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Sandip Garg
University of Pennsylvania

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Multiyear Cat Bonds and Investor Behavior*

Sandip Garg†

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The management of catastrophic risk comprises a growing social, political, and economic challenge of our time. Recent natural disasters have dramatized the need for supplemental insurance avenues, including long term insurance and multiyear cat bonds, which hedge against long term liability exposure. An empirical examination of cat bond issuance volume over the past decade reveals that long term, multiyear cat bonds with tenors of more than 3 years pale in liquidity versus short term cat bonds. The paper helps to explain this asymmetry by building an integrated behavioral finance model for economic decision making in catastrophic contexts and by using results from the investor psychology literature.

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† The Wharton School, University of Pennsylvania, 3730 Walnut Street, Philadelphia, PA 19104. Contact: sandipgg@gmail.com.

Introduction

The management of catastrophic risk comprises a growing social, political, and economic challenge of our time. Natural catastrophes, the proverbial "acts of God," have grown in both frequency and severity over the last 15 years. While economic losses from natural disasters during the 10 years from 1950-1959 were $44.9 billion, this same figure had catapulted to over $700 billion from 1990-1999, eventually reaching historical records in 2004 and 2005 (Wharton Risk Center Extreme Events Project, 2008). In recent memory, Hurricane Katrina has become the costliest insured catastrophe in the last 36 years (see Figure 1), producing some $66.3 billion in aggregate insured damages. Indeed, 9 of the top 10 most costly insured disasters are natural (Kunreuther, 2007). Earthquakes, hurricanes, and tornadoes, among other events, have wrecked communities, disrupted economic growth, and forced a reexamination of the role of both the private sector and government in disaster management. The momentum for such a reexamination grows stronger especially when certain studies calculate implied *total* social costs (i.e. not just realized economic losses but projections about future loss). In New Orleans, this number is near $200 billion from Hurricane Katrina alone (Winterfeldt, 2006).

Figure 1: The 10 Most Costly Insured Catastrophes in the World, 1970-2006

Year	Event	Economic Cost (US 2006 US $ billions)	Victims (dead or missing)	Country/Area
2005	Hurricane Katrina	66.3	1,326	USA Atlantic Gulf
2001	9/11 Attacks	35.5	3,025	USA
1992	Hurricane Andrew	22.9	43	USA, Bahamas
1994	Northridge Quake	19.0	61	USA
2004	Hurricane Ivan	13.6	124	USA, Caribbean
2005	Hurricane Wilma	12.9	35	USA, Gulf of Mexico
2005	Hurricane Rita	10.4	34	USA, Gulf of Mexico
2004	Hurricane Charley	8.6	24	USA, Caribbean
1991	Typhoon Mireille	8.4	51	Japan
1989	Hurricane Hugo	7.4	71	USA, Puerto Rico

Source: Swiss Re, Wharton Risk Center, Insurance Information Institute (in Kunreuther, 2007)

The explanations for such climactic volatility and severity are varied. Global climate change certainly has a role to play in the escalation of adverse events, particularly in the Atlantic basin and Gulf regions where US hurricanes typically form. The value at risk of firms and properties has grown as well, both residential and commercial, while enhanced development in US coastal areas presupposes many communities – poor and rich alike – to the undiscriminating fury of a natural disaster (Greenough et al., 2001). On the policy front, homeland security imperatives and the protection of available energy reserves, paving the way for US energy independence, strongly contribute to a renewed focus on such disasters. Hurricane Katrina, just four years after 9/11, stirred national consciousness to the ineptitude and impotence of current disaster management programs, both public and private. It helped to reinforce a new paradigm for thinking about such risks as "endogenous security vulnerabilities" – that is, risks not entirely "acts of God" since human agents are still responsible for both ex ante and ex post risk management and mitigation (Auerswald, Branscomb, La Porte, & Michel-Kerjan, 2006).

This "endogenous vulnerability" model already seems to have captured the attention of the financial community and Wall Street. The management of weather risk has become accepted practice in the context of quarterly earnings guidance. The once popular refrain that adverse weather affected operating results no longer seems viable given the array of both over-the-counter (OTC) and exchange traded financial contracts available to manage such risks (Clemmons, 2002). This approach, proactive but not without risk itself, also is pervading the global community of policy and business leaders. Indeed, the most recent Global Risk Network Report at the World Economic Forum emphasizes a sense of shared leadership and proactive change in confronting the array of disaster risks facing the world (World Economic Forum, 2008).

In this context, this paper offers a contribution to an ongoing discussion concerning the role of capital markets in helping insurance and reinsurance firms manage catastrophic risk. In particular, the paper considers the role of catastrophe bonds (commonly called "cat" bonds), especially those with longer-term maturities (beyond 3 years), as viable market instruments. The growth of the use (and misuse) of capital market instruments to manage catastrophe risks has been strong generally, especially since the comparative size of financial capital available versus the realized financial loss from a single catastrophe is quite large. For example, the realized $66 billion loss from Hurricane Katrina is approximately equivalent to a mere 1 percent change in the value of the New York Stock Exchange (Jaffee & Russell, 1997). But despite the strong growth in cat bonds, a closer examination of the data reveals that longer-term cat bonds have not grown as fast as shorter-term securities. The paper deploys a behavioral analysis of the market – predominantly on the investor side – to explain why this is the case. The analysis is organized as follows. In part 1, the paper considers the current insurance and reinsurance landscape for managing catastrophic risks and the market failures it generates. Part 2 surveys the role of securitization and cat bonds theoretically and provides empirical data on issuance. Parts 3 and 4 set up the analytical framework whereby multiyear cat bonds are evaluated in terms of economic and psychological behavior. The final section concludes.

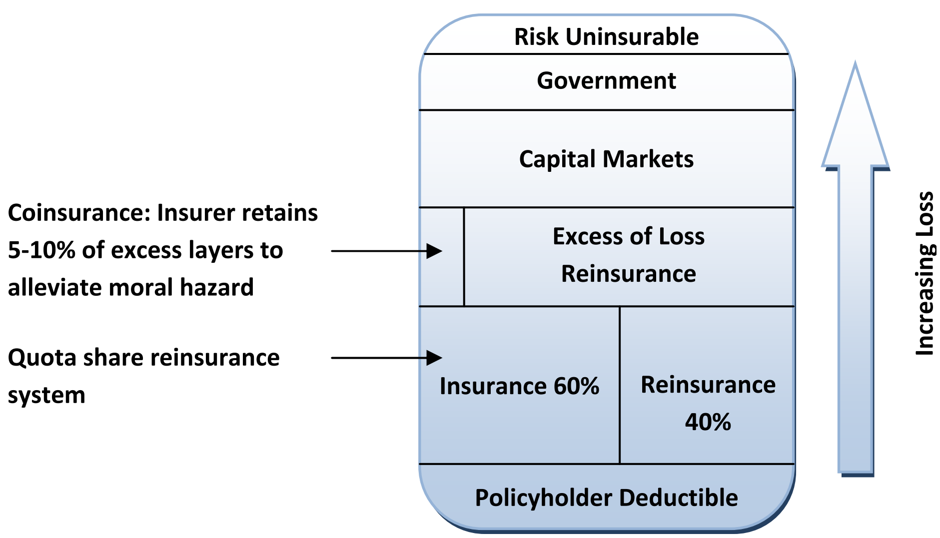
Part 1: The Current Structure for Managing Catastrophic Risk

Individuals, insurance and reinsurance firms, and government entities create a risk-sharing system for managing all types of risks, including those which are low probability, high loss events like natural catastrophes. Before describing such a system in detail, it is prudent to first consider the very nature of catastrophic risk and its insurability. The idea that individuals and businesses are risk averse promotes the adoption of risk mitigation via insurance. Such insurance is typically purchased at price levels, or premiums, that exceed the expected value of a future loss or indemnity level (given the risk aversion) and thus risk-bearing firms produce profits by the magnitude of this excess. This directly explains the existence and continued role of the insurance and reinsurance industry. Firms in the business will diversify the risk assumed by pooling across policyholders (Cummins, 2006).

According to Manes (1941), the ideal risks for which insurance would be effective are those that are accidental (not necessary or impossible), sporadic (scattered as to both location and time), regular (expected not too frequently or rarely), and statistically measurable or estimable – such requirements ensure pricing at actuarially fair levels and market liquidity. In this context, insurance seems to works best for high frequency, low severity, relatively stationary, and relatively independent events with good data, limited loss volatilities and identical probability distributions (Cummins, 2006). Catastrophic events are characteristically the very opposite of this example but do indeed satisfy the framework proposed by Manes (1941). The advent of new technology and hazard simulation models allow insurers, reinsurers, and financial institutions to better forecast natural disaster risk given a firm's current portfolio. These innovations, which are usually produced from a heightened consciousness of the nature of catastrophic risk itself, lead to better pricing models and risk assessment capabilities in the insurance industry. The insurability of natural disasters is more feasible if insurance premiums are allowed to reflect such risk, allowing individuals to better understand potential hazards and engage in cost effective mitigation measures (Wharton Risk Center Extreme Events Project, 2008).

We now consider how losses are managed in the industry via a risk distribution system. Figure 2 illustrates such a system, one that parallels asset claims by equity and debt holders in corporate finance.

Figure 2: Risk Transfer in Insurance Markets (Adapted from: Wharton Risk Center Extreme Events Project, 2008)



Since catastrophic risks have become a viable component of insurance coverage and insurers are fundamentally risk averse, the reinsurance industry has evolved as an additional layer of protection for the insurance company in much the same way the insurer protects the homeowner. The absence of a reinsurance layer would effectively transform companies and insurers into "concentrated warehouses of catastrophic exposures" and hence cripple underlying insurance capacity in the event of large losses (Froot, 2001). A typical risk distribution system thus starts with the homeowner deductible at the bottom, followed by a quota share of surplus losses between an insurance company and reinsurance company, followed by excess of loss reinsurance above a certain attachment level. At that level, it is common for the insurer to also bear 5-10 percent of the excess layers to alleviate moral hazard concerns, via coinsurance. Capital markets help absorb losses above the reinsurance cap (via securitization and cat bonds) and government intervention is usually required at the highest levels, in the event of market failure. Governments, it should be noted, help to provide information to private markets regarding risk profiles (for example, via the National Hurricane Center) while facilitating economic efficiency, political participation, and the protection of rights in the context of catastrophic loss (Inman & Rubinfeld, 1997; Kessler, 2008). Above some level of loss, such as a mega catastrophe terror attack, the risk becomes uninsurable.

The framework encapsulated in Figure 2 is vulnerable to many forms of economic and behavioral distortion and, ultimately, market failure. Its efficiency in managing all types of risks, especially those that are catastrophic in nature, relies upon many moving parts. This shared interdependence necessitates active ex ante and ex post risk management. Failures of coverage can be traced to the inherent cyclicality in the insurance industry, excess capital and "underleveraging" per regulations, all resulting in firms generating greater cash than can effectively be managed. Firms fail to pool capital effectively while constant government intervention, viewing insurance as a public service, produces externalities and costs for insurers and policyholders alike (Rode, Fischhoff, & Fischbeck, 2000). One broad result of these influences is the reduction in return on equity (ROE) for insurance firms, leading to distortions in the subsequent pricing of risk (Wharton Risk Center Extreme Events Project, 2008). Froot (2001) identifies 5 supply side and 3 demand side explanations for the intrinsic failure in the insurance industry for catastrophic risks:

1. Insufficient capital (supply side)
2. Market power (supply side)
3. Corporate structure inefficiency (supply side)
4. Frictional costs (supply side)
5. Informational asymmetry (supply side)
6. Ex post intervention by government (demand side)
7. Agency problems (demand side)
8. Behavioral factors (demand side)

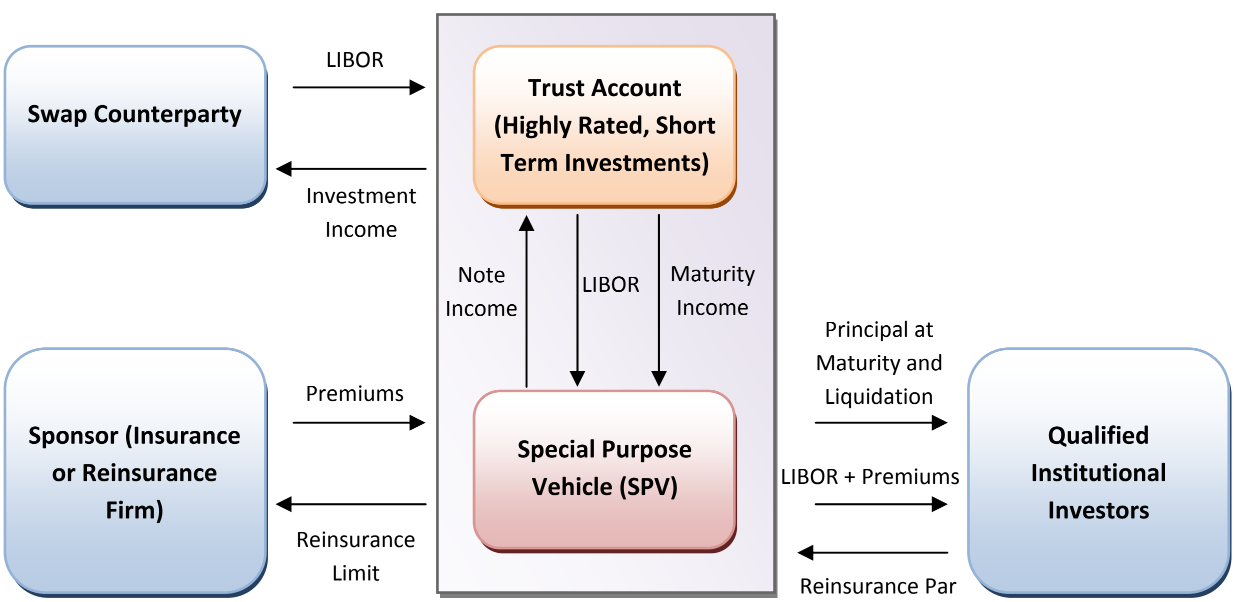
This categorization becomes our starting point for considering the specific role of capital markets in Figure 2. Securitization, specifically via cat bonds, is the additional layer of protection for insurers and reinsurers facing catastrophic risk vulnerabilities.

Part 2: On Securitization and Cat Bonds

Because catastrophes can create losses that supersede the available insurance capacity of insurers and reinsurers, the growth of insurance linked securities represents a somewhat logical extension of structured finance into the catastrophe risk business. By using the vast capacity of global capital markets, the insurance system could theoretically mitigate or even prevent the problems of market failure elucidated by Froot (2001). Several factors have contributed to the growth of securitization of catastrophic risks. One relates to a new intellectual climate that couples effective hedging with corporate financial management; that is, companies realize the economic benefits of managing risk by looking to financial markets. Froot (2001) cites Merton (1997) in that policyholders are more risk averse to firm credit quality than capital providers, and thus additional reinsurance capacity adds shareholder value. Naturally, financial institutions have met this increasing demand with new products amidst the remarkable growth of derivatives markets worldwide. Inefficiencies related to the current reinsurance system, such as unusually expensive products (seen empirically, Bantwal & Kunreuther, 2000) and default risk in catastrophic contexts (for example, reinsurers faced insolvency during Hurricane Andrew in 1992 and Hurricane Katrina in 2005) further motivate the use of capital markets. Finally, improved technology has created better and more accessible information about the risks, hence legitimizing the applicability of a given insurance linked security (Doherty, 1997).

The most popular and well understood insurance linked security for managing catastrophic risk is the cat bond. Originated in the mid-1990s, cat bonds function in the capital markets layer of Figure 2 and directly assist the transfer of catastrophic insurance risk by insurers and reinsurers to capital market investors, lowering credit risk and increasing liquidity. Over the past decade, the basic structure of the cat bond has more or less standardized. The interests of modeling firms, rating agencies, sponsors, sophisticated investors, and regulators have harmonized around the structure seen in Figure 3.

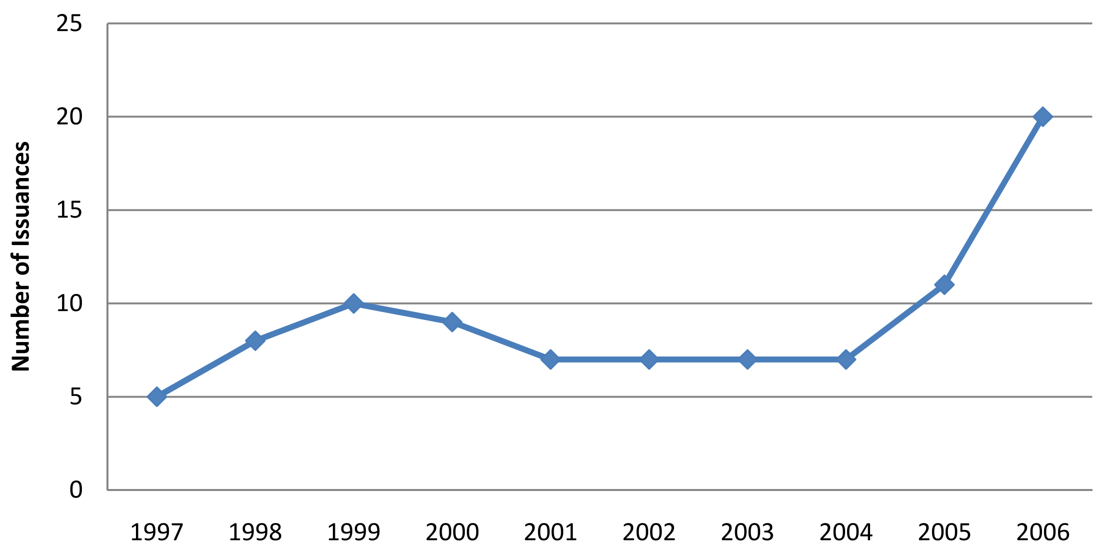
Figure 3: Structure of the Typical Cat Bond (Adapted from: MMC Securities Corp., 2007)



The special purpose vehicle is the entity which insures the sponsor firm in exchange for periodic premium payments. These premiums, in addition to LIBOR, are paid to investors as periodic coupons on the bond. Provided no trigger is incurred (i.e. no catastrophe takes place per an accepted definition[‡]), investors are returned the principal at maturity and liquidation of the SPV. Otherwise, investors forego the principal and interest payments on the bond underlying a pre-specified reinsurance par amount. This par amount subsequently reaches the sponsor firm in event of catastrophe. The SPV collateralizes the bond proceeds in a short term trust account consisting of highly rated securities. This trust account removes interest rate risk from the portfolio by swapping periodic investment income for LIBOR with another, highly rated swap counterparty. The LIBOR payments, coupled with any terminal income, are transferred to investors via the SPV (Michel-Kerjan & Morlaye, 2007).

We now consider some empirical data on cat bond issuance that will motivate the central research question. While outstanding aggregate risk capital (transaction size) totaled $663 million in 1997, this same figure had catapulted to nearly $2 billion in 2005, a 200 percent increase. The 2006 data report a 136 percent rise in one year from 2005, reaching an astonishing $4.7 billion in risk capital (MMC Securities Corp., 2007). The uncharacteristically severe hurricane season in 2005 directly contributed to worsening perceptions of risk vulnerability in insurance markets and heightened investor salience toward catastrophic risk. Given the market size and continued growth trajectory, Figure 4 compiles data on yearly issuance volume for the period 1997-2006.

Figure 4: Cat Bond Market Yearly Issuance Volume, 1997-2006
(Source: MMC Securities Corp., 2007; author analysis)



‡ Triggers determine when payouts occur on the bond. These can include indemnity triggers (tied to the size of the actual loss suffered by the sponsor) or the more remote index triggers (tied to some physical parameterization of the catastrophic event, an industry loss level, or a modeled loss level). More complex, multiple peril bonds might also use a hybrid trigger that incorporates multiple trigger types. The basis risk for the sponsor is greater for index triggers than indemnity triggers. In general, investors prefer index triggers due to lower moral hazard, higher transparency, and better liquidity (see MMC Securities Corp., 2007).

Expectedly, the doubling in issuance volume between 2005 and 2006 is commensurate with the rise in risk capital.

While these statistics are impressive, a closer examination of the data reveals an apparent asymmetry in the specific types of cat bonds gaining market acceptance. Specifically, consider disaggregating issuance volume by the maturity of the bond over the same time period, as in Figure 5.

Figure 5: Issuance Volume by Bond Tenor, 1997-2006

	1 Year	2 Year	3 Year	4 Year	5 Year	10 Year	TOTAL
1997	2	1	1	0	0	1	**5**
1998	7	0	0	0	1	0	**8**
1999	5	0	3	0	2	0	**10**
2000	3	1	4	0	1	0	**9**
2001	2	1	3	1	0	0	**7**
2002	0	1	4	2	0	0	**7**
2003	0	1	3	1	2	0	**7**
2004	1	2	1	1	2	0	**7**
2005	1	2	7	0	1	0	**11**
2006	2	4	12	1	1	0	**20**
TOTAL	**23**	**13**	**38**	**6**	**10**	**1**	**91**

Source: Wharton Risk Center Extreme Events Project, 2008; MMC Securities Corp., 2007

This disaggregation reveals that shorter-term securities, those with tenors from 1 to 3 years, disproportionately account for the rise in issuance volume over the 10 year period. Of the total 91 bonds issued, more than 80 percent have maturities of 3 years or less. Three year tenors represent approximately 42 percent of the entire volume and lead the sample set while 1 year tenors represent a quarter percent. The sharp rise from 2005 to 2006 was also asymmetric – new 3 year bonds in 2006 exceeded the entire issuance volume in 2005, across all maturities. What accounts for this asymmetry in terms of bond tenor? Is it possible to explain the lack of liquidity on the longer end of the cat bond market in terms of investor behavior? This paper subsequently argues that investor behavior, the eighth factor in the Froot (2001) categorization for market failure, is entirely relevant to understanding this empirical resistance to multiyear cat bonds, and might also help explain other market failure variables.

Before considering the nature of long term insurance and behavior in particular, the paper next looks at general theoretical dimensions of investor behavior as it relates to cat bonds.

Part 3: Behavioral Finance and Investor Psychology Applied to Cat Bonds

While the growth in cat bonds has been impressive during the last decade, aggregate risk capital underlying these securities is still miniscule compared to global insurance capacity. The nature of these relatively exotic instruments invites an examination of how investors and individuals perceive and process low probability, high consequence phenomena in the first place. In what follows, the paper integrates a number of perspectives in both behavioral finance (decision making under uncertainty) and investor psychology (risk perceptions) that augment prevailing models of economic rationality and expected utility which, many times, exclude the prevalence of non-linearity and “jump-type” stochastic volatility in markets. Yet these types of perturbations characterize natural disasters and help to rationalize an abundance of speculative mania and crashes seen empirically. In the discussion on behavioral finance, the paper builds an integrated model that supports observations of economic decision making in the context of catastrophic risk. In the discussion on investor psychology, the paper cites some well known results on how investors perceive such risk. This treatment provides the analytical framework to consider multiyear cat bonds explicitly in part 4.

Behavioral Finance

Olsen (1998) describes the modern behavioral finance discipline as an alternative to traditional models of subjective expected utility but with more realistic and empirically valid assumptions. In many ways, for example, economic decision making does not serve to maximize decision utility but rather experience utility: a decision strives to achieve maximum benefit given a past history of decisions, rather than optimize the current set without reference to any prior history or “sunk costs.” In this sense, decisions are not autonomous, identical or even independent of one another. The decision maker’s preferences are typically multifaceted, adaptive, and open to change (often during the decision itself) while the guiding strategy is usually to seek satisfactory, not optimal, solutions (Olsen, 1998). New research examining decision making under uncertainty aims to reconstruct, if not openly discard, the traditional paradigm of the rational economic agent who independently seeks to maximize expected utility. These models are more concerned with catastrophic risk since the traditional framework invariably assumes perfect linearity and smooth, predictable outcomes (Lewis, 2008). There are 4 key models that better accommodate the prevalence of catastrophic risk: Bayesian updating, alarmist learning, ambiguity aversion or comparative ignorance, and the natural disaster syndrome.

Bayesian updating refers to the natural extension of Bayes’s Rule to economic decision making. Bayes’s Rule provides a mathematical definition for calculating a simple conditional probability for two stochastic events, *A* and *B*. It relates the probability of event *A* given event *B* has occurred (A|B) with the reverse probability of event *B* given event *A* has occurred (B|A). As the rule is universally mathematically correct, it has real applications to decision theory and inference since the mathematical formulation implies that prior (or posterior) events have informational relevance for determining future outcomes (Cornfield, 1967). Bayesian updating thus encapsulates the ability for individuals to update forecasts or hypotheses about future outcomes based upon past information. Such a model of measuring risk is inviting because of its elegant mathematical simplicity. In all risk contexts, catastrophic or otherwise, individuals and investors use past history to simulate and forecast future outcomes. For example, Hurricane Ivan in 2004 heightened awareness in New Orleans to prepare for future catastrophes in the years to come, but the “dress rehearsal” was ultimately unsuccessful (Meyer, 2006). The simplicity of Bayesian updating derives from the ability to summarize all risks as probability measures, the exclusion of unobservable or unquantifiable risks, and the adoption of smooth probability distributions with no discontinuities. These characteristics are in fact liabilities when using Bayesian updating exclusively to analyze decision making in catastrophic contexts. Even more, Bayesian analysis may not be best suited to considering low probability, high consequence events because of difficulties in acquiring data. Thus the model is conceptually useful but empirically tenuous in this capacity.

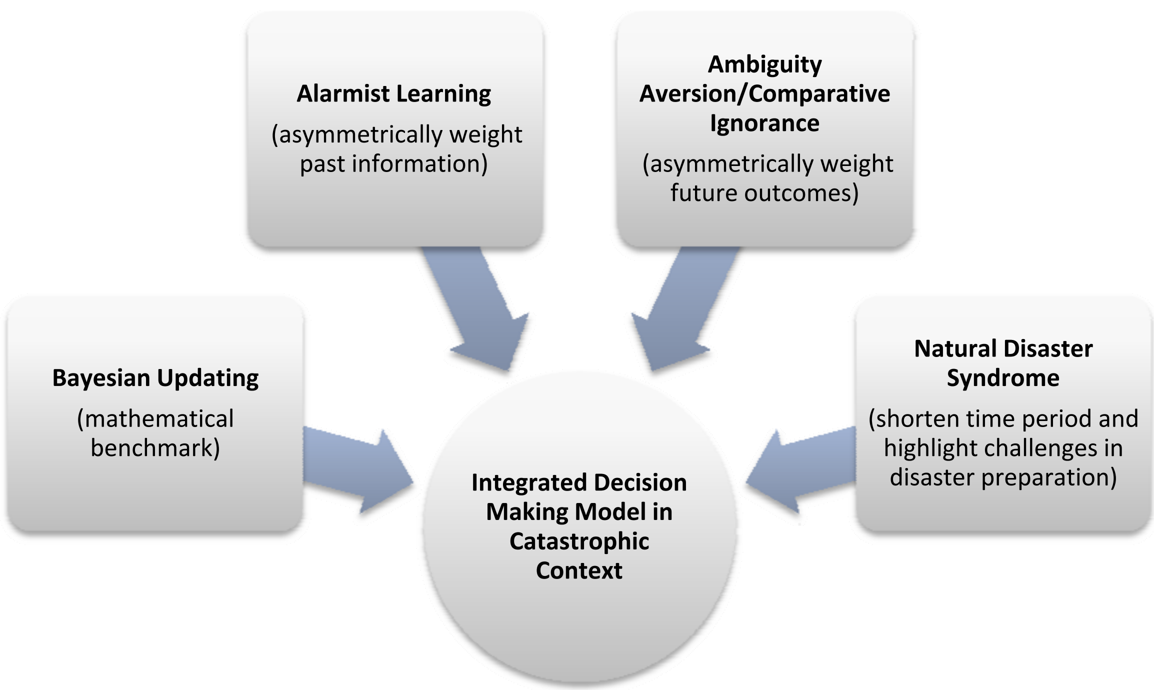
Alarmist learning does not discard the relevance of past information for future outcomes but instead uses such information asymmetrically, weighting highly publicized events and worse case scenarios as more salient and instructive for understanding decision making (Viscusi, 1997). The model assumes that individuals and investors react more strongly to certain events than others and that such an asymmetric response is reflected in all types of markets, including securities markets where risk premiums for cat bonds can be abnormally high per conventional Bayesian theory. In this sense, alarmist learning counters the traditional paradigm that more information accrued to the decision maker results in more optimal decisions. The type of information, particularly information including high risk assessments, can lead to severe digressions from rational economic behavior (Viscusi, 1997). For example, US public reaction to the risk of terrorism after 9/11 was perhaps the highest since Pearl Harbor in 1941. The availability bias can also help explain the salience of these events.

The third model that helps to understand how investors might conceptualize catastrophic risk vis-à-vis cat bonds is the model of ambiguity aversion or comparative ignorance. Epstein (1999) illustrates that “uncertainty” differs from “risk” in that the former cannot be represented or summarized via a probability measure. Most all natural catastrophes cannot be modeled with a degree of unambiguous certainty that provides a distinct probability of a future outcome. For example, a recent study of an event-based trading simulation for hurricanes provided three different sources of hurricane projections to participants and researchers: National Hurricane Center forecasts, Geophysical Fluid Dynamics Lab forecasts, and Climatology and Persistence forecasts (Kelly, 2008). All sources offered competing informational relevance for a potential decision maker facing hurricane risk. Ambiguity aversion thus refers to the underlying willingness of individuals to avoid ambiguous outcomes, and comparative ignorance refers to the implicit bias of favoring familiarity over non-familiarity (Fox & Tversky, 1995; Bantwal & Kunreuther, 2000). Such a model might subvert the applicability of a reliable insurance mechanism for catastrophic risk according to the original typology by Manes (1941).

Finally, the natural disaster syndrome (Kunreuther, 2006) describes underinvestment and unpreparedness before a natural catastrophe (ex ante failures) and massive public and private disaster intervention and mitigation after (ex post failures). Individuals are prone to underestimate the risks of catastrophe and hence are unprepared, leading to procrastination and implementation errors that maintain the status quo. The natural disaster syndrome implies that individuals focus on short term feedback, see the future myopically, and engage in hyperbolic discounting where long term phenomena are disproportionately discounted to today relative to short term phenomena (Meyer, 2006). In this fashion, the model conditions the Bayesian and alarmist models by a time variable (focusing on short term information) and supports the ambiguity aversion model since individuals tend not to take loss prevention measures voluntarily, particularly for catastrophic risk. A mixture of budget constraints, learning and feedback irregularities from prior disasters, biases in forecasting, and myopia contribute to failures in optimal decision making.

All 4 models are mutually compatible in understanding decision making amidst catastrophic risk. Bayesian updating provides a mathematical benchmark for relating past experiences to forecasting future outcomes. Alarmist learning asymmetrically weights past information while ambiguity aversion and comparative ignorance asymmetrically weight future outcomes. The natural disaster syndrome reduces the time horizon and clarifies the challenges of advance disaster preparation. The paper has developed an integrated catastrophe decision making model, as seen in Figure 6.

Figure 6: An Integrated Decision Making Model for Catastrophic Risk and Cat Bonds



<u>Investor Psychology</u>

Having sketched the contours of the decision making framework, we now consider how investors perceive the risk underlying a cat bond. Rode et al. (2000) synthesize 8 stylized facts about human behavior that have direct implications for the cat bond market:

1. Cognitive complexity
2. Exaggerated comprehensiveness

3. Aversion to asymmetric information
4. Violations of extensionality
5. Illusion of control
6. Reliance on availability
7. Overweighting small probabilities
8. Differences between psychological and actuarial perceptions of risk

Factors 1-4 relate to the workings of the cat bond transaction. Cognitive complexity derives from the nuanced structure typical of a cat bond (see Figure 3). The analysis of such a structure requires far greater learning and transaction costs than the vanilla stock or bond and investors may be overwhelmed with both hedging and comprehension. The same could be argued for catastrophic risk vulnerabilities (the underlying catastrophic risk), where the sources of information are numerous, complex, and often divergent (Kelly, 2008). Cognitive complexity thus precipitates sub-optimal heuristics which can distort pricing and undermine liquidity. The second factor, exaggerated comprehensiveness, implies that individuals commonly overestimate the completeness of a given decision. Since the sponsors issuing cat bonds have complex portfolios that are rarely transparent to the public, mispricing is often a result. The third factor, an aversion to asymmetric information that produces moral hazard and adverse selection problems, also supports this observation. Violations of extensionality, factor 4, refer to the availability heuristic whereby investors cannot readily compartmentalize a more complex investment structure that has both equity and debt features. An investor might use vanilla stock and bond heuristics to falsely extrapolate performance characteristics of a hybrid cat bond (Rode et al., 2000).

Factors 5-8 relate to the saliency of catastrophic events. With respect to the illusion of control, Langer (1975) conducted 6 discrete experiments whereby individuals who harbored an illusion of control over a given situation (by competition, choice, stimulus or response familiarity, active or passive involvement) were more confident and more willing to take risks. In effect, the perception of risk varied inversely with the perception of control. Applied to cat bonds, notwithstanding newer and better disaster modeling technologies, investors may still perceive catastrophes as "acts of God" and hence be less willing to assume such risk. According to the reliance on availability, events that happen recently or are particularly vivid (for example, Hurricane Katrina and 9/11) heighten awareness of catastrophic risk to a level that can misprice such risk. Coupled with factor 7, investors commonly overestimate risks that are naturally very infrequent (Slovic, 1987) or otherwise indicate "it cannot happen to me." The effect is even greater for risks like natural catastrophes which cause devastation that is not only financial in nature, but also physical, emotional, and psychological (factor 8). This helps constitute the so called "impact of worry" (Bantwal & Kunreuther, 2000).

These stylized facts, supported theoretically and empirically by Rode et al. (2000), provide the psychological underpinning to the decision making model in Figure 6. The perceptions of the cat bond transaction (factors 1-4) tie directly to the model of ambiguity aversion and comparative ignorance, where investors instinctively favor simplicity, transparency, and familiarity. The perceptions of catastrophic phenomena (factors 5-8) are consistent with the models of Bayesian updating and alarmist learning, where certain types of events harbor greater saliency and attention to risk. Such attention is typically acute and short term, as the natural disaster syndrome would indicate. The following section extends this general framework of investor behavior in catastrophic contexts to the specific empirical observation in part 2 – namely, the lack of liquidity in multiyear cat bonds.

Part 4: On Multiyear Cat Bonds and Long Term Insurance

Cat bonds with tenors of more than 3 years can be viewed as long term reinsurance solutions for sponsors facing long term insurance liabilities. The market for such products is small and represents less than 20 percent of total cat bond issuance volume between 1997 and 2006, as discussed in part 2. It is thus appropriate to examine the possibility of a long term insurance market for catastrophic risks in the first place. The existence of long term insurance policies would naturally generate sponsor (insurer or reinsurer) demand for long term cat bond protection. It should be noted that the market for long term insurance generally is quite small as well. For example, for the elderly in 2004, only 4 percent of long term expenditures were insured by the private marketplace (Brown & Finkelstein, 2007). In terms of long term homeowners insurance, the absence of premiums reflecting risk account for the small size of the market. Risk based premiums could thus facilitate the growth of long term reinsurance solutions like long term cat bonds and could better allow investors to trade such securities on the open market. But even as premiums are adjusted, long term affordability issues must be addressed by both private and public sectors (Wharton Risk Center Extreme Events Project, 2008). As such, what follows is a predominantly theoretical exposition of a potential long term catastrophe insurance market.

At the homeowner level, adverse events like hurricanes, tornadoes, and floods can exhaust an existing short term insurance contract and preempt the acquisition of additional insurance after the catastrophe due to budget constraints. As in New Orleans after Hurricane Katrina, the potential insurability for homeowners can severely contract if a catastrophe produces insolvencies in the industry. Thus one basic feature of a long term contract is the sustained stability and protection it provides for the end user (the homeowner) coupled with the promotion of cost effective risk mitigation practice. For leveraged homeowners, a typical mortgage anyway mandates insurance protection against losses from catastrophes, especially for those properties in high risk regions of the country. The long term contract, from the perspective of the sponsor, is thus best applied to the relevant property via the mortgage, not the homeowner. Tying the insurance policy to the mortgage is a directly feasible way to create markets for long term catastrophe insurance, as was seen in Japan after the Kobe Earthquake in 1995 (Kunreuther, 2007).

The sponsor providing this solution would charge a premium that reflects a best estimate of the risks involved over the long time horizon coupled with a load factor[§] that accommodates other administrative and processing costs. Altering the interest rate on the mortgage is an indirect way to price such a product. For those homeowners unable to attain a long term contract, assuming markets are efficient and such contracts are viable catastrophe risk management solutions, government

[§] A "load factor" is a convenient measure for assessing front loading and price gauging for insurance firms and is necessarily positive for profit-seeking entities. From the perspective of the policy holder, for every dollar paid in expected present discounted value premiums, 1-load is earned in expected present discounted value benefits (Brown & Finkelstein, 2007).

intervention could provide subsidies to ensure affordability (Kunreuther, 2007). However, Nutter (2006) suggests that US government involvement in catastrophe insurance markets is inevitably small, short term, and capped with limited funding capacity. Periodic election cycles are inherently incongruous with the goals of long term insurance provision. Harrington (2006) identifies 6 other obstacles for a potential policyholder considering catastrophe insurance:

1. Insufficient risk
2. Unwillingness to pay high premium loadings
3. Property owners usually do not bear the full costs of a catastrophic liability because of tax deductibility, limited liability and bankruptcy protection, and disaster assistance in the form of public, private, or charitable relief efforts
4. Risk mitigation (via physical investment) or risk avoidance (via relocation) might be better alternatives
5. For certain economic agents like crop producers, catastrophic risk is partially hedged by the price mechanism in the market
6. Behavioral factors

Nonetheless, provided the market exists, sponsors effectively realize cost savings from a long term insurance program because policyholders are more willing to invest in risk mitigation. This implies the risk of the overall portfolio of the sponsor decreases, leading to reduced reinsurance costs. Further diversification by type of risk, through an “all hazards policy,” would magnify the cost savings (Kunreuther, 2007).

A multiyear cat bond could be used to hedge against catastrophic risk vulnerability in a portfolio with outstanding long term insurance obligations. Investors are attracted to cat bonds generally because of the following features:

1. Cat bonds outperform other types of domestic bonds (Bantwal & Kunreuther, 2000)
2. Cat bonds are less volatile than either stocks or bonds
3. Cat bonds offer superior returns per unit of risk
4. Cat bonds help complete a market for a particular type of structured finance risk
5. Cat bonds are excellent for portfolio diversification and are uncorrelated with other instruments

Theoretically, in addition to these features, a multiyear cat bond also provides a way to spread fixed transaction costs over the long term, while minimizing reinvestment or rollover risk and interest rate risk for the investor (MMC Securities Corp., 2007). A long term bond would better match the liability exposure for a long term insurer or reinsurer and thus allow the sponsor a degree of stability to develop other parts of the business. It facilitates disaster planning and mitigation, both ex ante and ex post, but simultaneously creates moral hazard and adverse selection problems, especially depending on the type of trigger. Finally, there are real ambiguities associated with the appropriate pricing and valuation of a multiyear cat bond (Lee & Yu, 2007) along with the proper methodology for external rating and audit (Creswell & Bajaj, 2008).

Consistent with the sixth factor in the Harrington (2006) typology, the integrated model of behavioral finance (Figure 6) can help explain the lack of liquidity in the multiyear cat bond market. While a long term bond minimizes reinvestment and interest rate risk, the saliency of past catastrophes (alarmist learning) coupled with a fear of future ones (ambiguity aversion) might undermine any effort to hold catastrophic risk for an extended period of time. The idea of liability matching vis-à-vis long term insurance is undermined by the basic tenets of the natural disaster syndrome, which stresses myopia in individual and investor planning. Informational asymmetries, in the form of moral hazard and adverse selection, pricing ambiguities, and rating or operational constraints are all consistent with both alarmist learning and ambiguity aversion: investors will typically dissociate from instruments that exacerbate existing concerns. Multiyear cat bonds seem to extend the underlying difficulties associated with all cat bonds in terms of investor palatability, per behavioral finance theory.

Similarly, the framework of investor psychology by Rode et al. (2000) provides additional theoretical justification for the small size of the market. The first 4 factors relating to the transaction characteristics are aggravated with a longer bond tenor: investors must process more information (cognitive complexity), forecast a long time period with unverifiable certainty (exaggerated comprehensiveness), and deal with heightened moral hazard and adverse selection (aversion to asymmetric information), while still harboring violations of extensionality. The ambiguities concerning pricing, valuation, and external rating and audit exacerbate these psychological limitations. The last 4 factors relating to catastrophic phenomena limit the potential benefits of minimizing reinvestment and interest rate risk, matching long term liability exposure, and disaster planning and mitigation. The illusion of control can grow with time (Langer, 1975) while particularly vivid events deter the propensity to hold catastrophic risk for an extended period of time (factors 6-8). Figure 7 summarizes the analysis.

Figure 7: Behavioral Finance and Investor Psychology Applied to Multiyear Cat Bonds

Feature of Multiyear Cat Bond (Tenor > 3 Years)	Relevant Model(s) from Integrated Decision Making Framework (Fig. 6)	Relevant Factor(s) from Rode et al. (2000) Framework
Minimize reinvestment and interest rate risk	Alarmist learning; ambiguity aversion	Factors 5-8
Match long term insurance liability exposure, fostering stability	Natural disaster syndrome	Factors 5-8
Facilitate disaster planning and mitigation	Natural disaster syndrome	Factors 5-8
Informational asymmetry via moral hazard and adverse selection	Alarmist learning; ambiguity aversion	Factor 3
Ambiguities with pricing, valuation, external audit, operational control	Alarmist learning; ambiguity aversion	Factors 1, 2, 4

In other long term insurance markets, some have argued the lack of liquidity to be rational and not necessarily a case of market failure (Pauly, 1990). This paper does not aim to make a judgment regarding market failure. It merely seeks to apply established behavioral theory to an empirical observation in the cat bond market. Nonetheless, if behavioral factors are a legitimate reason for market failure generally in the catastrophe insurance business (Froot, 2001), then such factors can be readily applied to market failure for long term cat bonds, as in Figure 7. In this context, investor behavior becomes a powerful lens to rationalize market failure and explain other potential factors, such as insufficient capital.

Conclusions and Future Research

The compatibility between standard insurance and catastrophic risk seems at first instance remote. Cat bonds have developed in part to supply an alternative insurance avenue for such risk for corporations, insurers, and reinsurers. The instruments have also met investor demand for a new type of structured finance vehicle that is uncorrelated with conventional market instruments. The importance of this new market cannot be exaggerated given the volume and intensity of recent natural disasters in the US and abroad. Given the many reasons for such climactic volatility, both public and private entities have actively sought new sources of insurance capital to better prepare institutions and pubic communities for catastrophic disaster.

This paper motivated the research question by a simple empirical observation in the cat bond market over the past decade. Total issuance volume by bond tenor reveals that long term cat bonds, multiyear securities with tenors of more than 3 years, account for a very small segment of the market. By contrast, shorter term securities account for more than 80 percent of issuance volume. We tested the hypothesis that behavioral factors can help explain or rationalize this empirical asymmetry. Part 3 developed 2 lines of theoretical understanding. One line builds an integrated behavioral finance model for understanding economic decision making in catastrophic contexts. We use conventional Bayesian updating as a mathematical benchmark, then accommodate alarmist learning and ambiguity aversion (or comparative ignorance) to asymmetrically weight past and future outcomes, respectively. The natural disaster syndrome observes that individuals have short term horizons and instinctively under-prepare for natural hazards. The second line synthesized well known results in investor psychology related to perceptions of catastrophic risk. The categorization by Rode et al. (2000) provides an understanding of how investors perceive both the complexity of the cat bond transaction and the underlying catastrophic risk. Both lines of behavioral theory are mutually consistent.

This framework was then applied to the idea of long term insurance in general and multiyear cat bonds in particular in part 4. A multiyear cat bond can be viewed as a reliable hedge for an institution facing long term liability exposure. We briefly sketched the contours of a possible long term catastrophe insurance market, where end users can tie the insurance policy to the mortgage, sponsors can realize cost savings, risk based premiums can be applied, and government intervention can ensure affordability. In addition to the overall benefits of cat bonds, including low volatility, high returns, and minimal correlation vis-à-vis other market securities, long term cat bonds present 5 key features seen in Figure 7. The behavioral finance and psychology models in part 3 can be applied to each of these features.

Several domains entertained in this paper offer valuable starting points for future research. One area pertains to the optimization of pricing, audit, and operations for a long term cat bond. How should the risks and returns of a long term cat bond be adequately modeled? A controlled experiment might empirically validate the behavioral models in part 3, as well as design a model long term insurance market that would satisfy the private and public sectors. The long term market would need to address the nature of the underlying contracts and key institutional details such as government involvement and bond pricing and external review. Other studies might extend the discussion on cat bonds based solely on natural disasters to those also based on man-made disasters, such as terrorist attacks.

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