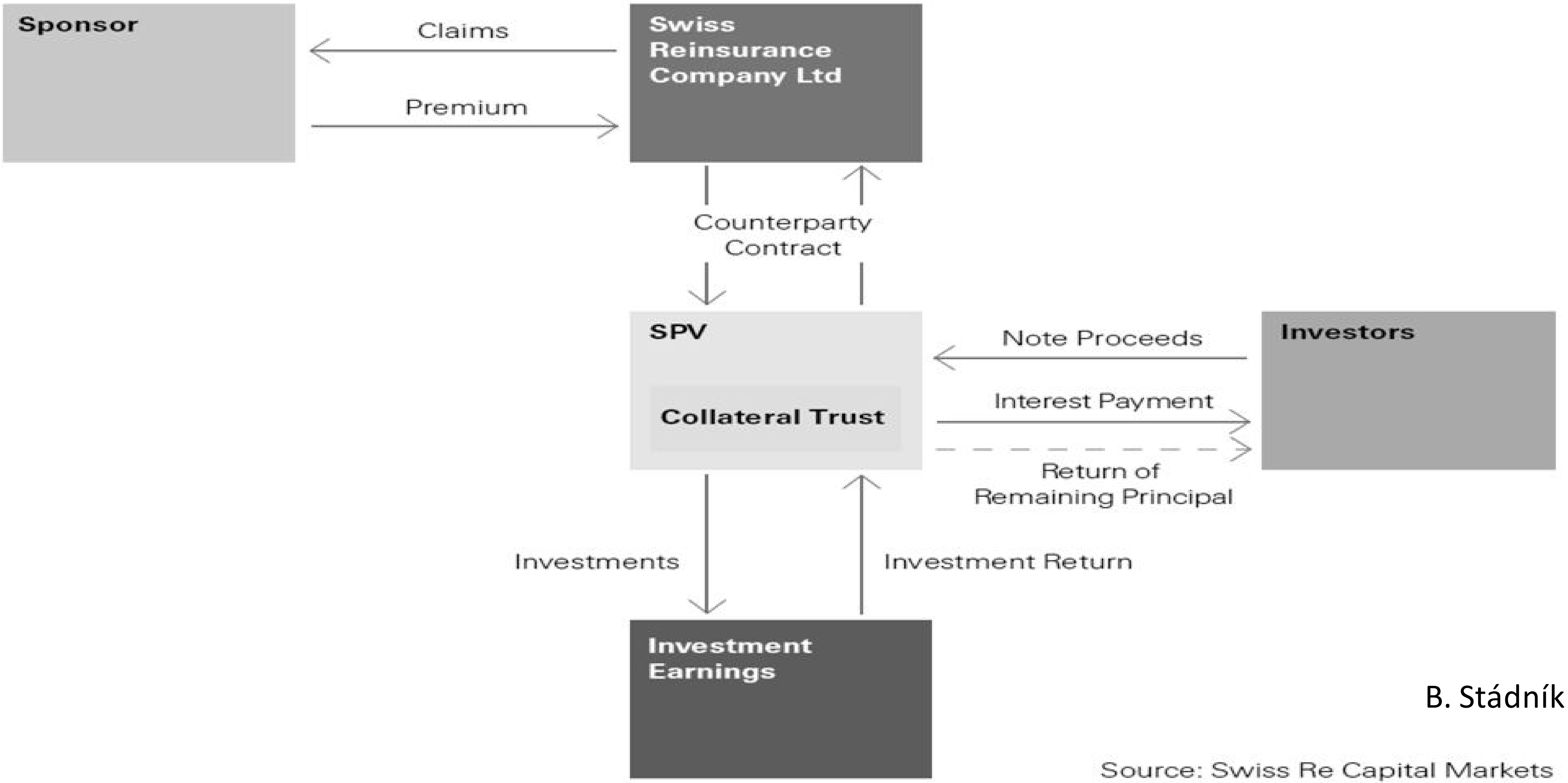
Securitization of life insurance assets and liabilities, optimal security design



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Source: Swiss Re Capital Markets

Extreme mortality bond (EMB), mortality catastrophe bonds

Events that lead to a large-scale loss of life are called extreme mortality events:

- Earthquake
- Pandemic
- Hurricane
- Others

Parameters:

- Maturity period 3-5 years
- If the issuing insurance company faces a loss due to the occurrence of a particular extreme mortality event, then the issuer may no longer be obligated to pay the interest or the principal amount, or both

Extreme mortality bond (EMB), mortality catastrophe bonds

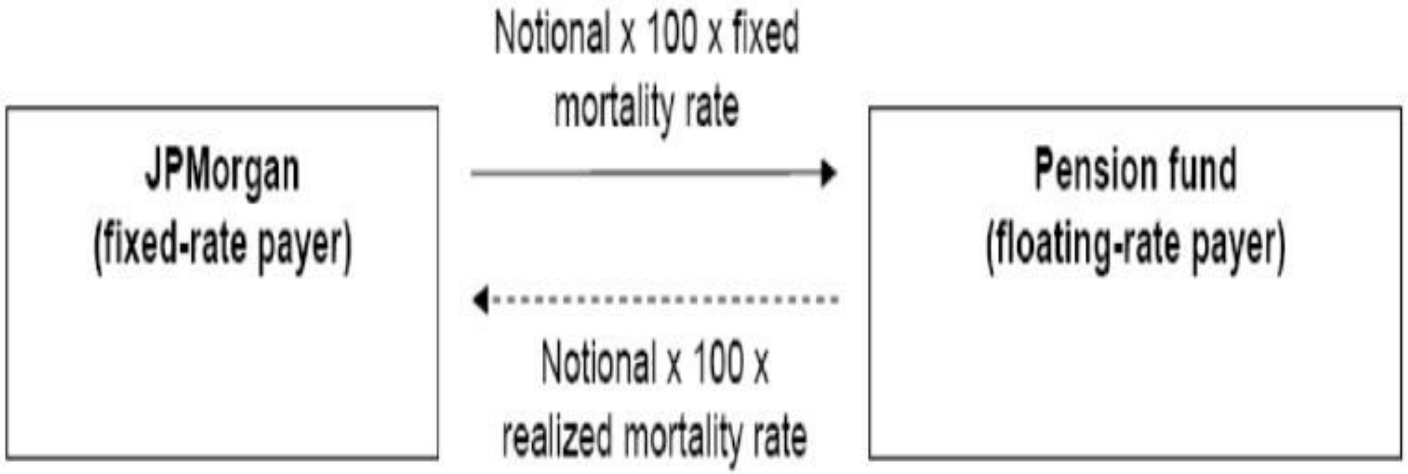
- A Win-Win EMBs offer a win-win situation for both the bond issuer and the bond investor. The issuing company mitigates the risk of high payments in the case of extreme events, while the bond buyer benefits if a disaster does not occur

- Since extreme mortality bonds are not linked to the stock market or other economic conditions, they offer a way to diversify

- Some EMBs require mortality for a specific region to increase as much as 20 to 40 percent beyond what is normal for that region before investors lose capital. In the United States, that would mean an additional 500,000 deaths a year

- Required a major mortality event such as a pandemic on par with the 1918 Spanish flu pandemic, a world war, the detonation of a nuclear bomb or a massive climate event or terrorist attack. Only some of the victims of such an event would be insured by a given EMB's issuer, further reducing the risk to investors.

Mortality swaps and forwards



A q-forward exchanges fixed mortality for realized mortality at the maturity of the contract. Source: Coughlan *et al.* (2007).

Mortality swaps and forwards

Notional amount	GBP 50,000,000
Trade date	31 Dec 2006
Effective date	31 Dec 2006
Maturity date	31 Dec 2016
Reference year	2015
Fixed rate	1.2000%
Fixed amount payer	JPMorgan
Fixed amount	Notional Amount x Fixed Rate x 100
Reference rate	LifeMetrics graduated initial mortality rate for 65-year-old males in the reference year for England and Wales national population Bloomberg ticker: LMQMEW65 Index <GO>
Floating amount payer	ABC Pension Fund
Floating amount	Notional Amount x Reference Rate x 100
Settlement	Net settlement = Fixed amount – Floating amount

Illustrative term sheet for a single q-forward to hedge longevity risk. Source: Coughlan *et al.* (2007).

Mortality/longevity futures and options

- No futures or options markets on mortality-linked securities are active to date

- New class of product – still being worked out as to the best way to package longevity derivatives to investors and insurer groups

CAT Bonds, how does it work?

- Catastrophe (CAT) bond or insurance-linked security with face value F is a financial instrument which is expected to provide a stream of cash payments c at the end of every period $t = 1,2,\ldots,T$, where T denotes the bond's maturity, so long as a particular catastrophe does not occur. At the CAT bond's maturity an investor receives both coupon payment and principal repayment. Provided a catastrophe occurs during the life of a CAT bond, an investor only receives a fraction of both coupon payment and principal repayment $\omega(F + c)$, where $\omega \in [0,1]$ denotes the fraction received. After this payment the bond is wound up.

- The periodicity t of the coupon payments c is usually quarterly and the maturity ranges between 1 and 5 years with an average of 3 years.

- The value of risk capital outstanding on catastrophe bonds globally increased from 12.2 billion U.S. dollars in 2010 to 25.3 billion U.S. dollars in 2017

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CAT Bonds, how does it work?, example

If an insurer has built up a portfolio of risks by insuring properties in Florida, then it might wish to pass some of this risk on so that it can remain solvent after a large hurricane. It could simply purchase traditional catastrophe reinsurance, which would pass the risk on to reinsurers. Or it could sponsor a cat bond, which would pass the risk on to investors. In consultation with an investment bank, it would create a special purpose entity that would issue the cat bond. Investors would buy the bond, which might pay them a coupon of LIBOR plus a spread, generally (but not always) between 3 and 20%. If no hurricane hit Florida, then the investors would make a positive return on their investment. But if a hurricane were to hit Florida and trigger the cat bond, then the principal initially contributed by the investors would be transferred to the sponsor to pay its claims to policyholders. The bond would technically be in default and be a loss to investors. Tansferred to the sponsor to pay its claims to policyholders. The bond would technically be in default and be a loss to investors.

CAT bonds design, trigger problematics

1. Indemnity trigger
2. Industry loss trigger
3. Parametric trigger
4. Modelled trigger

CAT bonds design, trigger problematics

Indemnity trigger

Loss of principal triggers when there is an excess of total losses over the attachment point. Also, exhaustion point is specified over which the principal is exhausted. This trigger favors the issuer and is not very attractive for investors. It may even cause moral hazard, e.g. construction in flood areas.

Industry loss trigger

Trigger is specified as total industry losses in excess of pre-specified amount. Independent third party then estimates total industry losses on the insured event. The danger of moral hazard is partly mitigated.

Parametric trigger

Parametric trigger is based on the occurrence of a specific natural event, e.g. the speed of wind in excess of 100 km/h. The danger of moral hazard is completely mitigated and thus parametric trigger favors the investors.

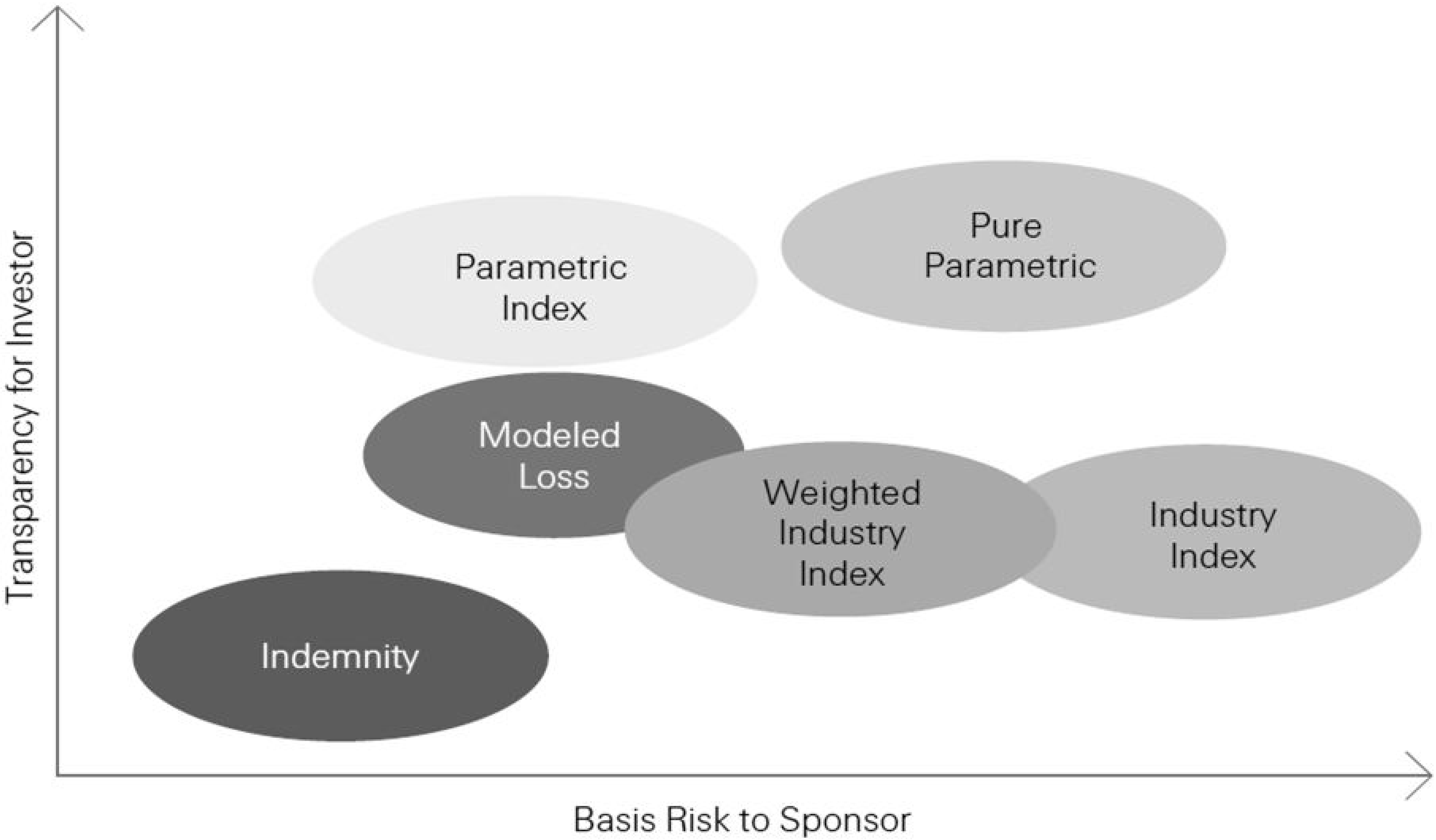
Modelled trigger

Very similar to indemnity trigger but is based on claims estimated by independent third party. The danger of moral hazard is partly mitigated.

Most CAT bonds have an indemnity or an industry loss trigger.

CAT bonds design, trigger problematics

Illustrative trigger comparison matrix



Source: Swiss Re Capital Markets

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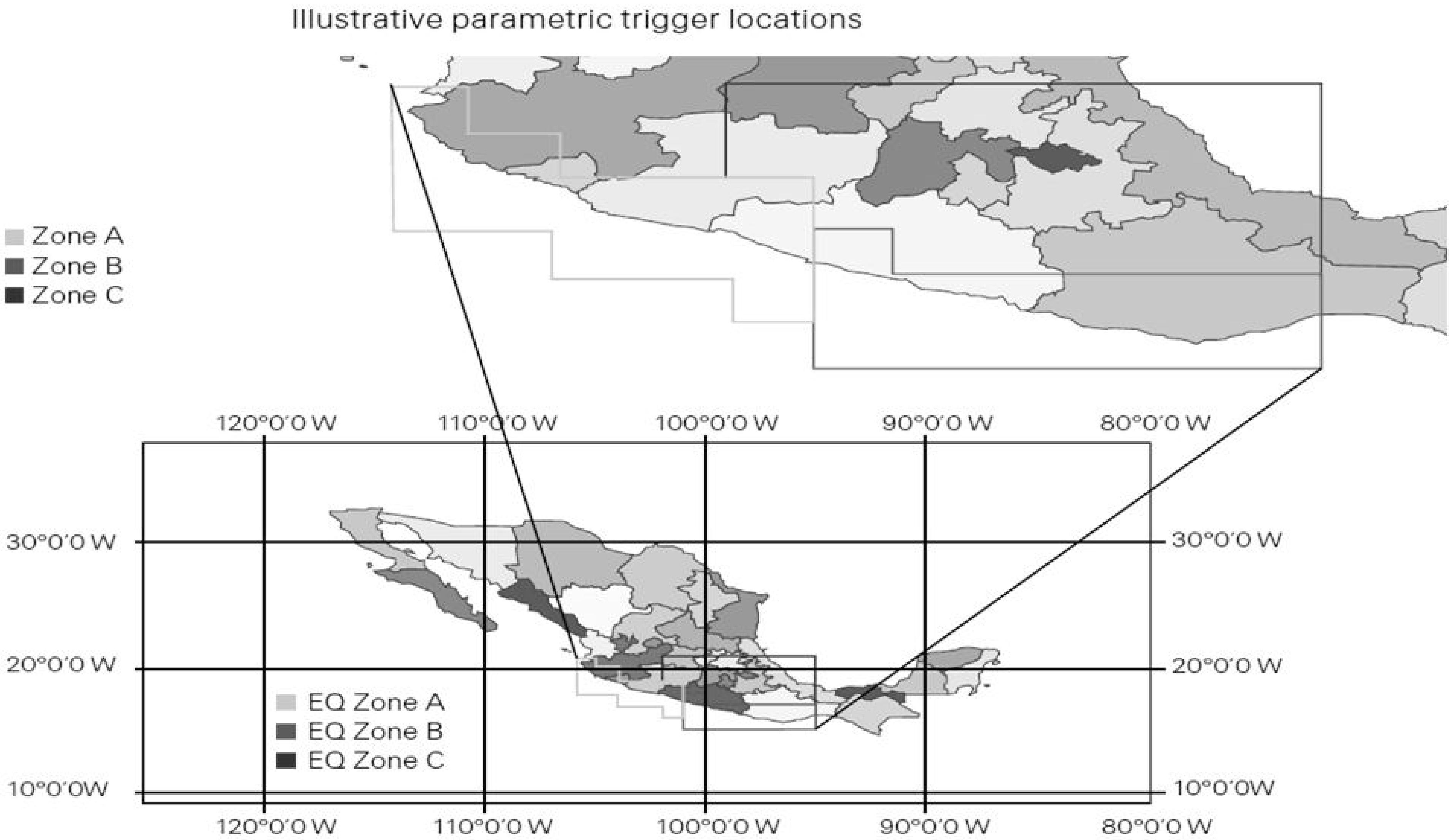
CAT bonds design, trigger problematics



Source: Swiss Re Capital Markets

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CAT bonds design, trigger problematics

Hurricane index formula:

$$\text{Hurricane index value} = K \times \sum_{i=1}^{j} w_i \times \langle v_i - L \rangle^n$$

- K is a constant
- j is the total number of locations
- i is the relevant location
- w_i is the relative weight of location i
- v_i is the calculated peak gust windspeed at location i
- L is a constant representing a threshold peak gust windspeed above which a damage potential exists
- n is a constant

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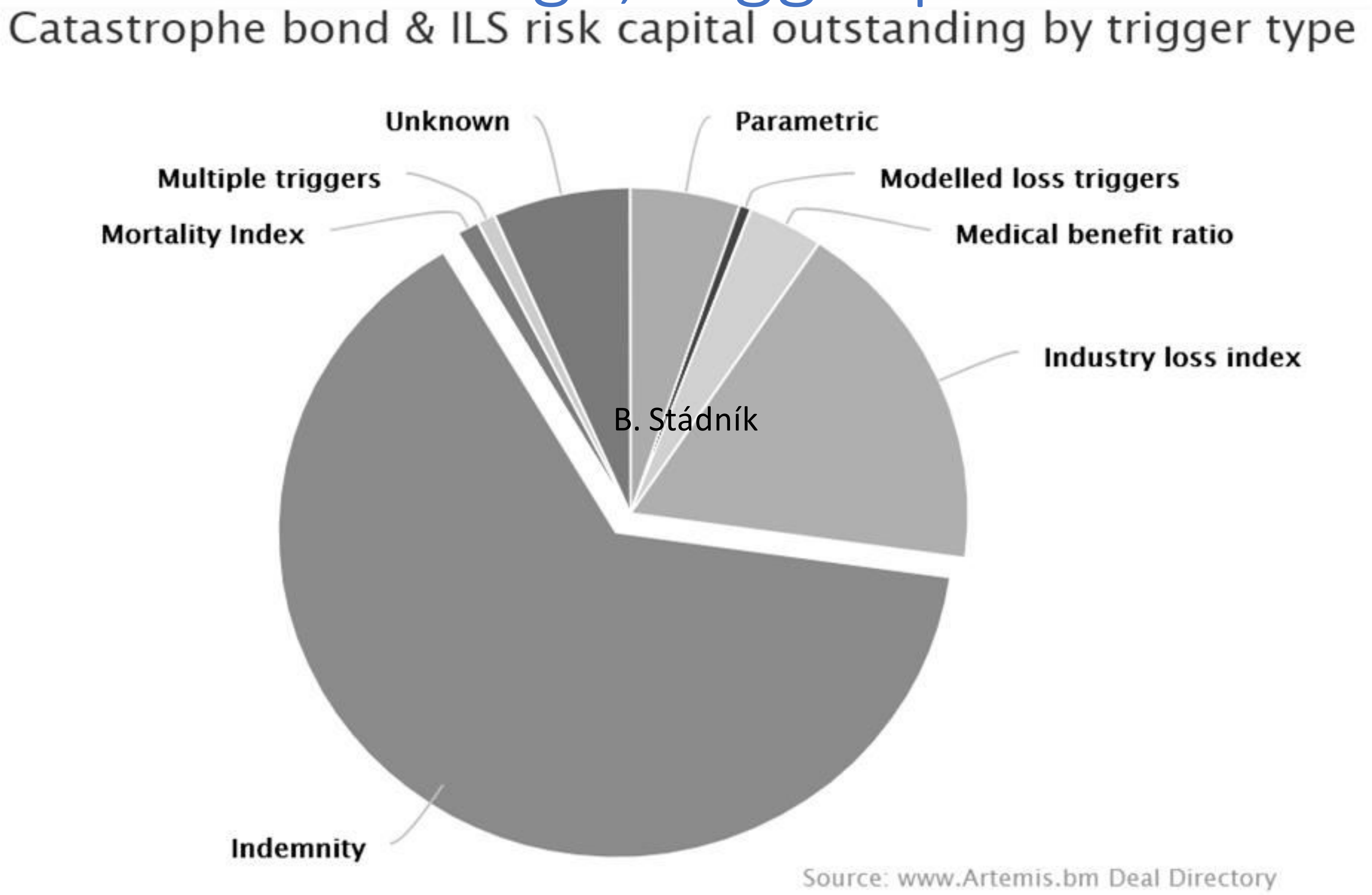
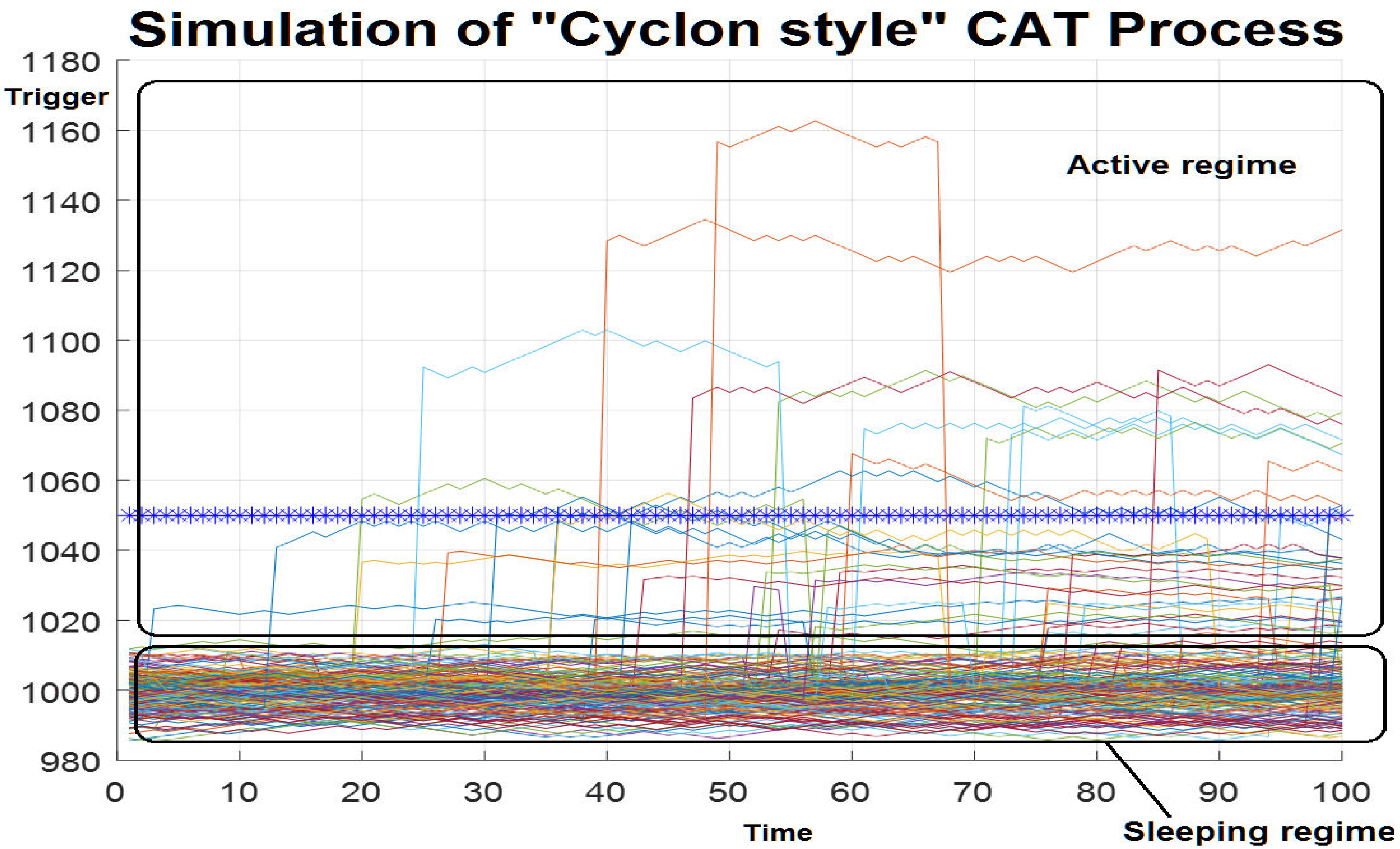
CAT bonds design, trigger problematics



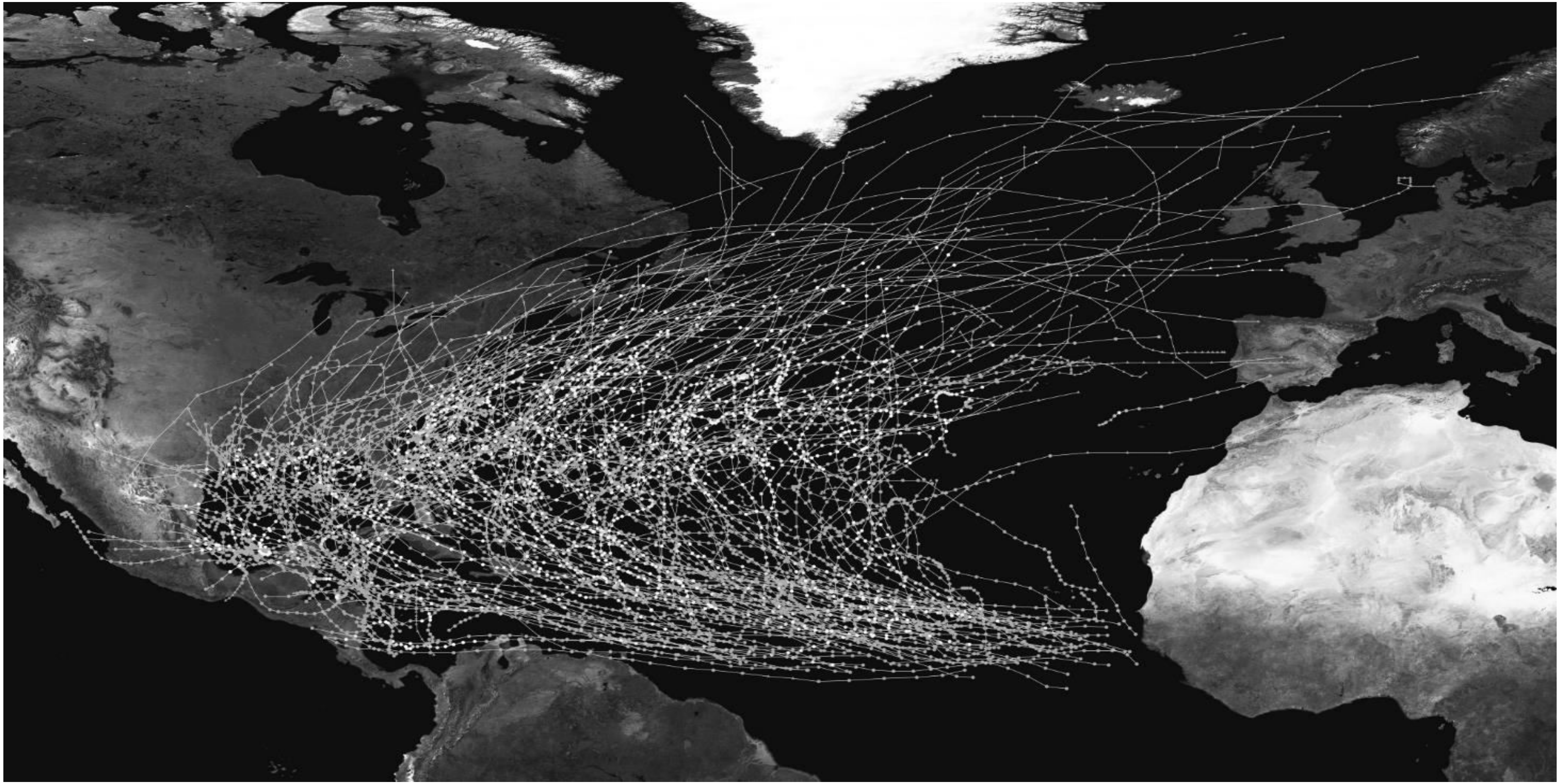
CAT bonds design, valuation approach



Simulated paths of the catastrophe process

Source: Stádník

CAT bonds design, valuation approach, cyclon process paths



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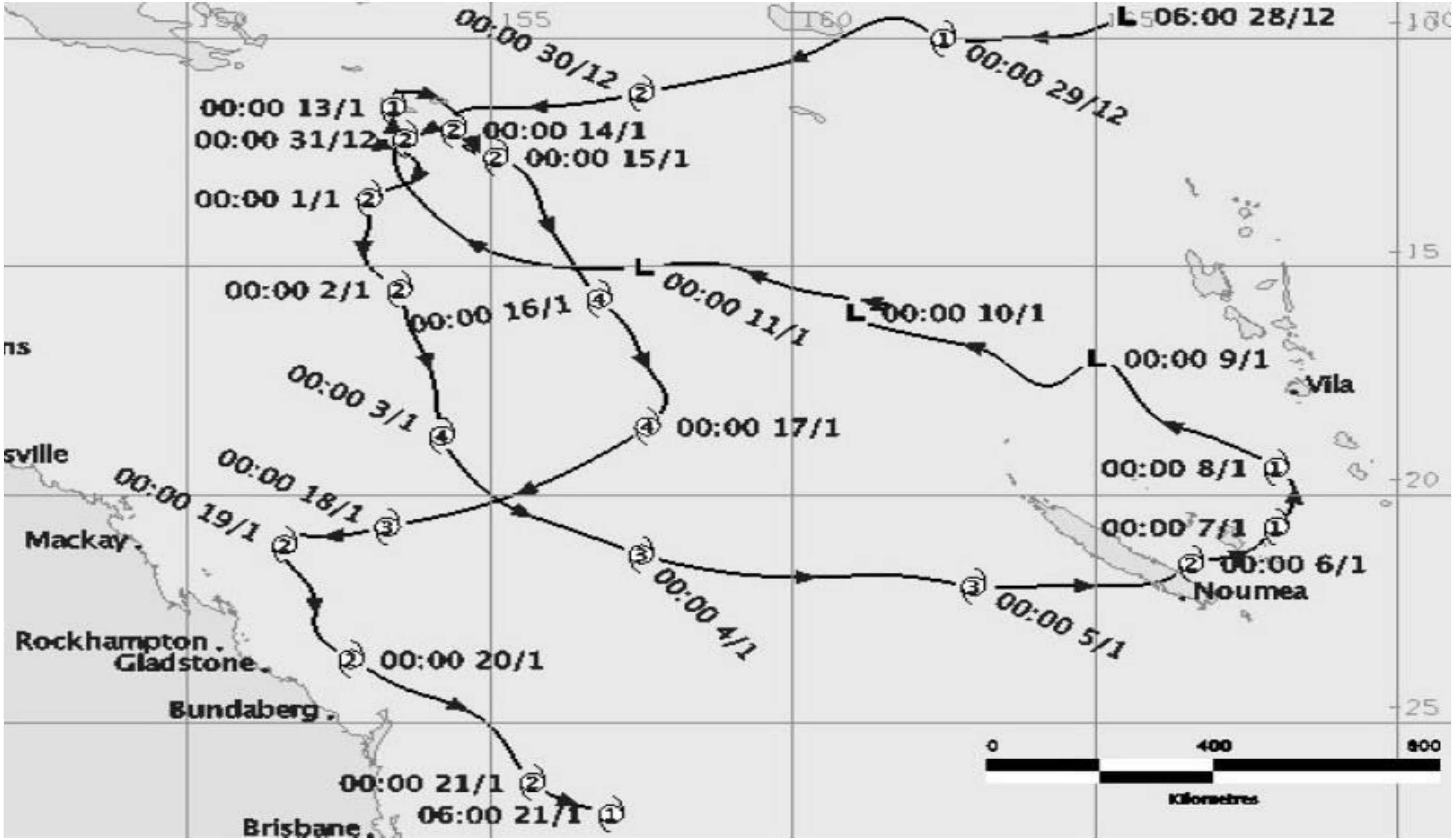
Source: Australian Bureau of Meteorology

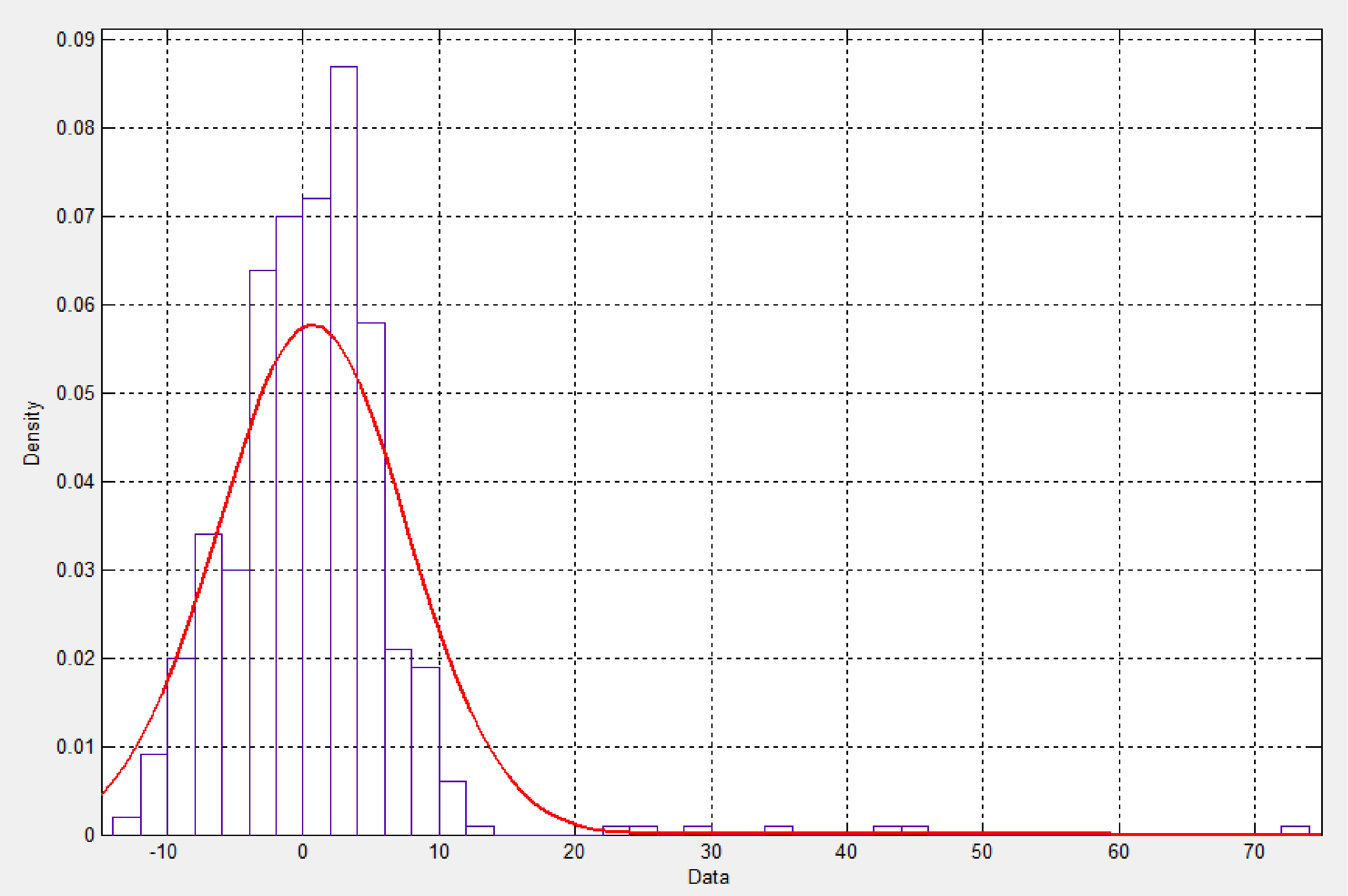
CAT bonds design, valuation approach, cyclon process path



B. Stádník

Source: Australian Bureau of Meteorology

CAT bonds design, valuation approach



Histogram of the simulated catastrophe process paths

Source: Stádník

CAT bonds design, valuation approach

$$P + R_{premium} = \frac{qS}{1+i}$$

P	CAT Bond Price
Rpremium	Reinsurance Premium
q	Probabilty of catstrophe
i	Risk free rate
S	Insured amount (max that insurance company will pay)

	0	1	
		q	(1-q)
Insurer	-P	S	0
Reinsurer=Issuer of CatBond	$R_{premium}$+F	-S	S
Investor	-F	0	S

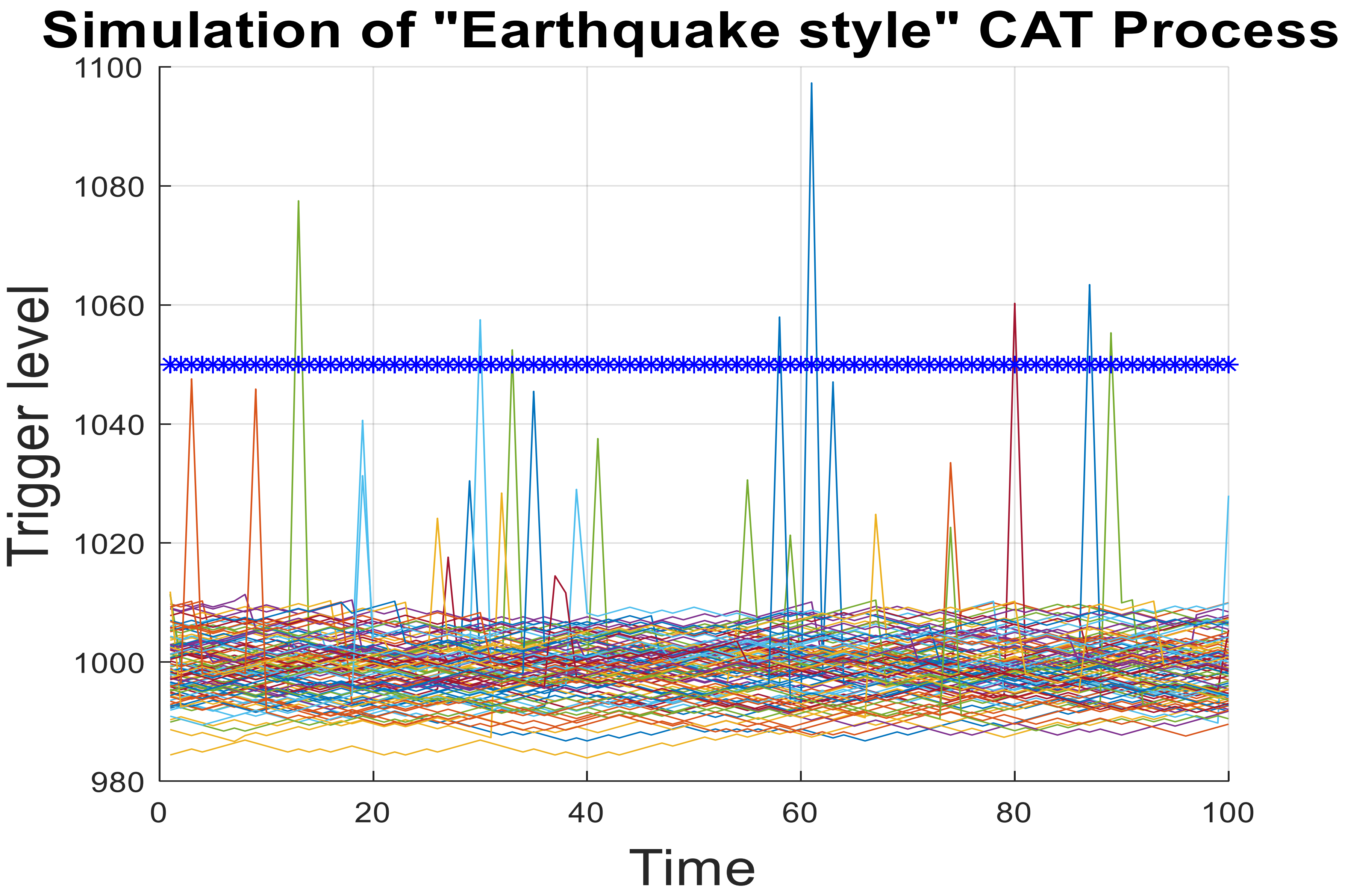
Source: B. Stádník

Valuation of the catastrophe, probability

- Modelling of catastrophe process
- The probability of catastrophe priced by the bond market

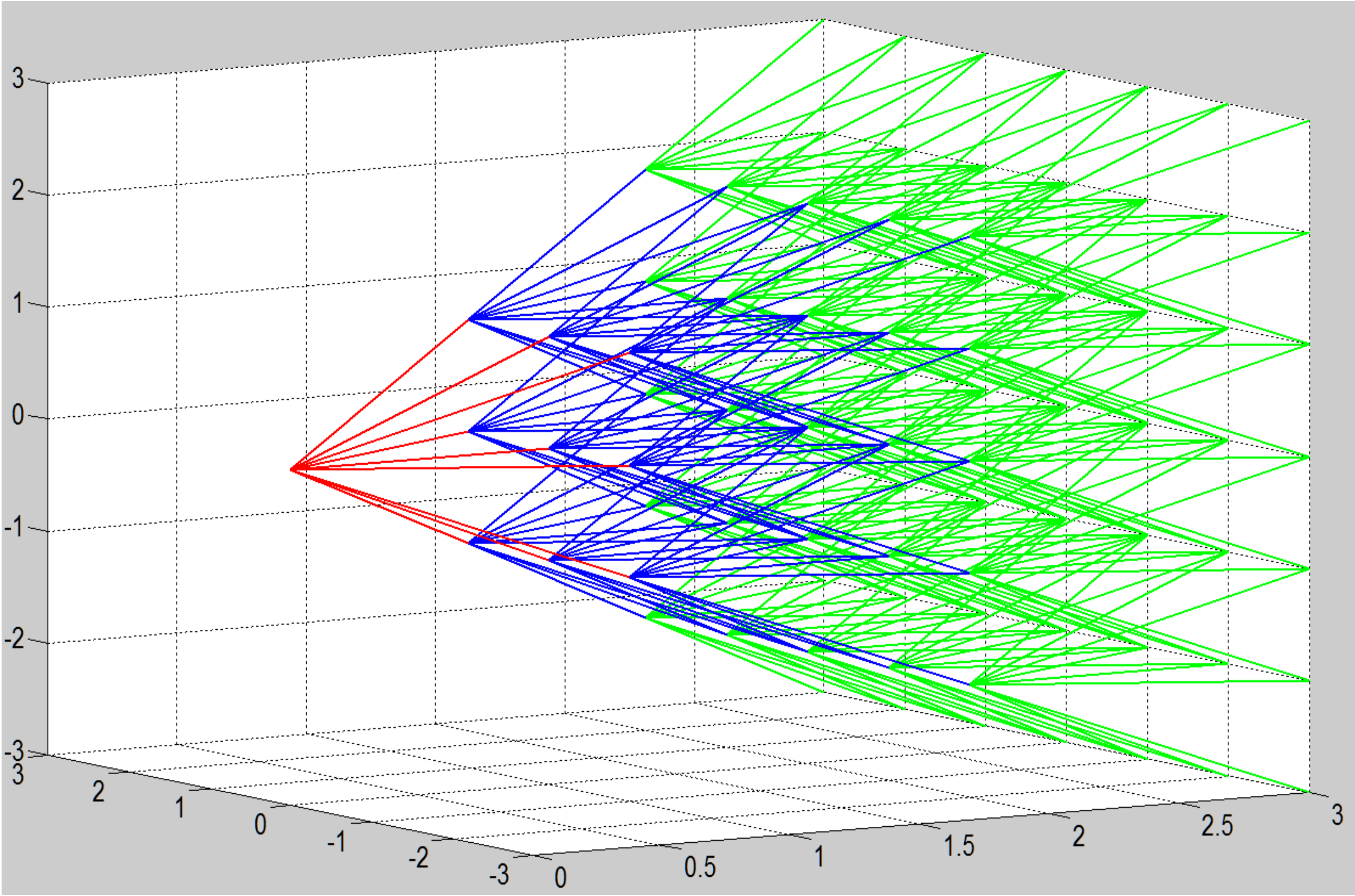
$$q = \frac{(P+R\_premium)(1+i)}{S}$$

CAT bonds design, valuation approach



Source: Stádník

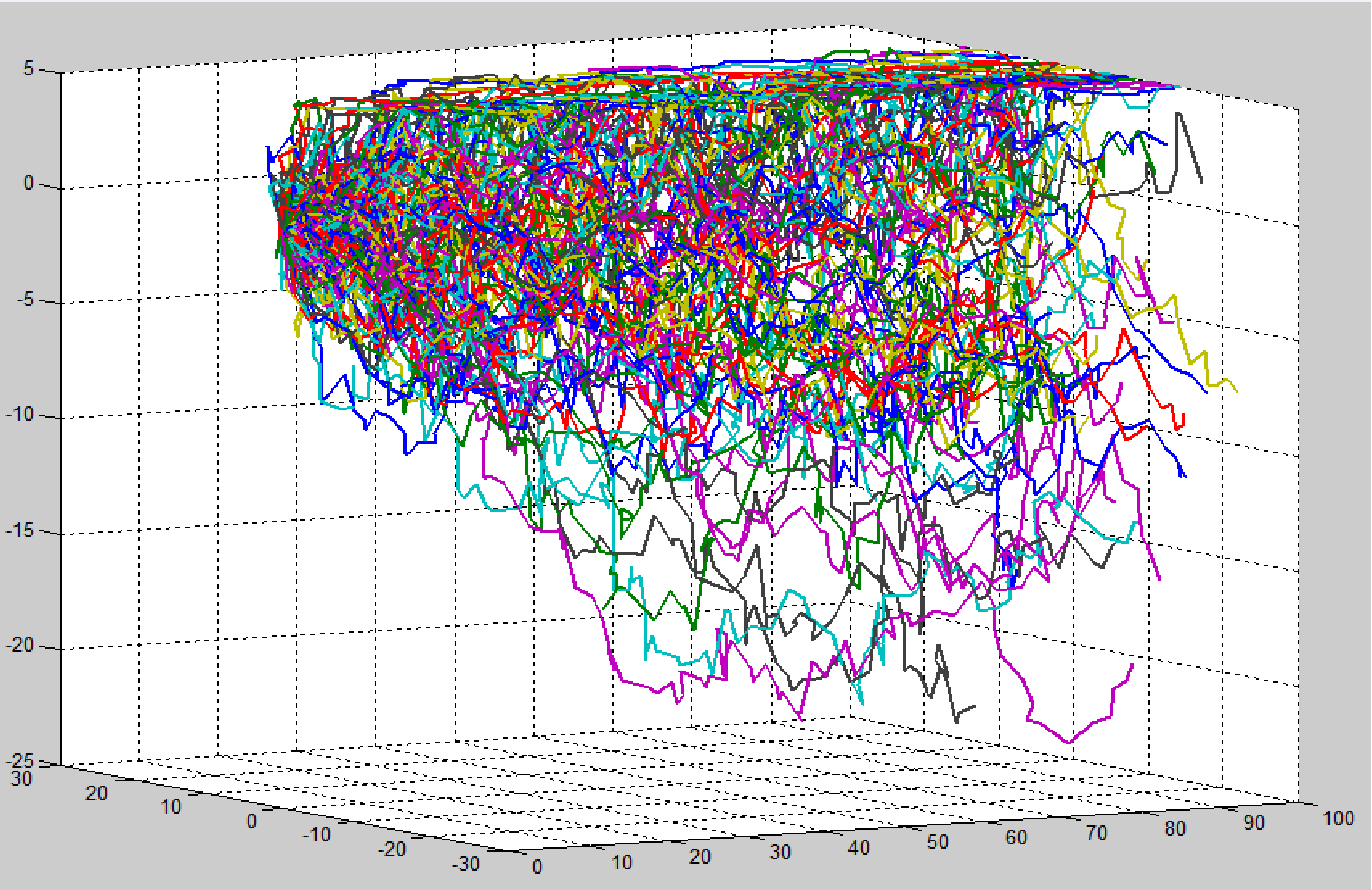
CAT bonds design, valuation approach, 3D tree



The simulation of the price paths using the 3D valuation tree

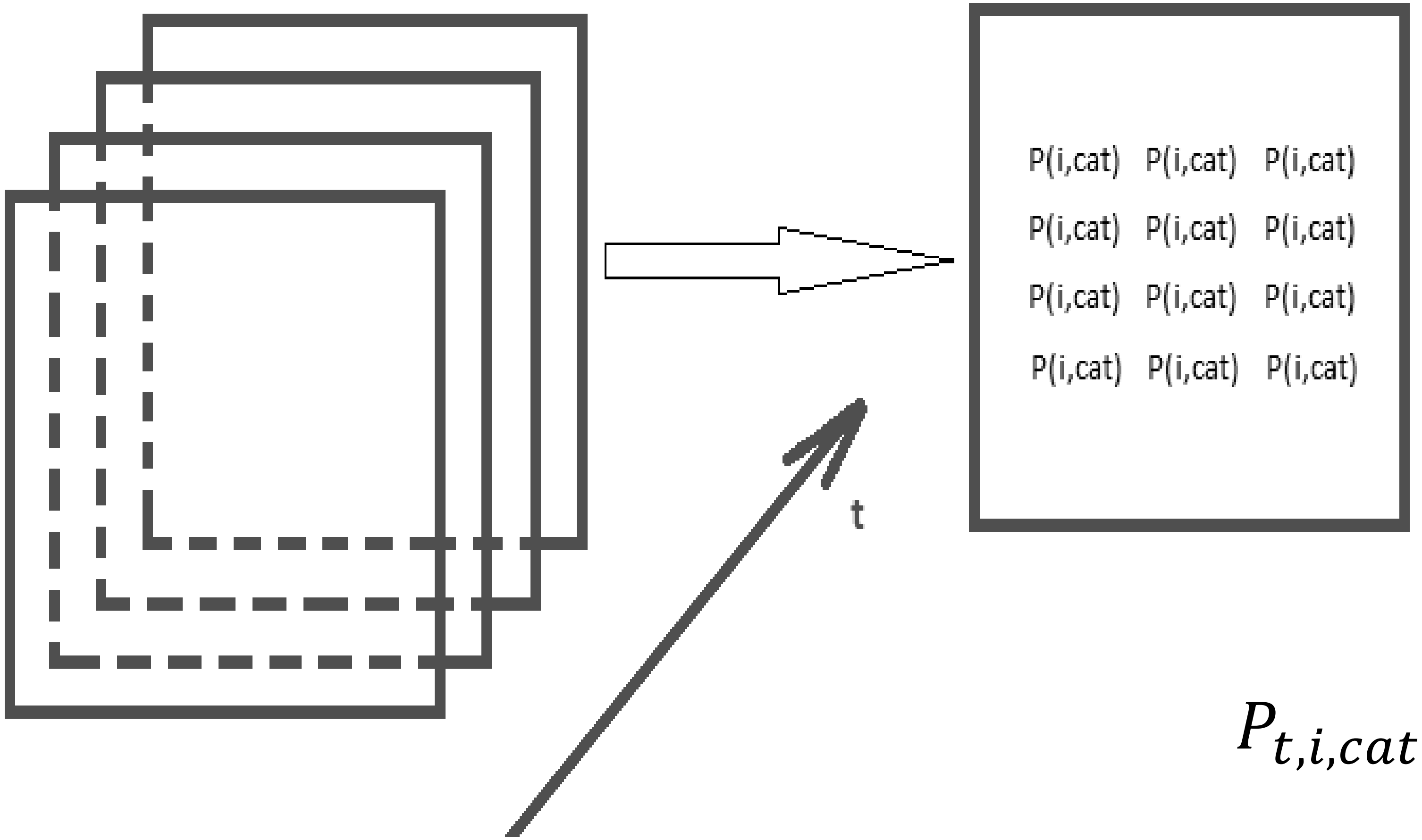
Source: Stádník

CAT bonds design, valuation approach, proces with trigger, simulation



Source: Stádník

CAT bonds design, valuation approach

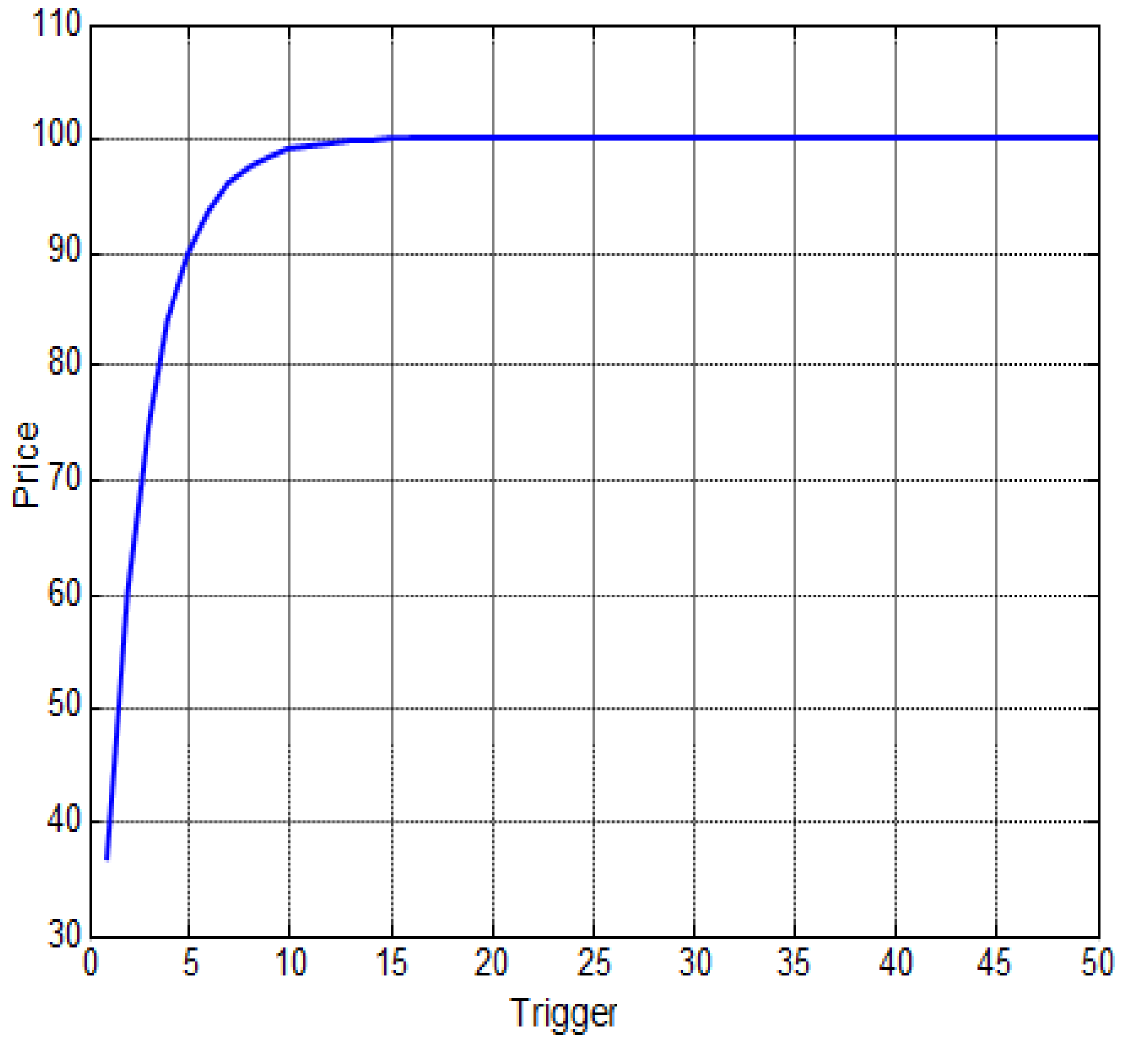


$$P_{t,i,cat} = \sum_{s=1}^{n} q_s \frac{P_{s,t+1}}{(1+i_t)}$$

Source: Stádník

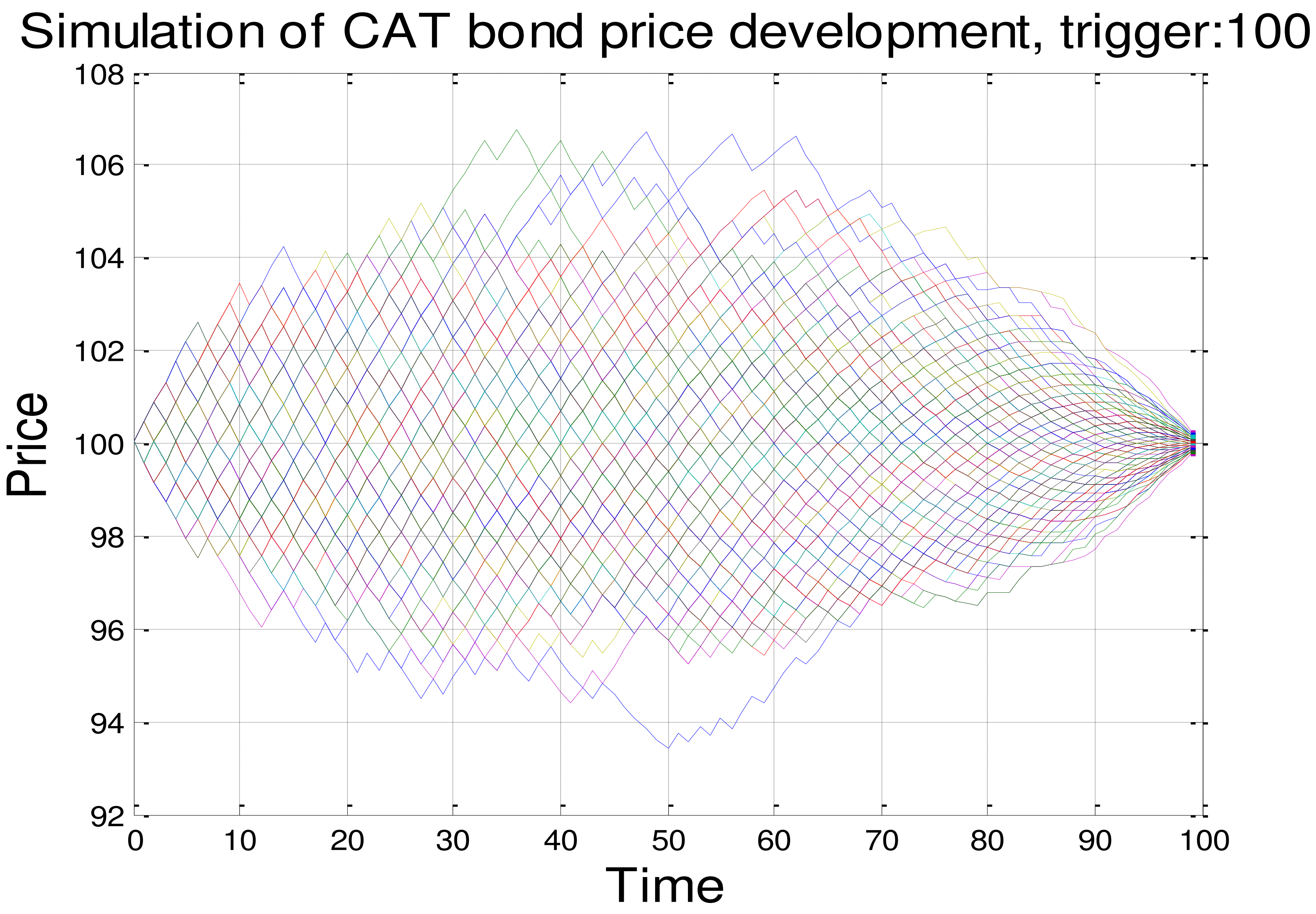
CAT bonds design, valuation approach

Trigger	Price (present value) of a CAT bond
1	36,76
2	60,03
3	74,77
4	84,10
5	89,99
6	93,72
7	96,07
8	97,56
9	98,49
10	99,07
11	99,44
12	99,67
13	99,81
14	99,89
15	99,95
16	99,98
17-100	100,00



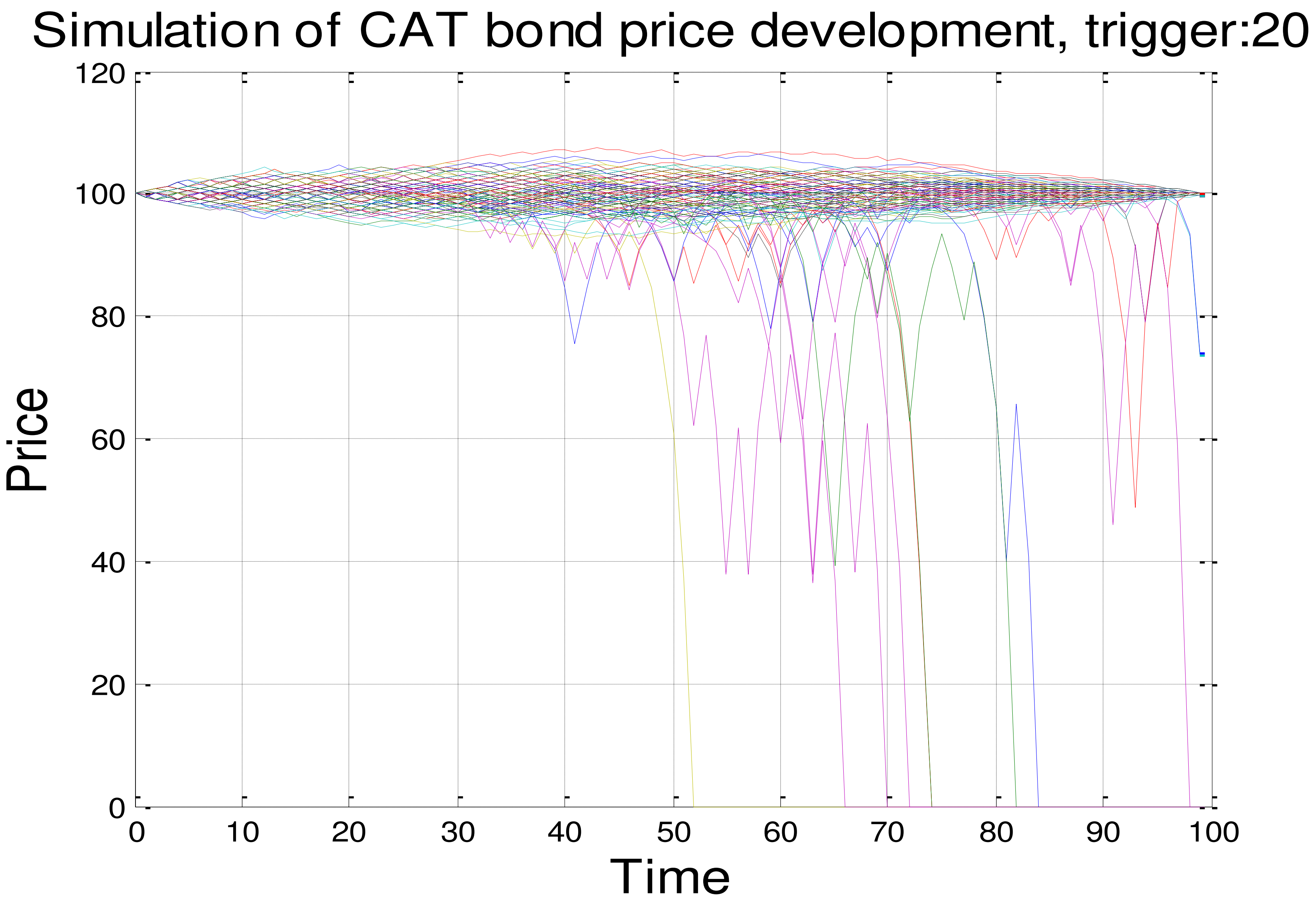
Source: Stádník

CAT bonds design, valuation approach



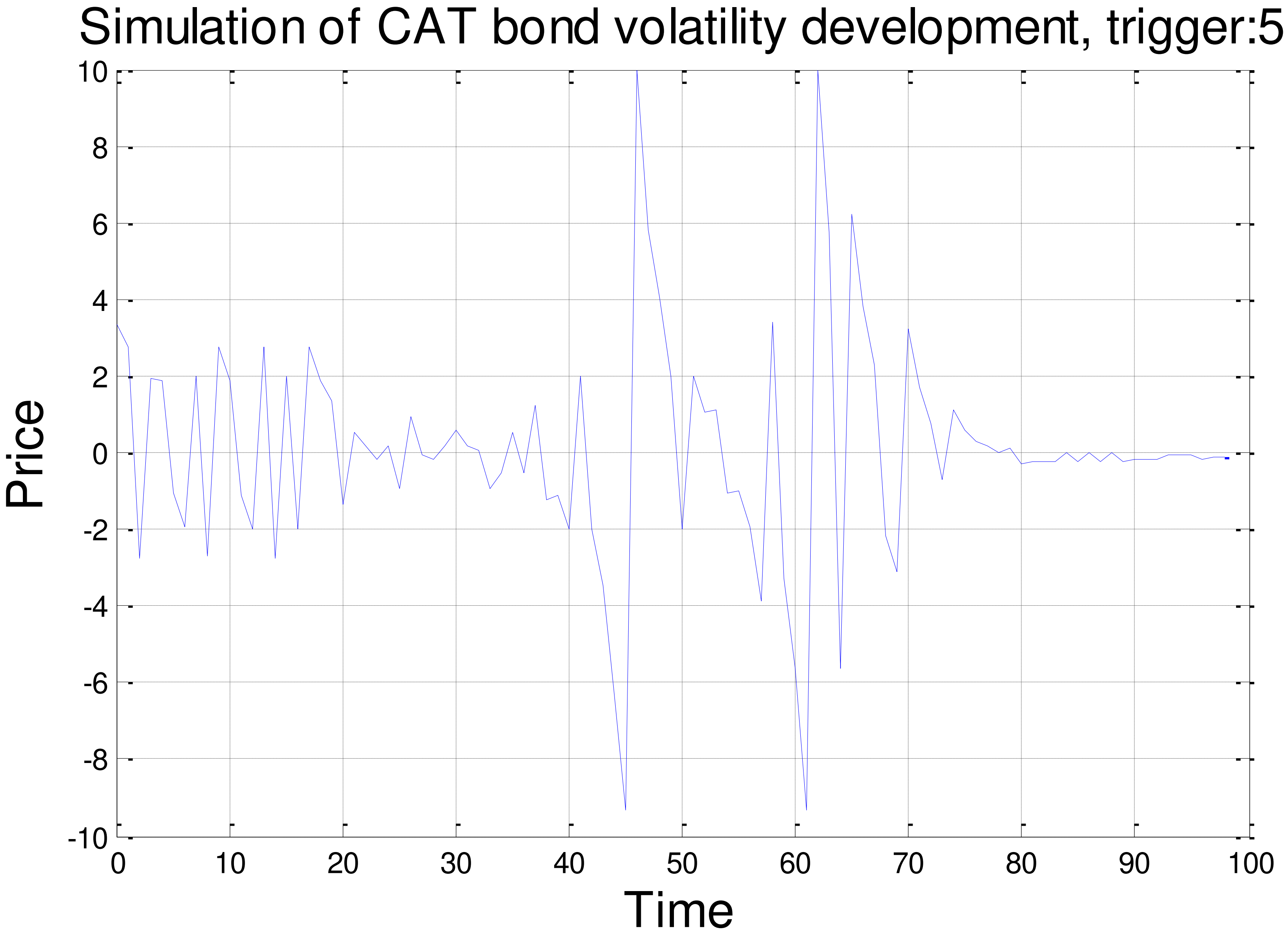
Source: B. Stádník

CAT bonds design, valuation approach



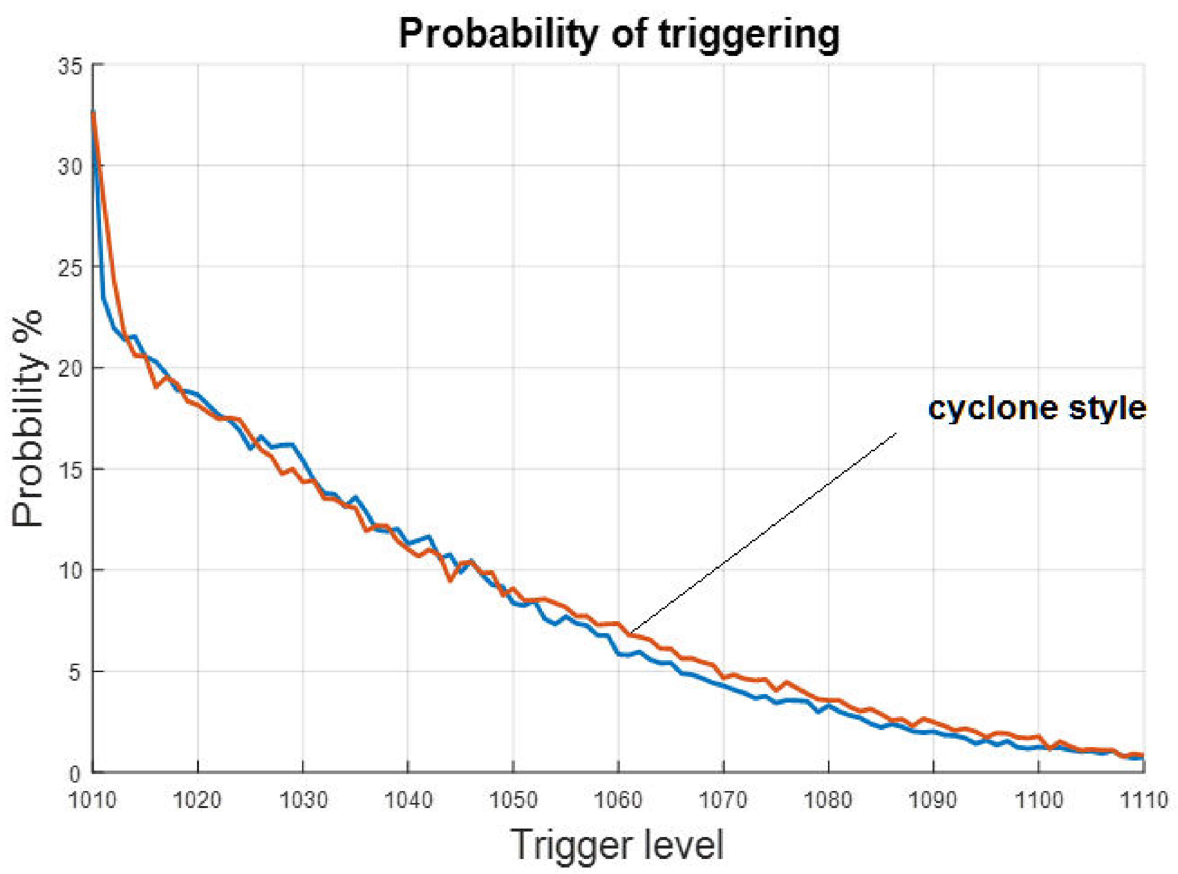
Source: Stádník

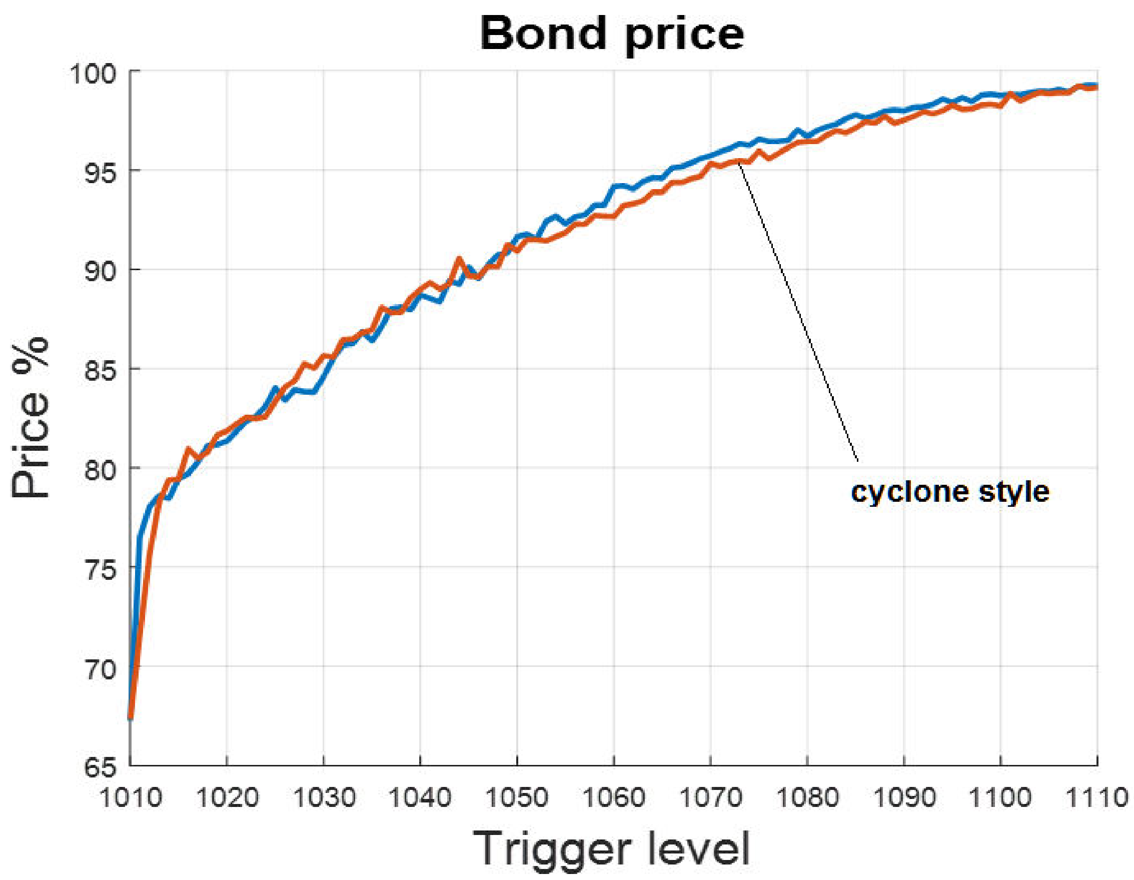
CAT bonds design, valuation approach



Source: Stádník

CAT bonds design, valuation approach

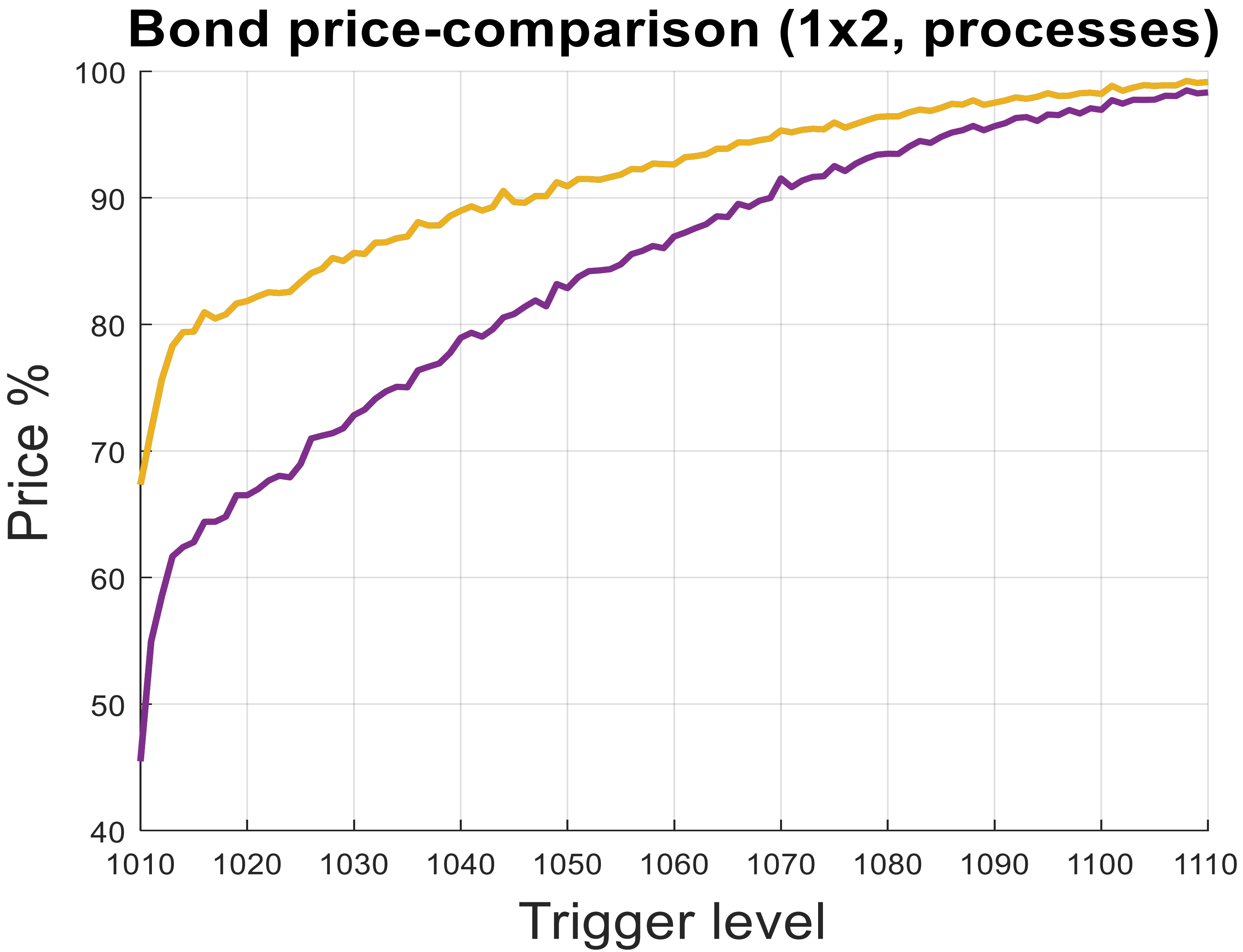




$$P_1 = \frac{(F+c)(1-q) + \omega(F+c)q}{1+i}$$

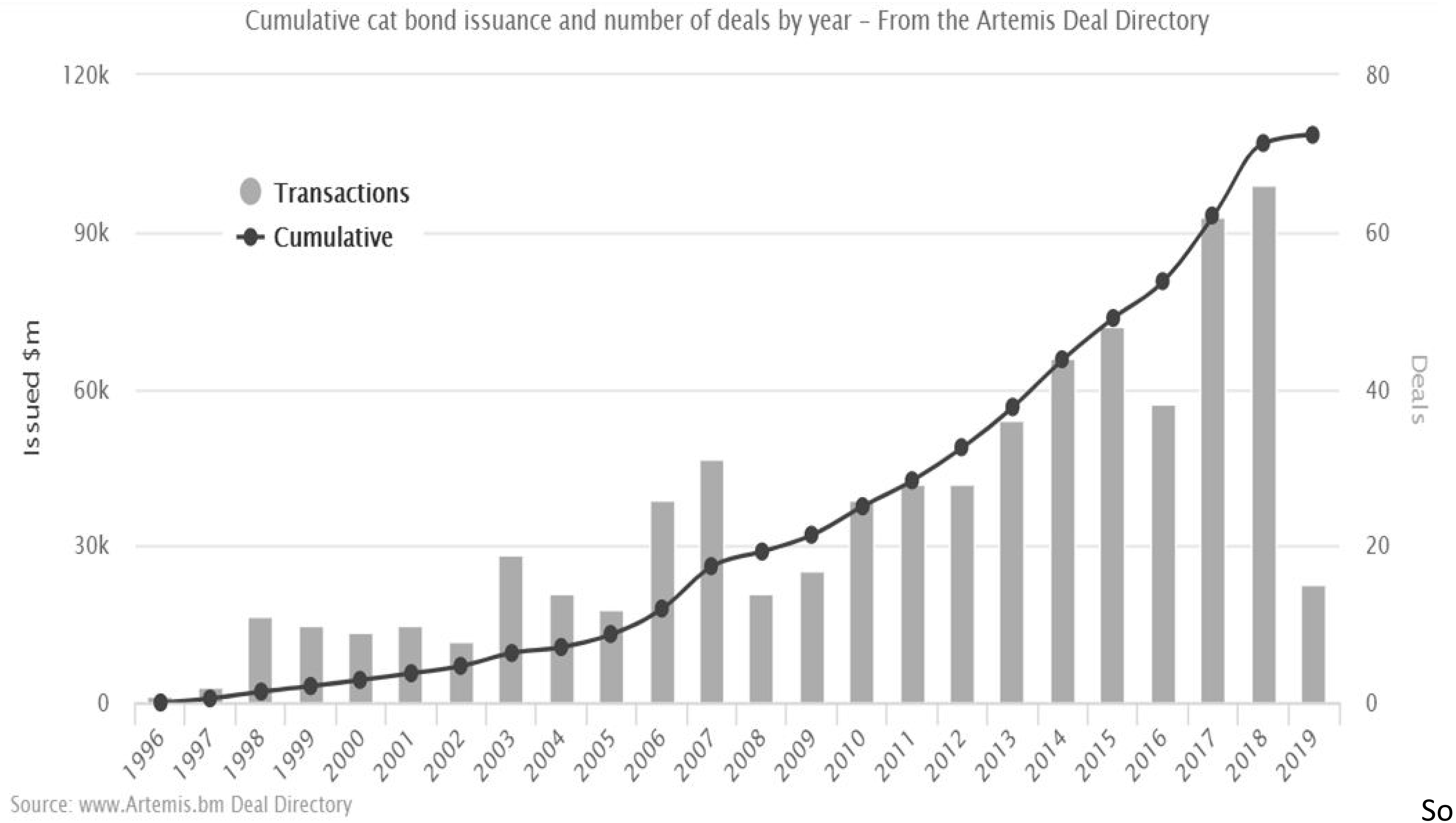
Source: Stádník

CAT bonds design, valuation approach



Source: Stádník

ILS market characteristics



Source: Stádník

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