

The Relationship Between Cat Bond Market and Other Financial Asset Markets: Evidence from Cointegration Tests

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ABSTRACT

This study examines the relationship between Cat Bonds market and the other financial markets. Precisely, cointegration tests (the Engle and Granger's methodology) were applied on weekly data of five indexes over the period 2012- 2019 to test for the existence of a long-run dynamic equilibrium relationship between Cat Bonds market and four financial markets, namely, Insurance Linked Securities (ILS) market, S&P 500 (first stock market), MSCI (second stock market) and Corporate Bonds market. In addition, a comparative analysis correlation vs cointegration was conducted to verify whether Cat Bonds can be really considered as zero-beta assets in the short-run (correlation) as well as the long-run (cointegration). For correlation analysis we employed three correlation coefficients (Pearson's Correlation Coefficient, Spearman's Rank Correlation Coefficient and Kendall's Rank Correlation Coefficient). Overall, the main findings of this study showed that in the short-run, Cat Bonds are partially zero-beta assets while over the long-run they are entirely zero-beta assets. Such results will be of great importance for investors in their decision choice between a short strategy or a long strategy in Cat Bonds' investing.

Keywords: Cat Bonds, zero-beta assets, correlation, cointegration.

Submitted : March 01, 2021

Published : March 23, 2021

ISSN: 2507-1076

DOI: 10.24018/ejbmr.2021.6.2.790

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I. INTRODUCTION

Natural disasters, terrorism and pandemics do not cause only humanitarian tragedies, but also of enormous economic losses, which can seriously damage insurance and reinsurance companies. For example, Hurricane Katrina caused more than \$80 billion of insured damage in August 2005. The amounts involved show the limits of the traditional insurance system and the value of setting up additional financial capacities. It is in such a context that the world of finance has experienced the emergence of the Insurance Linked Securities (ILS) which reflect a fusion of insurance and finance techniques by enabling the transfer of disaster risk in the capital market. Among the various financial market mechanisms created for this purpose, Cat Bonds are an excellent example of ILS.

Cat Bonds give the investor direct access to insurance risks (catastrophe risks) which are generally independent of market risks. Traditionally, the method used by investors was simply a participation in the capital of an insurance company. However, this does not represent quite a diversification as the results of an insurance company are very dependent on financial market risk. In contrast, Cat Bonds implicitly allow insurance risk to be separated from other financial risks. In other words, portfolio diversification theory tends to make these Cat Bonds very attractive to investors.

Indeed, Cat Bonds has the following additional advantages: Cat Bonds generally earn interest well above market rates to offset the risk of default on coupons or

principal payments by the Special Purpose Vehicle (SPV) in the event of a major disaster; the probability of losing money by investing in Cat Bonds is very low and the Sharpe ratio of Cat Bonds is commonly greater than 0.5, which is above of most other bonds securities for which this measurement is available. In addition, investors are increasingly interested in Cat Bonds because of their high expected yield and potential low correlation with other financial assets. It is in this context that we ask: Are investors right to consider Cat bonds as an asset allowing effective portfolio diversification?

Several studies have found a weak or even almost zero correlation between Cat Bonds market and the other financial markets, particularly, the stock market and the bond market. The results of these studies presented Cat Bonds as zero-beta assets and so the best for achieving portfolio diversification.

However, for Cat Bonds to be truly an effective portfolio diversification tool, two conditions should be met: First, the financial markets should not be affected by the occurrence of a natural disaster and second the Cat Bonds market should not be affected by financial crisis. Results of studies on these two conditions were rather mixed, which has called into question the validity of the assumption that Cat Bonds are zero-beta assets.

In this paper, we take a different approach to the issue by testing the existence of a long-run equilibrium relationship between Cat Bond market and the other financial markets. In other words, we test the cointegration between Cat Bonds market and the other financial markets. To the best of our knowledge, there is no empirical analysis on the cointegration

between Cat Bonds and the other securities traded in the financial markets (Stocks and Bonds).

The choice of our research methodology is guided by the fact that correlation and cointegration are two different concepts. According to Kat [1], a low (high) correlation does not necessarily imply low (high) cointegration and vice versa.

Indeed, the concept of correlation reflects a short-run relationship between two variables, while the concept of cointegration reflects the long-run relationship. According to Alexander, Giblin and Weddington [2]: «...correlation tells us nothing about the long-term behavior between two markets: they may or may not move together over long periods, and correlation is not an adequate tool to measure this». In other words, two cointegrated variables can display a correlation which is sometimes quite weak. This is because in the short term, cointegrated variables can temporarily diverge from their long-run equilibrium, for several reasons (temporary market crisis, false signal, extreme price movements etc.).

Consequently, the correlation results are very sensitive to the choice of the selected sample and the study period. The main advantage of the concept of cointegration is that it allows us to detect the existence of a long-run dynamic equilibrium relationship between Cat Bonds market and the other financial markets, while accepting their temporary divergences of their long-run co-movements equilibrium [3].

Finally, we point out that in this study, we also proceed by a comparative analysis between the correlation results and the cointegration results.

The remainder of this paper is organized as follows. First, we provide an overview on the specificities of Cat Bonds. Second, we present a brief literature review on the relationship between Cat Bonds market and the other financial markets. Then, we describe our research methodology (variables, hypothesis, sample and period study, correlation concept and cointegration concept (i.e., Engle and Granger Methodology [4]). Next, our empirical results are shown and explained with discussion of whether the hypotheses research are accepted or no. Finally, we conclude.

II. OVERVIEW ON CAT BONDS

The insurance industry has set up an insurance risk securitization system, namely, Insurance Linked Securities (ILS). This system is a fusion of insurance and finance techniques, which allows disaster risk to be transferred to capital market. Among the various financial market mechanisms created for this purpose, Cat Bonds are an excellent example of securitization of insurance risks.

A. Cat Bonds: Definition

Cat Bond is a high-yield bond whose coupon payment and principal repayment are conditioned on the occurrence of a predefined disaster, such as a storm, cyclone, earthquake, or pandemic, etc. This contingency can take three different forms:

- (i) principal protected / coupons at risk,
- (ii) principal at risk / coupons protected,
- (iii) principal and coupons at risk.

Cat Bond is typically issued by an insurance or reinsurance company through a special purpose legal entity called a

Special Purpose Vehicle (SPV), as is the case with loan securitization. Principally, the items of a Cat bond contract are the period of coverage, the nature of the catastrophic events covered, and the compensation mechanism.

B. Cat Bonds: History

The interest of insurers in securitizing insurance risks was due in large part to Hurricane Andrew, which devastated Florida in August 1992, causing nearly \$ 25 billion in insured damage, and ruining 63 insurance companies. The same year, many reinsurers in Bermuda entered this market. The first Cat Bonds, which were issued in 1994, were very successful. In 1995, the Chicago Board of Trade offered derivatives on a catastrophe index. Specifically, the first successful Cat Bond issue was carried out by AIG, Hannover Re, St. Paul Re and USAA, in the amount of \$ 85 million. Initially, the Cat Bonds concerned only one type of disaster in a single region (Atlantic Basin hurricane) with a horizon of one year. In 1999, Oriental Land Cie was the first non-financial company to issue Cat Bonds against the earthquakes at Tokyo Disneyland. The market did not take off until 1997 with \$ 714 million in issues. The Cat Bond Kamp Re 2005 Ltd. issued prior to Hurricane Katrina was the first unmatured Cat Bond, or otherwise the first failed Cat Bond. Indeed, on August 29, 2005, the investors of Kamp Re 2005 Ltd. were faced with an event that ended up turning their investment into a loss of \$ 190 million.

C. Cat Bonds: Process and Structure

The cedant (insurer, reinsurer, sponsor) creates an ad hoc entity (SPV: Special Purpose Vehicle), which simultaneously issues Cat Bonds and offers a risk transfer contract (reinsurance or derivative) to the ceding company, against payment of a periodic premium set for the Cat Bond duration. This contract commits the SPV to compensate the assignor, for the payment of a premium, following the occurrence of one or more predefined events in the Cat Bond clauses. The proceeds from Cat Bonds sales (principal) are retained by the SPV as the collateral of the risk hedging contract. Then, the principal is invested in high-rated securities held in a secure account (trust account) with a return often swapped against 3-month LIBOR (or possibly another benchmark rate). The investor compensation consists of two elements: The bonus paid by the seller and the LIBOR obtained through the swap. The investor returns are adjusted downward if one catastrophe event (or several) occurs and its intensity is sufficient to activate the hedging contract. The reduction of the principal paid back at maturity is then partial or total depending on the amounts paid by the SPV to the assignor (under the hedging contract). The investor returns will not be adjusted and the reduction in the principal paid back will be zero if no catastrophe event occurs or if a catastrophe event occurs, but its intensity is insufficient to activate the hedging contract.

D. Cat Bonds: Characteristics and Specificities

Cat Bonds are characterized by; the period of coverage, the Cat bond maturity, the terms of payment, the nature of the catastrophic events covered and the compensation mechanism.

The period of coverage: The duration at issue varies from 1 to 4 years, the most frequent duration is 3 years.

The Cat bond maturity: Normally it is equal to the coverage period, but in some cases it can be longer.

Payment terms: In most cases, the coupons are semi-annual, the principal is paid back in fine. In the case of the occurrence of one or more claims, the adjustment of the amounts will be paid in the form of coupons and the reduction of the principal will be paid back at maturity depending on the clause stipulated in the contract, namely, principal protected / coupons at risk or principal at risk / coupons protected or principal and coupons at risk [5].

The nature of the catastrophic events covered: In the absence of an underlying asset traded, Cat Bonds were structured around three types of trigger events:

(i) Indemnity triggers: when the indemnities paid to policyholders or even the claims themselves exceed a certain amount;

(ii) Index triggers, there are two types: the first is when a disaster index such as wind speed (Saffir-Simpson) or earthquake magnitude (Richter scale or Mercalli scale) exceeds a certain level, the second concerns an industry-level transaction index, the trigger threshold corresponds to a given level of the index, depending on the losses reported by certain insurance or reinsurance companies exposed to the same type of risk,

(iii) Hybrid triggers: when the trigger threshold is based on loss modeling, which are calculated using a predefined model based on various variables relating to the disaster [6].

The Compensation Mechanism: Cat Bonds' coverages are senior to reinsurance hedges purchased by the ceding company. This means that the Cat Bonds market cannot be affected until the reinsurance market has itself been significantly affected by an event. In other words, the issuance of Cat Bonds is done in addition to reinsurance on the highest tranches.

Finally, the specificity of a Cat Bond compared to an ordinary bond is clearly seen in the decomposition of a Cat Bond's performance. Indeed, the performance of a Cat Bond (principal and coupon) depends directly on a random variable (default), namely, the occurrence of an event (or several) or not. A call option is integrated into the Cat Bond and is triggered by the occurrence of the predefined event. Thus, the coupon yield of a Cat Bond is the sum of the yield of a default-free bond and the return on the contingent option. Therewith, the coupon yield of a Cat Bond will not be adjusted downward if there is no default.

III. LITERATURE REVIEW

During the last two decades, several research studies have been conducted on the ILS and particularly on Cat bonds. Mainly, these studies have focused on the pricing of Cat bonds. Nevertheless, studies on the relationship between catastrophe bonds and other financial assets (stocks, corporate bonds, and government bonds) are not very numerous. In this section, we present some important studies that have tried to answer the following question: Are Cat bonds zero-beta assets?

Litzenberger, Beaglehole and Reynolds [7] have found that Cat Bonds returns are weakly correlated with those of the other financial assets. Therefore, they have considered Cat bonds to be zero-beta assets [7]. These results were confirmed

by Tao [8] when he has showed that there is a positive but very weak correlation between Cat Bonds market and several equity markets (S&P 500, NASDAQ, Dow Jones, FTSE 100, DAX, and CAC 40). Indeed, by analyzing weekly data for the period from March 12, 2004 to April 8, 2011, Tao [8] has found correlation coefficients that varied from 0.0994 to 0.1904. Regarding the dependence between the Cat Bonds market and some corporate bond markets (TNX, FVX, EMTXg, EMTX3a and EMTXn) over the same period, Tao (2011) has found correlation coefficients that were close to zero and even sometimes negative like for example the correlation between Cat Bonds Index and TNX which was equal to -0.0363.

In contrast, Dieckmann [9] has found a significant correlation between Cat Bonds returns, consumption rates and traditional financial assets returns. More specifically, over the period 2002-2011, he has shown a strong correlation between Cat Bonds returns and several bond indexes. Galeotti, Gürtler, & Winkelvos [10] have found a positive correlation between corporate credit spreads and Cat Bond premiums. Moreover, they have noticed an increase of this correlation, especially in extreme market conditions.

Cummins and Weiss [11] have measured the correlation of the Cat Bonds market with other financial markets over the period 2002-2008. In addition, they have found that under normal market situations, Cat Bonds can be considered as zero-beta assets. However, Cummins and Weiss [11] have shown that during the crisis periods, there is a significant dependence between the Cat Bonds market and other financial markets.

Carayannopoulos and Perez [12] have replicated the study of Cummins and Weiss [11] by measuring the correlation coefficients between Cat Bonds, corporate bonds, government bonds and S&P 500 index returns over the three following periods: the pre-crisis period (January 2002 to November 2007), the period during the crisis (December 2007 to May 2009) and the post-crisis period (June 2009 to October 2013). Carayannopoulos and Perez [12] have found that during the pre-crisis period, Cat Bonds were not significantly correlated with the corporate bond index and the S & P500 index. However, they have found a significant low correlation (0.128) at 10 % significance level between Cat Bonds and government bonds. During the crisis period, they have found a significant correlation between Cat Bonds and the other financial assets (corporate bonds, government bonds and S&P 500). Finally, over the post-crisis period, Carayannopoulos and Perez [12] have found that the correlation coefficients between Cat Bonds and the three indexes displayed values that were too low and not significant. From these results, they have concluded that the crisis influenced the correlation between Cat Bonds and other financial assets. In addition, Carayannopoulos and Perez [12] have used the multivariate GARCH approach to analysis the behavior of the relationship between Cat Bonds and other financial markets (corporate bonds, government bonds and stocks) over the same three periods and they have found the same results. According to these results, Carayannopoulos and Perez [12] have concluded that Cat Bonds can be considered as zero-beta assets in periods without crisis but not in period of crisis.

Gürtler, Hibbeln and Winkelvos [13] have studied the impact of the financial crisis (the Lehman Brothers bankruptcy, 2008) and the natural catastrophe (Hurricane Katrina, 2005) on Cat Bonds premiums. They have used data from 387 Cat Bonds transactions issued between December 1997 and March 2012 that guaranteed natural disaster risk. The results of their study have indicated a significant impact of the financial crisis as well as major natural disasters on the Cat Bonds market. According to the authors, under extreme market conditions, Cat Bonds cannot be considered as zero-beta assets.

Cummins [14] have found that the occurrence of a mega-natural disaster affects both the Cat Bonds market and the financial markets. In such a case, the author has raised the possibility of a correlation between the two markets due to falling securities prices in financial markets and rising premiums in the Cat Bonds market. According to Cummins [14], the zero-beta hypothesis of Cat Bonds is only valid in normal market conditions.

The findings of Cummins [14] were confirmed by Krutov [15] who has stated that the no correlation hypothesis between Cat Bonds market and other financial markets was first questioned after Hurricane Katrina (2005) and subsequently after the financial crisis triggered by the bankruptcy of Lehman Brothers (2008) [15]. Similar results were obtained by Constantin [16] and Simões [17] who have found that Cat Bonds are not completely immune to financial market instability. The two authors have shown that during crisis-periods the correlation between Cat Bonds market and other financial markets increase considerably and significantly. In addition, Simões [17] has mentioned the presence of seasonality in Cat Bonds returns especially during hurricanes season.

Clark, Dickson, and Neale [18] have used the Dynamic Conditional Correlation (DCC) model and they have found the existence of a dynamic correlation aspect between Cat Bonds market and the other financial markets. Specifically, they have observed that this correlation increases both in financial crisis-periods and after a mega-natural disaster.

IV. RESEARCH METHODOLOGY

A. Variables

The Swiss Re Global Cat Bond Index (denoted CATBOND) is a market-value weighted index of four baskets (Global Unhedged, USD Cat Bonds, BB Cat Bonds and US Wind Cat Bonds) of natural catastrophe bonds tracked by Swiss Re Capital Markets. This index is used as a proxy for the global Cat bonds market.

The Eurekahedge ILS Advisers Index (denoted HILS) is ILS Advisers and Eurekahedge's collaborative equally weighted index of 33 constituent funds. We consider this index as a reasonable proxy for the insurance-linked securities (ILS) market.

The stock market is represented by two indexes, namely the S&P 500 Index (denoted SPIND) and the MSCI World Index (denoted MSCI). We have chosen the S&P 500 Index because most of Cat Bonds issues are denominated in U.S. dollars [19]. The MSCI World index is chosen because almost all Cat Bonds are issued in developed countries.

As a proxy for the corporate bonds market, the Bloomberg Barclays Capital Global Aggregate Bond Index (denoted CORPBOND) is chosen because it is used by more than 90% of investors in the United States and it is frequently considered by many researchers as the best total market bond index.

B. Data and Study Period

In this study we have used weekly data since Swiss Re publishes the Cat Bond index price data on a weekly basis. The data spans from 2012-01-01 to 2019.12.31, we have chosen this period because it covers many years of the subprime post-crisis period and it finishes before the COVID crisis period. The total sample consists of 416 observations. We have extracted the data from Bloomberg, Eurekahedge, Swiss Re and other sources.

C. Correlation Concept

We have used three correlation coefficients to measure the correlation (short-run relationship) between Cat Bonds market (CATBOND) and the other financial assets markets (HILS, SPIND, MSCI and CORPBOND). Indeed, we have chosen the most used correlation coefficients in practice and research studies, namely,

(i) Pearson's Correlation Coefficient (PCC measures a linear dependence between two variables X and Y. It is also known as a parametric correlation test because it depends to the distribution of the data),

(ii) Spearman's Rank Correlation Coefficient (SRCC measures the strength and direction of correlation between two ranked variables X and Y. It is a non-parametric version of Pearson's correlation coefficient),

(iii) Kendall's Rank Correlation Coefficient (KRCC measures the ordinal correlation between two variables X and Y. It is a non-parametric test since it does not rely on any assumptions on the distributions of X or Y).

D. Cointegration Concept

We have used the Engle and Granger's methodology to test the existence of a long-run equilibrium relationship between Cat Bonds and the other financial assets. Engle and Granger [4] developed a two-steps technique to test cointegration relationships in time series data of two variables X_t and Y_t .

First step:

This step involves an ordinary least square (OLS) estimation of the following regression equation:

$$Y_t = \alpha + \beta X_t + \varepsilon_t$$

where

Y_t is CATBOND on week t;

X_t is HILS, SPIND, EQUITYMSCI or CORPBOND on week t;

ε_t is the error term;

α and β are two regression OLS parameters to be estimated.

The aim of this first step is to extract the error terms ($\hat{\varepsilon}_t$) of the regression equation:

$$\hat{\varepsilon}_t = Y_t - \hat{\alpha} - \hat{\beta} X_t$$

It should be noted that there is a precondition for applying the cointegration test. Indeed, it is necessary that each

individual variable (X_t and Y_t) is integrated of order 1 ($X_t \sim I(1)$ and $Y_t \sim I(1)$).

The initial determination of nonstationary of the individual variables will be considered in this study as a pre-test to cointegration analysis [20]. For that purpose, we use a unit root test on each individual variable, namely the Augmented Dickey-Fuller test ADF(K^*) [21]. To determine the optimal lag order K^* , we have employed three information criteria, namely: Akaike Information Criterion (AIC), Schwartz (Information Criterion SIC), and Hann-Quin Information Criterion (HQIC).

Second step:

This step consists in testing the stationarity of the error terms ($\hat{\epsilon}_t$) which we have extracted in the previous step. For this, we use the same unit root test, namely the ADF (K^*), as well as the same three information criteria (AIC, SIC and HQIC).

Thereafter, if the error terms ($\hat{\epsilon}_t$) are found to be stationary ($\hat{\epsilon}_t \sim I(0)$), then we conclude that there is a cointegration relationship between the two variables (X_t and Y_t). If the error terms ($\hat{\epsilon}_t$) are not stationary, we conclude that the two variables (X_t and Y_t) are not cointegrated.

E. Research Hypotheses

In this Study, we test eight research hypotheses. First, we test four hypotheses on the correlation between Cat Bonds market and the other financial markets and then we test four hypotheses about the cointegration of Cat Bonds market with the other financial markets.

Thus, the four hypotheses about correlation test can be stated as follows:

Hypothesis 1 (H1): There is a strong correlation between CATBOND and HILS.

Hypothesis 2 (H2): There is a weak correlation between CATBOND and SPIND.

Hypothesis 3 (H3): There is a weak correlation between CATBOND and MSCI.

Hypothesis 4 (H4): There is a weak correlation between CATBOND and CORPBOND.

Thereafter, the four hypotheses about cointegration test can be stated as follows:

Hypothesis 5 (H5): There is cointegration (long-run equilibrium) relationship between CATBOND and HILS.

Hypothesis 6 (H6): There is no cointegration (long-run equilibrium) relationship between CATBOND and SPIND.

Hypothesis 7 (H7): There is no cointegration (long-run equilibrium) relationship between CATBOND and MSCI.

Hypothesis 8 (H8): There is no cointegration (long-run equilibrium) relationship between CATBOND and CORPBOND.

In the literature, there is not a general rule to determine which correlation size is considered strong, moderate, or weak. In this study, we have considered correlations greater than 0.70 are strong; correlations between 0.20 and 0.70 are moderate and those less than 0.20 are considered weak.

V. EMPIRICAL RESULTS

A. Correlation Results

Table 1 presents correlation results between the catastrophe bond market (CATBOND) and the other financial markets (HILS, SPIND, MSCI and CORPBOND).

TABLE 1: CORRELATION RESULTS
Panel A: Pearson correlation coefficients (PCC)

	HILS	SPIND	MSCI	CORPBOND
CATBOND	0.921*** (0.000)	0.214*** (0.000)	0.198*** (0.001)	0.158*** (0.004)

Panel B: Spearman rank correlation coefficients (SRCC)

	HILS	SPIND	MSCI	CORPBOND
CATBOND	0.833*** (0.000)	0.195*** (0.000)	0.150*** (0.005)	0.142** (0.013)

Panel C: Kendall rank correlation coefficients (KRCC)

	HILS	SPIND	MSCI	CORPBOND
CATBOND	0.809*** (0.000)	0.163*** (0.000)	0.136*** (0.003)	0.129*** (0.009)

The null hypothesis is that the correlation coefficient is close from zero, while the alternative is that the correlation coefficient is different from zero. The correlation coefficient marked with (***) , (**) and (*) reject the null hypothesis at a significance level of 1%, 5% and 10% respectively. Numbers in parentheses represent p-value.

The results of Table 1 show that the three correlation coefficients (PCC, SRCC and KRCC) between CATBOND and HILS are significantly different from zero at 1% significance level. In addition, the PCC is equal to 0.921 and the SRCC and KRCC are both greater than 0.80, namely, 0.833 and 0.809, respectively. These results indicate that there is a strong correlation between the Cat Bond market and the ILS market. Thus, hypothesis 1 is accepted.

The results also show that the three correlation coefficients between CATBOND and SPIND are significantly different from zero at 1% significance level. The highest correlation coefficient is the PCC, which is equal to 0.214, indicating a moderate correlation between the two variables. However, the SRCC and KRCC are below 0.20 (0.195 and 0.163, respectively) indicating a weak correlation between Cat Bonds market and the stock market (S&P 500). Overall, these results allow us to accept hypothesis 2.

For the correlation between CATBOND and MSCI, we notice that the three correlation coefficients are significantly different from zero at 1% significance level. In addition, they are all less than 0.20 (PCC = 0.198, SRCC = 0.150 and KRCC = 0.136). These results lead us to conclude that there is a weak correlation between Cat Bonds market and the equity market (MSCI). Therefore, hypothesis 3 is also accepted.

Finally, concerning the correlation between CATBOND and CORPBOND, we note that the PCC and the KRCC are both significantly different from zero at 1% significance level and the SRCC is significantly different from zero at 5% significance level. Also, results of Table 1 show that these coefficients vary from 0.129 to 0.158, which signify that there is a weak correlation between Cat Bonds market and the corporate bond market. Hence, these results permit us to accept hypothesis 4 (H4).

B. Cointegration Results

Pre-test Results:

To apply the ADF (K^*) test on the time series of each individual variable (CATBOND, HILS, SPIND, MSCI and CORPBOND), we need to determine beforehand the optimal lag order (K^*) which is defined as the minimum lag order value (ranging between 1 and 10) for each of the three information criteria identified above. The results of the determination process of the optimal lag order (K^*) are shown in Table 2.

TABLE 2: OPTIMAL LAG ORDER (K^*) ACCORDING TO AIC, SIC AND HQIC

Panel A: According to AIC		
	Minimum Under AIC	Optimal Lag Order
CATBOND	0.757642	1
HILS	0.923468	1
SPIND	0.458732	4
MSCI	0.389031	5
CORPBOND	0.794339	7
Panel B: According to SIC		
	Minimum Under SIC	Optimal Lag Order
CATBOND	0.775492	3
HILS	0.948775	2
SPIND	0.471076	3
MSCI	0.413378	3
CORPBOND	0.818763	5
Panel C: According to HQIC		
	Minimum Under HQIC	Optimal Lag Order
CATBOND	0.760661	3
HILS	0.938273	1
SPIND	0.460216	1
MSCI	0.407617	2
CORPBOND	0.811682	1
Panel D: Optimal Lag Order According to the Three Criteria		
	Optima Lag Order (K^*)	
CATBOND	1 and 3	
HILS	1 and 2	
SPIND	1, 3 and 4	
MSCI	2, 3 and 5	
CORPBOND	1, 5 and 7	

The optimal lag orders obtained in Panel D of Table 2 are then used to apply the ADF(K^*) test on both levels and first differences of each individual variable (CATBOND, HILS, SPIND, MSCI and CORPBOND).

Table 3 shows the results of ADF(K^*) test. In interpreting these results, we can conclude that the five variables are integrated of order 1 (CATBOND~I(1), HILS~I(1), SPIND~I(1), MSCI~I(1) and CORPBOND~I(1)). In fact, for all optimal lag orders (K^*) retained, the ADF(K^*) statistics indicate that the level series of all variables are not significant even at 10 % significance level. In addition, for all optimal lag orders (K^*) retained, the ADF(K^*) statistics show that the first differences series of all variables are significant at 1 % significance level.

We take as an example, the case of the variable CATBOND. As we can see, the ADF(1) and ADF(3) statistics for the level series of CATBOND (-2.436621 and -2.295427, respectively) are not significant even at 10 % significance level. Thus, we cannot reject the null hypothesis, and therefore the level series of CATBOND is not stationary. However, the ADF(1) and ADF(3) statistics for the first

differences series of CATBOND (-7.456523 and -5.344656, respectively) are significant at 1% significance level. Hence, we can reject the null hypothesis and accept stationarity. Which means that CATBOND is integrated of order 1(CATBOND~I(1)).

Finally, considering all these results, we can argue that the five variables are candidates for the cointegration tests given that they are all integrated of order 1. In other words, the following four cointegration relationships can now be tested by Engle and Granger’s two-step test, namely, (CATBOND with HILS), (CATBOND with SPIND), (CATBOND with MSCI) and (CATBOND with CORPBOND).

TABLE 3: ADF (K^*) TEST ON LEVELS AND FIRST DIFFERENCES

	K^*	Levels	First differences
CATBOND	1	-2.436621	-7.456523***
	3	-2.295427	-5.344656***
HILS	1	-2.169804	-5.965760***
	2	-2.125778	-4.477342***
SPIND	1	-1.557238	-21.417692***
	3	-1.534367	-19.683429***
	4	-1.513994	-17.690043***
MSCI	2	-1.343528	-28.575664***
	3	-1.331276	-23.853701***
	5	-1.298856	-20.099865***
CORPBOND	1	-2.055823	-10.462772***
	5	-1.986585	-6.897821***
	7	-1.973378	-5.459912***

The null hypothesis of these tests is that variables contain a unit root (implying non stationarity), while the alternative is that the variables are $I(0)$. The statistics of the ADF(K^*) tests marked with (***), (***) and (*) reject the null hypothesis at a significance level of 1%, 5% and 10% respectively.

First step of Engle and Granger’s cointegration test:

In order to test for cointegration between Cat Bonds market and the other financial markets, we need first estimate by Ordinary Least Square (OLS) the following four linear regression equations:

$$\text{Equation \#1: } CATBOND_t = \alpha + \beta HILS_t + \varepsilon_t$$

$$\text{Equation \#2: } CATBOND_t = \alpha + \beta SPIND_t + \varepsilon_t$$

$$\text{Equation \#3: } CATBOND_t = \alpha + \beta MSCI_t + \varepsilon_t$$

$$\text{Equation \#4: } CATBOND_t = \alpha + \beta CORPBOND_t + \varepsilon_t$$

The OLS results are not presented here since our aim in this first-step of Engle and Granger test is to extract the error terms ($\hat{\varepsilon}_t$) of each linear regression equations.

For example, from the OLS results of the equation #1, we have extracted its error terms ($\hat{\varepsilon}_{1,t}$) as follows:

$$\hat{\varepsilon}_{1,t} = CATBOND_t - \hat{\alpha} - \hat{\beta} HILS_t.$$

The same approach allowed us to extract the error terms from the other equations, namely, $\hat{\varepsilon}_{2,t}$, $\hat{\varepsilon}_{3,t}$ and $\hat{\varepsilon}_{4,t}$.

Second step of Engle and Granger’s cointegration test:

In this second step, we have used again the ADF (K^*) tests to analyze the stationarity of the four error terms ($\hat{\varepsilon}_{1,t}$, $\hat{\varepsilon}_{2,t}$, $\hat{\varepsilon}_{3,t}$ and $\hat{\varepsilon}_{4,t}$) that we have extracted in the previous step.

In addition, we have employed the same three information criteria (Akaike Information Criterion (AIC), Schwartz (Information Criterion SIC), and Hann-Quin Information Criterion (HQIC)) to determine the optimal order K^* . Table 4 presents the results of the process of determining of the optimal lag order K^* of the four error terms.

TABLE 4: OPTIMAL LAG ORDER OF ERROR TERMS ACCORDING TO AIC, SIC AND HQIC

Panel A: According to AIC		
Error Terms	Minimum Under AIC	Optimal Lag Order
$\hat{\epsilon}_{1,t}$	0.428274	5
$\hat{\epsilon}_{2,t}$	1.393746	3
$\hat{\epsilon}_{3,t}$	0.836705	4
$\hat{\epsilon}_{4,t}$	0.551883	8
Panel B: According to SIC		
Error Terms	Minimum Under SIC	Optimal Lag Order
$\hat{\epsilon}_{1,t}$	0.449139	2
$\hat{\epsilon}_{2,t}$	1.407443	1
$\hat{\epsilon}_{3,t}$	0.855721	1
$\hat{\epsilon}_{4,t}$	0.577229	1
Panel C: According to HQIC		
Error Terms	Minimum Under HQIC	Optimal Lag Order
$\hat{\epsilon}_{1,t}$	0.440658	3
$\hat{\epsilon}_{2,t}$	1.398411	2
$\hat{\epsilon}_{3,t}$	0.850076	1
$\hat{\epsilon}_{4,t}$	0.571864	5

Panel D: Optimal Lag Order According to the Three Criteria

Term Errors	Optima Lag Order (K*)
$\hat{\epsilon}_{1,t}$	2, 3 and 5
$\hat{\epsilon}_{2,t}$	1, 2 and 3
$\hat{\epsilon}_{3,t}$	1 and 4
$\hat{\epsilon}_{4,t}$	1, 5 and 8

Thereafter, we have used the optimal lag orders obtained in Panel D of Table 4 to apply the ADF(K*) test on the four error terms series: $\hat{\epsilon}_{1,t}$, $\hat{\epsilon}_{2,t}$, $\hat{\epsilon}_{3,t}$ and $\hat{\epsilon}_{4,t}$. Results of these tests are presented in Table 5.

TABLE 5: ADF (K*) TEST ON ERROR TERMS

Error Terms	K*	Levels
$\hat{\epsilon}_{1,t}$	2	-3.867621***
	3	-3.804438***
	5	-3.761847**
$\hat{\epsilon}_{2,t}$	1	-1.603892
	2	-1.478994
	3	-1.454712
$\hat{\epsilon}_{3,t}$	1	-2.066835
	4	-1.983788
	1	-3.015582*
$\hat{\epsilon}_{4,t}$	5	-2.873406
	8	-2.519683

The null hypothesis of these tests is that variables contain a unit root (implying non stationarity), while the alternative is that the variables are $I(0)$. The statistics of the ADF (K*) tests marked with (***), (***) and (*) reject the null hypothesis at a significance level of 1%, 5% and 10% respectively.

Foremost, we notice that the ADF(2) and ADF(3) statistics for the term errors of the equation #1 (-3.867621 and -3.804438, respectively) are significant at 1% significance level. However, the ADF(5) statistic (-3.761847) is significant at 5% significance level. This means that $\hat{\epsilon}_{1,t}$ is statically stationary ($\hat{\epsilon}_{1,t} \sim I(0)$). Overall, these results allow us to conclude that CATBOND and HILS are cointegrated and so we accept hypothesis 5 (H5).

Next, concerning the term errors of the equation #2, the ADF(K*) statistics for the three optimal lag orders retained (K* = 1, K* = 2 and K* = 3) indicate statistical non stationarity of $\hat{\epsilon}_{2,t}$ which means the non-existence of a cointegration relationship between CATBOND and SPIND. Thus, these results allow us to accept hypothesis 6 (H6).

Afterwards, for the term errors of the equation #3, the results of the ADF(k*) tests are supportive of hypothesis 7 (H7) since ADF(1) and ADF(4) statistics (-2.066835 and -1.983788, respectively) do not reject the hypothesis of non-stationarity of $\hat{\epsilon}_{3,t}$. These results allow us to conclude that CATBOND and MSCI are not cointegrated.

Finally, we note down that the ADF(1) statistic for the term errors of the equation #4 (-3.015582) is significant at 10% significance level which reject the null hypothesis of the non-stationarity of $\hat{\epsilon}_{4,t}$. Nevertheless, there are two other ADF(K*) tests, namely, ADF(5) and ADF(8) statistics (-2.873406 and -2.519683, respectively) which indicate the non-stationarity of $\hat{\epsilon}_{4,t}$. Although, in this case, the results of the ADF tests are mixed, but overall, they indicate the non-stationarity of $\hat{\epsilon}_{4,t}$. In other words, these results mean the non-existence of a cointegration relationship between CATBOND and CORPBOND. Therefore, Hypothesis 8 (H8) is also accepted.

VI. CONCLUSION

Cat Bonds and the other types of insurance-linked security (ILS) have provided insurers and reinsurers with alternative capacities by raising capital directly in the financial markets. Indeed, Cat Bonds constitute a specific mode of transferring insurance risks to the financial markets which is based on the same principle as traditional bonds (default risk) but with the particularity of being based on various triggers (storm, cyclone, earthquake, pandemic, terrorist attack, etc.)

Cat Bonds market has been constantly evolving in recent years (apart from the period of the financial crisis) to the point where they have become an important player in the capital management process of the traditional insurance industry. According to financial experts, Cat Bonds market is set to develop in the coming years, regardless of the increase in natural disasters. It is true that, investors operating in this market are aware and well informed of the possibility of incurring losses by investing in Cat Bonds. However, investors also know that the advantages of this special asset are multiple:

(i) Cat Bonds generally produce attractive returns that are higher than those generated by other traditional financial assets (stocks, corporate or government bonds),

(ii) the probability of losing money by betting on Cat Bonds is very low

(iii) the Sharpe ratio of Cat Bonds is commonly higher than that of most other types of bonds. In addition, the main advantage of Cat Bonds lies in the fact that they are sometimes presented as zero-beta assets and so an interesting tool for portfolio diversification which is likely to improve the efficient frontier of a portfolio by reducing the risk for a given level of expected return [5], [6].

Several research studies have analyzed the correlation between Cat Bonds market and the other financial markets. Most of these studies have found a weak correlation over different time periods and samples. However, there are also some studies which have shown that the hypothesis of a weak correlation between Cat Bonds market and the other financial markets is not valid in the case of extreme market conditions. Indeed, these studies have found an increase in this

correlation especially after a financial crisis or a mega-natural disaster.

In this paper, we have tested the presence of a cointegration relationship between Cat Bonds market and the other financial markets, namely the stock market, the bond market, and the ILS market. Specifically, we have conducted a comparative analysis between the correlation results versus the cointegration results to verify whether Cat Bonds can be really considered as zero-beta assets in the short term as well as the long term. In econometrics, it is well known that the correlation concept reflects a short-run relationship between two variables, while the cointegration concept reflects their long-run relationship. Thus, given that the two concepts are different, the non-existence of short-run dependence (correlation) between Cat Bonds market and the other financial markets does not necessarily imply non-existence of a long-run equilibrium relationship (cointegration) between them [1]-[3].

Over a study period of 2012-01-01 to 2019.12.31, weekly data for five indexes were used, namely, the Swiss Re Global Cat Bond Index (Cat Bonds market), Eurekahedge ILS Advisers Index (ILS market), the S&P 500 index (first stock market), the MSCI World index (second stock market) and the Bloomberg Barclays Capital Global Aggregate Bond Index (Corporate Bonds market).

Results of the correlation analysis have showed the existence of a significant strong correlation between Cat Bonds market and the ILS market. However, we have found significant weak correlations between Cat Bonds market and the other financial markets (stock markets and corporate bonds market). Thus, the results of short-run dependency do not allow us to consider Cat Bonds entirely as zero-beta assets. This will be the case, if we have found correlations that are not significantly different from zero. For the cointegration tests, the results have showed that Cat Bonds market is cointegrated with the ILS market, but not with the other financial markets (stock markets and corporate bonds market). In fact, the non-existence of a long-run equilibrium relationship between Cat Bonds market and both stock market and corporate bonds market, allows us to consider Cat Bonds entirely as zero-beta assets. In other words, according to our comparative analysis correlation versus cointegration, we can conclude that in the short-run, Cat Bonds are partially zero-beta assets while over the long-run they are entirely zero-beta assets. These findings are of great importance for the investors who adopt a short strategy or a long strategy in their investments in Cat Bonds.

Finally, we propose two possible extensions to our study. The first one is to extend the study period to include the period of the COVID-19 pandemic. This allows more general conclusions to be drawn especially on the short-run dependency between Cat Bonds and the other financial assets under extreme market conditions. The second extension consists to perform this comparative analysis correlation versus cointegration on the individual Cat Bond prices data instead of the Cat Bond Market Index data. This allows more relevant results to be obtained since the index reflects the overall behavior of all Cat Bonds and not the individual behavior of each Cat Bond issued on the market.

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