ADVANCES IN PACIFIC BASIN BUSINESS, ECONOMICS AND FINANCE

ADVANCES IN PACIFIC BASIN BUSINESS, ECONOMICS AND FINANCE

Series Editors: Cheng Few Lee and Min-Teh Yu

ADVANCES IN PACIFIC BASIN BUSINESS, ECONOMICS AND FINANCE VOLUME 7

ADVANCES IN PACIFIC BASIN BUSINESS, ECONOMICS AND FINANCE

EDITED BY

CHENG-FEW LEE
Rutgers University, USA

MIN-TEH YU
Providence University, Taiwan

emerald PUBLISHING

United Kingdom – North America – Japan
India – Malaysia – China

Emerald Publishing Limited
Howard House, Wagon Lane, Bingley BD16 1WA, UK

First edition 2019

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-1-78973-286-3 (Print)
ISBN: 978-1-78973-285-6 (Online)
ISBN: 978-1-78973-287-0 (Epub)

ISSN: 2514-4650 (Series)

EDITORIAL BOARD

CONTENTS

LIST OF FIGURES

Chapter 6

Chapter 9

LIST OF TABLES

Chapter 3

Chapter 4

Chapter 5

Chapter 6

Chapter 7

Chapter 8

Chapter 9

Chapter 10

Chapter 11

LIST OF CONTRIBUTORS

Peter Huaiyu Chen	Youngstown State University, USA
Thomas C. Chiang	Drexel University, USA
Stephan Dieckmann	University of Pennsylvania, USA
Yoke-Kee Eng	Universiti Tunku Abdul Rahman, Malaysia
Amy Yueh-Fang Ho	National Chung Cheng University, Taiwan
Yu-Jen Hsiao	Taipei Medical University, Taiwan
T. K. Jayaraman	Universiti Tunku Abdul Rahman, Malaysia
Naoyuki Kaneda	Gakushuin University, Japan
Chin-Yu Lee	Universiti Tunku Abdul Rahman, Malaysia
Hsin-Yu Liang	Feng Chia University, Taiwan
Yueh-Lung Lin	University of Nottingham Ningbo, China
Hsuan-Yu Liu	National Tsing Hua University, Taiwan
Sheen X. Liu	Washington State University, USA
Kasing Man	Western Illinois University, USA
Cheong-Fatt Ng	Universiti Tunku Abdul Rahman, Malaysia
Lei Qin	University of International Business and Economics, China
Alejandro Serrano	Penn State University, Abington, USA
Tumenjargal Tumurbaatar	Janchivlan Top Spring LLC, Mongolia
Cindy S. H. Wang	National Tsing Hua University, Taiwan
Junbo Wang	City University of Hong Kong, HKSAR
Chin-Yoong Wong	Universiti Tunku Abdul Rahman, Malaysia
Chunchi Wu	State University of New York at Buffalo, USA

This page intentionally left blank

A CONSUMPTION-BASED EVALUATION OF THE CAT BOND MARKET

Stephan Dieckmann

ABSTRACT

I build an equilibrium model trying to reconcile investor preferences with several features of the cat bond market. The driving force behind the model is a habit process, in that catastrophes are rare economic shocks that could bring investors closer to their subsistence level. The calibration requires shocks with an impact between −1% and −3% to explain a reasonable level of cat bond spreads. Such investor preferences are not only able to generate realistic cat bond returns and price comovement among different perils, but may also able to explain why cat bonds offer higher rewards compared to equally rated corporate bonds.

Keywords: Fixed income; insurance-linked security; natural disasters; Katrina; external habit; catastrophe bond

JEL classification: D51; D53; G12; G22

1. INTRODUCTION

The catastrophe bond market has been active for many years and has attracted a large but specialized investor base, which is typically told that an investment is beneficial due to substantial diversification benefits. The textbook treatment of cat bonds still claims they carry no or very little systematic risk, and they should be treated as zero-beta securities. Simultaneously, the small academic literature that has emerged about cat bonds focuses on computing accurate expected losses, but pays little attention to incorporating risk premiums. To my

Advances in Pacific Basin Business, Economics and Finance, Volume 7, 1−26

ISSN: 2514-4650/doi:10.1108/S2514-465020190000007002

knowledge, this assumption has never been proven. It has been tested to which extent cat bonds might correlate with stock market variables, but such a comparison lacks rigor because the stock market itself is an endogenous entity.

Until recently, a quantitative evaluation of cat bonds was difficult because data, not so much about the primary market but about the secondary market, were not available. This has changed in that Swiss Re has launched several performance indices, named Swiss Re Cat Bond Indices, that make the secondary market activity more transparent to investors. For the time period available starting in 2002, Table 1 shows correlations between the performance of the cat bond market and several other financial variables. It shows that cat bond returns covary positively with the stock market and the corporate bond market, high-yield as well as investment-grade. For example, the correlation between deflated quarterly excess returns of the broadest cat bond portfolio and the Financial Industry Regulatory Authority (FINRA) high-yield corporate bond portfolio is 41.4%. Measured in terms of monthly returns, the correlation is 27.0%, but the degree of correlation is smaller among all financial variables while measured monthly. Diversifying a portfolio using cat bonds would of course lead to benefits given such correlations. However, they are clearly not uncorrelated with other asset classes.

To understand whether cat bonds (should) carry a risk premium, we have to look into economic fundamentals, and the goal of this chapter is to link the cat bond market to consumption expenditures. Before explaining the link, note that Table 1 also shows correlations between the performance of the cat bond market and consumption growth rates. For example, I find that quarterly growth of real non-durable consumption expenditures and the deflated excess return of the broadest cat bond portfolio correlate with 27.5%. In monthly terms, this correlation is equal to 17.5%, which is the larger than the correlation between consumption and any other asset class. Most importantly, economic fundamentals and cat bond returns are clearly not uncorrelated – a key motivation for this chapter.

The claim here is that cat bonds are subject to severe natural perils that might have an impact on consumption. Only one of the nine outstanding cat bonds covering the Gulf region triggered due to hurricane Katrina in 2005. As pointed out by Cummins (2006), Katrina is the most severe natural disaster in the US in terms of economic impact up to date, with a total economic cost between USD 100 and 200 billion, and we should consider the possibility that cat bonds are subject to some amount of systematic risk. If even the costliest catastrophe was not severe enough to trigger the cat bond market at large, then market participants perceive that those bonds securitize mega-catastrophes. I show that the model provided in this chapter requires shocks with an impact between −1% and −3% only to explain a reasonable level of cat bond spreads. A data set of individual cat bonds also analyzed in this chapter allows for further insight: Cat bonds cover a variety of natural perils such as windstorms and earthquakes. Bonds linked to windstorm risks securitize events expected to occur roughly once every 40 years, those linked to non-windstorm risks once every 100 years. Bond spreads equally between

Table 1. Correlations between January 01, 2002 and April 29, 2011.

Quarterly	37 Obs CON all	CON nd	CAT bb	CAT all	SPX	VIX	CB hy	CB ig	BCB
CON all	1.000								
CON nd	0.807	1.000							
CAT bb	0.191	0.252	1.000						
CAT all	0.201	0.275	0.966	1.000					
SPX	0.396	0.452	0.366	0.426	1.000				
VIX	−0.153	−0.300	−0.213	−0.228	−0.689	1.000			
CB hy	0.305	0.436	0.455	0.414	0.634	−0.502	1.000		
CB ig	−0.036	0.002	0.263	0.218	0.108	−0.283	0.577	1.000	
BCB	0.497	0.472	0.452	0.441	0.288	−0.132	0.635	0.524	1.000
Quarterly	**36 Obs CON all**	**CON nd**	**CAT bb**	**CAT all**	**SPX**	**VIX**	**CB hy**	**CB ig**	**BCB**
CON all	1.000								
CON nd	0.751	1.000							
CAT bb	0.120	0.188	1.000						
CAT all	0.148	0.232	0.965	1.000					
SPX	0.358	0.423	0.345	0.410	1.000				
VIX	0.026	−0.147	−0.158	−0.186	−0.681	1.000			
CB hy	0.126	0.285	0.424	0.390	0.628	−0.406	1.000		
CB ig	−0.338	−0.302	0.201	0.166	0.025	−0.126	0.463	1.000	
BCB	0.283	0.232	0.447	0.459	0.229	0.166	0.510	0.312	1.000
Monthly	**112 Obs CON all**	**CON nd**	**CAT bb**	**CAT all**	**SPX**	**VIX**	**CB hy**	**CB ig**	**BCB**
CON all	1.000								
CON nd	0.521	1.000							
CAT bb	0.148	0.158	1.000						
CAT all	0.156	0.175	0.966	1.000					
SPX	0.119	−0.011	0.230	0.251	1.000				
VIX	−0.076	0.012	−0.198	−0.199	−0.690	1.000			
CB hy	0.028	−0.007	0.270	0.250	0.591	−0.478	1.000		
CB ig	0.004	0.032	0.300	0.268	0.217	−0.334	0.607	1.000	
BCB	0.107	0.099	0.407	0.384	0.278	−0.365	0.537	0.769	1.000

Notes: The table shows pairwise correlations among the following variables: CON all and CON nd are the growth rates of real US personal consumption expenditures, total and non-durables, respectively; CAT all and CAT bb are the excess returns of the Swiss Re cat bond portfolios, all bonds (SRCATTRR) and bb-rated bonds (SRBBTRR), respectively; SPX is the excess return of the S&P 500 index; VIX is the change in the VIX index; CB hy and CB ig are the excess returns of the FINRA corporate bond portfolios, high-yield (NBBHTR), and investment grade (NBBITR), respectively; BCB is the excess return of the Barclays bond index (BNDUS), formerly the Lehman Bros corporate bond Index. The T-Bill return is assumed to compute excess returns, all return series are deflated. The source for financial data is Bloomberg; the source for consumption and cpi data is FRED. The top panel is based on 37 quarterly observations; middle panel is based on 36 quarterly observations excluding the third-quarter of 2008; the bottom panel is based on 112 monthly observations.

two and three times expected losses after controlling for bond-specific characteristics, which is similar in magnitude to the prices discussed in Cummins and Weiss (2009). But given such a generous reward for investors in terms of spreads and a relatively small impact on consumption, where does the amplification effect come from?

The proposed model assumes that preferences contain a habit process in that catastrophes are rare economic shocks that could bring investors closer to their subsistence level. Bantwal and Kunreuther (2000) were the first to point out the difficulties in reconciling cat bond prices with economic fundamentals based on standard constant relative risk aversion (CRRA) preferences – the required economic shocks are simply too large. In contrast, preferences in which individuals do not measure their felicity with respect to the absolute level of consumption but with respect to a subsistence level, originally proposed by Campbell and Cochrane (1999), allow for an amplification effect due to increased effective risk aversion. Such time non-separable preferences have become a workhorse in financial economics and have been successful in explaining several features of capital markets. This includes the level of the equity premium at various horizons, the excess volatility of the stock market, reconciling predictability of returns and growth rates as in Menzly, Santos, and Vernoesi (2004), and features of the riskless term structure as in Wachter (2006). Motivated by this, I find it relevant to explore to what extent such preferences can explain the cat bond market.

A convenient way of modeling catastrophes is to incorporate Poisson risk as it captures the highly skewed law of motion in natural hazards. Several chapters have argued to incorporate rare events into traditional models in asset pricing, including Rietz (1988), Naik and Lee (1990), Longstaff and Piazzesi (2004), and more recently Du (2011) also in the context of habit preferences. In addition to Poisson risk, my model is also subject to normal economic risk represented by Brownian motion. The calibration requires a relatively small amount of catastrophic risk compared to normal economic risk. Specifically, 25% of the total quadratic variation in fundamentals corresponds to catastrophes, and the remaining 75% corresponds to normal economic shocks. In contrast, the calibrated model of Du (2011) requires more than 50% of risk in fundamentals stemming from rare events in order to explain the volatility smirk for index options. Although such percentages are far more reasonable than those required under standard preferences, the magnitude of the required shocks suggests that cat bond prices contain a "Peso problem" in that an event triggering the market at large has indeed not yet occurred.

The model also highlights an important difference between the market price of normal economic risk and catastrophe risk. Chen, Collin-Dufresne, and Goldstein (2009) link the level of corporate bond spreads to consumption data based on habit preferences in the case of normal economic risk. The new question is: Should investors expect a similar reward in the cat bond market? For a clear-cut comparison, I assume that corporate bonds are subject to normal economic risk, and first derive the spread of corporate bonds as in Chen et al. (2009). While holding expected losses constant across bonds, I find that cat bond spreads can be multiples of the equivalent corporate bond spread; the theoretical result is ambiguous, but for most states of the economy, cat bonds should offer a larger reward for investors. After matching individual cat bonds with equally rated corporate bonds, I show that this prediction is confirmed in the data.

1.1. The Cat Bond Market

The cat bond market enables the transfer of cat risk exposure from the seller to the buyer of the bond. The key feature of a cat bond is a provision causing interest and/or principal payments to be lost in the event a specified catastrophe. The bond's payoff is linked either to an indemnity trigger or to an index trigger. The indemnity trigger represents an actual loss value, whereas an index trigger links to an industry loss index or to a parametric index. Payoffs can take on a step structure depending on the severity of the loss. Consequently, a cat bond might have a probability attached to a first loss, average loss, full loss, or a more complex conditional loss distribution.

A cat bond origination typically involves a special purpose vehicle (SPV), and reinsurers are the dominant sponsors. A sponsor enters into a reinsurance contract with an SPV, and the SPV then hedges itself by issuing cat bonds to investors in the capital market. The proceeds from the sale of the securities are invested in high-grade securities typically held in a collateral trust, minimizing credit risk in the transaction. An unusual event happened in September 2008 after the Lehman Brothers collapse: Losses occurred on four cat bonds which involved Lehman Brothers in the SPV construction, as some of the collateral was invested in securities which had lost substantial value. Such an SPV failure, however, only occurred once. Typically, bondholders receive full payment if the stipulated event does not occur. If the catastrophe does occur, however, the SPV makes a payment to the sponsoring company instead. To rule out that the SPV failure in September 2008 significantly affected the correlation structure among cat bonds, economic fundamentals, and other asset classes, I show the correlations excluding the respective quarter, see Panel B of Table 1. The degree of correlations is slightly lower relative to Panel A, but not only with respect to cat bond returns but also among other asset classes.

More than 170 cat bonds have been issued during the last 15 years, the outstanding capital at risk was USD 13 billion as of December 2010, according to Swiss Re. This might appear small compared to the dimension of other financial innovations such as credit derivatives. However, the cat bond market is only a window allowing us to look into pricing of severe layers of risk, and it complements other insurance-linked securities, reinsurance programs, extreme weather derivatives, and so forth, which should also carry the risk premiums studied here. Whether these risk premiums should be visible in the stock market is difficult to say since it is unclear to which extent corporations expose themselves to such extreme layers of risk. The model here has no direct implications for the size of the cat bond market as investors are assumed to be homogeneous.

Further background information is provided by Bantwal and Kunreuther (2000), Cummins, Lalonde, and Phillips (2004), Cummins and Weiss (2009), and Michel-Kerjan, Zelenko, Cardenas, and Turgel (2011).

I utilize two data sets in the quantitative evaluation of the model. First, the indices provided by Swiss Re. They are a series of performance indices constructed to track the total rate of return of cat bond portfolios. The broadest index corresponds to a basket containing all outstanding USD denominated catastrophe bonds. Subindices, such as only BB-rated bonds, are also available. After injecting consumption shocks to model, the resulting returns of a hypothetical cat bond appear realistic. They are realistic in the sense that the consumption-based return series and the Swiss Re return series correlate more than 30%, and the variations of returns are also similar.

The second data set contains price information about individual cat bonds. Prices are represented as a yield spread in basis points, in this case as a per annum spread relative to the interest rate swap market, a typical representation in the cat bond market. Descriptive statistics are shown in Table 3. Unfortunately, this individual cat bond data are not available for the entire time period. However, it does include the important event of hurricane Katrina, and a requirement for a bond to be included is that it exists at Katrina's landfall in August 2005. To keep the cross section of bonds constant, I only consider bonds that are alive and prices are recorded within three-quarters prior and post to that event. This leads to a total of 61 cat bonds, representing 90% of the cat bond volume outstanding during that time. Part of the evaluation of the model is to derive a prediction about how cat bonds reacted to Katrina. A commonly held view is that economic agents might revise their estimates about the likelihood or impact at the occurrence of a catastrophe (see Born and Viscusi, 2006). While this could of course also matter in the context of Katrina, the purpose of this exercise is to illustrate what effects arise simply due to increased effective risk aversion. I find the model can explain up to 6.5% increase in the market price of windstorm risk, and even 10% increase in the market price of non-windstorm risk, which is about a third of the market reaction during that time. In Zanjani (2002), the cost of capital is an important argument in his model on pricing and allocations in catastrophe insurance. However, the goal of his chapter is not to develop an equilibrium model where the cost of capital arises endogenously from economic primitives. Hence, my work complements Zanjani (2002) in illustrating the possible economic nature of such capital costs.

The cat bond market is also subject to features that the model does not capture. While I try to control for them to have a cleaner view of the risk premium component, it is insightful to also interpret the bond-specific characteristics shown in Table 4. First, I find that the presence of an indemnity trigger is priced in the cat bond market. It is likely that a trigger related to reported losses leads to a moral hazard issue possibly reflected in higher spreads, see Doherty and Richter (2002) or Froot (2001). The counterpart basis risk, of course, could be similarly reflected in cat bonds subject to non-indemnity triggers.[1] My finding is that cat bonds with indemnity triggers reward investors with more than 110 basis points additional premium.

Second, I control for variables capturing illiquid market conditions. Adapting hypotheses already tested in the corporate bond market, I follow the suggestions by Edwards, Harris, and Piwowar (2007) and measure liquidity by age and issue size. I expect that a bond's age (amount) is positively (negatively) associated with cat bond spreads if investors require an additional reward for facing a potentially illiquid market. The finding is that neither the age nor amount adds any consistent insight, possibly a reflection that the cat bond market is in the hands of a specialized investor base. Third, the results show a moderately upward-sloping cat bond term structure. Every month of remaining time to maturity increases the level of spreads between 1.45 and 1.88 basis points on average. In comparison, we also have evidence that the term structure of spreads is usually upward-sloping in the corporate bond market, see, for example, Helwege and Turner (1999). Although the model does have implications for the shape of the cat bond term structure, those effects are outside of the scope of the current chapter.

2. THE MODEL

2.1. Exogenous Risk and Economic Primitives

Suppose consumption is subject to multiple sources of uncertainty and follows the process:

$$\frac{\mathrm{d}C_t}{C_{t-}} = \mu_c \mathrm{d}t + \sigma_c \mathrm{d}B + \sum_{i=1}^{2} \kappa_{ci} \mathrm{d}N(\lambda_i) \quad t \in [0,\infty). \tag{1}$$

First, normal economic risk enters through a standard Brownian motion B with a volatility parameter $\sigma_c > 0$, as typical in the continuous-time formulation of an exchange economy. Second, the economy is subject to two separate sources of catastrophic risk, that is, windstorm risk and earthquake risk, or more generally non-windstorm risk. Non-windstorm risk enters through a Poisson process with arrival intensity λ_1 and impact size κ_{c1}, non-windstorm risk enters through a Poisson process with arrival intensity λ_2 and impact size κ_{c2}.. I assume no common occurrences among windstorm risk and non-windstorm risk, and impact sizes to be in the interval $(-1, 0)$ to ensure that consumption remains positive. The deterministic growth rate of the economy is given by μ_c For simplicity, I assume all exogenous parameters to be constant values. For regular economic risk, this appears to be reasonable as time-variation of growth rates and volatility in economic fundamentals is difficult to detect. For natural perils, this assumption allows me to abstract from phenomena like seasonality in windstorm risk, or the evolution of faults and plates in case of earthquake risk.

The surprise element of the occurrence of a catastrophe, however, is essential to the model.

The assumed process in Equation (1) nests a case in which consumption is subject to only one type of catastrophic risk, but has a random impact size drawn from an independent two-point distribution. For example, suppose $\lambda = \lambda_1 + \lambda_2$ and $p = \lambda_1/\lambda$, then consumption follows the process given by:

$$\frac{\mathrm{d}C_t}{C_{t-}} = \mu_c \mathrm{d}t + \sigma_c \mathrm{d}B + \kappa_c \mathrm{d}N(\lambda), \tag{2}$$

and is subject to three sources of uncertainty, that is, normal economic risk, catastrophic risk with the arrival intensity λ, and a random impact size κ_c. The impact of a catastrophe can be large with size κ_{c1} and likelihood p, or small with size κ_{c2} and likelihood $1-p$. The main focus of this section will be the equilibrium characterization corresponding to the formulation in Equation (1). However, I will also use the latter formulation to tie the model to a hypothetical cat bond that is subject to multiple perils.

The economy is populated by educated and informed investors with external habit formation preferences as in Campbell and Cochrane (1999). A representative investor maximizes expected utility given by:

$$E\left[\int_0^\infty e^{-\rho t} \frac{(C_t - X_t)^{1-\gamma} - 1}{1-\gamma} \mathrm{d}t\right], \tag{3}$$

where C_t is the investor's level of consumption, X_t measures the habit level, γ is the risk aversion coefficient, and ρ is the subjective discount factor. As usual, it is convenient to characterize this economy in terms of the surplus consumption ratio defined as:

$$S_t = \frac{C_t - X_t}{C_t}, \text{ and } s_t = \ln(S_t).$$

The surplus consumption ratio has the assumed dynamics given by:

$$\mathrm{d}s_t = \phi(\bar{s} - s_t)\mathrm{d}t + \theta\sigma_c \mathrm{d}B + \sum_{i=1}^{2} \kappa_{si} \mathrm{d}N(\lambda_i), \tag{4}$$

with a central tendency parameter given by $\bar{s}$ and a reverting rate of ϕ. While the process of s_t is standard with respect to normal economic risk as in Campbell and Cochrane (1999), catastrophic risk can also lead to changes in the investor's (habit and) surplus consumption level. Essential to the solution of this problem is therefore the proper identification of the sensitivity parameters, that is, θ for the case of normal economic risk, as well as κ_{s1} and κ_{s2} for the case of catastrophic risks.