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# Insurance Options: Beating the Benchmark. Are Catastrophe Bonds more profitable than Corporate Bonds?

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## ABSTRACT

In this paper, we establish a comparison between one of the most traded financial derivatives in the markets, the so-called catastrophe bonds (abbreviated as cat bonds) and the corporate bonds. In the first section, we start from a brief definition as well as some basic concepts. In section two, we will enumerate the type of investors to whom these products might interesting and how to price them. Afterwards, in section three we move onto the analysis of the trading rule proposed, that is, the comparison with Corporate bonds, our benchmark, in terms of expected returns. In sections four and five, we will point out some key issues on how the credit risk associated to these products can be reduced and, finally, in the last section, we will conclude with some discussions and remark the state-of-the-art research on this field.

**Keywords:** catastrophe bonds, corporate bonds, risk securitization, risk transferring, structured product, insurance-linked securities, reinsurance risk, derivatives pricing, credit risk.
**JEL classification:** G11; G12; G14.
**MSC2010:** 60G20; 62P20; 91G40.

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# Opciones de seguros: superando la referencia. ¿Son más rentables los bonos catástrofe que los bonos corporativos?


## RESUMEN

En este artículo establecemos una comparación entre uno de los derivados financieros más negociados en los mercados, los llamados bonos catástrofe (abreviados como bonos CAT) y los bonos corporativos. En la primera sección comenzamos con una breve definición y algunos conceptos básicos. En la sección dos, enumeraremos el tipo de inversores para quienes estos productos pueden ser interesantes y cómo se podría fijar el precio. Posteriormente, en la sección tres, pasamos al análisis de la regla de negociación propuesta, es decir, la comparación con los bonos corporativos, nuestro punto de referencia, en términos de rentabilidad esperada. En las secciones cuatro y cinco señalaremos, respectivamente, algunas cuestiones clave sobre cómo se puede reducir el riesgo de crédito asociado a estos productos y, finalmente, en la última sección, concluiremos con algunas discusiones y comentaremos las investigaciones más recientes sobre este tema.



**Palabras clave:** bonos catástrofe, bonos corporativos, titulización del riesgo, transferencia de riesgo, productos estructurados, valores vinculados a seguros, riesgo de reaseguro, precios de derivados, riesgo de crédito.
**Clasificación JEL:** G11; G12; G14.
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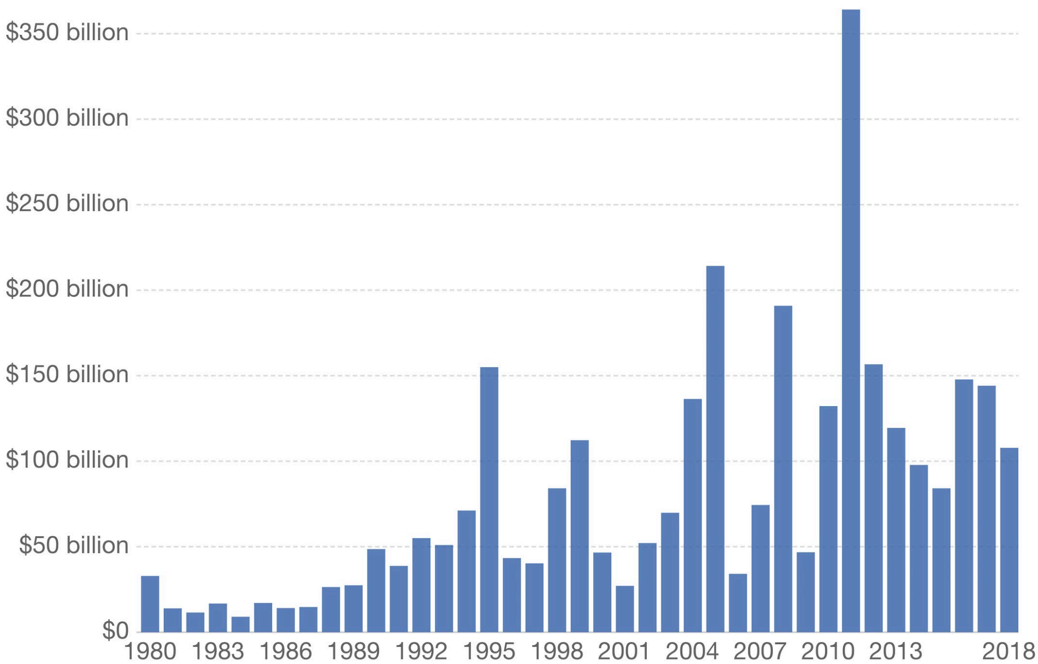
## 1. Introduction: definition and basic concepts.

According to the *Emergency Events Database* (EM-DAT)[1], in 2018 the economic cost of disasters were 107.77 billion US$. Such losses may have a significant financial impact on governments if the damages are not fully insured or, at least, partially protected. For developing countries, this mishap may cause a cutout in the state funds for development projects, to disaster relief and rebuilding efforts. One way to avoid this financial risk is through catastrophe risk securitization instruments. Therefore, this allows governments to raise money from investors willing to bet against the likelihood of a disaster occurring in a particular place during a particular time period.

Figure 1 shows the evolution of such costs since 1980 (note that in 2011 the amount rose to more than 350 billion US$).

**Figure 1. Global damage costs from natural disasters.**




Source: EMDAT: OFDA/CRED International Disaster Database, Université Catholique de Louvain -Brussels - Belgium. Retrieved from: https://ourworldindata.org/natural-disasters

There are a variety of insurance linked securities instruments, such as options, swaps, and bonds. Among them, Catastrophe bonds (from now on CAT bonds) are the largest issued and most successful product. According to the website Artemis[2], the CAT bonds and insurance-linked securities risk capital issued, have topped nearly 14 billion USD in 2018 and are set to be the highest of all times (still to close 2019).

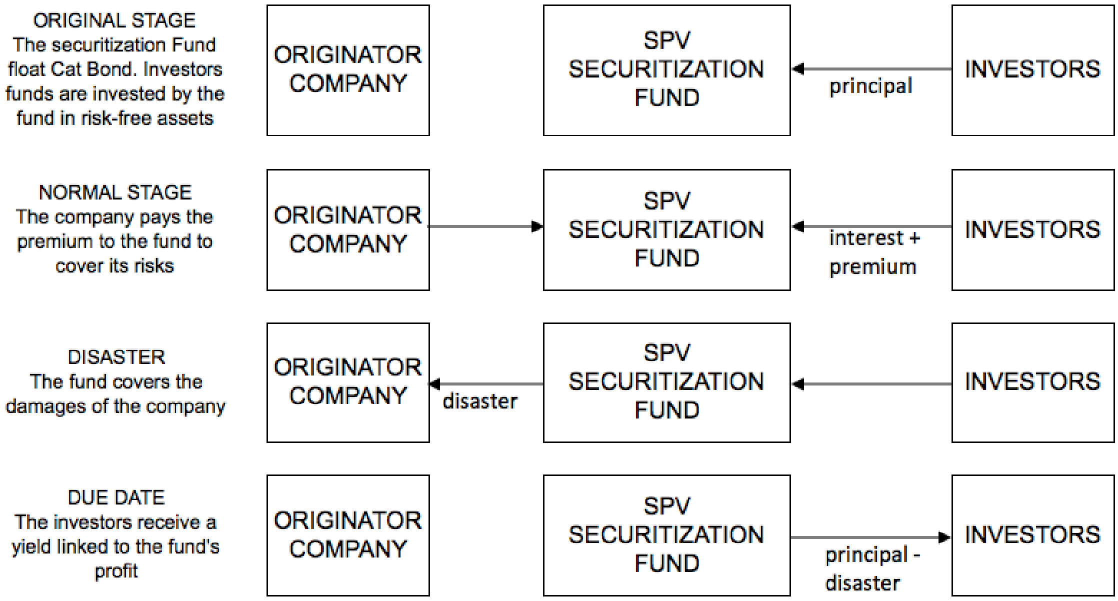
A CAT bond is conceptually a structured note where the coupon payment and/or principal repayment by the issuer is contingent upon the non-occurrence of a specified event-typically, a catastrophe event such hurricanes, droughts, floods, earthquakes, wildfires, extreme weather, etc. In

[1] The EM-DAT is a database launched by the Centre for Research on the Epidemiology of Disasters (CRED) https://www.emdat.be/

[2] The Catastrophe Bond, Insurance Linked Securities & Investment, Reinsurance Capital, Alternative Risk Transfer and Weather Risk Management Portal: Homepage Steven Artemis.bm - https://www.artemis.bm/

essence, the CAT bond structure creates a direct nexus between payment of interest or principal and the catastrophe risk.

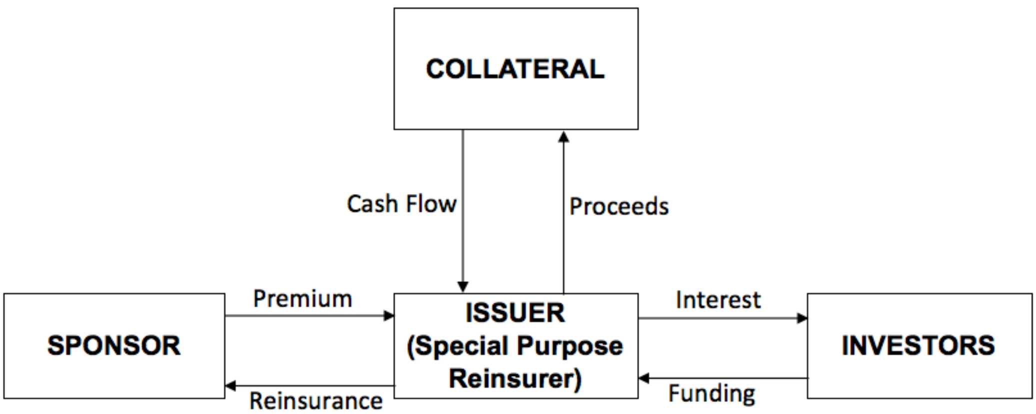
**Figure 2. Basic functioning of a CAT bond.**




Source: Author's adaptation of information from Artemis from https://www.artemis.bm/

The basic functioning and structure of a CAT bond is showed in the figures 2 and 3, respectively. More explicitly, for example, if an insurer has built up a portfolio of risks by insuring proper ties in Florida, then he or she might wish to pass some of this risk on so that he/she can remain solvent after a large hurricane. They could simply purchase traditional catastrophe reinsurance, which would pass the risk on to reinsurers. Alternatively, they could sponsor a CAT bond, which would pass the risk on to investors. In consultation with an investment bank, they 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 something from 3 to 20%. If no hurricane hits Florida, then the investors made a healthy return on their investment. However, if a hurricane hits Florida and triggers the CAT bond, then the principal initially paid by the investors is forgiven, and is instead used by the sponsor to pay their claims to policyholders.

**Figure 3. Structure of a CAT bond.**




Source: Author's adaptation of information from Artemis https://www.artemis.bm/

CAT bonds issues are typically undertaken by an insurer to hedge its losses upon the occurrence of a catastrophe event. The issues are generally structured as follows:

- The issuer of the bond is a special purpose vehicle[3], which is generally located in a tax haven.
- The insurer seeking reinsurance cover enters into a reinsurance contract with the SPV. The insurer pays a premium to the SPV in return for assuming the insurance risk.
- The SPV issues the CAT bond to transfer the reinsurance risk assumed in the transaction to investors in the bonds.
- The SPV uses the proceeds of the issue to purchase high quality securities (generally US Treasury securities).
- The SPV pays the CAT bond investors a coupon that is equivalent to the coupon on the US Treasury securities and the reinsurance premium received by the SPV.
- The principal repayment is contingent on the occurrence of the specified catastrophe event:
  1. If there is a catastrophe event, the investors will lose principal up to the full face value of the transaction. The loss to the insurer will be paid out under the reinsurance contract by the SPV and funded out of the US Treasury securities held.
  2. If there is no catastrophe event, then the principal will be paid in full to the investor out of the maturing US Treasury investment pool.

A CAT bond is designed to achieve the following objectives:

- To allow investors access to insurance linked investments: the packaging of the reinsurance risk into a fixed income security format allows investors, who may otherwise be prevented from entering into transactions involving insurance risk, to participate in this structure.
- To reduce credit risk of the transaction: the credit risk on the reinsurance contract is reduced as the obligations to cover losses are fully collateralized by the US Treasury securities. Indeed, the investors provide the insurer with the hedge against losses through the forgiveness of the issued debt.
- To provide structured exposure to insurance risk: the CAT bond format allows the exact degree and level of exposure to the insurance event to be precisely structured to meet investor requirements.
- To transfer risks: for the issuer - typically governments, insurers, and reinsurers - CAT bonds signify financial protection in case of a major natural catastrophe, such as a hurricane or an earthquake. For the investor, buying the bonds means they may get high returns for their investment, which is not subject to financial market fluctuations. As Lakdawalla and Zanjani (2004) points out, these collateralized instruments are useful in a risk transfer market when insurers cannot write contracts with a full menu of state-contingent payments.

## 2. Type of investors.

The CAT bonds have proved more attractiveness to institutional investors because of the fixed interest investment format that denies the need to enter into separate derivative transactions, also they are interesting to investors seeking leveraged risk profiles because, unlike other option contracts they do not provide the inherent leverage potential.

Particularly, investors choose to invest in catastrophe bonds because their return is largely uncorrelated with the return on other investments in fixed income or in equities, so CAT bonds help investors achieve diversification. Investors also buy these securities because they generally pay higher interest rates (in terms of spreads over funding rates) than comparably rated corporate instruments as long as they are not triggered.

[3] An SPV is an organizational mechanism for creating cells of specific expertise focused on Alternative Risk Transfer.

## 3. Pricing CAT Bonds.

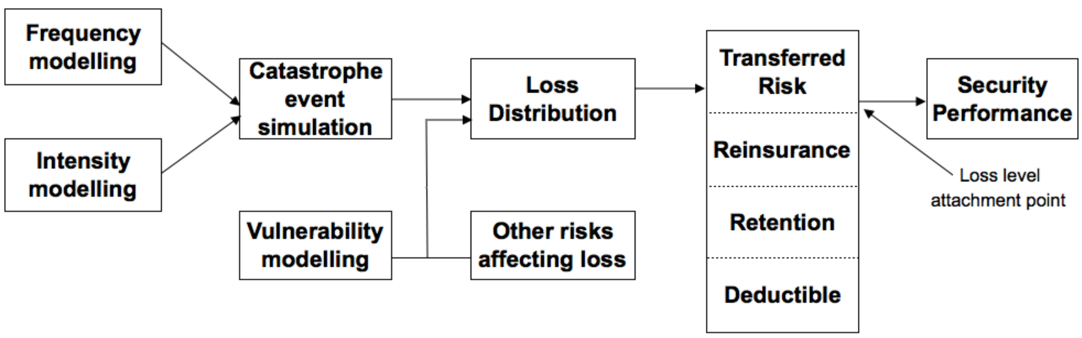
Pricing CAT bonds typically involves the decomposition of such bond into a position which pays risk free rate in order to compensate investors for holding the capital for the period (similar cash flows to a corporate bond) and a CAT option, a derivatives contract based on the value of an index that measures catastrophe losses in a given time (usually a quarter).

A related issue is the rating of CAT bonds which are often rated by an agency such as Standard & Poor's, Moody's or Fitch Ratings. A typical corporate bond is rated based on its probability of default due to the issuer going into bankruptcy, whereas a cat bond is rated based on its probability of default due to an earthquake or hurricane triggering loss of principal.

This probability is determined with the use of catastrophe models. Each agency uses their own models to rate these securities. The methodology used focuses on estimating expected loss and the other factors affecting bond's performance. The analysis concentrates on:

- *The catastrophic event*: modelled using computer simulation models.
- *The conditional loss amount*: refers to the loss level transfer point that must be exceeded before being borne by the investor.
- *The structure of the transaction*: any special transaction features, which may influence loss.

**Figure 4. Catastrophic event backed bond analysis.**




Source: Author's own elaboration.

As is shown in figure 4, the key elements of the modelling are:

- **Frequency modelling:** likelihood of a long term event occurrence within a probabilistic framework. This is done with any form of stochastic analysis using probability distribution functions to simulate event occurrence (typical distributions are Poisson or Negative Binomial).
- **Intensity modelling:** the potential of the event for destruction using dependency relationships between key variables, which influence the amount of damage.
- **Vulnerability analysis:** potential for damage in the event of the catastrophe occurring and is based on property specific attributes such as types of building and property.
- **Aggregate Loss Distribution:** which is based on the distribution of frequency and intensity. It is used to generate the aggregate loss distribution to cover the relevant event. This may be done using a number of techniques such as Monte Carlo simulations, sampling techniques and event trees.
- **Other factors:** data quality, policy coverage, geographical concentrations and loss management.

Most CAT bonds are rated BB or B, which indicates that the risk of incurring a reimbursement value reduction is assessed to be in the 1% region.

The development of CAT bonds market depends on the reasonable prices, so the scientific pricing is the key problem to the field of CAT bonds research. As kind of catastrophe risk securitization product, the value of CAT bonds results from the probability of the catastrophe risk and the loss in the catastrophe, for CAT bonds have the dual properties of bonds and options. Moreover, for the highly skewed property of the catastrophe risk distribution, valuing CAT bonds has become very complicated.

Following the line of work of pricing these instruments, Ahrens, Füss and Kestel (2009), for instance, analyzed the impact of the hurricane season 2005 on the pricing of CAT bonds, checking that highly rated CAT bonds compared to sub-investment bonds show a different relation between objective risk measures and the spread. More recently, Braun (2015), presented empirical evidence at the time of identify the determinants of the CAT bond spread at issuance, for that, the author uses a series of OLS regressions with heteroskedasticity- and autocorrelation-consistent standard errors.

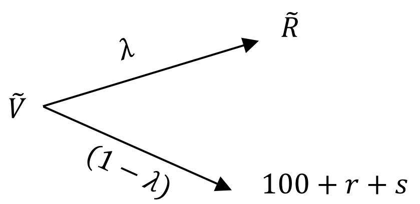
## 4. Beating the benchmark: the strategy.

### 4.1. First approach: one period binomial model.

In our study, we use the data obtained from Lane (1998) and Canabarro, Finkemeier, Anderson, and Bendimerad (2000), we focused on the simple strategy of determine the CAT bond excess return and compare them with the corporate ones.

To evaluate the risk-adjusted performance of the CAT bond asset class, different methods have been used empirically. In our case, we have used the one period binomial model.

**Figure 5. Valuing catastrophe linked securities using a one-period binomial model.**




Source: Author's own elaboration.

We sell a small amount $\lambda$ of the portfolio and we invest it in the new asset $V_i$:
$\pi' = (1-\lambda)\pi + \lambda V$ and where $\tilde{R}$ is the recovery value, stochastic too, $r$ and $s$ are the principal plus the risk free rate interest (5.5%) which we assume are not stochastic.

$$E[\pi'] = (1-\lambda) \cdot E[\pi] + \lambda E[V] \quad (1)$$

$$Stdev[\pi'] = (1-\lambda) \cdot Stdev[\pi] + \lambda^2 + \sigma^2 + 2(1-\lambda)\,\lambda\,\rho\,\sigma\,Stdev[\lambda] \quad (2)$$

We can measure the relative value of a bond in terms of its Sharpe ratio:

$$R = \frac{(1-\lambda)E[\pi] + \lambda E[V] - r_f}{(1-\lambda)Stdev[\pi]} = \frac{E[\pi] - r_f}{Stdev[\pi]} = \lambda \frac{E[V] - r_f}{Stdev[\pi]} \quad (3)$$

where $\rho$ and $\lambda$ take small values between $[1\% - 5\%]$ and $Stdev[\pi'] \simeq (1-\lambda)s$.

The Sharpe ratio, namely the excess return per unit of volatility, is actually the commonly used measure of return and risk performance, it is as well susceptible to gaming by managers.

So, from now on and like most of the performance measurements proceed we can just play with the Sharpe ratio for analytical interpretations, so following (3), for $E[V] > r_f$ the Sharpe ratio increases by moving a small amount into the new asset.

Table 1 presents a relative value analysis of several recent CAT bonds as well as comparable traditional high yield debt (corporate bonds). For the CAT bonds, the attachment probabilities, expected recovery rates, standard deviations of recoveries and expected losses were taken directly. This analysis indicates that CAT bonds are much more attractive than high yield bonds in terms of Sharpe ratio. It would be interesting to check whether this difference would disappear if we vary the high-yield default probabilities, as well as, to introduce an analysis on the spread over Libor, which was done by the authors, showing that despite of this, the difference does not disappear. In fact, Canabarro et al. (1998) show that, under certain assumptions, the CAT bonds, stochastically dominates the corporate bonds[4].

**Table 1. Relative value analysis: (*) For CAT Bonds they multiplied the quoted spreads by #d/360, where #d is the total number of days over which interest is paid.**

| *Speculative Grade* | *Historical Default Probability* | *Recovery Rate %* | *Standard Deviation* | *St. Deviation of Return* | *Expected Loss* | *Sharpe Ratio* |
|---|---|---|---|---|---|---|
| | *p* | | *E(R)* | *Sd(R)* | *Sd(V)* | |
| Ba2 | 0.60% | 51.26 | 25.81 | 4.75 | 0.33% | 0.25 |
| Ba3 | 2.70% | 51.26 | 25.81 | 10.02 | 1.51% | 0.02 |
| B1 | 3.80% | 51.26 | 25.81 | 11.91 | 2.15% | 0.01 |
| B2 | 6.70% | 51.26 | 25.81 | 15.66 | 3.79% | -0.09 |
| B3 | 13.20% | 51.26 | 25.81 | 21.49 | 7.54% | -0.22 |
| Principal Protected Tranche | Attachment Probability | | | | | |
| R. Re'97 | 1.02% | 48.30 | 30.60 | 7.01 | 0.63% | 0.80 |
| Paramet. | 1.02% | 41.23 | 30.04 | 7.57 | 0.70% | 0.54 |
| Trinity | 1.53% | 54.61 | 38.27 | 8.14 | 0.83% | 0.39 |
| R. Re'98 | 0.87% | 42.67 | 35.72 | 7.06 | 0.58% | 0.54 |
| Mosaic A | 1.13% | 61.40 | 30.05 | 6.06 | 0.55% | 0.70 |
| Mosaic B | 4.29% | 52.98 | 32.71 | 14.09 | 2.62% | 0.42 |
| Principal Protected Tranche | Attachment Probability | | | | | |
| R. Re'97 | 1.00% | 75.05 | 16.22 | 3.72 | 0.34% | 0.76 |
| Paramet. | 1.02% | 73.47 | 15.02 | 3.78 | 0.35% | 0.56 |
| Trinity | 1.53% | 80.91 | 18.14 | 3.86 | 0.39% | 0.39 |
| Mosaic | 1.13% | 83.53 | 15.03 | 3.03 | 0.28% | 0.75 |

Source: Canabarro et. al. (1998).

Several authors have documented the appeal of CAT bonds. Froot, Murphy and Stern (1995), show that CAT investments over-performed domestic bonds and that the returns on CAT risks are less volatile than either stocks or bonds. Litzenberger, Beaglehole and Reynolds (1996), demonstrated that

[4] An asset A, stochastically dominates asset B if the probability of asset A's rate of return exceeding any given level is larger than or equal to that of asset B's rate of return exceeding the same level.

returns on CAT bonds are uncorrelated with the market, making them excellent tools for portfolio diversification. Given that, this is not the aim of this paper we will not enter into more details.

Another difference between corporate bonds and CAT bonds lies in the different information flow and therefore price movement process. In the case of corporate bonds, new information about the financial condition of the issuer tends to arrive gradually. A severe catastrophe event would strike with only a few hours' notice. For the price of the security as a function of time, this implies that corporate bond prices have a larger diffusion component, while CAT bond prices are characterized by large sudden jumps, which may be a drawback for investors compared with corporate bonds.

**4.2. Second approach: probability transform.**

It would be interesting to have another approach given that in our analysis, we are trying to prove the statement that for investors, it is desirable to compare the relative attractiveness of the yields spreads between CAT bonds and corporate bonds. Such approach is also proposed in Wang (2004). In order to compare risk-adjusted performance of various asset classes, we would need a common yardstick that is applicable to all types of risks.

As we know for mutual funds, for instance, a widely used measure of risk-adjusted performance is the above-mentioned Sharpe ratio. Which works well for assets whose returns follow normal distributions, clearly speaking, they have usually attractive Sharpe ratios, even under very bad scenarios. However, for a single CAT bond issue, it is questionable to apply the traditional Sharpe ratio concept since the asset return is skewed and with jumps (stochastically in volatility what is really far from the Black-Scholes concept of pricing derivatives): most of the probability mass is centered at zero loss, while there is a small probability of potentially large negative returns. For our task, we used the probability transform to try to extend the Sharpe ratio concept to credit risk, so that we can evaluate the risk adjustment performance of the CAT bonds asset class.

The following formulation is proposed:

$$S^*(x) = \Phi\left(\Phi^{-1}\left(S(x)\right) + \lambda\right) \tag{4}$$

$$S^*(x) = Q\left(\Phi^{-1}\left(S(x)\right)\right) \tag{5}$$

$$S^*(y) = Q\left(\Phi^{-1}\left(S(y)\right) + \lambda\right) \tag{6}$$

with $\lambda$ as a direct extension of the Sharpe ratio and $\Phi$ the *Standard Normal Cumulative Function*, for a given loss variable, $L$ and $S(x) = Prob\{X < x\}$ is the probability that the CAT loss $X$ will exceed amount $x$ and it includes information of expected frequency of default and the recovery rate given default.

For $S(x)$ being an empirically estimated probability distribution, before adjustment for parameter uncertainty. If we combine the later in (4) and (5), which is the pure risk adjustment we get (6) which yields to the two-factor model.

Table 2 shows this probability transform and the two-factor model for a different rated corporate bond.

**Table 2. Transformed default frequency. Corporate bonds include the historical default frequencies "p".**

| *Corporate Bond* | **Probability Transform** | | **Two-factor model** | |
|---|---|---|---|---|
| | ***p**** | ***p*/p*** | ***p***** | ***p**/p*** |
| AAA (0.00015) | 0.0077 | 5.15 | 0.00971 | 64.73 |
| AA (0.0004) | 0.00185 | 4.62 | 0.01362 | 34.05 |
| A (0.00075) | 0.0322 | 4.29 | 0.01721 | 22.95 |
| BBB (0.0017) | 0.00659 | 3.87 | 0.02393 | 14.08 |
| BB (0.0075) | 0.02372 | 3.16 | 0.04735 | 6.31 |
| B (0.02) | 0.05438 | 2.72 | 0.07995 | 4.00 |
| CCC (0.08) | 0.16977 | 2.12 | 0.18821 | 2.35 |

Source: Wang (2004).

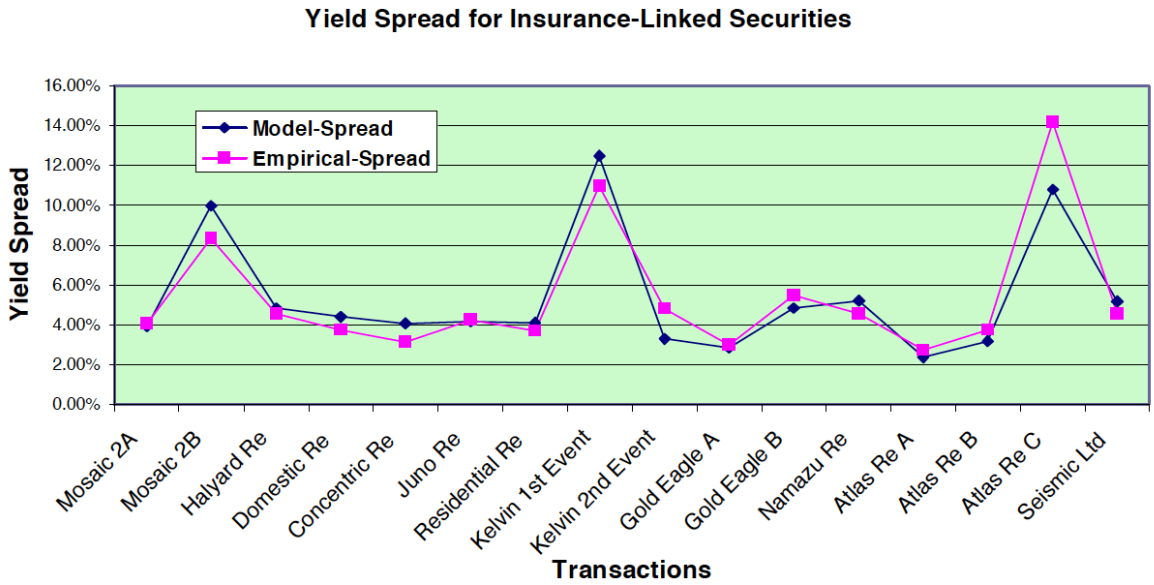
Notice that the number in parenthesis corresponds to the historical default frequencies. We can see that for the two-factor model the difference is much bigger, although as soon as the rating decreases, the probabilities are much closer (i.e., B and CCC rating). On the other hand, table 3 shows the fitted two factor model yield spreads versus empirical spreads for 16 CAT bond transactions during the year of 1999. Based on minimizing mean-squared error, the best fit parameters are $\lambda$ =0.453 and $k$ =5 for the Student-*t* degrees of freedom and the corresponding graph is showed in figure 6, where we can check that our model-spread fits quite well.

**Table 3. Fitted two-factor model yield spreads vs. empirical yield spreads for 16 CAT bond transaction in 1999.**

| *CAT Bond Transaction* | *Probability of first $ loss* | *Probability of last $ loss* | *Expected loss given default* | *Model yield spread* | *Empirical yield spread* |
|---|---|---|---|---|---|
| Mosaic2A | 0.0115 | 0.0012 | 0.3652 | 3.88% | 4.06% |
| Mosaic2B | 0.0525 | 0.0115 | 0.5410 | 10.15% | 8.36% |
| HalyardRe | 0.0084 | 0.0045 | 0.7500 | 4.82% | 4.56% |
| Domest.Re | 0.0058 | 0.0044 | 0.8621 | 4.36% | 3.74% |
| ConcenRe | 0.0062 | 0.0022 | 0.6770 | 4.01% | 3.14% |
| JunoRe | 0.0060 | 0.0033 | 0.7500 | 4.15% | 4.26% |
| ResidentRe | 0.0076 | 0.0026 | 0.5789 | 4.08% | 3.71% |
| Kelvin1st | 0.1210 | 0.0050 | 0.3678 | 12.80% | 10.97% |
| Kelvin2nd | 0.0156 | 0.0007 | 0.1923 | 3.25% | 4.82% |
| GoldEagleA | 0.0017 | 0.0017 | 1.0000 | 2.81% | 2.99% |
| GoldEagleB | 0.0078 | 0.0049 | 0.8077 | 4.82% | 5.48% |
| NamazuRe | 0.0100 | 0.0032 | 0.7500 | 5.20% | 4.56% |
| Atlas Re A | 0.0019 | 0.0005 | 0.5789 | 2.35% | 2.74% |
| Atlas Re B | 0.0029 | 0.0019 | 0.7931 | 3.15% | 3.75% |
| Atlas Re C | 0.0547 | 0.0190 | 0.5923 | 11.01% | 14.19% |
| Seismic Ltd. | 0.0113 | 0.0047 | 0.6460 | 5.13% | 4.56% |

Source: Wang (2004).

**Figure 6. Fit the two-factor model (3) to empirical yields spreads for the 16 CAT bond transaction data in 1999 compiled by Lane Financial (fitted parameters $\lambda$ = 0.453 and k=5).**




Source: Wang (2004).

## 5. Reducing the impact sources of risk with CAT Bonds.

Several sources of risk may be reduced, or at least mitigated, with this type of instrument. Before 11th of September 2001 fund managers were less familiar with the CAT bond's asset class, being reluctant to expose themselves to potential career risks, since they had difficulties to explain losses from investing in CAT bonds, instead of conventional corporate bonds. However, since 2002 and 2003 the interest of fund managers in investing in CAT bonds grew significantly and what is more, according to *Aon Securities*[5], the amount invested in CAT bonds has increased rapidly from 22bn US$ in 2007 to 98bn US$ at the end of last year. This is because the superior performance of the CAT bonds has been known by the financial community and because the perceived credit risk of corporate bonds increased.

Nevertheless, most of the literature in CAT bonds princing does not take the credit risk influence into account. In this sense, for instance, Zimbidis, Frangos and Pantelous (2007) use *Extreme Value Theory* to get the numerical results of CAT bonds prices under stochastic interest rates in an incomplete market framework. In addition, Nowak and Romaniuk (2013) use Monte Carlo simulation method to price the CAT bonds with different payoff functions, but none of them treat the credit risk issue and how affect to the CAT bonds.

Actually, the credit risk has the probability of existence for the operating mechanism of CAT bonds. In this sense, is important to consider the credit risk in the valuation, which can improve the pricing validity. Liu, Xiao, Yan and Wen (2014), for instance, employ the Jarrow and Turnbull method to model the credit risks and get access to the general pricing formula using Extreme Value Theory in an attempt to include the credit risk in the CAT bond's pricing, because since 2008, catastrophic losses and financial turmoil have deeply shaken the insurance and reinsurance industries.

Severe difficulties encountered by sector leaders like AIG and Swiss Re have shed light on the potential fragility of the players, and have increased attention on the subject of reinsurance counterparty risk. Therefore, catastrophe bonds have been structured with total return swaps (TRS) to remove any

[5] A global professional services firm providing a broad range of risk, retirement and health solutions. Retrieved from: https://www.ft.com/content/9dc2441c-f23a-11e8-9623-d7f9881e729f

investment and credit risk face by investors, however, the severity of the credit and liquidity crisis, coupled with Lehman's bankruptcy, has challenged the true security provided by the 'double trigger' mechanism in the TRS. This mechanism was designed to protect investors and sponsors from simultaneous counterparty and collateral impairment risk.

The managing of the systemic risk has been also analyzed at the time of study the risk transferring possibility. Thus Vedenov, Epperson and Barnett (2006) proposed an attempt to design CAT bond products for agriculture products and examined the potential of these instruments as mechanisms for transferring agricultural risks from insurance companies to investors/speculators in the global capital market, specifically, they considered the Georgia cotton.

In addition, as a way of diversification, CAT bonds could be seen as an interesting vehicle to transfer the risk to the capital market. Mariani and Amoruso (2016) analyzed how investing in catastrophe instruments produces actual benefits for investors both in term of diversification and total return showing that CAT bonds are efficient in terms of stability due to its low volatility and stable returns, proving the advantages for the investor who operates in this market in terms of portfolio diversification.

## 6. Concluding remarks.

The discussions presented so far reflect an attempt to evaluate uncertainty in CAT models and to evaluate its effect on CAT securities pricing. However, what is the investor to make of this? How does uncertainty in CAT models compare with uncertainty in more traditional -corporate bond- securities? According to Bantwal and Kunreuther (2000), despite the attractivenes of the CAT bonds, spreads in this market remain higher than spreads for comparable speculative instruments.

The 1999 market transaction data and as well for the following year, Lane (2001) indicated that CAT bonds and corporate bonds offered similar risk-return trade-offs in terms of Sharpe ratio. However, CAT bonds and corporate bonds showed a student degrees of freedom, $k = 5$. In other words, investors demanded higher risk-adjustment for parameter uncertainty for CAT bonds than for corporate bonds. Other authors, for instance, Gürtler, Hibbeln and Winkelvos (2016), analyze how natural catastrophes and financial crises influence CAT bond premiums using a broad data set of secondary market CAT bond premiums from 2002 to 2012.

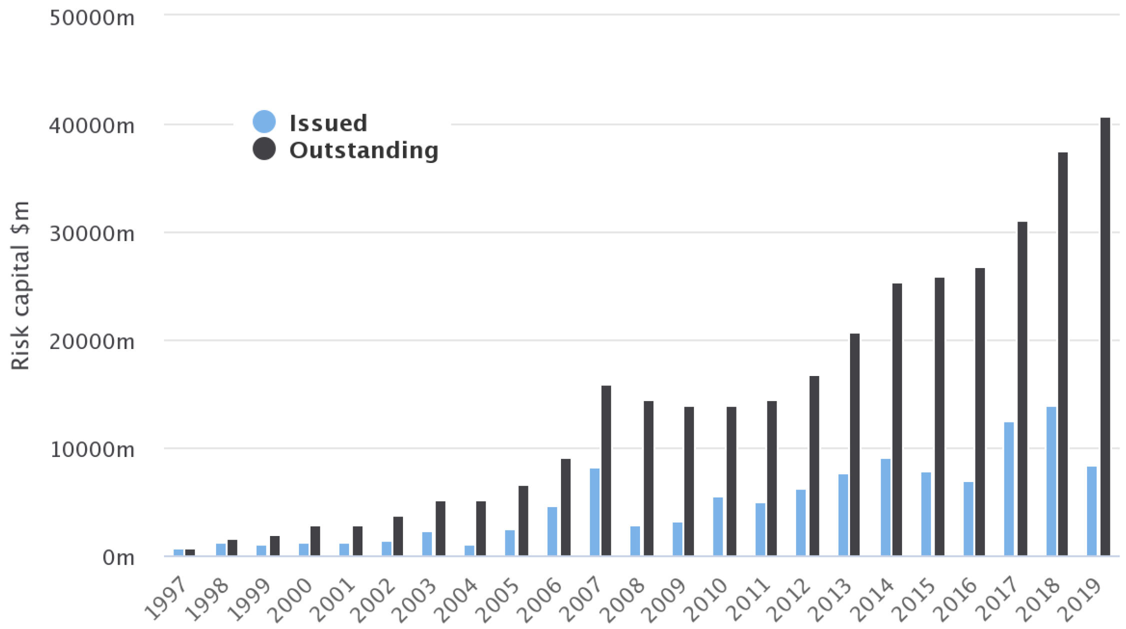
Even though a potential drawback of these types of CAT bonds is that they do not protect the issuer against all possible catastrophe losses, we could expect in the future that CAT bonds will shake up the insurance industry. Wall Street will steal market share from reinsurers, primary insurers with large catastrophe exposures will have better access to coverage, price volatility in the reinsurance market will moderate and many reinsurers will transform into intermediaries/consultants on risk-management strategies.

On the other hand, natural catastrophe risks offer an excellent means of diversification as they are marginally correlated to financial risks. In this sense, more and more investors will be interested in this market because investing in CAT bonds represents a more structured and documented way of assuming natural catastrophe risks exposure than investing in the equity of insurance companies. However, investing in CAT bonds implies a certain level of risk and must only be considered as part of a global strategy of diversification. CAT bonds produce a low level of risk correlation with other classes of assets and can, therefore, dramatically help improve the expected return/risk pattern of an investment portfolio.

DiFiore and Jian (2019), show that adding this kind of financial product at the time of modeling pension portfolios might help them to better achieve their objectives and minimizing the risks being taken against the duration, inflation and longevity assumptions embedded in the scheme's liabilities.

Up to date, CAT bonds have performed very well, despite some significant natural catastrophe events. The few CAT bonds, which have matured to date, have been redeemed in full without any loss to the investors. Figure 7 shows catastrophe bond issuance for the period from 1997 and through 2019, we can see that last year was the fourth for the hole period represented in the chart.

**Figure 7. CAT bonds and insured-linked securities issuance and capital outstanding from 1997 to 2019**




Source: Artemis.bm (2019). Retrieved from https://www.artemis.bm/dashboard/catastrophe-bonds-ils-issued-and-outstanding-by-year/

This proves the strength of the CAT bond market and according to Cory Anger (Artemis, 2016, p.3): *"overall, 2015 proved to be a strong issuance year for the cat bond market. In today's compressed rate environment, where the margin for error is low, investors will likely look towards higher quality risks. Especially as new sponsors continue to incorporate alternative capital into their strategies, we expect issuance to be similar to the last several years with further growth in the private CAT bond market".*

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