FINANCIAL SERVICES REVIEW

Financial Services Review 25 (2016) 303–329

Catastrophe (CAT) bonds: risk offsets with diversification and high returns

Richard J. Kish[a,*]

[a]Perella Department of Finance, Lehigh University, 621 Taylor Street, Bethlehem, PA 18015, USA

Abstract

Catastrophe bonds, a relatively new entry into the bond market, are a form of reinsurance in which insurance firms are able to offset the financial risks from both natural and man-made catastrophes. Although the primary offset is within the reinsurance market, starting in the 1990s insurance firms started using the financial markets to offset catastrophe risks. Anecdotal evidence shows that the entry of CAT bonds made the reinsurance market more efficient and allowed investors an opportunity to participate in what has been a very profitable investment opportunity. Our analysis shows that on average, CAT bonds have generated high returns but with the advantage of diversification when compared with similarly rated corporate debt. Thus, CAT bonds are a viable investment option within a diversified portfolio. © 2016 Academy of Financial Services. All rights reserved.

Jel classification: G11

Keywords: CAT bonds; reinsurance; catastrophe

1. Introduction

Catastrophes, both natural (hurricanes, earthquakes, floods, and droughts) and man-made (terrorist attacks, fire, aviation, maritime, and oil disasters), abound worldwide. Individuals, firms, and governments often hedge against the potential of extreme losses from these types of catastrophes. Economic losses from natural disasters alone have averaged $180 billion annually over the last decade.[1] However, the financial losses fail to encompass the full impact of these disasters. For instance, the 2015 earthquake overlapping the countries of

* Corresponding author. Tel.: +1-610-758-4205; fax: +1-610-758-6429.
E-mail address: rjk7@lehigh.edu

Afghanistan and Pakistan illustrates the magnitude of nonfinancial losses that are regularly associated with these disasters with over 300 deaths and over 17,000 families displaced when their homes were destroyed.[2] Most of these losses (both financial and human) are not insured, especially within developing countries. On average only 30% of losses worldwide are covered through insurance policies.[3] Because of the potential magnitude of these losses, most insurance companies as well as several developing countries offset part of their risk through reinsurance and other financial instruments such as bonds, futures, and sidebars.

This article focuses on catastrophe (CAT) bonds, their role as an insurance risk offset, and as a viable investment option within a diversified portfolio. Starting with a review of the literature, we position our article as a key to understanding CAT bonds from the investor's viewpoint. Background is a major factor in understanding CAT bonds as an investment option, so we define CAT bonds, outline their structure, and sketch how various triggers impact their returns. Documenting the historical costs to the insurance industry in the next section sheds light on the magnitude of the losses associated with catastrophic events, why insurance firms need to offset part of this risk, and the role the State of Florida played in the advancement of CAT bonds. This leads to the analysis of the historical returns using various proxies for an investment in CAT bonds. The conclusion ties the presentation together highlighting the fact that CAT bonds offer similar returns to comparable corporate issues with the added benefit of diversification.

2. Literature review

The analysis of CAT bonds has spanned a wide spectrum of research from descriptive to empirical. For instance, Cummins (2008 and 2012) outlines the state of the CAT bond market. In these two descriptive articles, Cummins demonstrates a tie between the role played by CAT bonds and the reinsurance market. Both CAT bonds and reinsurance offer the underlying insurance firms a means to offset the risk associated with catastrophic disasters, but CAT bonds offer insurance firms an alternative avenue of funding that taps into the capital markets. As reported in Cummins (2008), starting with the first successful CAT bond underwritten in 1994 for $85 million by Hannover Re, CAT bonds have been used primarily to offset the high layers of reinsurance protection. This sector is not typically covered within the reinsurance market because of the high margins taken by the reinsurers and the lack of faith in the creditability of the reinsurers to offer protection for the magnitude of these low probability events.

Froot (2001) stresses the role CAT bonds have on reducing the barriers of entry into the reinsurance marketplace by offering another avenue insurers can use to reduce their exposure to risk. By examining eight theoretical explanations concerning the pattern of hedging against catastrophe risks from the insurance firm's perspective, Froot finds that the decision between reinsurance and CAT bonds is a tradeoff between the lower adverse selection costs associated with reinsurance and the costs stemming from the reinsurance markup. The theoretical work of Finken and Laux (2009) continues this line of research by demonstrating that CAT bonds tied to parametric triggers offer an additional layer of protection to the underlying insurer beyond the reinsurance market. Because there is an imperfect correlation between the bond's payoff and the insurer's loss, diversification is an additional benefit offered by CAT bonds. Cummins et al. (2004), also exploring the effects of various triggers but through simulation, highlights the advantages to the insurer dependent on the trigger mechanism in place. In a related article, Subramanian and Wang (2015) attempt to explain why the CAT bond market is so small, even though its benefits have been highlighted in the literature (e.g., Bantwal and Kunreuther, 2000; Barrieu and Louberge, 2009; Cummins and Trainar, 2009; Dieckmann, 2011; Durbin, 2001; Hagendorff et al., 2014). Subramanian and Wang's claim is that insurers only utilize the CAT bond market when potential losses increase beyond where it is efficient to be covered within the reinsurance market.

The benefits of CAT bonds abound in the literature. For instance, Bantwal and Kunreuther (2000) rely on simulations to illustrate the benefits of CAT bonds to potential investors. The claim is that CAT bonds offer a unique opportunity to enhance portfolios with an investment option that provides a high-yielding return that is uncorrelated with the market. During the time of their study the spreads on investment linked securities (ILS), of which CAT bonds are a subset, were considerably higher than the spreads for comparable speculative-grade corporate debt. This wide spread is not supported within the current market. Barrieu and Louberge (2009) support earlier findings that the CAT bond market offers benefits through diversification and high returns, but the main focus of their research, similar to Subramanian and Wang (2015), is on explaining why the CAT bond market remains small. They argue for the introduction of a hybrid CAT bond tied to protection against a stock market crash to add appeal and hopefully expand the CAT bond market sector.

Cummins and Trainar (2009) deal with the supply side of the CAT bond market. Their core finding is that the benefits of CAT bonds versus reinsurance increase via the magnitude of the potential losses. From the demand side, Dieckmann (2011) supports the significant correlation between returns from CAT bonds and speculative grade corporate bonds, but warns of the effects of the low probability of a major catastrophe on returns. Durbin (2001), one of the earlier works within this field, reports on the advent of CAT bonds and their role in reinsurance from catastrophe events. Hagendorff et al., (2014) investigate the CAT bond market from the utilization side. They conclude that utilizers of CAT bonds are less likely to exhibit risky underwriting and thus have easier access to the financial markets (i.e., the CAT bond market); have more efficient hedging outcomes; and because of this easy access may lead to more risky behavior in the future. They also show a negative relationship between CAT bond issuance and the size of underwriting losses.

Hagendorff et al. (2013) takes a different track focusing on the lack of wealth effects to shareholders of the issuing firm as a motive for participating in the CAT bond market. Using data from 1970 through 1994, Froot and O'Connell (2008) uncover overpricing within the reinsurance market which contributed to the advent of the alternative catastrophe offsets such as CAT bonds. Lakdawalla and Zanjani (2012) through simulation illustrate the advantages of CAT bonds for improving the efficiency of offsetting risks for insurance firms within specific risk settings. Thus, most of the literature focuses on the advantages of CAT bonds from the issuer's viewpoint. Little work has been done on the actual returns to investors within this market sector, which is one of this article's contributions.

3. What is a CAT bond?

To understand the role of CAT bonds as an investment option, one must first understand what a CAT bond is. A catastrophe-link (CAT) bond is a debt obligation in which the interest (coupon payments) and the return of principal are tied to the payoff requirements of an insurance company.[4] Another common name for CAT bonds associated with natural disasters are “Act of God” bonds because their payoff is reduced or eliminated if an “Act of God” occurs. But catastrophes can also be man-made, such as the 9/11 terrorist attract on the World Trade Towers in New York City, which was the most costly man-made catastrophe in the United States with insured losses of $32.5 billion.[5] Similar to reinsurance, CAT bonds offer protection to the insurance firm against the extremes, that is, covered losses above a certain manageable threshold. For example, an insurance company could issue a series of bonds in which the payoff is tied to the payout of claims occurring from a natural disaster, such as a hurricane. The bonds offer a two-sided bet. The bondholders are betting that if a hurricane occurs, the insurance payout will be below the threshold established in the bond’s covenants. If the payouts are below the thresholds established, the bondholders will continue to receive their periodic coupon payments and the return of their principal at maturity. If on the other hand, the insurance payouts are above the established thresholds, coupon and principal will be reduced or eliminated to pay these claims. Thus, the risks of huge losses to the insurance firms are transferred to the bondholders.

3.1. The current and historical state of the CAT bond market

CAT bonds are a relatively new investment vehicle. They were first issued in the mid-1990s and reached record levels in 2015.[6] At the end of 2015, Bloomberg reported 189 active CAT bonds that were issued from insurance companies within three countries: Bermuda (132 issues; 69.8%), Cayman Island (43 issues; 22.8%), and Ireland (13 issues; 6.9%). The remaining bond was issued through a Supra National (SNAT).[7] The majority of issues were denominated in U.S. dollars (172 issues; 90.29%; $24,007MM), followed by Euros (12 issues; 7.72%; 2,053MM€), Japanese Yen (four issues; 1.72%; 457MM¥), and Swiss Franc (one issue; 0.07%; 71MM¥). There were only three bonds with fixed coupons (with an average coupon of 3.73%), 54 zero coupon bonds, and 132 bonds with floating rates.

The average floating rate coupon was 4.5%. The adjustments for the floating rate debt were constructed on a base three month rate (Euribor—nine issues; Libor—11 issues; and Treasury Bills—112 issues) plus a premium. The average premium was 575 basis points (Euribor—299 bps; Libor—562 bps; and Treasury Bills—611 bps). The average maturity was 3.5 years with 68 bonds also including an extension option averaging two additional years. The average size of an issue denominated in euros was 135 million; in yen was 13,284 million; and in U.S. dollars was 141 million. The top five managing firms held close to 70% of the securities outstanding.[8] Several firms were multiple issuers including the following seven firms (# issues: ticker) with six or more issues: Sector RE (24: SECTOR), Residential RE (17: RESID), Kane SAC (10: KANESL), Market RE (seven: MARKRE), Sanders RE (six: SANDRE), Tradewinds RE (six: TRDWYN), and Vitality RE (six: VITALI).

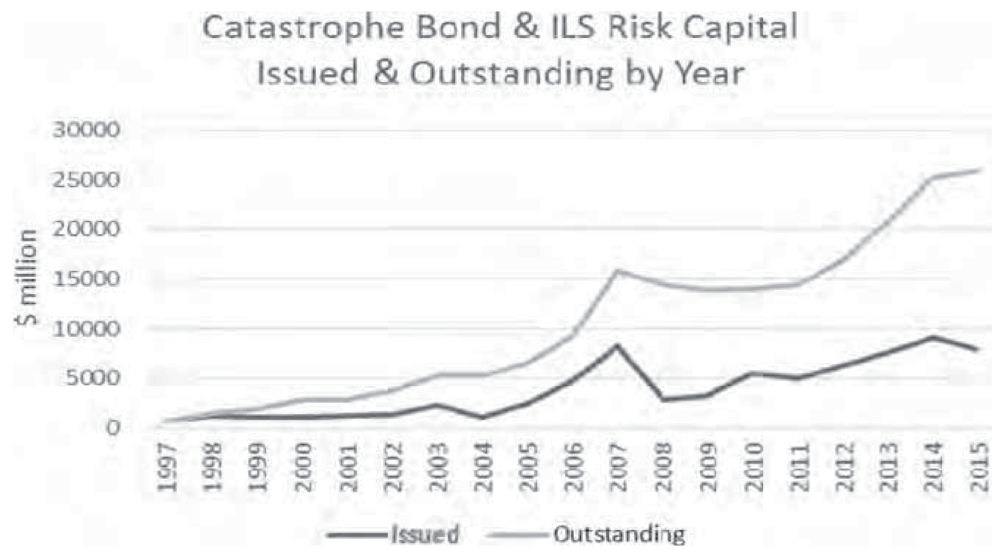

Fig. 1. Source: http://www.artemis.bm/deal_directory/cat_bonds_ils_issued_outstanding.html.

A summary of amounts issued and outstanding by year for CAT bond and insurance linked securities (ILS) are summarized in the Fig. 1. Over the period from 1997 through 2015, the yearly range of issues was $786 million (1997) to $9,094 million (2014) with an average yearly issue of $3,858 million. The cumulative bonds outstanding peaked in 2015 at $25.96 billion. There were several years in which the amount of outstanding bonds declined because of a small volume of new bonds being issued and a large volume of bonds maturing.

CAT bond payoffs are dependent on the lack of occurrence of the insured disasters. But even when they occur, if the underlying loss fails to reach the defined trigger point, then the bondholders suffer no loss. When the trigger point is breached, there will be a reduction in the expected return on the bonds. These triggers are typically based on the cumulative losses experienced by the underlying insurance companies. Triggers, which are defined in the bond indenture, can be structured in a variety of ways. For instance, they can be based on a cumulative loss threshold, a sliding scale of actual losses experienced by the issuer, or tied to an index of weather/disaster conditions. CAT bonds can be structured on a per-occurrence event (i.e., exposure to a single major loss event); on the aggregate (i.e., exposure to multiple events over the course of each annual risk-period); or on a multiple loss approach (i.e., payoff reductions are triggered by second and subsequent events).

All CAT bonds within the sample were issued under the SEC's 144A regulation which limits resales to qualified institutional buyers (QIBs). Thus, institutions, not individuals regardless of wealth or sophistication, are the only investors eligible to buy these securities within the first year.[9] Thus, access for the individual investors is only possible through participation in mutual or hedge funds that qualify as QIBs. One of the attractions of CAT bonds is that they typically offer a higher rate of return versus similarly rated corporate debt instruments. Many of the bonds offer variable rates based on a premium over some three month index such as Euribor, Libor, or U.S. Treasury Bills. This higher expected return could also be adjusted through the price because there are several zero coupon CAT bond issues. Besides the potential for high yields, CAT bonds also offer the buyer some diversification because of the fact that catastrophic events are not correlated with market cycles or

Table 1 Series 2012–1 Notes Class A

Ceding company	Travelers Indemnity Company (and several affiliates)
Original principal	$250,000,000
Initial modeled trigger probability	0.97%
Initial modeled exhaustion probability	0.77%
Initial modeled expected loss	0.88%
Modeling firm	AIR Worldwide
Risk period	June 7, 2012 through June 7, 2015
Trigger	Indemnity per occurrence
Covered event	Hurricane
Covered area	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia) and the District of Columbia
Rating (S&P)	BB+
Collateral	Treasury Money Market Funds
Investor spread	6.00%

Source: Swiss Re (2012b).

macroeconomic variables.[10] Even with these listed benefits, CAT bonds should only be a minor portion of an investor's portfolio because of the small possibility of a huge loss. This is what researchers within finance and economic studies have identified as tail risk.

There are varying amounts of risk depending upon where the bond's coverage occurs. CAT bonds issued against catastrophic events in the United States have more data for analysis available versus catastrophic events across the rest of the world. However, even with this additional data, there are no guarantees that historical data will capture the probability for future events as was the case with terrorist attack on the Twin Towers of the World Trade Center in New York City on September 11, 2001. Although, both natural and man-made disasters are rare, when they occur, the losses are often substantial. Thus, insurance firms need to protect themselves against this small probability of extreme loses that might cripple their ability to pay out claims and still stay operational. Besides the potential of having a loss of coupon and principal to the underlying insurance firm, other risks to investors of CAT bonds include a lack of liquidity (weak secondary market); lack of SEC oversight (unregistered securities without periodic disclosure issued under Rule 144A—thus only offered to qualified institutional buyers—QIBs) and counterparty risk (does the special purpose vehicle, SPV, have adequate assets to prevent default). One of the 189 issues outstanding was in default (Calabash Re III Ltd.: CALABA).

CAT bonds can cover large areas or be quite focused. For example a CAT bond issued by Travelers, an American insurance company in May 2012, through their SPV—Long Point Re III (Series 2012–1) covered excess losses against hurricanes in several northeast states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia) and the District of Columbia. The amount issued was $250 million.[11] Details of this issue are summarized in Table 1. Reinforcing the risks that CAT bond investors face are highlighted within the prospectus include the potential loss of principal or coupon payments because of the underlying trigger event, the option of the SPV to extend the maturity of the bond or to redeem the bonds before maturity, limited recourse to assets of the special purpose vehicle (SPV) and no recourse to the assets of Travelers, the possibility of insolvency of the issuer and the consequential loss of some or all of their investment, potential negative tax consequences, and limited liquidity.

Two additional examples of CAT bonds highlight the differences in the range of area covered by the underlying event. First, PennUnion Re Ltd. (Series 2015–1) was issued October 2015 by cedent Amtrak to cover U.S. storm surge (New York City and Delaware) and wind damage (Connecticut, Delaware, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, and Rhode Island) caused from named storms or earthquakes. The size of the issue was $275 million. The bond's rating by S&P was BB-. This noninvestment grade rating is typical within the CAT bond market. As with most CAT bond issues, this one originates in Bermuda, one of the leading reinsurance and CAT bond issuing countries.

The second example is the Compass Re II Ltd. (Series 2015–1) issued by one of the leading cedent, AIG. The primary coverage for this bond is protection from U.S. wind damage. The size of the issue was $300 million. This bond was rated by Fitch at B+. The coverage area is extensive ranging from the Gulf to the East Coast (Texas through Massachusetts). This is a short term bond lasting from the official start of the hurricane season (June 1 through November 30). This bond was structured as a zero coupon bond. As shown in Tables 2 and 3, the extent of damages from major catastrophe events has exposed insurance and reinsurance firms to the potential of huge losses. Thus, the CAT bond market was created to help further diversify the risks beyond the reinsurance market.

3.2. CAT bond structure

CAT bonds are issued through a SPV to separate the legal and financial liabilities of an insurance firm from the liabilities associated with the bonds. Similar to the reinsurance market, CAT bonds provide insurance firms an opportunity to offset payout risk above a predetermined threshold (trigger event). In addition to insurance firms, reinsurance firms and some government (both foreign and domestic) agencies also issue CAT bonds. Based on the underlying event being covered, the SPV sets the terms for the bonds (i.e., coupon rate, maturity, amount, and most importantly, defining the trigger event). As with all bond issues, the terms of the contract must be spelled out within the bond indenture.

After the terms of the bond are set, the SPV issues the CAT bonds to investors. The principal (selling price) is then deposited into a collateral account. Additionally, part of the insurance premiums are transferred on a periodic basis to the SPV as additional collateral. Both the principal and the partial premiums are held until they are earned by the bondholders. To maximize returns to the underlying firm, these held funds are reinvested in low risk securities typically highly rated money market funds. These combined cash flows are used to pay the CAT bond coupons that are commonly floating rate issues (based on three-month rates such as from Treasury Bills plus a fixed spread). The typical maturity for CAT bonds is three years and ranges from one to five years with coupon resets on an annual basis with payments of quarterly coupons. Because the investors' coupon, or interest payments, are made up of interest the SPV makes from the collateral and the premiums the sponsor pays, this aspect of the CAT bond returns is very safe. The size of a CAT bond issue is typically

Table 2 The 25 most costly insurance losses from natural disasters (1970–2014)

Rank[a,b]	Insured loss (Bn)[c]	Victims[d]	Date (start)	Event	Country
1*#	$78.638	1,836	8/25/2005	Hurricane Katrina; storm surge, damage to oil rigs	United States, Gulf of Mexico, Bahamas
2	$36.828	18,520	3/11/2011	Earthquake (M_w 9.0)[e] triggers tsunami	Japan
3#	$36.079	237	10/24/2012	Hurricane Sandy; massive storm surge	United States, Caribbean
4*#	$26.990	43	8/23/1992	Hurricane Andrew; floods	United States, Bahamas
5	$25.104	2982	9/11/2001	Terror attack on WTC, Pentagon, other buildings	United States
6	$22.355	61	1/17/1994	Northridge earthquake (M_w 6.6)	United States
7*#	$22.258	136	9/6/2008	Hurricane Ike	United States, Caribbean, Gulf of Mexico
8	$16.836	181	2/22/2011	Earthquake (M_w 6.3) aftershocks	New Zealand
9*#	$16.157	119	9/2/2004	Hurricane Ivan; damage to oil rigs	United States, Caribbean, Barbados
10	$15.783	815	7/27/2011	Floods caused by monsoon rains	Thailand
11*#	$15.234	35	10/19/2005	Hurricane Wilma; torrential rain, floods	United States, Mexico, Jamaica, Haiti
12#	$12.240	34	9/20/2005	Hurricane Rita; floods, damage to oil rigs	United States, Gulf of Mexico, Cuba
13	$11.339	123	7/15/2012	Drought in the Corn Belt	United States
14*#	$10.087	24	8/11/2004	Hurricane Charley	United States, Cuba, Jamaica
15	$9.813	51	9/27/1991	Typhoon Mireille	Japan
16#	$8.730	71	9/15/1989	Hurricane Hugo	United States, Puerto Rico
17	$8.682	562	2/27/2010	Earthquake (M_w 8.8) triggers tsunami	Chile
18	$8.458	95	1/24/1990	Winter storm Daria	France, United Kingdom
19	$8.241	110	12/25/1999	Winter storm Lothar	Switzerland, United States, France
20	$7.681	321	4/22/2011	Major tornado outbreak: 343 tornadoes; hail	United States
21	$7.418	177	5/20/2011	Major tornado outbreak: 180 tornadoes	United States
22	$6.959	54	1/18/2007	Winter storm Kyrill; floods	Germany, United Kingdom
23	$6.456	22	10/15/1987	Storms and floods in Europe	France, United Kingdom
24#	$6.449	38	8/26/2004	Hurricane Frances	United States Bahamas
25	$6.134	50	8/22/2011	Hurricane Irene; torrential rainfall, flooding	United States, Canada, Bahamas

[a](*) Also listed under bankrate.com's "10 Costliest natural disasters. Other disasters not included in the above table include: 1988 drought and heat wave affecting Central and Eastern United States ($76.4 billion damages and 5,000 to 10,000 deaths); 1994 Northridge earthquake in California ($67 billion in damages and 60 deaths); 1980 drought and heatwave affecting Central and Eastern United States ($54.8 billion damages and 10,000 deaths); and 1993 Midwest floods affecting Central United States (32.8 billion damages and 48 deaths. (*Source:* http://www.bankrate.com/finance/insurance/top-10-costliest-natural-disasters-1.aspx).

[b](#) Also listed under CNBC.com's "10-Most Expensive Hurricanes in U.S. History (*Source:* http://www.cnbc.com/2013/10/03/The-10-most-expensive-hurricanes-in-the-history-of-the-United-States.html?slide=11).

[c] Table values in US$ billion, 2014 prices.

[d] Dead or missing.

[e] M_w is the earthquate magnitude scale ($M_w = 2/3 \log_{10} (M_o) - 10.7$ where M_o is the seismic moment).

Source: Swiss Re Sigma No. 2/2015.

Table 3 Disasters consequences

	Disasters	Natural	Man-made	No. victims	Natural	Man-made
Victims						
2010	304	167 (55%)	137 (45%)	303,573	297,127 (98%)	6,446 (2%)
2011	325	175 (54%)	150 (46%)	34,729	29,026 (84%)	5,703 (16%)
2012	318	168 (53%)	150 (47%)	13,929	8,948 (64%)	4,981 (36%)
2013	325	166 (51%)	159 (49%)	25,903	20,201 (78%)	5,702 (22%)
2014	336	189 (56%)	147 (44%)	12,777	7,066 (55%)	5,711 (45%)
Five-year average	322	173 (54%)	149 (46%)	78,182	72,474 (93%)	5,709 (7%)

Note: No. victims equals dead or missing.

	Total losses	Insured losses	Natural	Man-made
Financial losses				
2010	218,000	43,475 (20%)	39,869 (18%; 92%)	3,606 (2%; 8%)
2011	370,000	115,814 (31%)	110,021 (30%; 95%)	5,794 (1%; 5%)
2012	186,000	77,238 (42%)	71,279 (38%; 92%)	5,960 (4%; 8%)
2013	138,000	44,917 (33%)	37,047 (27%; 82%)	7,870 (6%; 18%)
2014	110,000	34,708 (32%)	27,749 (25%; 80%)	6,958 (7%; 20%)
Five-year average	204,000	63,230 (31%)	57,193 (28%; 90%)	6,038 (3%; 10%)
	$US Million	$US Million (insured/total; insured/natural or man-made)		

Note: Insured losses account for property and business interruptions, excluding liability and life insurance losses.

Source: Swiss Re Sigma 2011–2015.

over $100 million to help compensate for the transaction costs, modeling risks, and marketing fees.

Although CAT bonds have a low probability that the underlying catastrophe will occur and consequential forfeiture of principal and future coupons, they are still classified as high risk bonds. Thus, they are usually rated within the BB, B, and CCC categories, which indicates non-investment (high yield or junk) grade securities by the three large rating agencies (Fitch, Moody's, and S&P). Although the rating agencies, the insurance firms, and reinsurance firms have their own security analysts, a few key firms specializing in risk assessment (i.e., probability modeling, weather forecasts, seismology, and other technical factors associated with the events being analyzed) dominate the analysis of this type of bond from both the buyer's and seller's vantage. Catastrophe modeling is vital to CAT bond transactions to provide analysis and measurement of events which could cause a loss, as well as, to define the exposed geographical region. Bond modeling is much more prevalent within the U.S. market because of the amount of historical data available. These analysts rely on the modeling of historical and simulated data to estimate the likelihood of a catastrophic event occurring and the financial impact of the event if it occurs. Thus, mutual and hedge fund investors with CAT bond holdings are at a disadvantage to the insurance and reinsurance firms when undertaking the risk assessment of CAT bond holdings. This is definitely not a level playing field. One other distinct disadvantage to the potential investor, is that these bonds are not subject to SEC registration and disclosure requirements.

Besides the risk of a triggering event, CAT bondholders are also exposed to additional risks. As previously mentioned, there is modeling risk. Even the best models cannot fully

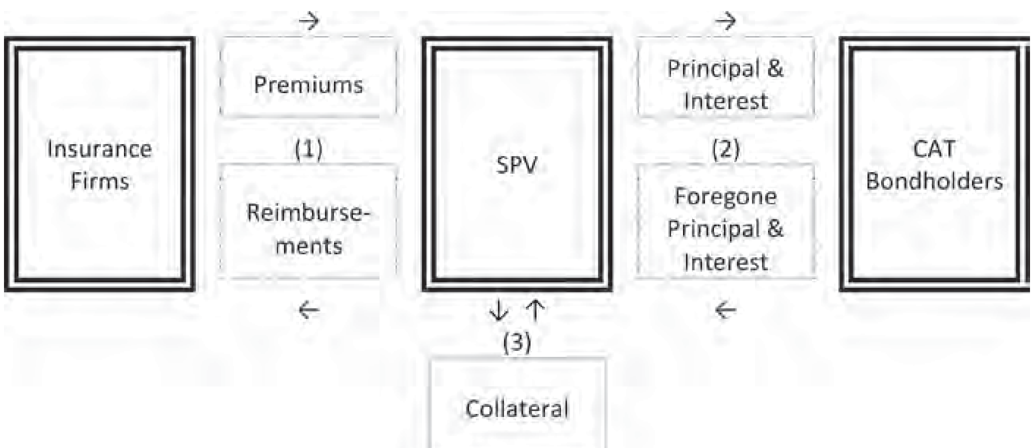

Fig. 2. Cash flow analysis. *Notes:* (1) Insurance/Reinsurance/Government Agency enters into a risk transfer contact (i.e., the creation of CAT bonds) with a special purpose company (SPV) established specifically for this transaction. (2) The SPV issues the catastrophe (CAT) bonds to investors in the capital markets in an amount equal to the limit of the risk transfer contract. (3) Proceeds from the sale of the bonds and the periodic premiums transferred to the SPV are invested in a collateral trust account of safe investments such as U.S. Treasury Bills or other money market investments. (a) If no covered event occurs, the bonds will be redeemed at face value. (b) However, if a covered event meeting the defined threshold limits occurs, funds will be withdrawn from the collateral account to cover this excess above the threshold. Thus, bondholders could lose all of their principal and any remaining coupons. *Source:* Swiss Re (2012a).

account for the differences between simulated events and actual events. This showed up in the mismatch of forecasted hurricanes between 2001 and 2005 and the actual number of hurricanes that occurred. Industry models to forecast extreme meteorological events are weak at best. A second risk to consider is liquidity because of the fact that CAT bonds are highly illiquid. Typically, they are bought and held with little aftermarket trading. Third, is marketability, that is, CAT bonds are issued under Rule 144A which makes them accessible to QIBs only during the first year of the offering. These bonds are not subject to normal SEC filings that makes pricing and risk assessment that much harder. Finally, these bonds have counterparty risk. If the associated insurance firm runs into financial distress, the bondholders may not receive all that is promised. Additionally, CAT bonds can be issued as a single class or as a multiple class bond with various tranches. This is comparable to collateralized mortgage obligations (CMOs) in which each class has different risks and thus different compensation. CAT bonds, like any other bond class, can be bundled into CDOs (collateralized debt obligations) further obscuring the relationships between risk and return.

The SPV must monitor for the trigger event. This could be a single or multiple event clause. If a qualifying event occurs that triggers a payout, the SPV liquidates enough collateral required to make the payment and reimburse the counterparty to satisfy the terms of the CAT bonds. Thus, the promised cash payments (coupons) stop flowing to the bondholders, along with the expected principal that would have occurred at maturity. These funds are transferred back to the insurers to cover the catastrophic event. If no trigger event occurs, then the bondholders receive their expected cash flows and any remaining collateral is liquidated at maturity and firm's investors are repaid. Fig. 2 shows a typical CAT bond structure including where the capital flows from one party to another. Depending on if and when the trigger event occurs, the SPV may be forced to extend the maturity of the bond (from three months to two years) until the insurance loss is verified.

3.3. Classification of triggers events

One of the key areas of contention with CAT bonds, highlighted by Finken and Laux (2009), Froot (2001), and Cummin et al. (2004), is what qualifies as a trigger event. For instance, the Financial Industry Regulatory Authority (FINRA) outlines the five key trigger descriptions: parametric, modeled loss, industry loss index, indemnity, and hybrid.[12] A parametric bond is triggered if specific, objective "parameters" are met—for example, wind speed for a hurricane-linked bond or ground acceleration for an earthquake-linked bond. This is the most transparent and easiest to verify of the triggers and presents the least potential for a sponsor to influence the bond's performance. It typically pays a lower yield than bonds with other trigger types, as it may not cover all of sponsor's losses.

The second category, modeled loss, measures the sponsoring firm's exposure or expected loss. It is calculated by computer models that use objective data, such as actual wind speeds or ground acceleration. The bond is triggered if the sponsor's exposure exceeds a specified dollar amount. It allows for faster verification than the industry-loss or indemnity triggers described below, but there is a heavy reliance on computer modeling to determine when the trigger has occurred. If the computer program is good, then the estimates are good.

Within the industry-loss index, a bond is triggered when the amount of the overall industry loss from an event, usually determined by an independent third party, exceeds a certain amount. In this situation, there is minimal potential for a sponsor to influence the bond's performance, as the index is based on industry-wide losses for each event. It typically pays a somewhat higher yield than for parametric triggers, but compared with parametric and modeled loss triggers, it takes longer to compute the final amount of industry loss, leading to increased uncertainty for investors.

Within the indemnity category, a bond is triggered when the sponsor's actual underwritten loss on specific insurance policies exceeds a predetermined amount. For example, a sponsor's insurance claims resulting from a Florida hurricane may need to exceed $1 billion to the sponsor before investors lose their interest and principal. It typically pays the highest yield of the different trigger types, as it provides the best protection to the sponsor, but it presents the most potential for the sponsor to influence bond performance, as payouts are based on the individual policy claims against the sponsor and the way the sponsor settles those claims. Furthermore, a long period of time can be needed to calculate total loss claims, again leading to increased uncertainty for investors.

The fifth classification, a hybrid trigger, is created by combining any of the above triggers. It is useful for bonds linked to multiple events and can be structured to cushion investors' losses and/or enhance yield potential. However, depending on the components of the hybrid trigger, it can be complicated and difficult to understand or verify. According to Swiss Re (2012a, 2012b), the natural catastrophic bond trigger breakdown by classification were industry index (40%), indemnity (37%), parametric index (12%), modeled losses (6%), hybrid (4%), and other (2%).

4. Catastrophic costs and the need for offsetting risks

Catastrophic costs vary from disaster to disaster and from year to year. For instance, the tenth costliest natural disaster in the United States between 1980 and 2010 reported by bankrate.com was Hurricane Katrina in 2005.[13] The states impacted the most were Alabama, Florida, Louisiana, and Mississippi with total damages of $145 billion ($79 billion insured) and 1,836 deaths. The top 10 disasters totaled over $500 billion in damages and more than 20,000 deaths. Besides hurricane damage, terroristic attacks (ex. The 2001 9/11 New York City Twin Tower Attack: $32.5 billion of insured losses and 2,976 deaths) and earthquakes (ex. 2011 9.0 Mw Tohuku Japan earthquake: $36.8 billion of insured losses and 18,520 deaths). From a worldwide perspective, 2011 produced the largest economic losses from earthquakes and natural disasters tallying over $365 billion and over 20,000 deaths. Several of these disasters, such as the 2011 Japanese earthquake and the 9/11 bombing of the Twin Towers in New York City, illustrate the type of disasters in which claims are not settled for years after the disaster occurred.

4.1. Historical loss perspective

Table 2 tallies the 25 costliest worldwide insurance losses from natural disasters. For instance, Hurricane Katrina in 2005 is listed as the costliest natural disaster tallying $78.6 billion in insured losses from the United States (primarily Alabama, FL, LA, and Mississippi), Mexico, and the Bahamas). Table 2 also attributes 1,836 deaths (dead or missing) occurring directly because of this hurricane. Thus, the key takeaway from the complete listing is the massive amount of losses that have occurred overtime. These losses justify the need for insurance companies to have a mechanism to offset part of their exposure to catastrophic risks. Jarzabkiwski, Bednarek, and Spee (2015) detail that the primary offset in the past has been through the reinsurance market, but that a small and growing segment for this offset is within the financial markets primarily with CAT bonds.

4.2. Need for offsetting risks

Swiss Re, a leading reinsurance firm, offers additional support for the need of insurance firms to offset catastrophic risks. As shown in Table 3, over the past five years the average annual number of disasters was 322; 173 (54%) from natural disasters and the remaining 149 (46%) from manmade disasters. The breakdown between natural and manmade disasters was consistent over the last five years. Although the number of victims over this same five year period averaged 78,000, this average was highly skewed by one event in 2010. During that year, the 7.0 earthquake in Haiti accounted for 222,570 deaths, which is more than the total from the next four years combined. The Haiti earthquake also accounted for over 300,000 injured and 1,200,000 homeless individuals. Although the insured losses totaled $100 million, this was a minuscule amount compared with the total damage of over $10 billion. The bottom half of Table 3 focuses on the financial losses over this same five year period (2010–2014). The average annual loss was $204,000 million with approximately 30% of the total insured losses. The proportion of these insured losses from natural versus man-made disasters was 9 to 1.

4.3. The Florida impetus

As the financial markets have become more heavily regulated, reserve capital requirements have increased. This is one of the reasons insurance firms have been forced to offset part of their risks onto the financial markets. An additional reason for reinsurance and the assorted financial instruments they have sprouted flow from the desire of insurance firms to stay solvent. An illustration of a key driver within the reinsurance market was the reaction of the State of Florida to the financial crisis caused by Hurricane Andrew in 1992. After Hurricane Andrew caused unprecedented damage (over $16 billion of insured losses) in Florida, the insurance industry was in a crisis. Seven Florida based companies and one national firm became insolvent as several others become "technically insolvent."

Because of the extent of damages from this storm, many of the firms were threatening to withdraw from the Florida market. In 1992, the Florida Department of Insurance enacted two emergency rules (4ER92–11 and 4ER92–15). The first rule limited the ability of insurance firms to abandon the high-risk areas of the Florida market. The rule placed a 90 day moratorium on all firms wishing to withdraw. During this time a firm wishing to withdraw from the Florida market had to file a written statement of intent including details for the withdrawal and any projected effects it would have on the market. It also limited the firm to withdrawing only 5% of their policies per year. This rule was originally to last only 6 months, but was extended for an additional three years.[14] The second rule established the Florida Property and Casualty Joint Underwriting Association (FPCJUA) to make sure that insurance coverage would be available to all. This was combined with the Florida Windstorm Underwriting Association (FWUA), which insured beach-front properties, together to form Citizens Property Insurance Corporation (CPIC) in 2012. This new entity is the largest insurer for hurricane disasters in the Florida market. In 2012, CPIC sponsored the second-largest transaction in the market's history by floating $750 million in CAT bonds.[15]

Florida created the Florida Hurricane Catastrophe Fund (FHCF) in 1993 to provide additional reinsurance capacity following Hurricane Andrew. This is a state government trust fund, exempt from federal taxes, which requires all insurers (residential and commercial) operating within the state to provide a cushion against catastrophic losses caused from future hurricanes. The creation of new laws, the CPIC, and the FHCF were just part of the six key changes to the insurance market in the aftermath of Hurricane Andrew which included: (1) more carefully managed coastal exposure; (2) a larger role of government (both federal and state) in insuring risks; (3) the introduction of hurricane deductibles; (4) greater use of reinsurance capital from worldwide sources including the financial markets; (5) the expansion and refinement of sophisticated catastrophic modeling; and (6) support and enforcement of tougher building codes.[16]

The FHCF has been a success in ensuring the solvency of insurance firms operating within Florida as evidenced by the Florida Office of Insurance Regulation terminating the 1.3% assessment on most property insurance policies 18 months ahead of schedule on July 22, 2014.[17] Further support is offered in the annual "Report Prepared for the Florida Hurricane

Catastrophe Fund (FHCF): Claims-Paying Capacity Estimates," which forecasts Florida's ability to weather future hurricanes very positively.[18] Key factors leading to this conclusion include: (1) the requirement of all insurers within the state to contribute to FHCF; (2) forecasts of 50, 100, and 250 years to capture one in a lifetime events; (3) strong debt ratings (AA by all three rating agencies—Moody's, Standard & Poor's, and Fitch) with capacity for future borrowings; (4) the ability to levy emergency assessments on all property and casualty insurance lines; and (5) successful entry into the reinsurance and financial markets.

5. Analysis of returns

The reinsurance market was very lucrative from the 1990s through the early 2000s. Warren Buffett in his 50th anniversary letter to Berkshire Hathaway investors states the above average returns the firm was able to generate was because of the insurance/reinsurance market.[19] Because of the firm's strong capital base, they were a "go to" reinsurance firm. Insurance firms participating in reinsurance with Berkshire Hathaway projected little risk of failure to pay claims so it is surprising that the firm is pulling back from their participation in future reinsurance investments. Buffett feels that because of the amount of competition from other reinsurance firms, hedge funds, and the financial markets, the expected returns do not justify the risk being undertaken.[20] Thus, the financial markets have helped make the reinsurance market more competitive. However, the prediction of future catastrophic risks from population migration to areas of potential catastrophic disasters, such as the hurricane belts across Florida, dictate the need for insurance firms to continue to offset these risks. An additional complication is the rise in extreme weather patterns associated with climate change. Note also that it is rare for CAT bondholders to lose all their funds. The *Insurance Journal* in 2013 cite that "only eight … deals issued since 1997 have been triggered—four triggered as a result of losses from natural disasters and others by damages as a result of the 2008 financial crisis."[21] However, what type of returns have CAT bondholders received?

5.1. CAT indices

Returns from CAT bonds are difficult to calculate because they are traded infrequently so a number of proxies are used. Our first test relies on two broad proxies, the Eurekahedge ILS Advisors Index (ILS) and the Mercury Investible Catastrophe Risk Index (MiCRIX). The Eurekahedge ILS Advisors Index tracks the performance of participating Insurance Linked Investment Funds. This index allows a comparison between different fund managers in the insurance-linked securities, reinsurance, and CAT bond investment field. Eurekahedge, the index manager, is the world's largest compiler of alternative asset fund databases and ILS Advisers are an independent advisory service for insurance-linked investments. A sample of monthly returns from this index are shown in Table 4 over the period 1/2010 through 3/2016. The mean monthly return is 0.41% coupled with a 0.61% standard deviation. The maximum and minimum monthly returns over this period is 1.20% and −3.94%, respectively. Although not shown in Table 4, since its inception in 2005, the best monthly return is 1.60% versus the worst monthly return of −3.94%. The Sharpe ratio, as a measure of reward to volatility,

Table 4 ILS and MiCRIX historical monthly performance

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
ILS												
2016	0.21%	0.54%	0.37%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2015	0.39%	0.24%	0.21%	0.08%	0.16%	0.15%	0.40%	0.84%	1.03%	0.27%	0.31%	0.08%
2014	0.50%	0.50%	0.45%	0.32%	0.08%	0.21%	0.41%	0.81%	0.86%	0.61%	0.14%	0.43%
2013	0.68%	0.75%	0.64%	0.85%	0.44%	0.00%	0.40%	0.92%	1.20%	0.64%	0.49%	0.42%
2012	0.18%	0.19%	0.32%	0.43%	0.59%	0.57%	0.62%	0.94%	1.19%	−0.51%	0.27%	1.02%
2011	0.70%	0.18%	−3.94%	0.06%	0.21%	0.71%	0.67%	0.12%	0.53%	0.73%	−0.04%	−0.04%
2010	0.92%	0.94%	0.45%	0.49%	0.29%	0.16%	0.52%	0.75%	1.17%	0.90%	0.29%	0.42%
Mean		0.41%	Standard deviation			0.61%	Maximum		1.20%	Minimum		−3.94%
MiCRIX												
2016	0.54%	0.40%	0.33%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2015	0.42%	0.42%	0.32%	0.23%	0.23%	0.61%	0.81%	2.06%	2.74%	1.44%	0.48%	0.42%
2014	0.54%	0.53%	0.40%	0.28%	0.28%	0.70%	0.92%	2.28%	3.03%	1.64%	0.58%	0.52%
2013	0.63%	0.63%	0.48%	0.35%	0.35%	0.91%	1.19%	2.97%	3.95%	2.11%	0.69%	0.61%
2012	0.74%	0.74%	0.56%	0.39%	0.39%	0.99%	1.29%	3.28%	4.42%	−12.39%	0.87%	0.79%
2011	0.58%	0.57%	−14.93%	0.22%	0.22%	0.90%	1.18%	3.29%	4.51%	2.39%	0.64%	0.55%
2010	0.61%	0.60%	0.44%	0.30%	0.30%	0.85%	1.07%	2.75%	3.70%	2.00%	0.66%	0.59%
Mean		0.72%	Standard deviation			2.63%	Maximum		4.51%	Minimum		−14.93%

Source for ILS index: http://www.artemis.bm/eurekahedge_ils_advisers_insurance_linked_securities_fund_index/; source for MiCRIX index: http://www.artemis.bm/mercury_micrix/

ILS = investment linked securities; MiCRIX = Mercury Investible Catastrophe Risk Index.

at 0.1897 indicates a positive return for the risk undertaken. The percentage of positive returns over the period 1/2010 through 3/2016 is 94.7% (71 out of 75 months). Table 4 shows the historical monthly returns over this seven year period and Table 5 shows a summary of the statistics over various sample periods.

The second index used as a proxy for the CAT bond performance is the Mercury Investible Catastrophe Risk Index (MiCRIX). It was started in 2006 to track the performance of a diversified portfolio of peak peril industry loss warranties (ILW's). Mercury Capital Ltd. is a Bermuda based fund manager. Their index data are based on prices collected from a panel of reinsurance brokers. The MiCRIX index tracks the performance of a balanced portfolio of the peak peril exposures from US Quake, US Regional Wind, European Wind, Japanese Quake, and Japanese Wind. The index experienced only three down months in the 87 months since inception. This index shows a mean monthly return from 1/2010 through 3/2016 of 0.72% matched with a monthly standard deviation of 2.63%. Similar to the ILS index, there is a positive Sharpe ratio (0.1605). Summary statistics over the same time periods as the ILS index are shown in Table 5. Monthly returns, shown in the bottom half of Table 4, indicate higher returns compared to the ILS index, but with greater variability. The three year correlation of monthly returns between these two CAT indices (ILS and MiCRIX) is 0.74 indicating a strong positive relationship between these two CAT performance proxies.

To analyze the performance of these two broad CAT bond proxies, their returns are evaluated against the returns from the Merrill Lynch (ML) non-investment grade corporate bond indices.[22] Monthly returns of the ML indices are shown in Table 6. The top half of the table shows the returns from the BB rated bond index; the middle section shows the returns from the B rated corporate bond index; and the bottom section, the returns from the CCC

Table 5 Summary statistics for catastrophe (CAT) indices

Period	Statistic	ILS	MiCRIX	Swiss BB	Swiss G	Swiss US
Whole	Mean	0.41%	0.72%	0.48%	0.61%	0.63%
	σ	0.61%	2.63%	0.90%	0.80%	0.88%
	Max	1.20%	4.51%	2.55%	2.23%	2.45%
	Min	−3.94%	−14.93%	−4.89%	−3.56%	−3.92%
	# Positive	71	73	64	68	66
	Sharpe	0.1897	0.1605	0.1963	0.3894	0.3714
	Count	75	75	75	75	75
1 year	Mean	0.35%	0.85%	0.27%	0.35%	0.36%
	σ	0.30%	0.81%	0.48%	0.48%	0.53%
	Sharpe	0.8890	0.9471	0.3886	0.5482	0.5302
	# Positive	12	12	8	10	9
2 years	Mean	0.40%	0.91%	0.31%	0.42%	0.44%
	σ	0.27%	0.83%	0.44%	0.44%	0.48%
	Sharpe	0.3976	0.7529	0.0412	0.2926	0.3127
	# Positive	24	24	17	21	20
3 years	Mean	0.47%	1.02%	0.41%	0.57%	0.60%
	σ	0.30%	0.95%	0.45%	0.49%	0.53%
	Sharpe	1.2346	0.9682	0.6873	0.9493	0.9223
	# Positive	36	36	29	33	32
4 years	Mean	0.47%	0.81%	0.46%	0.63%	0.66%
	σ	0.34%	2.20%	0.58%	0.63%	0.69%
	Sharpe	1.0441	0.3130	0.5864	0.8053	0.7723
	# Positive	47	47	39	43	42
5 years	Mean	0.38%	0.65%	0.42%	0.57%	0.58%
	σ	0.66%	2.90%	0.92%	0.81%	0.89%
	Sharpe	0.1993	0.1389	0.1894	0.3941	0.3761
	# Positive	51	53	45	49	47
6 years	Mean	0.42%	0.73%	0.48%	0.62%	0.63%
	σ	0.62%	2.69%	0.91%	0.82%	0.90%
	Sharpe	0.2376	0.1731	0.2334	0.4305	0.4085
	# Positive	68	70	61	65	63

Note: 1 year period (1/2015–12/2015); 2 year period (1/2014–12/2015); 3 year period (1/2013–12/2015); 4 year period (1/2012–12/2015); 5 year period (1/2011–12/2015); 6 year period (1/2010–12/2015); and Whole period (1/2010–3/2016). ILS = investment linked securities.

rated corporate bond index. The highest monthly return during the 1/2010–3/2016 period for the BB, B, and CCC bonds are 4.07%, 4.00%, and 10.03%, respectively. However, this is contracted with the lowest returns over the same period of −2.67%, −2.85%, and −6.54%. The mean monthly returns (standard deviations) for these three indices are 0.54% (1.20%), 0.45% (1.43%), and 0.47% (2.83%), respectively, for the BB, B, and CCC indices, which is similar to the CAT proxies (ILS and MiCRIX). These three ML indices are highly correlated with each other (BB with B 0.89; BB with CCC 0.77; and B with CCC 0.93) as expected for three noninvestment grade bond indices. The correlations are summarized in Table 8.

Because we wish to compare results (monthly returns from CAT proxies and the ML speculative bond indices) by matched time periods, our analysis focuses on the inferences about the mean of the differences between the two populations in a paired difference tests.[23] For this test of the mean of the differences, our null hypothesis test forecasts no difference between the monthly returns of the junk bond indices and the CAT bond indices as:

Table 6 BB and B rated corporate debt historical monthly performance

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
BB												
2016	−0.90%	1.17%	2.32%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2015	0.57%	1.50%	−0.27%	0.85%	0.47%	−0.57%	0.08%	−0.70%	−1.31%	2.28%	−1.03%	−1.42%
2014	0.35%	1.07%	0.18%	0.53%	0.46%	0.36%	−0.99%	1.12%	−1.19%	1.26%	−0.10%	−0.42%
2013	0.83%	0.43%	0.62%	1.17%	−0.20%	−1.94%	1.91%	0.14%	0.96%	1.57%	0.55%	0.47%
2012	2.16%	1.51%	0.32%	0.85%	−0.27%	1.22%	1.39%	1.00%	1.11%	0.97%	0.41%	1.02%
2011	1.31%	0.87%	0.54%	0.92%	0.58%	−0.52%	1.05%	−2.54%	−2.67%	4.07%	−1.02%	1.72%
2010	1.14%	1.09%	2.50%	1.09%	−1.85%	1.32%	2.39%	0.64%	2.17%	1.47%	−0.78%	1.18%
Mean		0.54%	Standard deviation			1.20%	Maximum		4.07%	Minimum		−2.67%
B												
2016	−2.18%	−0.17%	3.63%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2015	−0.17%	2.25%	−0.37%	1.31%	0.58%	−0.89%	−1.64%	−2.35%	−2.64%	1.78%	−2.13%	−2.31%
2014	0.54%	1.06%	0.34%	0.48%	0.51%	0.57%	−0.84%	1.00%	−1.19%	0.54%	−0.45%	−1.56%
2013	1.25%	0.68%	0.95%	1.05%	0.02%	−1.39%	1.74%	0.21%	0.87%	1.60%	0.66%	0.47%
2012	2.11%	1.55%	0.47%	0.90%	−0.53%	1.37%	1.48%	0.99%	1.32%	1.04%	0.73%	1.09%
2011	1.70%	1.09%	0.50%	1.04%	0.53%	−0.34%	0.84%	−2.85%	−2.48%	4.00%	−0.92%	1.43%
2010	1.05%	0.22%	2.51%	1.37%	−2.05%	1.24%	2.68%	0.34%	2.33%	1.59%	−0.40%	1.70%
Mean		0.45%	Standard deviation			1.43%	Maximum		4.00%	Minimum		−2.85%
CCC												
2016	−3.85%	−2.42%	10.03%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2015	−0.31%	2.86%	−0.66%	1.13%	0.13%	−1.77%	−2.83%	−3.06%	−2.72%	0.90%	−4.07%	−5.10%
2014	1.22%	0.94%	0.52%	1.01%	0.96%	0.37%	−1.14%	0.14%	−2.21%	−1.16%	−0.89%	−3.07%
2013	3.20%	0.62%	1.49%	2.15%	0.74%	−1.92%	1.90%	0.45%	0.75%	1.90%	1.18%	0.62%
2012	4.14%	3.63%	0.59%	0.98%	−2.71%	2.43%	1.25%	1.75%	2.48%	0.91%	0.22%	2.90%
2011	2.68%	1.29%	0.57%	1.54%	0.05%	−1.29%	0.49%	−6.54%	−6.38%	7.98%	−3.89%	2.59%
2010	2.65%	0.58%	4.85%	3.23%	−4.45%	0.92%	2.87%	−1.00%	3.14%	3.58%	−0.29%	3.40%
Mean		0.47%	Standard deviation			2.83%	Maximum		10.03%	Minimum		−6.54%

Source: Bloomberg, Bank of America-Merrell Lynch US High Yield BB, B, and CCC Debt Indices with maturities of one to five years.

Table 7 Means of the differences tests for CAT indices *t*-values

	ILS	MiCRIX	Swiss BB CAT	Swiss Global CAT	Swiss US CAT
BB corporate					
Whole	0.853	−0.530	0.377	−0.433	−0.506
1 year	−0.835	−1.809	−0.583	−0.741	−0.769
2 year	−1.241	−2.759**	−0.761	−1.214	−1.281
3 year	−1.236	−3.301***	−0.812	−1.667	−1.796
4 year	−0.213	−1.041	−0.096	−1.159	−1.282
5 year	0.293	−0.534	0.030	−0.755	−0.807
6 year	0.737	−0.584	0.253	−0.557	−0.623
B corporate					
Whole	0.183	−0.775	−0.151	−0.892	−0.946
1 year	−1.635	−2.204*	−1.401	−1.508	−1.511
2 year	−2.072*	−3.111***	−1.678	−2.014	−2.051
3 year	−1.826	−3.412***	−1.482	−2.162*	−2.257*
4 year	−0.871	−1.320	−0.743	−1.613	−1.707
5 year	−0.261	−0.749	−0.429	−1.167	−1.202
6 year	0.180	−0.786	−0.182	−0.937	−0.987
CCC corporate					
Whole	0.168	−0.548	−0.018	−0.426	−0.466
1 year	−2.303*	−2.753**	−2.111	−2.188	−2.190
2 year	−2.821***	−3.541***	−2.531**	−2.777**	−2.805**
3 year	−1.936	−3.106***	−1.727	−2.212*	−2.288**
4 year	−0.699	−1.229	−0.641	−1.215	−1.292
5 year	−0.534	−0.863	−0.625	−1.073	−1.104
6 year	0.068	−0.655	−0.142	−0.586	−0.626

Note: CAT = catastrophe; ILS = investment linked securities; MiCRIX = Mercury Investible Catastrophe Risk Index.

Significance levels: * (0.025% significance); ** (0.010% significance); *** (0.005% significance).

$$H_0: \mu_D = 0 \text{ versus } H_A: \mu_D \neq 0$$

The test statistic is a one-sample t, because we are analyzing a single sample of differences:

$$\text{Test statistic: } t = \frac{\bar{x}_D - 0}{SD/\sqrt{n_D}}$$

Where μ_D = the mean of the difference of the monthly returns of the speculative (junk) bond index and the CAT bond index; $\bar{x}_D$ = sample mean of differences; s_D = sample standard deviation of differences; and n_D = number of differences.

A comparison of the monthly differences of returns using the 3 ML speculative corporate bonds indices (BB, B, and CCC) and our two broad CAT indices (ILS and MiCRIX) finds no cases in which the speculative corporate sector of bonds outperformed the CAT proxies. There are no incidences of positive t-values at any reasonable level of significance (10%, 5%, or 1%). That is, the null hypothesis of mean of the differences of monthly returns show either nonsignificant results favoring the returns from the CAT proxies versus the speculative grade bonds or in a few time periods statistically significant results favoring the CAT bond indices. See Table 7 for a summary of the significance tests over the total time period and the six yearly test periods (1-, 2-, 3-, 4-, 5-, and 6-years).

Table 8 Correlations for CAT indices

	SPX	BUSY13	BB	B	CCC	Swiss BB	Swiss G	Swiss US	MiCRIX	ILS
SPX	1.000	−0.166	0.743	0.727	0.596	−0.136	−0.152	−0.161	−0.092	−0.067
BUSY13		1.000	0.172	−0.046	−0.061	0.159	0.195	0.204	0.100	0.241
BB			1.000	0.894	0.772	0.008	0.034	0.029	−0.016	0.117
B				1.000	0.928	−0.052	−0.003	−0.012	−0.103	0.016
CCC					1.000	0.062	0.111	0.100	−0.124	0.113
Swiss BB						1.000	0.969	0.971	0.707	0.924
Swiss G							1.000	0.998	0.682	0.940
Swiss US								1.000	0.697	0.939
MiCRIX									1.000	0.744
ILS										1.000

Note: CAT = catastrophe; ILS = investment linked securities; MiCRIX = Mercury Investible Catastrophe Risk Index.

Adding to the diversification effect of the CAT bonds is the low level of correlation between these two CAT bond indices and the BB-rated, B-rated, and CCC-rated ML corporate bond indices. Correlation between MiCRIX and the BB, B, and CCC corporate bond indices are approximately 0 (i.e., −0.016, −0.103, and −0.124, respectively). For the Eurekahedge ILS index, the correlations are similar but slightly positive (i.e., 0.117, 0.016, and 0.113, respectively).[24] Further evidence of the diversification effects of an investment in CAT bonds is the lack of correlation between these two broad CAT bond proxies and the S&P 500 index and a one to three year maturity US Treasury index. The correlations are summarized in Table 8.

A second broad comparison was also undertaken using Swiss Re CAT Bond Indices. Swiss Re reports results from three indices: a BB rated CAT bond index, a Global CAT bond index, and a U.S. based CAT bond index. The results are similar to the results from the previous proxies. The means, standard deviations, and Sharpe ratios are similar: 0.48%/0.90%/0.1963, 0.61%/0.80%/0.3894, and 0.63%/0.88%/0.3714, respectively, for the BB, Global, and U.S. CAT bond indices. See the last three columns of Table 5 for a summary of the results.

Using the means of the differences hypothesis testing, there is no significant results indicating that speculative bond proxies outperformed the CAT bond proxies. With the exception of one test, all the results were negative with a few times periods showing significant results favoring the CAT proxies. Again, the correlations (shown in Table 8) reinforce the diversification effects offered by the CAT funds. Correlations with the three CAT fund proxies and the speculative bond indices ranged from 0.008 (Swiss Re BB and Corporate BB) to −0.052 (Swiss Re BB and Corporate B). The null hypothesis test results of the mean of the differences of monthly returns are summarized in the last three columns of Table 7.

5.2. CAT funds

Our final set of proxies for the performance of CAT bonds are a number of off-shore hedge funds investing primarily in CAT bonds. Table 9 summarize the monthly returns from a

Table 9 Catastrophe (CAT) funds historical monthly performance

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
AZ												
2016	−0.21%	0.27%	0.06%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2015	0.11%	−0.07%	−0.19%	−0.15%	−0.11%	−0.11%	−0.11%	0.21%	0.28%	−1.03%	0.17%	−0.28%
2014	0.17%	0.08%	0.13%	0.02%	−0.06%	−0.06%	0.08%	0.26%	0.06%	0.13%	0.09%	0.08%
2013	0.35%	0.37%	0.31%	0.31%	0.11%	−0.02%	0.04%	0.29%	0.36%	0.19%	0.06%	0.08%
2012	0.02%	−0.16%	0.06%	0.20%	0.48%	0.38%	0.43%	0.31%	0.41%	−0.08%	0.10%	0.39%
Mean		0.09%	Standard deviation			0.25%	Maximum		0.48%	Minimum		−1.03%
GAM												
2016	0.02%	0.18%	0.29%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2015	0.23%	0.05%	−0.03%	−0.04%	−0.12%	−0.16%	0.45%	0.71%	1.05%	0.25%	0.10%	−0.08%
2014	0.57%	0.42%	0.48%	0.34%	−0.15%	0.15%	0.38%	0.78%	1.11%	0.71%	0.04%	−0.05%
2013	0.77%	1.15%	0.93%	1.01%	0.43%	0.10%	0.48%	1.00%	1.35%	0.90%	0.51%	0.39%
2012	0.17%	0.07%	0.29%	0.27%	0.97%	1.82%	0.31%	1.27%	1.55%	−0.75%	0.93%	1.22%
Mean		0.49%	Standard deviation			0.51%	Maximum		1.82%	Minimum		−0.75%
LGT												
2016	−0.45%	−0.54%	1.08%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2015	1.28%	0.34%	−1.68%	1.71%	−0.34%	−1.01%	0.43%	1.51%	5.99%	1.18%	−1.96%	−4.10%
2014	3.13%	3.06%	3.07%	1.11%	−3.13%	−2.37%	2.05%	4.85%	8.07%	1.26%	−0.83%	−1.59%
2013	12.91%	15.99%	7.31%	9.81%	6.50%	−0.14%	0.83%	8.74%	8.16%	6.07%	1.83%	4.77%
Mean		2.69%	Standard deviation			4.45%	Maximum		15.99%	Minimum		−4.10%
Plenum												
2016	0.63%	0.52%	1.86%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2015	1.23%	0.27%	−0.27%	−0.74%	0.54%	−0.13%	0.81%	2.95%	6.26%	2.64%	0.41%	4.42%
2014	2.92%	1.92%	2.94%	2.78%	−1.01%	−2.27%	−0.88%	3.22%	8.36%	5.98%	0.55%	−0.88%
2013	5.40%	11.39%	9.77%	11.93%	3.75%	0.90%	1.78%	4.73%	12.17%	3.93%	2.43%	2.37%
Mean		2.96%	Standard deviation			3.64%	Maximum		12.17%	Minimum		−2.27%
Schrod												
2016	−0.03%	1.72%	2.83%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2015	4.56%	1.08%	−4.44%	2.79%	−5.38%	−8.69%	12.04%	36.16%	19.62%	−1.97%	5.75%	0.40%
2014		37.76%	20.96%	11.92%	−33.25%	13.08%	25.68%	64.88%	32.98%	32.24%	−8.96%	−3.56%
Mean		10.01%	Standard deviation			19.81%	Maximum		64.88%	Minimum		−33.25%
Solidum												
2016	−0.43%	6.74%	1.89%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2015	1.25%	0.14%	0.08%	0.28%	−0.86%	−0.79%	0.59%	1.83%	2.84%	−4.73%	0.46%	1.12%
2014	1.59%	1.00%	0.91%	0.65%	−0.88%	0.44%	0.93%	2.81%	1.39%	2.27%	−0.04%	2.04%
2013	3.02%	4.72%	4.13%	2.14%	1.00%	−0.64%	0.75%	4.42%	4.86%	2.90%	1.56%	1.00%
Mean		1.37%	Standard deviation			1.99%	Maximum		6.74%	Minimum		−4.73%

Table 10 Summary statistics for catastrophe (CAT) funds

Period	Statistic	AZ	GAM	LGT	Plenum	Schroder	Solidum
Whole	Mean	0.10%	0.49%	3.25%	3.39%	10.01%	1.48%
	σ	0.24%	0.51%	5.05%	4.48%	19.81%	2.09%
	Max	0.48%	1.82%	17.09%	19.85%	64.88%	6.74%
	Min	−1.03%	−0.75%	−4.10%	−2.27%	−33.25%	−4.73%
	Positives	39	43	29	33	18	33
	Sharpe	−0.8332	0.3655	0.5375	0.7320	0.4901	0.5377
	Alpha	−0.001	0.076	0.057	0.032	0.147	0.040
	Beta	0.337	0.330	0.372	0.333	0.316	0.325
	Count	53	51	41	40	26	40
1 year	Mean	−0.11%	0.20%	0.28%	1.53%	5.16%	0.19%
	σ	0.34%	0.37%	2.49%	2.12%	12.46%	1.86%
	Positives	4	7	7	9	8	9
2 years	Mean	−0.01%	0.30%	0.92%	1.75%	11.11%	0.64%
	σ	0.26%	0.37%	2.89%	2.61%	20.85%	1.54%
	Positives	14	17	15	17	16	19
3 years	Mean	0.06%	0.45%	2.91%	3.13%		1.26%
	σ	0.25%	0.43%	4.56%	3.74%		1.83%
	Positives	25	29	26	29		30
4 years	Mean	0.10%	0.51%				
	σ	0.25%	0.52%				
	Positives	35	40				
Inception: Earliest		11/1/2011	10/31/2011	5/1/2001	9/6/2010	10/21/2013	9/30/2009
Inception: Latest		10/1/2013	8/31/2015	12/16/2013	9/29/2014	3/31/2015	4/5/2012

Note: 1 year period (1/2015–12/2015); 2 year period (1/2014–12/2015); 3 year period (1/2013–12/2015); 4 year period (1/2012–12/2015); and Whole period varies by fund.

sample of six funds representing the six fund families: AZ CAT Bond (8 funds), GAM CAT Bond (14 funds), LGT CAT Bond (22 funds), Plenum CAT Bond (15 funds), Schroder CAT Bond (12 funds), and Solidum CAT Bond (4 funds). See the Appendix for a fuller description of the funds within LGT CAT Bond fund family as representative of the range of funds found within each of the CAT fund families.[25] Note that funds within each fund family may differ by currency, fee structure (front and back loads, management fees, and performance fees), inception dates, and country of incorporation. Several of the individual funds are relatively new (i.e., only established in 2015).

Fund returns have been mixed over time. The monthly returns, reported for a represented fund within each fund family, are very variable as shown by the range of monthly returns that vary from extremes in the Schroder fund (minimum −33.25%; maximum 64.88%; mean 10.01%; standard deviation 19.81%) to the more compact set of returns fund within the AZ fund (minimum −1.03%; maximum 0.48%; mean 0.09%; standard deviation 0.25%). Monthly return values are reported in Table 9. The percentage of months with negative returns ranged from a low of 15.7% (GAM CAT Bond) to a high of 29.3% (LGT CAT Bond).

Other relevant factors show low betas (0.3) for all six funds which supports the CAT bonds role in diversifying a portfolio and alphas of approximately 0. More summary statistics by time period are reported in Table 10. A cautionary factor is that not every fund within the fund family duplicates these results. The summaries are just representative of the results. All

Table 11 Correlations

	SPX	BUSY13	BB	B	CCC	AZ	GAM	LGT	Plenum	Schrod	Solidum
SPX	1.000	−0.166	0.743	0.727	0.596	−0.242	0.044	0.142	0.088	−0.050	−0.166
BUSY13		1.000	0.172	−0.046	−0.061	0.207	0.205	−0.004	0.166	0.095	0.231
BB			1.000	0.894	0.772	−0.128	0.170	0.210	0.137	0.021	−0.016
B				1.000	0.928	−0.059	0.136	0.299	0.132	−0.029	0.002
CCC					1.000	0.126	0.229	0.437	0.179	−0.067	0.103
AZ						1.000	0.601	0.568	0.469	0.440	0.863
GAM							1.000	0.838	0.846	0.796	0.751
LGT								1.000	0.789	0.700	0.672
Plenum									1.000	0.518	0.652
Schroder										1.000	0.593
Solidum											1.000

the CAT funds have positive correlations among each other ranging from 0.44 (AZ and Schroder) to 0.86 (AZ with Solidum). This offers support that the funds are operating within the same set of investments. The CAT funds show low correlations with the ML speculative grade bond funds (range −0.128 to 0.440 with most correlations close to 0). Correlations to the S&P500 index are also close to 0. See Table 11 for the complete correlation table.

Similar to the earlier analysis, the null hypothesis of the test of the mean of the differences predicting no advantage of to either the CAT fund or the speculative rated corporate funds show in general that the CAT funds outperformed the speculative grade corporate bond indices as indicated by their negative values except within the analysis of the outlier fund AZ CAT fund. For example, Plenum CAT Bond Fund shows significantly higher returns over all 3 speculative bond funds (BB, B, and CCC) during the whole period and over both the two- and three-year periods. However, the AZ CAT fund shows positive values indicating subpar performance when measured against the speculative grade corporate bond sector. Unlike the previous comparisons for the broad market CAT proxies, there are many cases of statistically significant results. A summary of the results are shown in Table 12. In general, the null hypothesis of equal returns between the speculative bond sector and the CAT bond sector could not be supported.

6. Conclusion

CAT bonds were created to give insurance firms, reinsurance firms, and government entities an additional option for hedging catastrophic risks from disasters (both natural and man-made). These risks are documented as extremes further justifying the need for an offset. Through a set of proxies (indices and hedge funds), the returns generated more than offset the risks undertaken by investors, as indicated by the results from the mean of the difference tests. The CAT bond indices produced similar to superior monthly returns versus those within the speculative grade bond sector. With returns at or above the speculative grade bond sector coupled with a low probability of the bondholder losing both interest and principal if the threshold losses experienced by the underlying insurance firm are met offer an additional investment opportunity for a diversified investment strategy. Thus, CAT bonds which

Table 12 Means of the differences tests for catastrophe (CAT) funds *t*-values

	AZ	GAM	LGT	Plenum	Schroder	Solidum
BB corp						
Whole	2.581***	−0.126	−3.763***	−4.359***	−2.518**	−3.298***
1 year	0.365	−0.436	−0.325	−1.858	−1.375	−0.182
2 year	0.631	−0.778	−1.282	−2.720**	−2.530**	−1.175
3 year	1.202	−1.100	−3.560***	−4.594***		−2.838***
4 year	2.424**	−0.430				
B corp						
Whole	1.194	−0.873	−4.118***	−4.623***	−2.608***	−3.550***
1 year	−0.790	−1.346	−0.963	−2.143	−1.468	−0.780
2 year	−0.724	−1.742	−1.805	−3.021***	−2.607**	−1.745
3 year	0.053	−1.754	−3.917***	−4.836***		−3.179***
4 year	1.202	−1.052				
CCC corp						
Whole	0.543	−0.464	−4.228***	−4.551***	−2.682***	−2.937***
1 year	−1.641	−2.077	−1.857	−2.536*	−1.651	−1.412
2 year	−1.862	−2.592**	−2.584**	−3.395***	−2.728**	−2.433*
3 year	−0.673	−1.914	−4.492***	−5.054***		−3.339***
4 year	0.582	−0.826				

Note: Significance levels: * (0.025% significance); ** (0.010% significance); *** (0.005% significance).

provide returns comparable to the risk undertaken with the added benefit of diversification could be used to supplement a small portion of a diversified portfolio.

Notes

1 The UN Office for Disaster Risk Reduction reports economic losses from natural disasters average between $250 billion and $300 billion annually. This average includes two components: (1) the international insurance industry's global loss ($180 billion to $200 billion) and (2) $70 billion to $100 billion in losses from developing countries from smaller-scale floods, fires, and storms. http://globalnews.ca/news/1865514/economic-losses-from-natural-disasters-between-250-billion-and-300-billion-un/

2 For data on the Afghanistan and Pakistan earthquake see http://www.huffingtonpost.com/entry/afghan-quake-death-toll-mounts-as-survivors-still-wait-for-aid_5630c8a4e4b063179910268d

3 Swiss Re Sigma No. 2/2015 http://media.swissre.com/documents/sigma2_2015_en_final.pdf

4 See http://www.artemis.bm/library/what-is-a-catastrophe-bond.html for more information.

5 See http://www.claimsjournal.com/news/national/2011/09/09/190969.htm

6 At the end of 2015, there were over $25.9 billion of CAT bonds outstanding. http://www.finra.org/investors/alerts/catastrophe-bonds-and-other-event-linked-securities

7 A comprehensive database containing the details of these CAT bonds can be found at http://www.artemis.bm/deal_directory/

8 The investment managers held 21.32% of the securities outstanding. The five leading investment managers are Stone Ridge Asset Management LLC (26.78%); UNICREDIT SPA (15.63%); JP Morgan Chase & Co. (10.61%); Clariden Lue LTD (9.15%); and Falcon Fund Management LTD (7.03%).

9 Since 2008, the SEC has granted exceptions to allow resales after a 6-month window. See http://media.mofo.com/files/Uploads/Images/FAQRule144A.pdf for answers to frequently asked questions about rule 144A.

10 The correlation of a representative number of CAT Funds, used as proxies for the CAT bonds, with the market is approximately 0. See Tables 8 and 11.

11 See Swiss Re (2012b).

12 See http://www.finra.org/investors/alerts/catastrophe-bonds-and-other-event-linked-securities

13 See following 3 web links: http://www.bankrate.com/finance/insurance/top-10-costliest-natural-disasters-11.aspx; : http://citywire.co.uk/money/the-world-s-10-biggest-insurance-claims/a433781#i=10; and http://www.iii.org/fact-statistic/catastrophes-global

14 See McChristian (2012) and Cummins (2007).

15 See http://www.propertycasualty360.com/2013/03/15/top-5-catastrophe-bond-market-trends?page=5

16 See http://www.insurancejournal.com/news/southeast/2012/08/21/2559960.htm

17 See http://www.florir.com/PressReleases/viewmediarelease.aspx?id=2069

18 See http://www.sbafla.com/fhcf/Portals/5/Advisory%20Council/20150514_FHCF_May2015BondingCapacity.pdf;

19 See http://www.artemis.bm/blog/2015/03/02/reinsurance-the-engine-of-berkshire-hathaway-warren-buffett/ and http://www.artemis.bm/blog/2014/03/15/warren-buffett-u-s-catastrophe-rates-too-low-for-berkshire-hathaway/ for summaries and http://berkshirehathaway.com/letters/2014ltr.pdf for the actual Buffett letter.

20 See http://www.finra.org/investors/alerts/catastrophe-bonds-and-other-event-linked-securities

21 See Insurance Journal article “Pension Funds Looking for Higher Yields from CAT Bonds.” http://www.insurancejournal.com/news/international/2013/04/09/287723.htm

22 Two other speculative bond indices (Bank of America/Merrill Lynch 1–3 year U.S. Cash Pay Fixed Maturity High Yield Constrained Index—J1HC and Bank of America/Merrill Lynch 1–3 year U.S. Cash Pay High Yield Index—J1A0) were used with similar results.

23 The differences between two populations of means is not an appropriate test. The null hypothesis that there is no difference in the mean returns from the CAT bonds proxies (mutual funds and indices) and similarly rated corporate debt (BB, B or CCC: speculative grade debt or junk bonds) matched with the alternative hypothesis is that there is a significant difference in their monthly returns (i.e., H_0: $(\mu_{\text{CAT}} = \mu_{\text{Junk}}) = 0$ versus H_A: $(\mu_{\text{CAT}} = \mu_{\text{Junk}}) \neq 0$) fails to consider the timing of the returns. Thus, a test that relies on the two-sample t statistic where $S_p^2 = \dfrac{(n_{CAT}-1)S_{CAT}^2 + (n_{Junk}-1)S_{Junk}^2}{n_{CAT}+n_{Junk}-2}$ and

$t = \frac{(\bar{x}_{CAT} - \bar{x}_{Junk}) - 0}{\sqrt{S_p^2\left(\frac{1}{n_{CAT}} + \frac{1}{n_{Junk}}\right)}}$ is not appropriate for this analysis because the assumption of independent samples is invalid.

24 The correlation between the ILS-Eurekahedge index and the BB-rated and B-rated debt was 0.21 and 0.17, respectively. For the MiCRIX index the corresponding correlation values were 0.002 and 0.013. The analysis was also undertaken against the CCC bond index with similar results.

25 A listing of the funds within each of the six CAT fund families is available from the author.

Appendix: fund summaries

LGT CAT Bond Fund is a family of funds. The first group is an open-end fund incorporated in Luxembourg. The objective of the fund is to achieve a return in the reference currency of the individual share classes in excess of the three-month money market (Libor). The fund invests in insurance-linked securities of all kinds that are traded on a stock exchange. This fund family consists 11 of separate funds:

Luxembourg Based: **(1)** LGT-CAT BD—CHF C (FIGI BBG003FWF7N9; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 9/28/2012; Share Class Institutional); **(2)** LGT-CAT BD—EUR B (FIGI BBG003FWDRX6; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 9/28/2012; Share Class Institutional); **(3)** LGT-CAT BD—USD C (FIGI BBG003FWF6T5; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 9/28/2012; Share Class Institutional); **(4)** LGT-CAT BD—EUR B2 (FIGI BBG003FWF2V1; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 9/28/2012; Share Class Institutional); **(5)** LGT-CAT BD—B EUR (FIGI BBG003FWF1H9; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 9/28/2012; Share Class Retail); **(6**) LGT-CAT BD—EUR B2 (FIGI BBG003FWF2D1; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 9/28/2012; Share Class Institutional); **(7)** LGT-CAT BD—CHF B2 (FIGI BBG003FWF544; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 9/28/2012; Share Class Institutional); **(8)** LGT-CAT BD—EUR C (FIGI BBG003FWF759; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 9/28/2012; Share Class Institutional); **(9)** LGT-CAT BD—CHF B (FIGI BBG003FWF1Z9; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 9/28/2012; Share Class Retail); **(10)** LGT LUX I-CAT BOND FUND—IMUSD (FIGI BBG003QTSBH8; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 12/27/2012; Share Class Institutional); and **(11)** LGT-CAT BD—CHF F (FIGI BBG007QVL1V7; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 12/22/2014; Share Class Retail).

The second group of funds are based in Switzerland. This open-end fund invests in a broadly diversified portfolio of catastrophic bonds. The fund's objective is a stable return that is above the money-market yield and has only a low correlation to other movements on the financial markets. This fund family consists five of separate funds:

Switzerland Based: **(S1)** LGT CH-CAT BOND FUND—EUR A (FIGI BBG000LXPP00; Front Load 3.0% Back Load 0.0%; Management Fee 1.75%; Performance Fee 0.0%; Inception Date 5/01/2001; Share Class Retail); **(S2)** LGT CH-CAT BOND FUND—USD A (FIGI BBG000LXPPP3; Front Load 3.0%; Back Load 0.0%; Management Fee 1.75%; Performance Fee 0.0%; Inception Date 5/01/2001; Share Class Retail); **(S3)** LGT CH-CAT BOND FUND—CHF A (FIGI BBG000LXPB47; Front Load 3.0%; Back Load 0.0%; Management Fee 1.75%; Performance Fee 0.0%; Inception Date 5/01/2001; Share Class Retail); **(S4)** LGT CH-CAT BOND FUND—CHF IA (FIGI BBG000VBXYZ1; Front Load 2.5%; Back Load 0.0%; Management Fee 1.25%; Performance Fee 0.0%; Inception Date 2/29/2008; Share Class Institutional); and **(S5)** LGT CH-CAT BOND FUND—EUR 1A (FIGI BBG000V1TVF6; Front Load N.A. Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 5/31/2010; Share Class Institutional).

The third group of funds are based in Liechtenstein. The fund invests in a broadly diversified portfolio of catastrophic bonds. This open-end fund's objective is a stable return above the money-market yield and has a low correlation to other movements on the financial market. This fund family consists six of separate funds:

Liechtenstein Based: **(L1)** LGT SELECT-CAT BOND—IM (FIGI BBG005T7CJJ6; Front Load N.A.; Back Load 0.0%.; Management Fee N.A.; Performance Fee 0.0%; Inception Date 12/16/2013; Share Class Institutional); **(L2)** LGT LIE-CAT BOND FUND—CHF B (FIGI BBG000NFWSZ5; Front Load N.A. Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 7/31/2009; Share Class Retail); **(L3)** LGT LIE-CAT BOND FUND—USD B (FIGI BBG0030NFWXD8; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 7/31/2009; Share Class Retail); **(L4)** LGT LIE-CAT BOND FUND—EUR D (FIGI BBG000NFXZY9; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 7/31/2009; Share Class Institutional); **(L5)** LGT LIE-CAT BOND FUND—EUR B (FIGI BBG000NFWVN1; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 7/31/2009; Share Class Retail); and **(L6)** LGT LIE-CAT BOND FUND—CHF D (FIGI BBG000NFWXY5; Front Load N.A.; Back Load N.A.; Management Fee N.A.; Performance Fee N.A.; Inception Date 7/31/2009; Share Class Institutional).

References

Bantwal, V, & Kunreuther, H. (2000). A CAT bond premium puzzle? *Journal of Psychology and Financial Market, 1*, 76–91.

Barrieu, P., & Louberge, H. (2009). Hybird CAT bonds. *Journal of Risk and Insurance, 76*, 547–578.

Cummins, J. D. (2008). CAT bonds and other risk-linked securities: State of the market and recent developments. *Risk Management and Insurance Review, 11*, 23–47.

Cummins, J. D. (2012). CAT bonds and other risk-linked securities: Product design and evolution of the market. *The Geneva Reports: Risk and Insurance Research, 5*, 39–61.

Cummins, J. D., Lalonde, D., & Phillips, R. D. (2004). The basis risk of catastrophic-loss index securities. *Journal of Financial Economics, 71,* 77–111.

Cummins, J. D., & Trainar, P. (2009). Securitization, insurance, and reinsurance. *Journal of Risk and Insurance, 76,* 463–492.

Dieckmann, S. (2011). *A Consumption-Based Evaluation of the CAT Bond Market*. Working Paper (Darden School of Business, University of Virginia).

Durbin, D. (2001). Managing natural catastrophe risks: The structure and dynamics of reinsurance. *The Geneva Papers on Risk and Insurance, 26,* 297–309.

Finken, S., & Laux, C. (2009). Catastrophe bonds and reinsurance: The competitive effect of information-insensitive triggers. *Journal of Risk and Insurance, 76,* 597–605.

Froot, K. A. (2001). The market for catastrophe risk: A clinical examination. *Journal of Financial Economics, 60,* 529–571.

Froot, K. A., & O'Connell, P. G. (2008). On the pricing of intermediated risks: Theory and application to catastrophe reinsurance. *Journal of Banking & Finance, 32,* 69–85.

Hagendorff, B., Hagendorff, J., & Keasey, K. (2013). The shareholder wealth effects of insurance securitization: Preliminary evidence from the catastrophe bond market. *Journal of Financial Services Research, 44,* 281–301.

Hagendorff, B., Hagendorff, J., Keasey, K., & Gonzalez, A. (2014). The risk implications of insurance securitization: The case of catastrophe bonds. *Journal of Corporate Finance, 25,* 387–402.

Jarzabkowski, P., Bednarek, R., & Spee, P. (2015). *Making a market for Acts of God: The practice of risk-trading in the global reinsurance industry.* Cambridge: Oxford University Press.

Lakdawalla, D., & Zanjani, G. (2012). Catastrophe bonds, reinsurance, and the optimal collateralization of risk transfer. *The Journal of Risk and Insurance, 79,* 449–476.

McChristen, L. (2012). Hurricane Andrew and insurance: The enduring impact of an historic storm. *Insurance Information Institute, August 2012,* 1–19.

Subramanian, A. & Wang, J. (2015). *Catastrophe Risk Transfer*. Working Paper. (available at http://ssm.com/abstract=2321415).

Swiss, R. (2012a). *What are Insurance Linked Securities (ILS), and Why Should They be Considered?* Presentation to the CANE Fall Meeting, September. 1–12.

Swiss, R. (2012b). *Long Point Re III Case Study*. Presentation to the CANE Fall Meeting, September 13–17.