



A MULTIFACTOR PRICING MODEL FOR CAT BONDS IN THE SECONDARY MARKET

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Keywords:

Cat Bonds,
ILS,
Secondary market,
Indicative spread,
Panel data.

ABSTRACT

Given the relevance that Cat Bonds are taking in the financial markets, as well as their appeal for different types of investors, it becomes pertinent to understand the price dynamics of these securities in the secondary market. Several authors have developed and proposed different valuation approaches, focusing on the probability of occurrence of catastrophic events, as the main variable impacting the pricing of Cat bonds in the secondary market. However, the lack of inclusion of other factors considered relevant for investors, narrows the range of pricing driver's of Cat Bonds. This paper seeks to address the former need, presenting a panel data approach of a multifactor spread model, which comprehends 5 relevant variables. The results proved an adequate fitness and show that the model can be applied to both the P&C and, the Life market.

1. INTRODUCTION

Insurance Linked Securities (ILS) have been gaining force over the last decade, becoming a relevant mechanism in providing capacity and additional resources to the reinsurance industry. According to Aon Benfield (2014), in 2013 the total capital of the reinsurance industry was US\$540 billion, out of which 9.3% was considered as *Alternative capital* coming from ILS, and other Alternative Risk Transfer vehicles. The high cost of claims derived from catastrophic events was the leading reason motivating the insurance industry to transfer part of their risk into the financial markets.

According to Cummins (2008), Cat Bonds have been the most successful ILS so far, with a total capital outstanding of US\$18.6 billion (Guy Carpenter, 2013) reported at the end of 2013. These securities are defined as "fully collateralized instruments that pay off on the occurrence of a defined catastrophic event" (Cummins 2008). Their success derives from its innovative structure, being attractive to the sponsors as an alternative to reinsurance protection against catastrophic losses, and to investors as a high yield asset, which is uncorrelated to other financial securities

Therefore, given the relevance that Cat Bonds are taking in the financial markets, as well as their appeal for different types of investors, it becomes important to understand the price dynamics of these securities.

This research aims to address this need by developing a multifactor spread model, in which the most relevant variables affecting the spread of Cat Bonds trading in the secondary market are identified.

The remainder of this paper is organized as follows: In section 2 we include a literature review, followed by section 3 in which we present a description of the data used for the construction of our proposed model. Section 4 describes a preliminary analysis of both the data and the methodology. Furthermore, section 5 presents the methodology applied, the empirical analysis and the statistical assessment of the results found. Finally in section 6 we summarize our main results and draw our conclusions.

2. LITERATURE REVIEW

Since Cat Bonds are considered to be “one of the more recent financial derivatives to be traded on the world markets” (Baryshnikov et al 2001), and since their success has been widely spread on a world-wide scale; over the last decades, it has been a boom of authors developing and proposing numerous valuation approaches for these type of securities.

Previous authors exploring the pricing of Cat Bonds in the secondary market, have focused on the occurrence of catastrophic events in order to value the bond as a function of the expected probability of loss. Cox and Pedersen (1997) propose a model in which the catastrophe reinsurance premium is expressed as a high-yield bond, depending on the risk free rate, the probability of a catastrophe (default) and an amount to be reinsured. The authors use stochastic processes and devise a binomial tree approach for pricing them. Their methodology is supported by an intuitive approach and a theoretical basis; no empirical results were contrasted.

Other authors have used the Poisson distribution to explain the behavior of a catastrophic event. That is the case of Baryshnikov et al (2001), who affirm that some catastrophic events have a power law distribution, for which they develop a model using the Poisson distribution. Jin-Ping and Min-Teh (2002), also use a Poisson distribution to model catastrophe probabilities. Additionally, they provide an assessment of how interest rates affect the Cat Bond price, and offer a solution by modeling them stochastically.

Loubergé et al (1999), on the other hand, proposed a valuation based on the resemblance of Cat bonds with financial options. They develop a valuation methodology exclusively for those Cat Bonds with an Industry Loss Index. They analyze these securities as financial portfolios combining a bond and a catastrophe options. “Using option pricing theory and simulation analysis in a stochastic interest rate environment, we show that investors attracted by the potential for diversification benefits should not overlook the optional features when including these securities in an asset portfolio.”

As previously mentioned, authors have focused on the probability of occurrence of catastrophic events, as the exclusive variable in determining the pricing of Cat bonds in the secondary market. Therefore, the lack of inclusion of other factors that are priced by investors, narrows the range of the price drivers for Cat bonds. This fact led us to seek alternative approaches for the pricing process. We propose a multifactor model and prove that several factors are relevant to the bond’s spread in the secondary market.

3. DATA

Due to the recent appearance of Cat Bonds as tradable instruments, and the fact that all investors that currently invest in them are institutional, the liquidity of these kind of assets is rather low. There is not a price marked to the market, as there are for other high liquid assets. Instead, financial agencies and reinsurance brokers, gather information from the transactions made, to create an indicative market price for every cat bond outstanding.

The information used in this research was taken from the information provided by Lane Financial L.L.C in their Annual Review for the four quarters, Q2 2012 to Q1 2013. They provide secondary market prices of Cat bonds, in a quarterly basis. Every public outstanding Cat bond has an average market indication of its spread for each of the 4 quarters taken.

Information from Lane Financial L.L.C was used to construct a data base with 324 observations, corresponding to 81 Cat Bonds outstanding from June 2012, through March 2013. Each Cat bond has an indicative market spread for 4 periods, being the database a temporal sample of the secondary market of Cat bonds.

From the observations in the database, one markedly outlier was identified, corresponding to Successor X-Class V F4, a Swiss Re Cat Bond issued in November 2011. This bond was issued with an expected Loss of 6.7% and Spread of 16.25%, which is a value within normal ranges compared to other Cat Bonds with similar Expected Loss. However, in the secondary market the Bond experienced a high volatility in its indicative spread, being 19.6% in June 2012, 17.3% in September 2012, followed by a steep rise of 26.8% in December 2012 and an outstanding 35.3% in March 2013.

This bond's volatility was caused by the occurrence of Hurricane Sandy in October 2012, threatening the trigger to be set. The Cat Bond covers Wind in the United States and Europe, for which after the Hurricane Sandy, investors speculated on whether the losses incurred would be high enough to set the trigger, losing the principal and remaining coupons. Such speculative period cause investors to perceive a higher risk, causing the spread in the secondary market to trade above twice its initial spread only 16 months later. This observation was removed from the database

3.1. Methodology

Panel data consist of multi-dimensional data arrays in which certain variables are observed for an individual, through several periods of time. Therefore, it allows assessing the impact of the variables in a dynamic setting. Some of the advantages of working under a panel data approach, is to better identify effects in variables, and to construct and test more complicated behavioral models than purely cross-section or time-series data.

According to the literature we reviewed, there is very narrow number of authors who have previously assessed Cat Bonds under a panel data approach. Tao (2011), and Cummins and Weiss (2009), proved that Cat Bonds are zero beta securities, by developing a comparative analysis with other financial securities, using panel data. Also, Gürtler et al (2012) explores the impact of the financial crisis on Cat bonds, in a dynamic stage using panel data.

However, to the best of our knowledge, panel data for assessing the spread of Cat bonds in the secondary market has not been explored yet, for which it becomes relevant to develop an approach under a multi-dimensional framework in order to understand the complex dynamics of Cat bonds spread traded in the market.

The variable we will be modeling is the average market indicative spread in the secondary market (Indicative spread), which is the spread to maturity as a function of the built-in price of market agents, according to their appreciation of the Cat Bond price. The price of a bond in the secondary market can trade at premium or at discount, and in either case such price can be reflected in an indicative spread rate. Since Cat bonds usually have a floating coupon rate, the price movements of such bonds are reflected into the fixed component of the rate (spread). Therefore, the average market indicative spread of Cat bonds reflects the price perception of investors over that security.

3.2. Explanatory variables

There has not been a wide exploration of variables affecting the spread in the secondary market. Our initial hypothesis is based on the inclusion of several internal and external variables as significantly explaining the spread movements in the market. Those variables are the following:

1. **Spread at Issue:** A previous research on the primary spread of Cat Bonds (Gomez and Carcamo 2014) proved that the initial spread depends on several factors, all of which ultimately reflect the risk of the Cat Bond, translated into the spread of the security. Therefore, we expect investors to value this factor along the life of the bond, affecting its price on the secondary market.
2. **Expected Loss:** Empirical evidence in proving this factor as relevant for the spread of Cat Bonds in the primary market, has already been provided in several studies (Bodoff and Gan 2009, Lane and Mahul, 2008; Dieckmann, 2009; Galeotti et al., 2012). The expected loss is proved to be one of the most relevant factors in a Cat Bond price, since it represents the risk undertaken by investors, for which in return they expect compensation translated on the spread. We expect it to remain a relevant factor for investors when pricing Cat Bonds in the secondary market.
3. **Credit Rating:** "Obtaining a financial rating is a critical step in issuing a Cat Bond because buyers use ratings to compare yields on Cat Bonds with other corporate securities. Consequently, almost all bonds are issued with financial ratings." (Cummins 2008). Most Cat Bonds are rated below investment grade, since the rating rationale focuses on likelihood of losing the investment, rather than on the financial creditworthiness of the sponsor. We will assess whether this factor is important in the pricing of these securities in the secondary market.

We converted all ratings to the S&P's scale, and used a dummy variable for those bonds lying above and below the investment grade. We have defined 3 types of credit ratings: Investment grade (rated above or on BBB-), non-investment grade (rated below or on BB+) and not rated.

4. **Time to Maturity Factor:** Since bonds are sensitive to time, knowing that the longer the term the higher its risk, we have defined a proxy for reflecting the time to maturity each bond has in every period of time assessed, which under the bonds dynamics should be relevant in the indicative spread.

Our proxy is represented by the following Factor, based on the reciprocal of time to maturity:

$$\frac{1}{(T - t)}$$

Being T the expiration date and t the date of assessment.

One of the methods for pricing securities consists in discounting to time zero, the security's future cash flows. For example the price of a Bond is the present value of its coupons and principal. The notion of Present Value is a function of time and interest rate in the market, and is the foundation of pricing. Following the role of a bond's maturity as a discount factor, we have defined the above mentioned proxy for measuring the impact of the number of days remaining to maturity over the indicative spread, by resembling a discount factor.

5. **BB- Bonds Index:** We have chosen the *Credit Suisse's high yield II Index* as a good proxy for evaluating the benchmark that investors use when comparing the spread of Cat Bonds against other low rated securities. Following Braun (2012), who explains the importance of capturing the influence of the corporate bond market in the Cat Bonds behavior, since "the vast majority of Cat Bonds exhibit a BB rating" we expect this index to be a relevant driver of the spread of Cat Bonds in the secondary market.
6. **Interest Rate:** The general notion of interest rate that affects the price of bonds, and the direct impact on Cat bonds coupons of floating rate securities, lead us to consider a risk free interest rate as a price determinant in the secondary market. Our proxy is the 3-month US dollar denominated Libor correspondent to every quarter under assessment.
7. **Swiss Re Cat Bond Total Return Index (SCATRR):** The reinsurer Swiss Re has develop an index to track the total rate of return for a basket of outstanding USD denominated Cat Bonds, priced by them. It is one of the most used proxies to understand the performance of Cat bonds price movements in the secondary market.

By definition of the former variables, the indicative spread has no influence on them, meeting one of the assumptions of panel data analysis: Strict Exogeneity.

4. PRELIMINARY ASSESSMENTS

Some of the explanatory variables previously defined (i.e. Spread at issue, Expected Loss, and Credit Rating) are time invariant. The other variables are time variant, for which it becomes relevant to evaluate whether any of those is integrated, since our approach is developed for stationary series.

We use the Levin, Lin & Chu Unit Root test for panel data, in order to evaluate stationarity. The test was run for the Indicative spread, Time to Maturity Factor, BB- Bond Index, Libor and SCATRR, for which all p-values were smaller than 0.05, concluding all former series are stationary.

Additionally, we made a prior assessment of Breusch-Pagan test, in order to determine whether there is unobserved heterogeneity, which would imply working with Panel Data instead of Ordinary least Squares (OLS). The F-statistic from the test yielded a p-value of 0.000, and this allows us to conclude that Panel Data is the most convenient methodological approach.

Now that we have concluded Panel Data is the best methodology for assessing our data, and after meeting its assumptions, we must now define which of the models (fixed Effects, Random Effects) will better suit our data. We use a Hausman test, which p-value resulted in 0.9993, leading us to conclude Random Effects as the preferred model for working the data.

5. MULTIFACTOR SPREAD MODEL

We run a Generalized Least Squares (GLS) regression for the data base constructed from 81 registers. The 324 observations are set as panel data. We use a 5% confidence interval for identifying those variables with a significant impact in the spread of Cat Bonds. Later, we make an evaluation on whether the model is static or dynamic, in order to draw more accurate conclusions from the results obtained through the methodology applied under a hypothesis of static conditions. Finally, results are evaluated against the original values in order to conclude about the model fitness. We used the *Stata* software to run the regressions and perform further analysis.

5.1. Model Specification

The final expression for calculating the spread according to the results from the regressions is:

$$Spread_{it} = \alpha + \beta_{Spread} * Spread_i + \beta_{EL} * EL_i + \beta_{Maturity} * TTM Fatcor_{it} + \beta_{HY} * HY_{it} + \beta_{SCATRR} * SCATRR_{it} + C_i + U_{it}$$

Where:

α = Constant

$Spread_i$ = Initial spread at time of issuance of every bond

EL_i = Expected loss probability attached to every bond.

$TTM\ Factor_{it}$ = Time to maturity factor for every bond in every period of time.

HY_{it} = High Yield Index corresponding to every observation

$SCATTRR_{it}$ = Swiss Re Cat Bond index return for every observation

C_i = Unobserved heterogeneity

U_{it} = Error

Table 1: Determinants of the Spread for Cat Bonds in the Secondary Market

Indicative Spread	Coefficient	Standard Error	t-statistic	Prob.
Constant	0.1679	0.0728	2.3100	0.0210
Spread at Issue	0.8669	0.0780	11.1200	0.0000
Expected Loss	0.3800	0.1595	2.3800	0.0170
Time to Maturity Factor	-1.6966	0.5711	-2.9700	0.0030
High_Yield	0.0003	0.0001	2.4100	0.0160
SCATTRR	-0.0023	0.0007	-3.1400	0.0020

Source: Stata regressions results.

The results in table 1 show 5 specific factors contributing to the indicative spread given by the market in any moment of the secondary market. The variable with the highest coefficient is the time to maturity factor, since as explained before; it has a direct relation in the pricing of Bonds. The coefficient is negative because of the definition of the factor ($1/(T-t)$), in which our proxy represents the reciprocal of time to maturity. Therefore, the lower the factor, the longer days remain for the bond to expire, being higher the risk (maturity risk) and rising the spread.

Regarding internal factors, the Initial Spread and Expected Loss are both significant with positive coefficients. Initial Spread is positive, since as mentioned, the higher the issuance rate, the higher the risk embedded by the bond, for which a higher perception of risk persists. Similarly, the higher the expected loss defined for every Cat Bond, the higher the spread in the secondary market.

Credit rating and interest rate (i.e Libor) proved to be not significant in the secondary market. On a research led by Gomez and Carcamo (2014) in regards to the factors influencing the spread of Cat Bonds when first issued in the market, both of those factors proved to be relevant. Therefore, we conclude that factors like the Credit rating and interest rate only have a relevant role in the primary market, after which that risk information becomes reflected in the initial spread.

In regards to the external factors, both the High Yield index and Cat Bond Index proved to be relevant in the indicative spread. High Yield Index has an inverse effect in the primary and secondary market, having a negative effect for the spread in the primary market

(Gomez and Carcamo 2014), and positive for the secondary market.

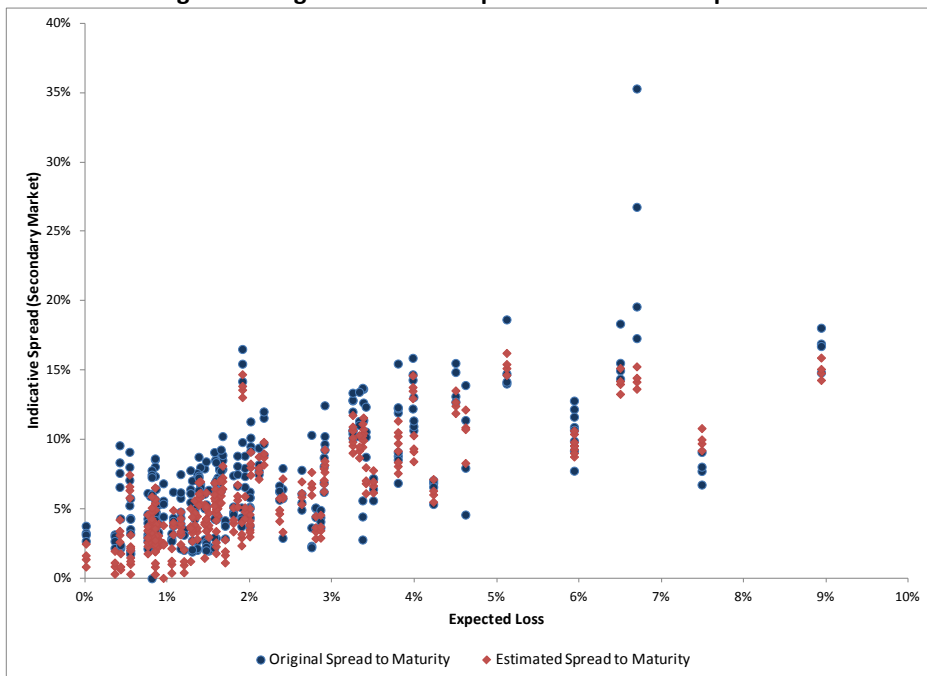
In the former it worked as a benchmark for other securities with non-investment grade, for which a rise in the index (price) was translated in a fall in the interest rate for such securities. Therefore, following the resemblance to Cat Bonds, the spread at issue from these securities fell as well. In the secondary market the index also works as a benchmark, for comparing the attractiveness of Cat Bonds against other non-investment grade securities. Therefore, a rise in the index (price) reflects a fall in the indicative spread of these securities, which reflects a higher demand for those securities. Now, according to the definition of substitute goods, investors would be demanding less Cat Bonds, which will lower the price of Cat Bonds, raising their spread to maturity.

Finally, the Swiss re Cat Bond total return index (SCARRTT) used as a proxy for the development of the secondary market of Cat Bonds, has a negative effect proving the lower the index (price), the higher the interest rate, which must be directly reflected on the yield of Cat Bonds.

5.2. Fitness of the Regression Model

The multifactor spread model for secondary spreads is now evaluated against the original indicative spreads, in order to conclude about the accuracy of the model and fit with the real data. Results proved and average absolute deviation of 1.75%.

Figure 1: Original Indicative Spread Vs Estimated Spread



The model has a better adjustment for those Cat Bonds with lower expected loss, which are generally the ones trading at lower spreads. However, the spread in the secondary market of those Cat Bonds with a high expected Loss and a longer time to maturity, tends to have a very volatile behavior, for which our model tends to either under or overestimate the spread to maturity.

Table 2: Descriptive Statistics for the deviation of the Modeled Indicative Spread Vs Original Spread

Deviation	0% - 1%	1%-2%	2%-6%	>6%
Average Indicative Spread	6.44%	6.65%	8.41%	9.51%
Average Initial Spread	8.97%	8.18%	9.08%	11.83%
Average Expected Loss	2.46%	2.08%	2.39%	3.50%
Average Time to Maturity Factor	0.0017	0.0015	0.0020	0.0011
Number Observations	90	134	94	6
% Sample	28%	41%	29%	2%

Table 2 shows a clear relation of high deviations (above 6%), with higher initial spreads, Expected Loss and days to maturity. Future research can better focus on the particular performance of highly risk Cat Bonds, in order to better identify potential additional factors influencing the price perception of investors in the secondary market.

5.3. Static Model Assessment

Our hypothesis assumes that the indicative spread for each Cat Bond depends on the initial spread exclusively. However the question on whether the indicative spread on t is influenced by the indicative spread in $t-1$ arises.

We therefore evaluate whether the model is static or dynamic, estimating the regression using the one-step GMM system estimator of Blundell-Bond.

Table 3: Regression Output using GMM system estimator (Blundell-Bond)

Indicative Spread	Coefficient	Standard Error	t-statistic	Prob.
L1.	0.0584	0.5033	0.1200	0.9080
Constant	-0.1677	0.2156	-0.7800	0.4370
Initial Spread	1.5726	1.0298	1.5300	0.1270
Expected Loss	2.0325	1.2391	1.6400	0.1010
Investment	3.1787	2.2984	1.3800	0.1670
Non Investment	0.3995	0.2888	1.3800	0.1670
Time to Maturity Factor	5.0873	4.6742	1.0900	0.2760
High_Yield Index	0.0003	0.0004	0.7300	0.4620
SCATRR	-0.0029	0.0014	-2.1600	0.0310

Source: Stata results from Blundell-Bond estimator

From table 3 we can see that the variable L1, corresponding to the lagged indicative spread, has a p-value of 0.9, concluding our model is static and the results shown in the previous regression remain valid.

6. CONCLUSIONS

Previous authors exploring the dynamics of Cat Bonds' spread in the secondary market have focused exclusively in the probability of occurrence of a catastrophic event. Those models fall short in providing a robust model for explaining the spread of Cat Bonds, arising therefore the need to widen the scope of factors impacting these securities. Our research seeks to satisfy that need by including 3 internal and 2 external variables, to design a multifactor spread model.

Results suggest that 5 variables have a significant impact over the spread of Cat Bonds in the secondary market. Time to maturity was the most relevant factor, since it has a direct relation and high impact in the pricing of Bonds. However, other internal variables proved to be priced by investors, being the Spread at Issue and Expected Loss. Additionally, external factors like a benchmark with other non investment grade bonds, and the reinsurance index, tracking the total rate of return of a sample of Cat Bonds.

Our proposed model shows to have a high accuracy on replicating the spread of Cat Bonds in the secondary market. Furthermore, unlike those of most authors, our model has a general application, relevant both for the P&C and Life market of Cat Bonds. Therefore, we have developed not only a pricing tool, but an insightful model for understanding the variables that directly affect the pricing dynamics of Cat Bonds, in order for investors to make sound decisions.

Some areas for further research should focus in identifying additional factors impacting the spread of Cat Bonds in the secondary market, especially given the fact that these securities are relatively new, and their increasing attractiveness in financial market are

continuously changing their dynamics and structure, to better fit the market players' needs.

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