Natural Catastrophes and Insurance Securitization: Performance and Risk Implications for Insurance and Reinsurance Firms

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The candidate confirms that the work submitted is his own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

Thesis Section	**Jointly-authored Publication**
Chapter 5:	
The Performance Implications of Insurance Securitization: The Case of Catastrophe Bonds and Issuing Firms	Hagendorff, B., J. Hagendorff, and K. Keasey (2013). The Shareholder Wealth Effects of Insurance Securitization: Preliminary Evidence from the Catastrophe Bond Market. *Journal of Financial Services Research*, forthcoming.

The candidate confirms that he is the principal author of the publication listed above. The work contained in the article arose directly out of the work of this PhD thesis. For the article, the candidate undertook the literature review, data collection and statistical analysis and made significant contribution to the conceptual framework used.

Thesis Section	Solely-authored Publication
Chapter 3 (background chapter):	
The Market for Catastrophe Risk and Insurance Securitization	Hagendorff, B. (2009). Chapter 2.1 - 2.3: What are Insurance-linked Securities?, in: Hagendorff, B., Insurance-linked Securities – Here to Stay?, Leeds, University of Leeds.

As part of the background chapter (which gives an overview of the market for catastrophe risk and insurance securitization, including market size, market participants as well as recent market developments), this PhD thesis includes parts of the candidate‘s Master thesis (Chapter 2.1 – 2.3). The candidate confirms that the parts included from his Master thesis make up only a very small piece of this PhD thesis (approximately 2,000 words) and do not directly contribute to the analyses and main findings of this work.

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Abstract

Insurance and reinsurance firms have seen a remarkable increase in underwriting losses associated with natural catastrophes during the past decade. Yet, the volume of global risk-financing capacity of catastrophe events has remained limited to date. This raises concerns over the effect of insolvencies and disruptions in insurance and reinsurance markets in the event of a severe natural catastrophe. Insurance securitization has long been hailed as an important tool to increase the underwriting capacity of firms exposed to catastrophe risk. Surprisingly, however, global volumes of insurance securitization have remained low to date.

The thesis provides the first comprehensive analysis of the expected losses to U.S. insurers (as reflected in stock market returns) linked to a series of large natural catastrophes. The results show that, overall, the expected performance implications of mega-catastrophes are by no means devastating for insurers as the sample of natural catastrophes causes only relatively modest value losses for firms with catastrophe exposure.

The thesis also provides the first empirical investigation into both the performance effects and the risk effects for insurance and reinsurance firms which engage in insurance securitization by issuing catastrophe bonds. The results show that insurance securitization provides issuers with potential cost advantages (compared to other forms of catastrophe risk management) and that insurance securitization is an effective tool for hedging catastrophe risk.

In sum, while the relatively modest performance effects of natural catastrophes on insurance firms put a ceiling on the potential benefits of insurance securitization to firms exposed to catastrophe risk, the thesis shows that catastrophe bonds have some benefits for their issuers. Therefore, this thesis argues that insurance securitization is less valuable as a tool for capacity building in the market for catastrophe underwriting and more useful as a tool to realize cost efficacies and hedging benefits for insurance and reinsurance firms.

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List of Abbreviations

AR	Abnormal return(s)
bn	Billion
Cat	Catastrophe
CAR	Cumulative abnormal return(s)
CDS	Credit default swap
CRSP	Center for Research in Security Prices
e.g.	Exempli gratia ("for example")
et al.	Et alia ("and others")
etc.	Et cetera
i.e.	Id est ("that is")
EU	European Union
GDP	Gross domestic product
ILS	Insurance-linked securities
ISO	Insurance Services Office
LIBOR	London interbank offered rate
NAIC	National Association of Insurance Commissioners
p.a.	Per annum
PCS	Property Claims Service

pg.	Page
P&C	Property and casualty
P&L	Property and liability
ROL	Rate on line
SPV	Special purpose vehicle
TRS	Total return swap
USD	United States Dollar
U.S.	United States (of America)

1
Introduction

1.1 Introduction

Eight out of the ten most expensive natural catastrophes (in terms of insured losses) have occurred in the past ten years (Swiss Re, 2012b). Overall, the past decade has seen a remarkable increase in economic losses from natural catastrophes such as hurricanes, earthquakes and floods. The recent tsunami in Japan or Hurricane Katrina in 2005 which caused projected economic losses in excess of $200 billion and $100 billion respectively are two examples which bear testimony to this trend.

To avoid large and unexpected losses from natural catastrophes, owners of physical capital (i.e. mainly households and business firms) have a strong incentive to share their exposure to catastrophe risks with others through the purchase of insurance. Insurance firms which underwrite these catastrophe risks also have an incentive to purchase insurance (referred to as reinsurance). Without reinsurance, insurance firms could risk major financial losses and even insolvency in the event of severe natural catastrophes (Froot, 2001 or Cummins et al., 2002). For example, four U.S. insurance firms became insolvent (amongst them the third largest homeowners' insurer in Florida) as a result of the severe hurricane season in 2005 (A.M. Best Company, 2006).

However, the total volume of global risk-financing capacity of natural catastrophes in both insurance and reinsurance markets has remained limited to date (Froot, 2001; Cummins et al., 2002; Froot and O'Connell, 2008). As a result, the market for catastrophe risk is unable to share catastrophe risk widely and efficiently among market participants. Since this means that insurance firms face difficulties in transferring their catastrophe risk exposure to reinsurance firms (Froot, 2001; Froot and O'Connell, 2008), the bulk of economic losses linked to catastrophe risk is retained by individuals and business firms (see also D'Agostino, 2002).

Next to capacity constraints in the market for catastrophe risk, two additional trends compound the risk that a large natural catastrophe may cause severe instability and numerous insolvencies in global insurance and reinsurance markets: (i) strong growth rates in the value of physical asset and (ii) growth in the population living in high-risk zones such as coastal areas for hurricanes.

Prima facie, capital markets (rather than insurance and reinsurance markets) could be a viable source for firms exposed to catastrophe-related risks to increase the global risk-financing capacity for natural catastrophes. For example, Cummins et al. (2002) estimate a loss of $100 billion would equal approximately 30% of the equity capital of the U.S. property-liability (P&L) insurance industry (based on 1997 capitalization), but would be less than 0.5% of the value of U.S. stock and bond markets. Further, the transfer of catastrophe risk to capital markets could be at considerably lower costs (as compared to the traditional transfer through reinsurance), because capital markets can draw on a larger, more liquid and more diversified pool of capacity than the equity of reinsurance firms (e.g., Jaffee and Russell, 1997; Durbin, 2001; Niehaus, 2002).

Insurance securitization in general, and catastrophe (Cat) bonds in particular, have long been hailed as the most promising vehicles for efficiently accessing capital markets for additional risk-financing capacity (e.g. Jaffee and Russell, 1997; Froot, 2001; Kunreuther and Heal, 2012). Cat bonds are the most commonly used securitization vehicles to date. In simple terms, a Cat bond is an insurance derivative whose payoffs depend on the occurrence of a catastrophe loss event. As such, the issuing firm may forfeit on principal and/or coupon payments when a specified catastrophe loss event occurs.

While the market for Cat bonds has undergone rapid growth in response to recent increases in the amount of catastrophe-related underwriting losses, the overall volume of insurance securitization continues to lag behind expectations. For example, the total outstanding risk capital of Cat bonds issued between 1997 and 2011 corresponds to only 8% of insured catastrophe losses during that period (according to calculations based on Swiss Re Sigma Reports dating from 1997 to 2011).

Given the capacity constraints in the market for catastrophe risk, the limited use of insurance securitization by both insurance and reinsurance firms raises two main set of questions. First, is there a need for additional underwriting capacity for insurance and reinsurance firms? Arguably, the hitherto low issuance volume of Cat bonds and other insurance securitization vehicles can be explained by the fact that the financial losses associated with natural catastrophes (and, relatedly, the need for additional underwriting capacity) are not as great as frequently argued (Froot, 2001; Cummins et al., 2002; Froot and O'Connell, 2008). The second question addresses concerns regarding the effectiveness of insurance securitization as a risk management tool for insurance and reinsurance firms. If the benefits of insurance securitization for the firms which issue securities such as Cat bonds are limited (for instance, if Cat bonds are not effective in hedging catastrophe underwriting risk), this could equally explain the limited use of insurance securitization to date.

1.2 Contributions of the Thesis

Against the background of both an increase in underwriting losses from natural catastrophes and capacity constraints in the market for catastrophe risk, a clearer understanding of the need for additional risk-financing capacity by insurance and reinsurance firms as well as the effectiveness of insurance securitization as a risk management tool are important issues. For this purpose, this thesis analyses the performance implications of natural catastrophes and the performance and risk implications of insurance securitization for insurance and reinsurance firms.

In three main empirical chapters, this thesis provides novel evidence. Specifically, the empirical chapters seek to answer the following three research questions:

(i) Chapter 4: What are the performance implications of natural catastrophes for insurance and reinsurance firms?

(ii) Chapter 5: What are the performance implications of insurance securitization for insurance and reinsurance firms which issue Cat bonds?

(iii) Chapter 6: What are the risk implications of insurance securitization for insurance and reinsurance firms which issue Cat bonds?

Overall, the results presented in this thesis show a mixed picture. Chapters 5 and 6 draw a positive picture of the usefulness and effectiveness of insurance securitization by showing that insurance securitization can provide insurance and reinsurance firms with cost advantages (as compared to other forms of catastrophe risk management) and that insurance securitization is an effective tool for transferring catastrophe risk to capital markets.

However, Chapter 4 casts doubt on the need for insurance and reinsurance firms for additional underwriting capacity. This is because the empirical evidence provided in Chapter 4 reveals that the expected performance implications of mega-catastrophes (as reflected in equity market valuations of insurers around the time a catastrophe event occurs) are by no means devastating for insurers. This finding challenges the view that firms exposed to catastrophe risks have much to gain from additional catastrophe risk underwriting capacity.

In summary, the results presented in this thesis show that insurance and reinsurance firms have coped relatively well with large natural catastrophes. At the same time, firms which engage in insurance securitization by issuing Cat bonds realize some costs and hedging benefits. Put differently, while the potential benefits of insurance securitization to firms exposed to catastrophe risk are limited ex ante, the results presented in this thesis are the first to show that insurance and reinsurance firms still benefit from issuing Cat bonds. It could be argued, therefore, that the ex ante limited potential for firms to benefit from Cat bonds provides a possible explanation for the hitherto reluctance of insurance and reinsurance firms to make more extensive use of insurance securitization.

To provide a more detailed discussion of the findings as well as contributions of this thesis to the extant literature, the next three subsections summarize the contributions of each empirical chapter.

1.2.1 The Performance Implications of Natural Catastrophes for Insurance and Reinsurance Firms

The first empirical question that this thesis addresses is related to the performance implications of natural catastrophes for insurance and reinsurance firms. For this purpose, Chapter 4 uses a large dataset on homeowners' insurance coverage by state, firm, and year to examine the stock returns of U.S. P&L insurers in response to a series of nineteen large U.S. natural catastrophes (mega-catastrophes) spanning from 1996 to 2010. In doing so, Chapter 4 provides the first comprehensive analysis of the market performance effect of a series of natural catastrophes on the U.S. P&L insurance industry. Also, the chapter identifies new firm-specific and catastrophe-specific factors which impact on the post loss stock price reaction of insurers.

The rationale behind Chapter 4 is to gain some insights into the need for insurance and reinsurance firms for additional underwriting capacity by assessing the expected performance effects linked to mega-catastrophes (as reflected in insurer stock prices). Arguably, one of the reasons why insurance and reinsurance firms may have been reluctant to make more extensive use of insurance securitization to date could be that capacity constraints in the market for catastrophe risk may not pose as much of a risk to them as argued by various commentators (e.g. Froot, 2001; Cummins et al., 2002; Cummins and Trainar, 2009).

The capacity-constraint hypothesis posits that underwriting capacity is negatively related to underwriting profitability (Gron, 1994). That is, the lower the available capacity in the market for catastrophe risk the higher the expected profits from offering insurance against catastrophe risk. In line with the capacity-constraint hypothesis, natural catastrophes usually lead to additional premium earnings due to sharp price increases for catastrophe risk insurance (Zanjani, 2002 or Froot and O'Connel, 2008) as well as more profitable insurance business in the following non-catastrophe years (Born and Viscusi, 2006). This raises the question whether, following a catastrophe event, the benefits of additional premium earnings due to sharp price increases for catastrophe risk insurance outweigh insurers' initial underwriting losses.

The overall performance effect of mega-catastrophes on insurance firms has remained unknown to date. This is because previous studies on the market valuation effects of catastrophes tend to focus on a single event (e.g. the San Francisco earthquake in 1989, Hurricane Andrew in 1992 or the Northridge earthquake in 1994) and have reached conflicting conclusions over whether the value effect of mega-catastrophes on insurers is negative or positive.

For example, Lamb (1995; 1998), Cagle (1996), and Cummins and Lewis (2003) find that insurers realize negative abnormal returns, on average, for the specific catastrophe events they study, while Shelor et al. (1992), Aiuppa et al. (1993) and Lamb and Kennedy (1997) find positive equity valuation effects linked to the specific events they study. Moreover, an additional challenge faced by research which focuses on a single (or a very low number of catastrophe events) is that these studies cannot distinguish between effects which are unique about a particular event from the more general effects of a catastrophe on insurers.

The findings reported in Chapter 4 have two main implications. First, Chapter 4 shows clear evidence that across the series of nineteen U.S. mega-catastrophes examined, shareholders in U.S. P&L insurers realize wealth losses on average. Also, the results reveal that the stock price response varies significantly among firms based on the existence as well as the size of the loss exposure. Thus, by using detailed data on the underwriting activities of insurers (by state and type of catastrophe event) from the National Association of Insurance Commissioners (NAIC), results show that only firms with exposure to mega-catastrophes experience wealth losses. That means the findings do not support the view that, subsequent to a mega-catastrophe, additional premium earnings due to sharp price increases for catastrophe risk insurance outweigh insurers' initial underwriting losses.

Nevertheless, the magnitude of share price losses during the examined event period of less than 1.5% experienced by the sample as a whole are rather moderate. This casts doubt on the view that catastrophe events cause large and unexpected losses for insurers and that additional underwriting capacity is needed so that insurers can cope with the underwriting losses from natural catastrophes.

In summary, Chapter 4 shows that, while natural catastrophes are associated with wealth losses for insurance and reinsurance firms with catastrophe risk exposure, the losses are not as severe as expected (Froot, 2001; Cummins et al., 2002; Cummins and Trainar, 2009). This is interpreted as evidence that insurance and reinsurance firms are (on average) able to cope rather well with the losses linked to mega-catastrophes. Consequently, the results show that insurance securitization vehicles, such as Cat bonds, may have a role to play in mitigating the effects of natural catastrophes on the firms which underwrite catastrophe risks. At the same time, however, the low negative returns (in absolute terms) associated with natural catastrophes put a ceiling on the potential benefits of Cat bonds to issuing firms and suggest that such benefits may be limited.

1.2.2 The Performance Implications of Insurance Securitization for Insurance and Reinsurance Firms

The second empirical question of this thesis relates to the performance implications of insurance securitization for insurance and reinsurance firms. For this purpose, Chapter 5 examines changes in the market value of an international sample of insurance and reinsurance firms which announce their engagement in insurance securitization by issuing Cat bonds. In doing so, Chapter 5 provides the first empirical investigation into the wealth benefits of issuing Cat bonds and, also, helps to understand the motivations as to why firms issue them. This is particularly important because previous work on Cat bonds has been mostly theoretical (e.g. Bantwal and Kunreuther, 2000; Lakdawalla and Zanjani, 2006), leading to considerable uncertainty as to the actual effects of Cat bonds on the issuing firm.

The focus of the analysis in Chapter 5 is on assessing the validity of the two most prominent arguments proposed by the literature as to why firms may benefit from issuing Cat bonds, namely, that (i) Cat bonds allow firms to hedge against catastrophe-related underwriting losses (e.g. Niehaus, 2002; Harrington and Niehaus, 2003; Cummins et al., 2004) and that (ii) Cat bonds can help firms with catastrophe exposure to realize cost savings on catastrophe-related risk management (e.g. Jaffee and Russell, 1997; Niehaus, 2002; Kunreuther and Heal, 2012).

Consistent with the hitherto underwhelming contribution of insurance securitization to global risk financing capacity, Chapter 5 provides evidence that Cat bonds do not lead to strong wealth gains for shareholders in the issuing firm. Nevertheless, Chapter 5 also reports large variations in the distribution of wealth effects in response to the issue announcement. The results show that the wealth effects for shareholders in firms which issue Cat bonds appear to be driven by explanations according to which Cat bonds offer cost savings (relative to other forms of catastrophe risk management) and less by the potential of Cat bonds to hedge catastrophe risk.

For example, the results in Chapter 5 show that the value effects linked to Cat bond issues are particularly pronounced for firms with less volatile losses from their insurance business. This is in line with the argument that this particular group of firms is likely to benefit from lower information acquisition costs in financial markets when they substitute reinsurance coverage using Cat bonds (see Gibson et al. 2011). In the same vein, since Cat bond prices are fixed over a multi-year period and remain unaffected by future price increases in the market for catastrophe coverage, results show that issuer abnormal returns are particularly high during periods of low catastrophe reinsurance prices when the costs of raising capital via Cat bonds are relatively low too.

Overall, the results of the analysis of the performance implications of insurance securitization for insurance and reinsurance firms provide evidence in support of the argument that insurance securitization can help firms with catastrophe exposure to realize costs savings on catastrophe-related risk management (as proposed by Jaffee and Russell, 1997, Niehaus, 2002 or Kunreuther, 2012).

However, Chapter 5 also casts doubt on the effectiveness of insurance securitization in general (and Cat bonds in particular) in hedging underwriting risks. The latter finding offers another possible explanation for the underwhelming use of insurance securitization by firms exposed to catastrophe risks to date and, therefore, is further examined in the subsequent chapter.

1.2.3 The Risk Implications of Insurance Securitization for Insurance and Reinsurance Firms

The final empirical question of this thesis analyses the risk implications of insurance securitization for insurance and reinsurance firms. In doing so, Chapter 6 helps to further assess the findings of the previous chapter which challenge the effectiveness of insurance securitization in hedging underwriting risks. For this purpose, Chapter 6 examines the impact of Cat bonds on the default risk of an international sample of insurance and reinsurance firms which issue them.

The motivation for this investigation are concerns that underwriting losses linked to catastrophe events may prove so large that they cause distress and, ultimately, have an effect on the default-likelihood of an insurer (Cummins et al., 2002; Harrington and Niehaus, 2003). Consequently, if Cat bonds are effective in transferring catastrophe underwriting risk from issuers to market investors, they should lead to a commensurate reduction in the issuers' default risk.

Using the Merton distance to default model to gauge default risk, Chapter 6 provides the first empirical evidence that Cat bonds lower the default risk of the firms which issue them. Also, and consistent with explanations according to which insurance securitization reduces exposure to catastrophe risk and to default risk more generally, the results reveal that Cat bonds lead to larger risk reductions for issuers with higher exposures to either catastrophe or default risk. Finally, Chapter 6 shows that basis risk (which results when Cat bond payouts are independent of the issuers' realized losses) does not prevent issuers from realizing risk benefits.

Therefore, Chapter 6 shows that insurance securitization in general, and Cat bonds in particular, are effective vehicles for insurance and reinsurance firms for transferring catastrophe-related underwriting risks to capital markets.

1.3 Structure of the Thesis

This thesis is organized as follows.

- Chapter 2 and Chapter 3 both serve as background chapters to the three empirical chapters of this thesis. For this purpose, Chapter 2 presents an institutional setting for insurance and reinsurance including both an explanation of the fundamentals of risk and insurance as well as a detailed discussion of the development of the private insurance and reinsurance industry in recent years. This is followed by Chapter 3, which provides an overview of the market for catastrophe risk and insurance securitization. Also, the concept of insurance securitization in general (and Cat bonds in particular) is explained in detail.

- Chapter 4 (the first of the following three empirical chapters) analyses the performance implications of natural catastrophes on insurance and reinsurance firms by examining the impact of a series of natural catastrophes on the stock market valuation of a sample of U.S insurance and reinsurance firms.

- Chapter 5 examines the performance implications of insurance securitization on insurance and reinsurance firms by analyzing changes in the stock market valuation of an international sample of insurance and reinsurance firms which announce their engagement in insurance securitization by issuing Cat bonds.
- Chapter 6 assesses the risk implications of insurance securitization for insurance and reinsurance firms by analyzing the impact of Cat bonds on the default risk of an international sample of insurance and reinsurance firms which issue them.
- Chapter 7 draws together the conclusions, policy implications and limitations of this thesis. Also, directions for further research are discussed in this chapter.

2
Insurance and Reinsurance - Fundamentals and Institutional Setting

2.1 Introduction

This chapter is the first of the two background chapters (Chapters 2 and 3) of this thesis and presents an overview of the institutional setting for insurance and reinsurance. The discussion consists of a description of the market participants as well as the development of the private insurance and reinsurance industry including recent developments and future challenges. In order to lay out the foundations for this discussion, the chapter starts by explaining the fundamentals of risk and insurance. For this purpose, the concept of insurance is described in the context of modern risk management, and the nature and functions of insurance as well as the different types of insurance are laid out.

The chapter provides an important motivation for this thesis, by giving evidence that insurance and reinsurance firms have become more vulnerable than ever before to the financial consequences of large underwriting losses and that, as a result, the management of the exposure to large underwriting losses has become crucially important for insurance and reinsurance firms in order to remain profitable. Two reasons for this development are offered in this chapter. First, insurance and reinsurance firms have been struggling to generate significant premium growth in recent years. Second, insurance and reinsurance firms increasingly face difficulties in maintaining high levels of investment income and, therefore, can no longer rely on the investment income to offset underwriting losses.

2.2 Fundamentals of Risk and Insurance

Before the institutional setting for insurance and reinsurance is investigated, this subsection first lays out the fundamentals of risk and insurance. It starts by providing an introduction to modern risk management as well as a description of the nature and functions of insurance. Finally, the elements of an insurable risk are presented and the different types of insurance are discussed.

From the discussion below, it will become evident how the concept of insurance is integrated into modern risk management theory and why insurance firms are crucial in the process of insuring and managing the risks that individuals and business firms are exposed to.

2.2.1 Introduction to Modern Risk Management

Modern risk management in its current practice is a relatively new and evolving discipline which has its roots in the early 1950s.[1] As such, risk management has been defined in a range of different ways which vary in detail. Nonetheless, according to Vaughan and Vaughan (2003, pg. 15), all definitions of risk management offered

[1] One of the earliest references to the concept of risk management can be found in the article 'Risk Management: A New Phase of Cost Control' by Gallagher (1956) published in the *Harvard Business Review*.

thus far share principally the same key characteristics and, therefore, can be summarized in one universal definition as follows:

"Risk management is a scientific approach to dealing with pure risks by anticipating possible accidental losses and designing and implementing procedures that minimize the occurrence of loss or the financial impact of the losses that do occur."

According to this definition, risk management is fundamentally concerned with *pure risks* and involves different tools to managing those risks. As a result, to fully appreciate the concept of risk management, it is important to distinguish between the meaning *risk* and *pure risk*, and to be aware of the different risk management tools available.

Until today, the literature lacks a universally accepted definition of the term *risk*. Thus, *risk* is variously defined and includes (i) the possibility or chance of loss, (ii) the dispersion of actual from expected results, (iii) uncertainty, or (iv) the probability of any outcome different from the one expected. All definitions have in common that they either refer to an indeterminate outcome or that at least one of the possible outcomes is undesirable, i.e. it involves the possibility of loss. In this context, *risk* can be classified as either pure risk or speculative risk (as in Mowbray and Blanchard, 1961, pgs. 6-7).[2] The term *pure risk* refers to a condition which involves only the possibility of loss or no loss, such as the possibility that a person's

[2] Next to the distinction between pure risk and speculative risk, risk may also be classified in other ways. These classifications include the distinction between financial and non-financial risks, static and dynamic risks (Willett, 1951, pgs. 14-19) as well as fundamental and particular risks (Kulp, 1956, pgs. 3-4).

house is damaged or destroyed. The term *speculative risk*, in contrast, describes a condition in which there is a possibility of loss, but also the possibility of gain. Gambling and almost all investment activities are examples of speculative risks.

In order to deal with pure risk, risk management offers different risk management tools. These tools are usually grouped into two broad approaches, namely (i) risk control and (ii) risk financing.

Risk control comprises of techniques which are designed to minimize the risk of losses to which individuals and business firms are exposed to. Risk control includes risk avoidance techniques as well as risk reduction techniques. Risk avoidance techniques aim at preventing a risk from even coming into existence (e.g. to avoid the risk of damages to an automobile, individuals and business firms can decide not to buy an automobile at all). Risk reduction techniques, however, are designed to reduce the likelihood of loss or the potential severity of losses (e.g. to reduce the likelihood of vandalism to a building, individuals and business firms can install security cameras or put up fences surrounding the building).

Risk financing ultimately deals with all remaining risks which cannot be avoided or reduced through risk control. In contrast to risk control, risk financing consists of techniques which guarantee the availability of funds to meet losses associated with the occurrence of pure risks. For this purpose, individuals or business firms can either transfer or retain the risks they are exposed to. The primary approach to transfer risk is the purchase of insurance. An alternative approach of transferring risk is the use of insurance securitization. Since insurance securitization is the subject of Chapters 5 and 6, it will be explained in a separate chapter (Chapter 3). Finally, all risks which cannot be avoided, reduced or transferred, have to be retained by individuals and business firms.

So far, the discussion implicitly assumed that individuals and business firms are aware of all risks which they are exposed to. However, the overall risk exposure of individuals and business firms generally consists of both perceived as well as unperceived risks. For obvious reasons, risks cannot be intentionally managed, when they are not recognized as such. For example, the decision to avoid, reduce, transfer or retain a certain risk can only be deliberately taken if individuals and business firms are in fact aware of this particular risk. In the absence of this awareness, risks will be retained unintentionally. Yet, the amount of unperceived risks is usually reduced as a result of managing the perceived risks. For example, if individuals or business firms decide not to buy an automobile, they simultaneously avoid all unperceived risks associated with owning an automobile. Figure 2-1 summarizes the aforementioned risk management techniques and various stages involved in the risk management process.

Next to knowing about the different risk management tools, it is equally important for individuals and business firms to know which risks are ideally to be avoided, reduced, transferred or retained. For this purpose, risk is usually broken down into two main criteria, namely (i) the severity of risk potential (i.e. the degree of potential damage) and (ii) the frequency of risk potential (i.e. the probability of the risk occurring). Depending on the combination of both severity and frequency of the risk potential, some risk management tools are more preferable than others.

Figure 2-1
Risk Management Tools and Process

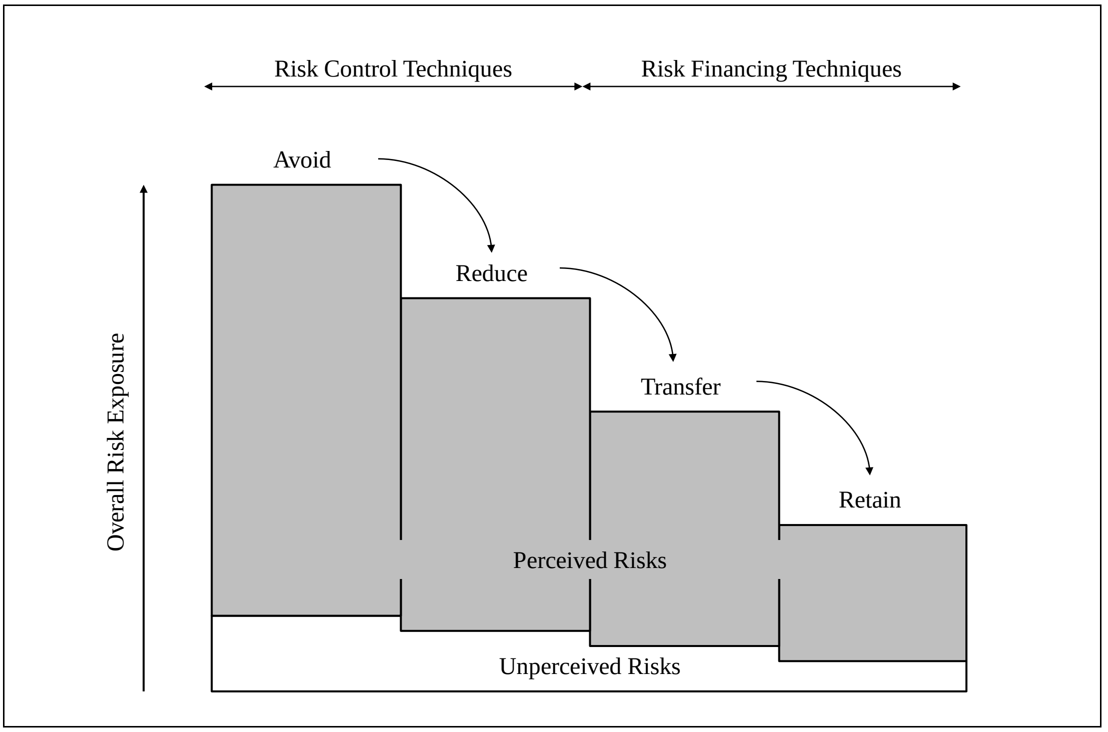
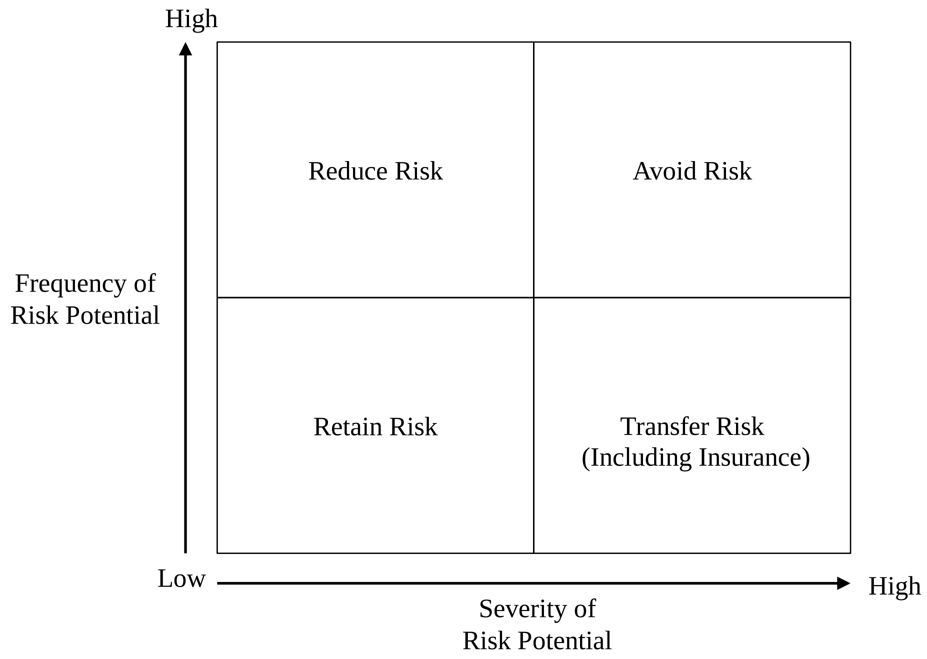


Figure 2-2 shows a so called risk matrix (as in Alexander and Marshall, 2006) which illustrates the different combinations of severity and frequency of the risk potential as well as the preferred risk management tools to deal with them. Accordingly, individuals and business firms are recommended to avoid any risks which bear both a high frequency and a high severity of risk potential, to reduce risks which bear a high frequency but a low severity of risk potential, to transfer risks which bear a low frequency but a high severity of risk potential, and to retain those risks which bear both a low frequency and a low severity of loss exposure. Therefore, individuals and business firms are best off insuring those risks which rarely happen but, if they do, usually cause substantial damages.

Figure 2-2
Risk Matrix



Source: Alexander and Marshall (2006).

2.2.2 Nature and Functions of Insurance

From the discussion above, it can be concluded that insurance is a risk management tool which belongs to the group of risk financing techniques aimed at transferring pure risks away from individuals and business firms. The transfer of risk, however, is only one of the two fundamental characteristics of insurance. The sharing (or pooling) of losses associated with the transferred risks among the members of a group (on some equitable basis) is equally essential for insurance to work properly. To better understand the way in which insurance works and to appreciate why insurance firms are crucial to the process of insuring those risks which individuals and business firms are exposed to, the following example is presented.

For the sake of simplicity, it is assumed that there are 1,000 individuals who each own a house worth $100,000. Further, each of those houses is exposed to the pure risk of catching fire. Consequently, each owner of a house faces the risk that a fire may result in a financial loss of up to $100,000. Given the realistic assumption that the event of all houses catching fire within the next year is highly unlikely, it can be expected that some owners will suffer a financial loss (of up to $100,000) due to a fire and some will not. However, if all 1,000 individuals agree to share the cost of losses equally among each other as they occur, individuals no longer had to face the risk of suffering a $100,000 loss. Instead, individuals would now have to pay a share of up to $100 each time a house catches fire. As a result, through the agreement to share the losses (i.e. the insurance agreement), the economic burden of an individual (i.e. the risk that an individual's house catches fire and causes an individual's financial loss of up to $100,000) is spread among the group of 1,000 individuals. In other words,

"*insurance does not decrease the uncertainty for the individual as to whether an event will occur, nor does it alter the probability of occurrence, but it does reduce the probability of financial loss connected with the event"* (Vaughan and Vaughan, 2003 pg. 34).

Since some members of the group might refuse to pay their proportionate of the amount of the loss in case of a house catching fire, members must pay their share in advance. This, however, creates problems, as the actual number of houses catching fire in the next year and the amount of the share members must pay to offset these future losses is unknown a priori. This is why insurance firms are crucial, because they can predict the future amount of losses on the basis of past experience within rather narrow limits. The reason why insurance firms are able to more accurately predict future losses (as compared to individuals and business firms) is based on the law of large numbers. According to the law of large numbers, the accuracy of empirical statistics (i.e. the proportionate individuals have to pay in order to offset future losses) tends to improve with the numbers of trials (i.e. the number of individuals which are exposed to the risk of their houses catching fire). Thus, by pooling thousands of homogeneous exposure units, insurance firms are able to make more accurate predictions for the exemplified group.

In doing so, insurance provides a more optimal utilization of capital as compared to retaining the risk. This is because individuals and business firms would have to maintain relatively large capital reserves to meet the risks they assume if insurance did not exist. Yet, through insurance, individuals and business firms can substitute a small certain cost (the insurance premium) for a large uncertain financial loss (the contingency insured against), and can use the released funds for investments possibilities.

Theoretically, all possibilities of losses could be insured. Nevertheless, for practical reasons, insurance firms are not willing to accept all risks which individuals and business firms seek to transfer to them. This is why the next subsection explains which elements a risk must meet in order to be accepted by insurance firms as an insurable risk.

2.2.3 Elements of an Insurable Risk

According to Vaughan and Vaughan (2003), risks which are typically insured by insurance firms *ideally* share the following characteristics:

(i) *Large number of homogeneous exposure units*: As mentioned earlier, successful insurance markets are based on the operation of the law of large numbers. Consequently, a large number of homogeneous exposure units increases the accuracy of future loss predictions by insurance firms.

(ii) *Definite and measurable loss*: For losses to be insurable, they need to be relatively difficult to counterfeit (i.e. the insurance firm must be able to tell when a loss has actually taken place), and they need to be financially measurable (i.e. the insurance firm must be able to put a price to the extent of it).

(iii) *Fortuitous or accidental loss*: The loss needs to be fortuitous, i.e. the event that constitutes the trigger of a claim must be something that may or may not happen. An event which is certain to happen (such as depreciation) is generally not considered insurable. Further, the event should be beyond the control of the insured. If the event was not beyond the control of the insured, losses would not occur as a result of chance and the prediction of future losses (which are based on the assumption that past experience was a result of chance happening) would be unreliable.

(iv) *Limited risk of dependent and very large losses*: Insurable losses are ideally independent, meaning that it is unlikely that a single loss event affects a very large number of exposure units at the same time, and that individual losses are not severe enough for an insurance firm to become insolvent.

As mentioned above, in order to be accepted by insurance firms as insurable, risks should *ideally* meet all of the aforementioned characteristics. However, it is possible for certain risks to be insured, even though they do not meet all of the characteristics listed above. One example of a risk which can be insured although it collides with at least one of the characteristics of an insurable risk is a natural catastrophe (such as a hurricane), as it bears the potential of affecting many exposure units at once as well as severely threatening an insurance firm's solvency. The discussion of natural catastrophes is, however, postponed until Chapter 3.

2.2.4 Types of Insurance

Next to knowing about the nature and functions of insurance as well as the elements of an insurable risk, another important issue relates to how the risks which individuals and business firms seek insurance for can be classified and how these different classifications of risk form the various types of insurance.

According to Vaughan and Vaughan (2003), all risks which exist for individuals and business firms can be classified under one of the following: (i) personal risks (such as the loss of income due to premature death or unemployment), (ii) property risks (such as the loss or loss of use of property due to natural catastrophes), (iii) liability risks (such as the unintentional injury of other persons or damage to their property), or (iv) risks arising from failure of others (such as the failure of a contractor to complete a construction project as scheduled).

In several countries, for some of these risks, it is required by law to buy insurance cover against the financial losses which might result from them. This type of insurance is generally referred to as *social insurance*. Social insurance is usually (but not always) organized and operated by the government and its primary emphasis is on social adequacy.[3] One of the most prominent examples of social insurance is the unemployment insurance, in which case workers contribute a fixed percentage of their gross salary in order to be entitled to some benefits (such as living allowances) in the case of unemployment.

Insurance which covers all remaining risks, for which there is no legal requirement to buy insurance for, is referred to as *private insurance*. Private insurance, therefore, consists of insurance programs which are (for the most part) voluntary for individuals and business firms. Private insurance is generally viewed as two distinct segments, i.e. life insurance and non-life insurance (which is sometimes referred to as general insurance). Life insurance is designed to protect individuals or their dependents against the financial losses of premature death or superannuation (i.e. the risk of outliving one's income-earning ability) by providing lump sums or annuities in the case of an insured event. Non-life insurance, on the other hand, is designed to protect against financial losses resulting from damage or loss of property (i.e. property insurance), financial losses arising from legal liability (i.e. liability insurance) as well as financial losses caused by sickness or accidental bodily injury (i.e. health insurance). This is why in some countries, for example the U.S., non-life insurance is further broken down into property and liability (P&L) insurance as well as health insurance. For a better overview, Figure 2-3 illustrates the different types of insurance.

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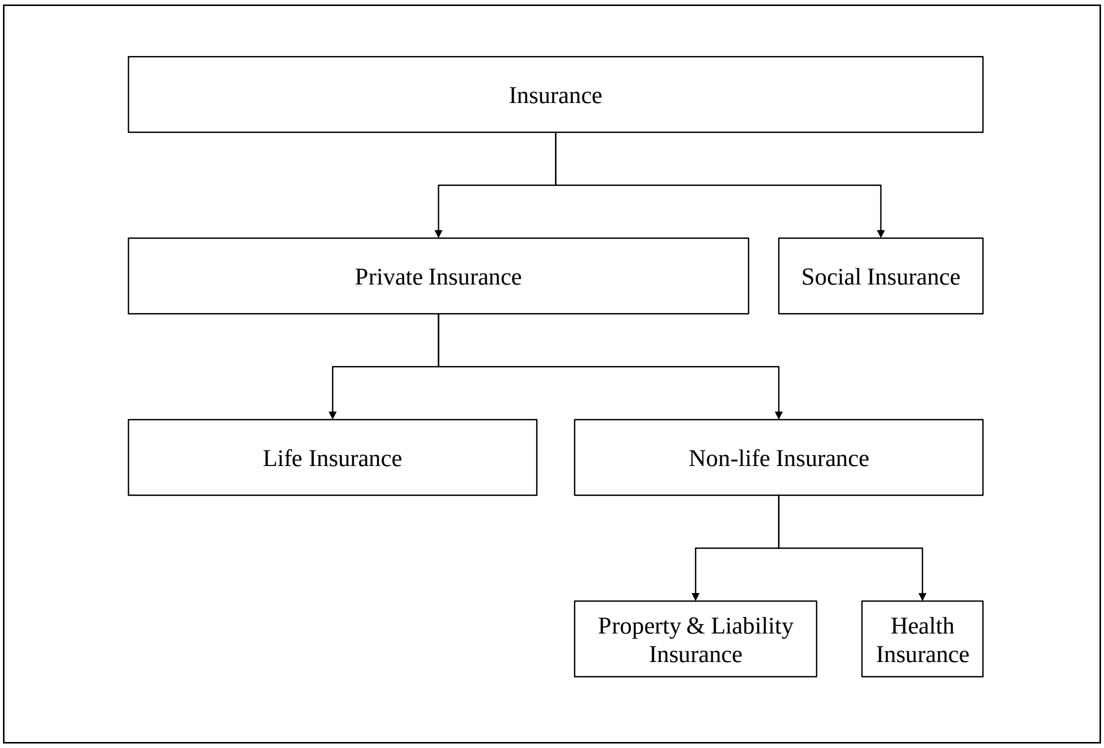
[3] Strictly speaking, insurance can still be considered as a form of social insurance even though it is not organized and operated by the government. One example is workers compensation in the U.S. (which provides benefits to workers in case of occupational injury or disease) which is sold by private insurance firms.

Figure 2-3
Types of Insurance



2.3 The Institutional Setting for Insurance and Reinsurance

This section now turns to the institutional setting for insurance and reinsurance. Since this thesis deals with firms of the private insurance and reinsurance industry, the institutional setting is concerned with the private insurance and reinsurance industry only. As a result, social insurance is not further investigated. The section starts by describing the different market participants as well as the most common forms of ownership for private insurance and reinsurance firms. Next, a detailed analysis of both the private insurance and reinsurance industry with a focus on recent developments and future challenges is presented. Finally, the importance of the investment income for both insurance and reinsurance firms is explained.

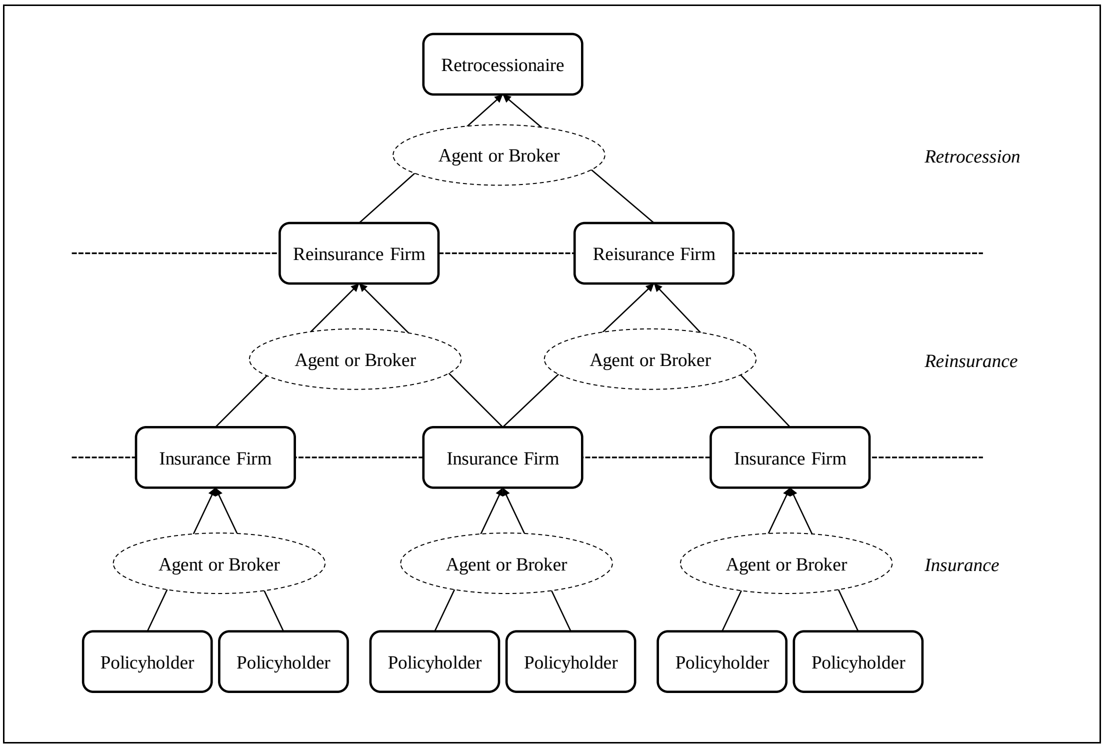
2.3.1 Market Participants and Forms of Ownership

Basically, the private insurance industry comprises of three main participants, i.e. (i) the buyers of insurance, (ii) the providers of insurance, as well as (iii) the distributors of insurance. Individuals and business firms (i.e. the policyholders) are generally referred to as the buyers of insurance, while insurance firms are referred to as the providers of insurance. Finally, brokers and agents are referred to as the distributors of insurance which interact between the insurance buyers and providers.

The main difference between brokers and agents is that agents are generally seen as the representatives of the insurance firm, while brokers are seen as the representatives of the policyholder. Brokers and agents mainly function as the marketing systems of the insurance industry, i.e. they mainly sell and consult both the buyers and providers of insurance. Yet, neither brokers nor agents are mandatory for the process of transferring risk from policyholders to insurance firms, i.e. policyholders can buy insurance directly without the intermediation of brokers or agents at all.

However, insurance firms themselves may buy insurance from other insurance firms. This process is called reinsurance and the insurance firms which offer reinsurance are referred to as reinsurance firms. As a result, insurance firms can act as providers as well as buyers of insurance. Likewise, reinsurance firms may buy reinsurance (either directly or through agents and brokers), a practice known as retrocession. Reinsurance firms which sell reinsurance are commonly referred to as retrocessionaires. For a better understanding, the relationships between the different market participants in insurance and reinsurance markets are summarized in Figure 2-4.

Figure 2-4
Insurance, Reinsurance and Retrocession



Based on their form of ownership, insurance and reinsurance firms can be classified as either stock insurers or mutual insurers.[4] The most common form of ownership is the stock insurer which is owned by its stockholders who, ultimately, assume the risks which are being transferred by the policyholders. As such, policyholders and owners are separated in the case of a stock insurer. Stock insurers generally provide two types of diversification benefits. First, stock insurers diversify the assumed risks internally (by issuing policies to many different policyholders in different lines of businesses and geographical regions). Second, the stockholders

[4] There exist even more forms of ownership for insurance and reinsurance firms (e.g. reciprocals, Lloyd's associations, health expense associations or government insurers). However, these forms of ownership account for only a very small percentage of global insurance and reinsurance firms and, as a result, are left out for the sake of simplicity.

offer additional diversification benefits by holding diversified portfolios (consisting of stocks of firms in other industries) which eliminate firm-specific risks. Since mutual insurers are owned by their policyholders, the latter diversification benefits cannot be released.

Another distinguishing characteristic between stock insurers and mutual insurers is that stock insurers require an upfront capital investment by their stockholders which is used to guarantee solvency in the event of adverse loss experiences. This is because the premium which stock insurers charge their policyholders is final, i.e. the premium does not include some form of contingent liability as in the case of mutual insurers. Thus, mutual insurers may collect further funds from policyholders at any time if the premium income is not sufficient to cover operating expenses and reimbursements to policyholders.

The need to access capital and the desire for further diversification benefits have caused several mutual insurers to change their ownership structure to a stock or modified stock insurer in recent years. Also, many insurance firms nowadays operate in groups (sometimes referred to as fleets), which consist of a number of insurance firms under common management and common ownership. Insurance groups were initially formed during the so called monoline era when the writing of both property and casualty business within one insurance firm was prohibited. Although this reason no longer exists, insurance groups expanded to now include not only life insurance firms, but also reinsurance firms under one roof. For example, the world's largest reinsurance firm Munich Re owns Ergo, which writes both life and non-life business. Also, Allianz (one of the biggest insurance firms in the world) writes both life and non-life business and owns a reinsurance firm called Allianz Re.

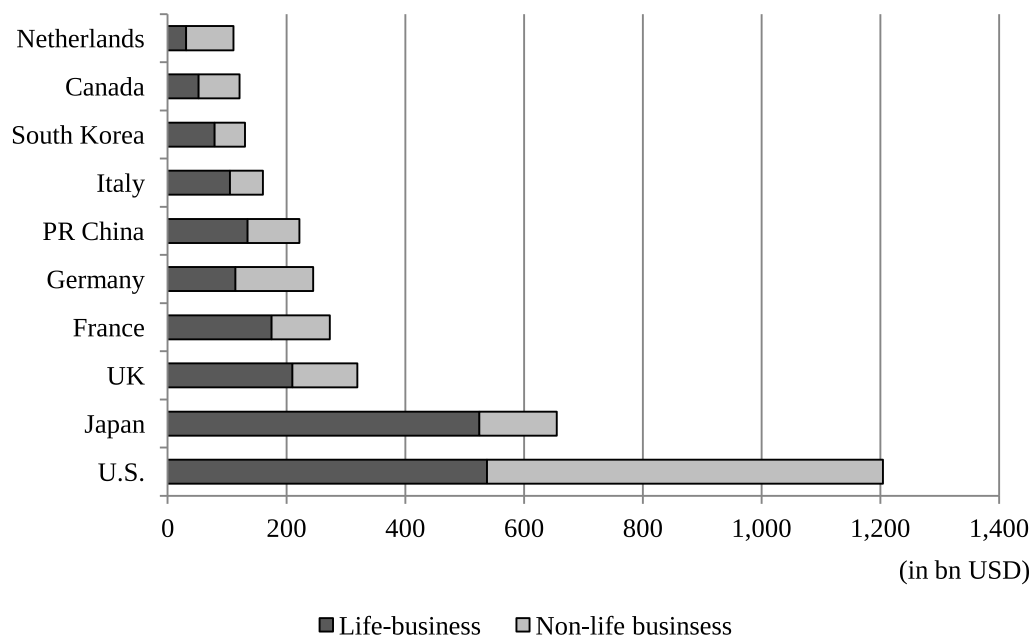
After the fundamentals of risk and insurance as well as the different participants of the insurance and reinsurance market have been described, the next three subsections will now give a broad overview of the recent developments and future challenges of both the private insurance and reinsurance industry. Also, an explanation of why the income from investment activities is fundamental for insurance and reinsurance firms is given. In doing so, the following subsections can provide a better understanding of the market size of the private insurance and reinsurance industry as well as the business activities of insurance and reinsurance firms in general.

2.3.2 The Private Insurance Industry: Recent Developments and Future Challenges

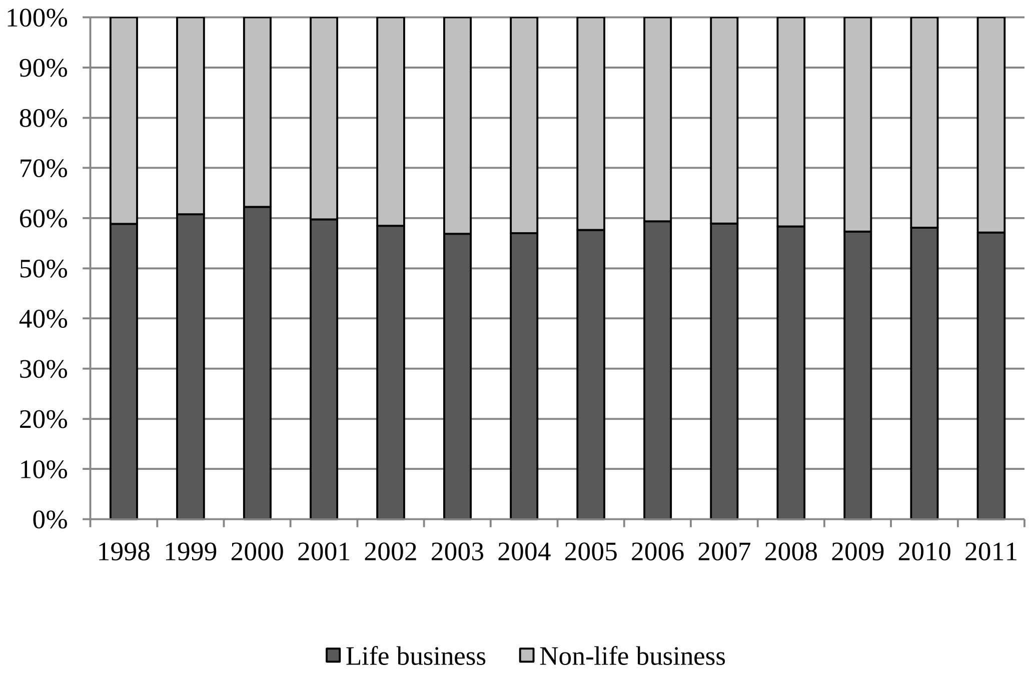
In 2011, the volume of global insurance premiums (including both life and non-life business) reached a record of $4,597 billion. With a total of $1,205 billion in total premium volume, the U.S. constituted by far the largest share of the global insurance market, followed by Japan ($655 billion), the UK ($ 320 billion) and France ($273 billion). Among the top ten countries in terms of total insurance premiums in 2011 (Figure 2-5 Panel A), most countries generated relatively higher premium incomes from life business as compared to non-life business. This is consistent with the historical trend in the global insurance market where the share of life premiums in global premium volume has ranged between 57% and 62% between 1998 and 2011 (Figure 2-5 Panel B).

Figure 2-5
Global Insurance Premium Volume by Year and Class of Business

Panel A: Top 10 Countries by Global Insurance Premium Volume in 2011



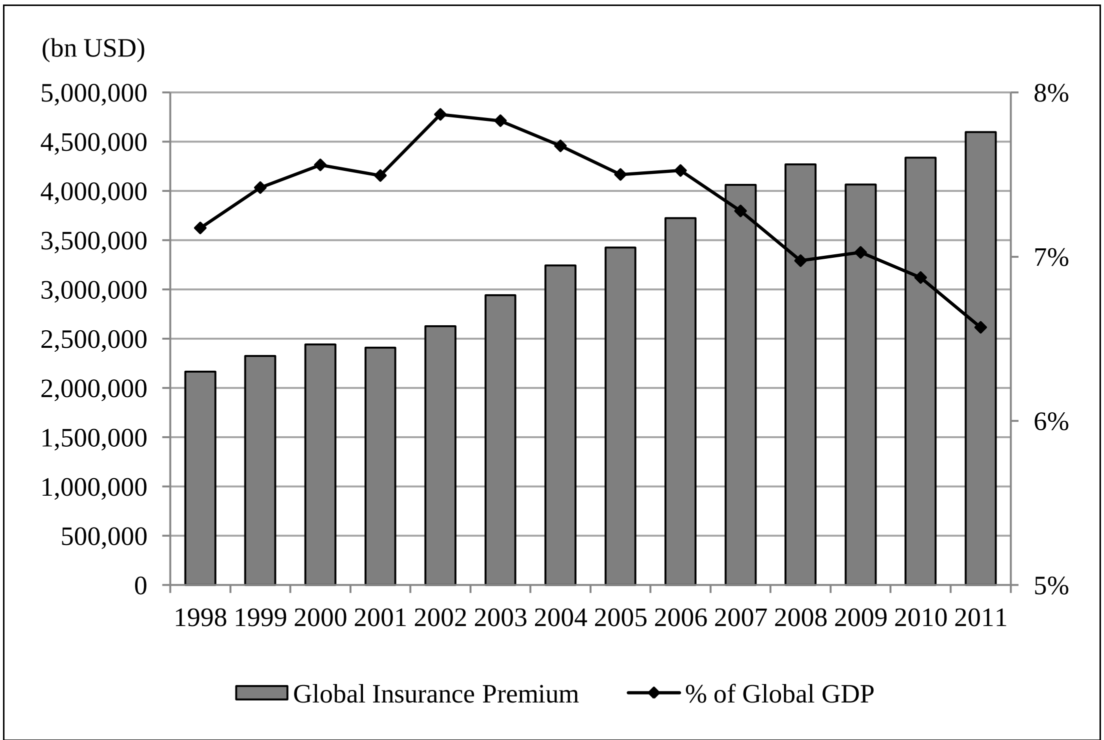
Panel B: Global Insurance Premium Volume by Class of Business



Notes: Insurance premiums are based on written premiums and are from Swiss Re (2012a).

The recent development of global insurance premium income is illustrated in Figure 2-6. The figure shows both the nominal (not adjusted for inflation) global insurance premium income as well as the percentage of global insurance premiums to global GDP for the period 1998 to 2011. It becomes apparent that, even though the volume of global insurance premiums has more than doubled during 1998 to 2011, the insurance market has recently struggled to generate significant premium growth. For example, the global insurance premium income increased by only less than 8% between 2008 and 2011. Also, the ratio of global insurance premium to global GDP fell from 7.8% in 2002 to 6.5% in 2011. This is a critical development for the insurance industry as it suggests that the premium growth in global insurance markets has underperformed global economic growth in the past ten years.

Figure 2-6
Nominal Global Insurance Premiums

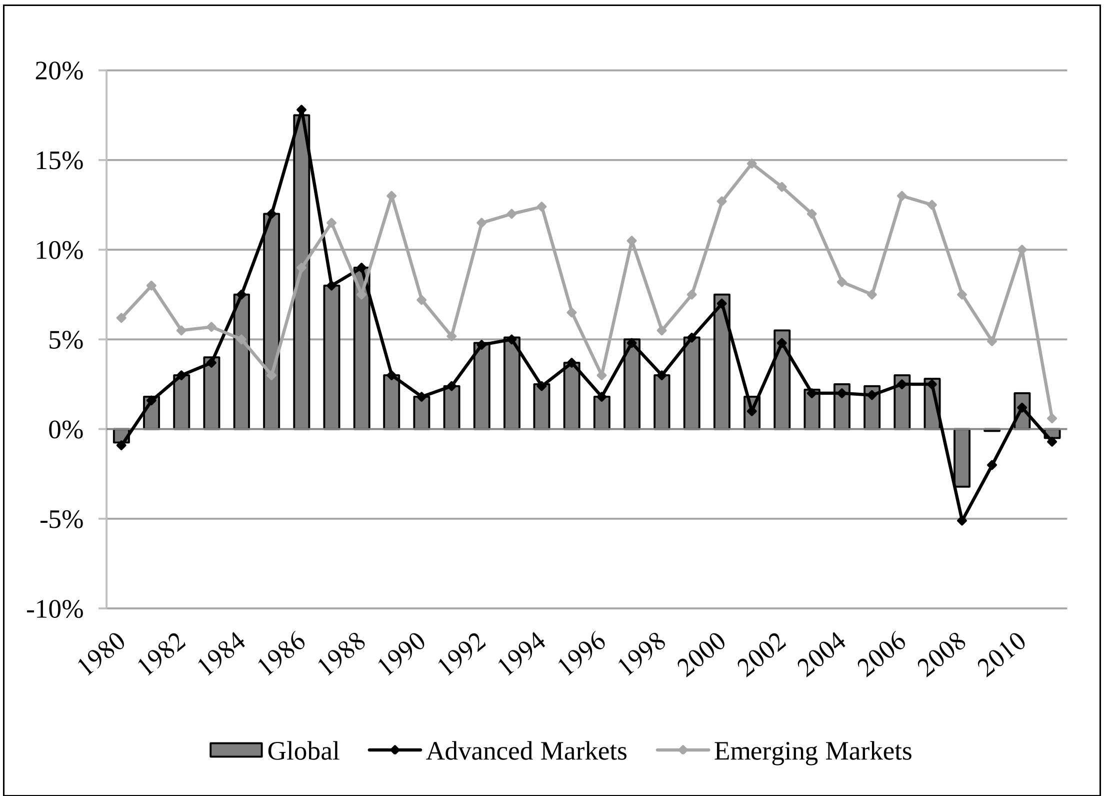


Notes: The figure shows nominal (not adjusted for inflation) global insurance premiums (including life and non-life business) and the percentage of global insurance premiums to global GDP for the period 1998 to 2011. Insurance premium data are based on written premiums and are from Swiss Re (2012a). GDP data are from IMF (International Financial Statistics database).

The recent trend towards low growth rates in global premium income is even more evident when global premiums are expressed in real terms as in Figure 2-7 which shows inflation-adjusted premium growth rates for the period 1980 to 2011 for (i) global insurance markets, (ii) advanced markets (i.e. North America, Western Europe, Continental Europe, Japan and Oceania) and (iii) emerging markets (i.e. South and East Asia, Latin America and the Caribbean, Central and Eastern Europe, Africa as well as Middle East and Central Asia). Thus, not only have the real growth rates in global insurance markets steadily declined since 1986 (when the insurance industry experienced its record year-to-year increase in premium income of nearly 18%), global growth rates have turned negative in the case of three years since 2008.

When comparing the growth rates in advanced markets with the growth rates in emerging markets, it becomes obvious that the downward trend in global insurance market premium income is clearly driven by advanced markets. Thus, there is a high correlation between growth rates in global insurance markets and growth rates in advanced markets. In contrast to the trend in both the global market and advanced markets, emerging markets have been able to generate significant premium growth throughout the past 20 years of nearly 8.5% per annum (p.a.). Yet, the relatively small share of emerging markets in global premium income of less than 20% has, so far, prevented a more noticeable influence on global premium growth.

Figure 2-7
Real Global Premium Growth

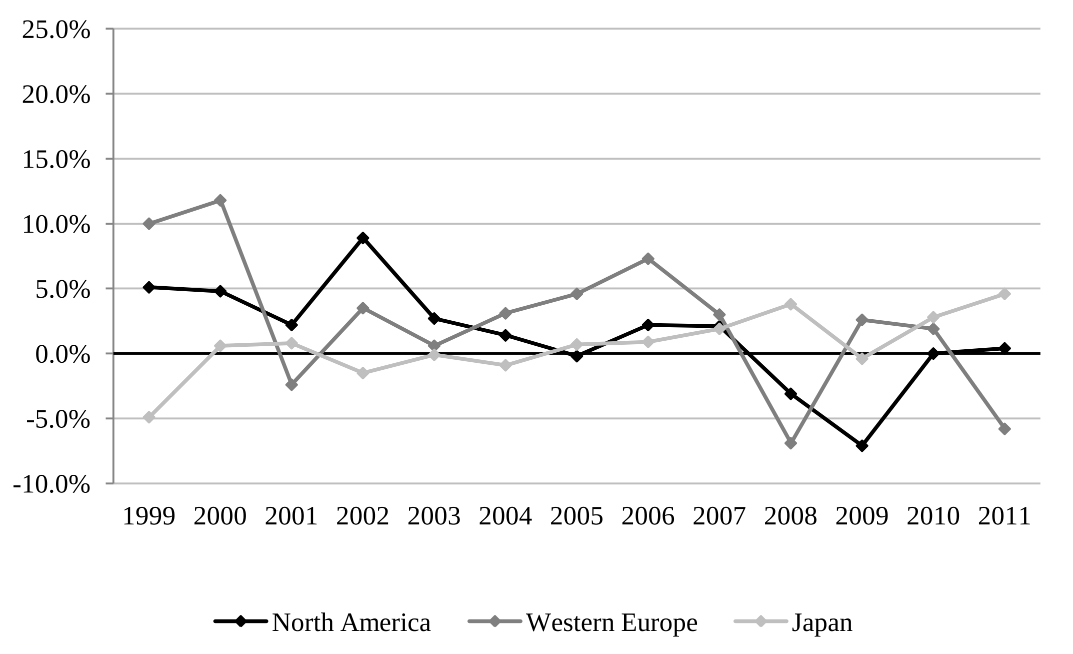


Source: The figure shows the real (inflation-adjusted) global premium growth (including life and non-life business) as well as the premium growth for both advanced and emerging markets for the period 1980 to 2011. The real growth rates are calculated using written premiums in local currencies which are adjusted for inflation using the individual consumer price index for each country. The data are from Swiss Re (2012a).

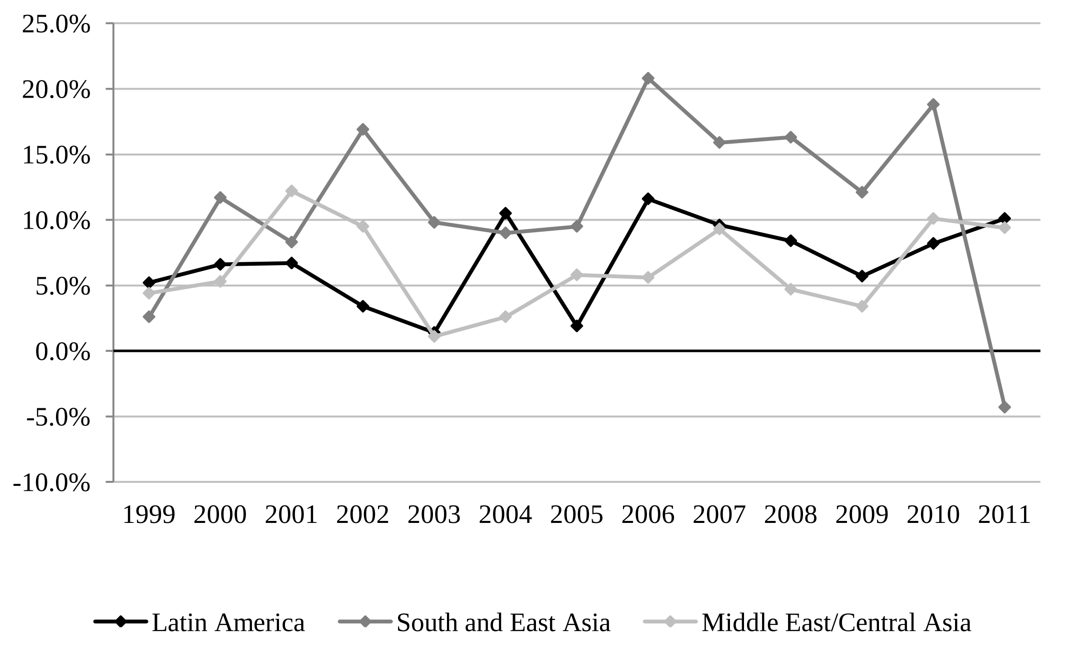
Figure 2-8 provides a closer look at the real (inflation-adjusted) premium growth rates in selected regions for both advanced markets (Panel A) and emerging markets (Panel B) for the period 1999 to 2011. The figure shows that, while the advanced markets North America and Western Europe have been struggling to generate positive premium growth rates in recent years (Panel A), the emerging markets Latin America, South East Asia or Middle East/Central Asia have had premium growth rates well in excess of 10% (Panel B). Among the emerging markets, especially South and East Asia have witnessed some of the strongest premium increases of up to 21% in 2006.

Figure 2-8
Real Premium Growth in Selected Regions

Panel A: Advanced Markets



Panel B: Emerging Markets



Notes: The figure shows real (inflation-adjusted) global premium growth (including life and non-life business) for a selection of countries in both advanced (Panel A) and emerging markets (Panel B) for the period 1999 to 2011. The real growth rates are calculated using written premiums in local currencies which are adjusted for inflation using the individual consumer price index for each country. The data are from Swiss Re (2012a).

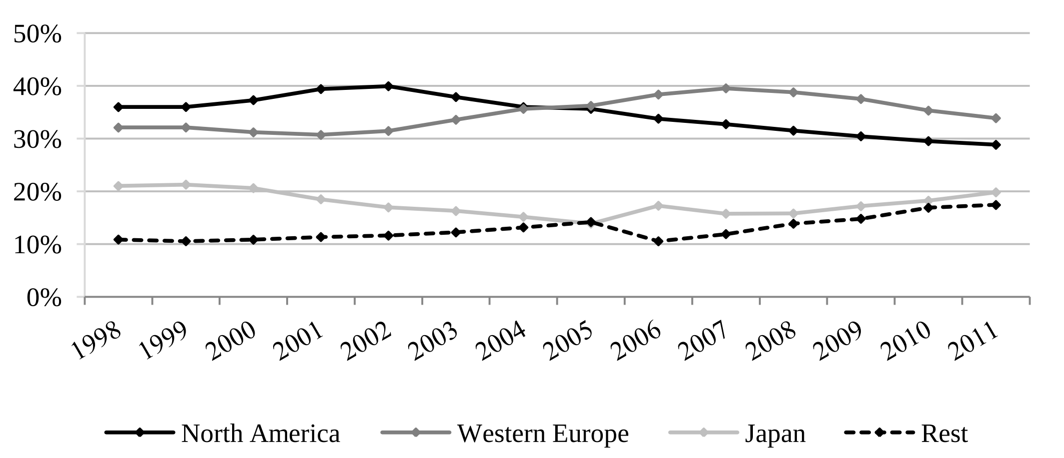
One effect of the substantial premium growth rates in countries such as Latin America or South East Asia in recent years is the shift in global market share of emerging markets. To illustrate this shift, Figure 2-9 shows the market share of North America, Western Europe and Japan (i.e. the vast majority of advanced markets) as compared to the rest of the world (i.e. mostly emerging markets) for the period 1998 to 2011. This comparison is done for the total insurance business including both life and non-life business (Panel A), as well as for life business (Panel B) and non-life business (Panel C), respectively.

Since 2004, Western Europe has replaced North America as the world's largest insurance market and, in 2011, Western Europe accounted for nearly 34% of global premium income (Panel A). The relative loss in market share of North America is mostly ascribed to two reasons. First, Western Europe and Japan have experienced a significant increase in their market share in life business during 2002-2007 and 2008-2011, respectively (Panel B). Second, North America, which has always been the largest non-life insurance market, has lost substantial market share in this business sector to emerging markets (Panel C). Thus, North America's share in non-life business dropped from 50% in 2001 to only 37% in 2011.

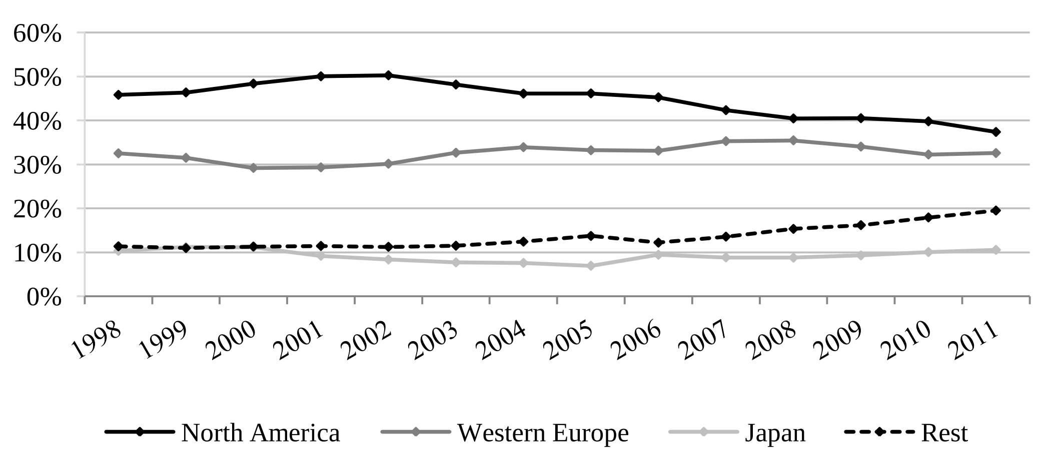
Nevertheless, Western Europe too has lost market share to both emerging markets as well as Japan in recent years. As a result, while the combined market share of Western Europe and North America accounted for nearly 70% in 2007, it dropped to 57% in 2011. During the same time period, emerging markets have almost doubled their market share from 10% in 2007 to nearly 18% in 2011, while Japan's market share increased by nearly 4% to 20%.

Figure 2-9
Market Share by Region and Business Class

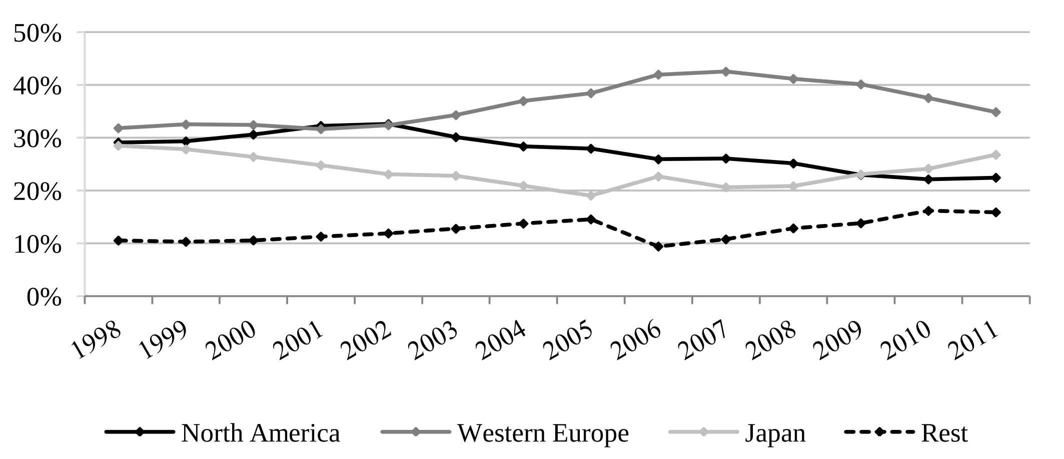
Panel A: Total Business (Non-life and Life Business)



Panel B: Non-life Business



Panel C: Life Business



Notes: The figure shows the changes in market share by region and year for total business (Panel A), non-life business (Panel B) and life business (Panel C). The data are from Swiss Re (2012a).

The substantial premium increase in both emerging markets as well as Japan is also evident in Table 2-1 which shows the world's 25 largest insurance firms in terms of premium income in 2010. For example, the two largest insurance firms *Axa S.A.* ($108 billion) and *Assicurazioni Generali S.p.A.* ($54 billion) which are both domiciled in Western Europe experienced only marginal premium income growth rates of less than 3% in 2010. At the same time, the Japanese insurer *Meiji Yasuda Life Insurance Company* as well as the Indian insurer *Life Insurance Corporation of India* could generate premium increases of nearly 22% and 18%, respectively.

Table 2-1
World's Largest Insurance Firms by Premium Income 2010

	Company Name	Country of Domicile	2010 Net Insurance Premiums Written USD (millions)	% Change since 2009
1.	Axa S.A.	France	107,912	0.20
2.	Assicurazioni Generali S.p.A.	Italy	87,166	2.87
3.	UnitedHelath Group Inc.	U.S.	85,405	7.68
4.	Allianz SE	Germany	84,433	6.25
5.	Japan Post Insurance Co. Ltd.	Japan	80,985	-4.77
6.	National Mut Ins Fed of Agricultural Co-ops	Japan	63,643	2.08
7.	Munich Reinsurance Co.	Germany	57,841	9.78
8.	WellPoint Inc.	U.S.	54,109	-2.51
9.	Aviva plc	UK	53,237	7.15
10.	China Life Insurance Co.	China	52,873	15.48
11.	Nippon Life Insurance Co.	Japan	52,182	-4.40
12.	State Farm Group	U.S.	55,296	2.32
13.	American International Group Inc.	U.S.	46,227	-5.34
14.	Kaiser Foundation Group of Health Plans	U.S.	45,025	-5.59
15.	Zurich Financial Services Ltd.	Switzerland	44,282	-7.69
16.	CNP Assurances	France	41,655	-0.46
17.	Life Insurance Corporation of India	India	41,326	18.32
18.	Dai-ichi Life Insurance Co. Ltd.	Japan	39,968	12.47
19.	Prudential plc	UK	37,456	21.20
20.	Meiji Yasuda Life Insurance Co.	Japan	35,630	21.97
21.	ING Groep N.V.	Netherlands	34,247	-9.50
22.	Sumitomo Life Insurance Co.	Japan	33,369	20.30
23.	Humana Inc.	U.S.	32,712	9.31
24.	Berkshire Hathaway	U.S.	30,916	10.88
25.	Tokio Marine Holdings Inc.	Japan	29,755	-4.26

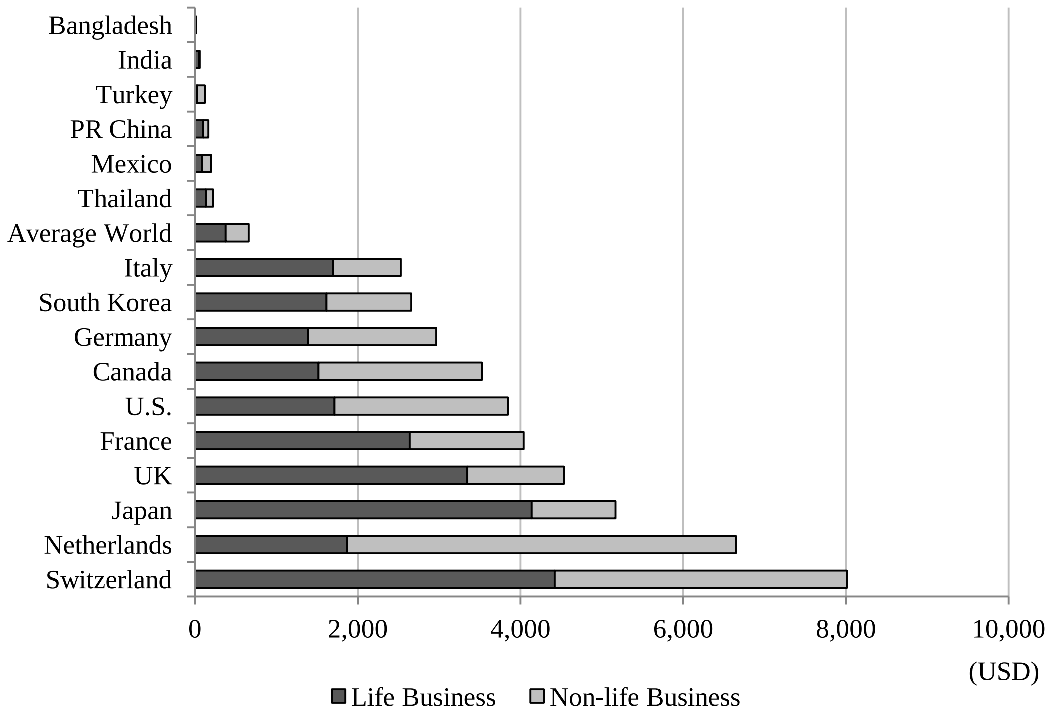
Notes: Insurance premiums include both life and non-life business and are from A.M. Best (2012).

It is expected that advanced markets such as Western Europe and North America will continue to face difficulties in generating significant premium growth in the next years. Emerging markets, however, are expected to benefit from future premium growth rates and, consequently, are likely to further increase their global market share in both life and non-life business segments. To provide evidence for this expectation, Figure 2-10 compares the insurance density (Panel A) as well as the insurance penetration (Panel B) for selected countries in both advanced and emerging markets in 2011. Both measures are commonly used to gauge the growth and development potential of insurance markets. While insurance density measures the per capita spending on insurance, insurance penetration measures premiums as a share of GDP. Lower than average insurance densities or insurance penetrations are generally interpreted as signals of future growth opportunities.

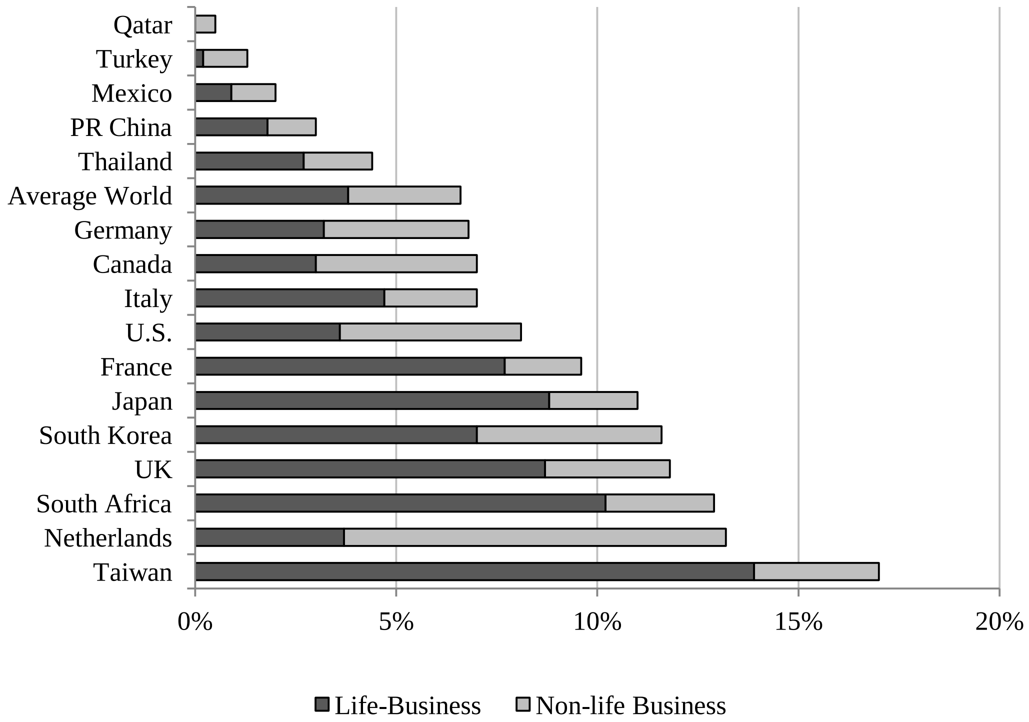
The global average per capita spending in 2011 totaled $661, including both life business ($378) and non-life business ($283). While it is less surprising to find that advanced countries are above this average, it is interesting to note that the insurance density varies extremely among countries, reflecting different stages of economic development. For example, the highest per capita spending of more than $8,000 is found in Switzerland while the emerging markets China and India produced a per capita spending of only $163 and $59, respectively. Similar results can be found as regards the insurance penetration in 2011. Thus, for most advanced markets the ratio of premiums to local GDP is weigh above the global average of 6.8% while the ratios in emerging markets such as China and Turkey are 3% and 1.3%, respectively. As a result, both the insurance density and insurance penetration point towards future premium growth in the insurance industry of emerging markets.

Figure 2-10
Insurance Density and Penetration for Selected Countries in 2011

Panel A: Insurance Density (Premiums per Capita, 2011)



Panel B: Insurance Penetration (Premium in % of GDP, 2011)



Source: Swiss Re (2012a).

2.3.3 The Private Reinsurance Industry: Recent Developments and Future Challenges

Reinsurance, as mentioned above, is the technique whereby insurance firms may transfer parts of the risks they assume (in insuring individuals and business firms) to other insurance firms (referred to as reinsurance firms). The risks which insurance firms transfer (or 'cede') to reinsurance firms are typically restricted to low-frequency but high-severity events such as natural catastrophes. As a result, the size of the global reinsurance industry should be much smaller as compared to the size of the global insurance industry.

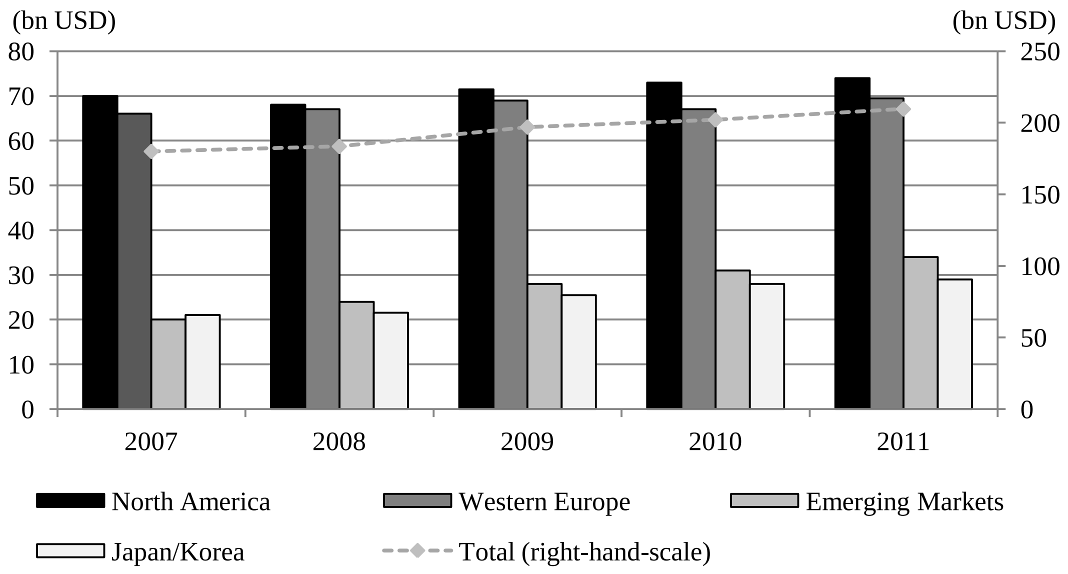
Figure 2-11 illustrates the size of the global reinsurance industry in terms of total reinsurance premium income (including life and non-life business) for the period 2007 to 2011. Also, the figure reports the premium income for North America, Western Europe, Japan and Korea as well as the aggregates for emerging markets (Panel A), and shows the corresponding growth rates (Panel B) during that time period.

Two important conclusions can be drawn from Figure 2-11. First, the volume of global reinsurance premiums has grown from less than $180 billion in 2007 to approximately $210 billion in 2011 (Panel A). This means that the global reinsurance industry (in terms of premium income) is indeed much smaller than the insurance industry (where the volume of global premium income has ranged between $4,000 billion and $4,600 billion during the same time period; see Figure 2-6). Second, and similar to the insurance industry, the advanced markets North America and Western Europe have struggled to produce significant premium growth in recent years as compared to emerging markets (such as China, India or South and East

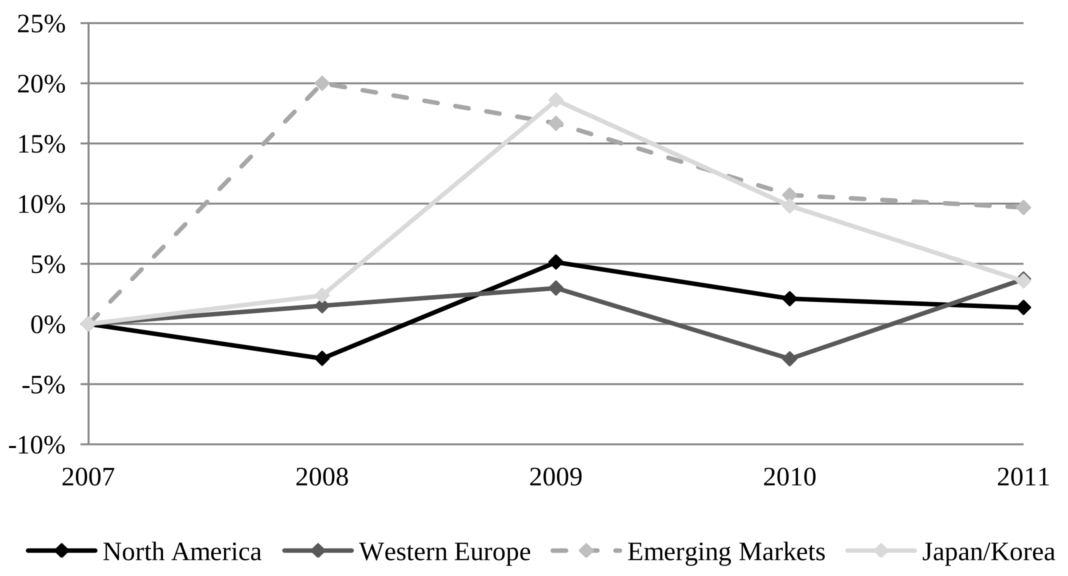
Asia) or Japan and Korea (Panel B). Thus, while the average annual premium growth rate in North America and Western Europe was only 1% p.a. during 2007 and 2011, emerging markets and Japan/Korea grew (on average) by 14% and 9%, respectively.

Figure 2-11
Reinsurance Premium Income and Growth by Region

Panel A: Global Reinsurance Premium Income by Region



Panel B: Reinsurance Premium Growth by Region



Notes: Insurance premiums are based on nominal (not adjusted for inflation) written premiums (including both life and non-life business) and are from Guy Carpenter (2012b).

Nevertheless, despite the strong growth rates in emerging markets in recent years, amongst the 25 largest reinsurance firms (in terms of written premium) in 2010 which are displayed in Table 2-2, there are only two reinsurance firms domiciled in emerging markets, i.e. *China Reinsurance Group Inc.* ($4 billion) and *General Insurance Corporation of India* ($3 billion). The largest reinsurance firms are *Munich Reinsurance Co.* ($31 billion), followed by *Swiss Reinsurance Co. Ltd.* ($25 billion) and *Hannover Rueckversicherung AG* ($15 billion).

Table 2-2
World's Largest Reinsurance Firms by Premiums Written 2010

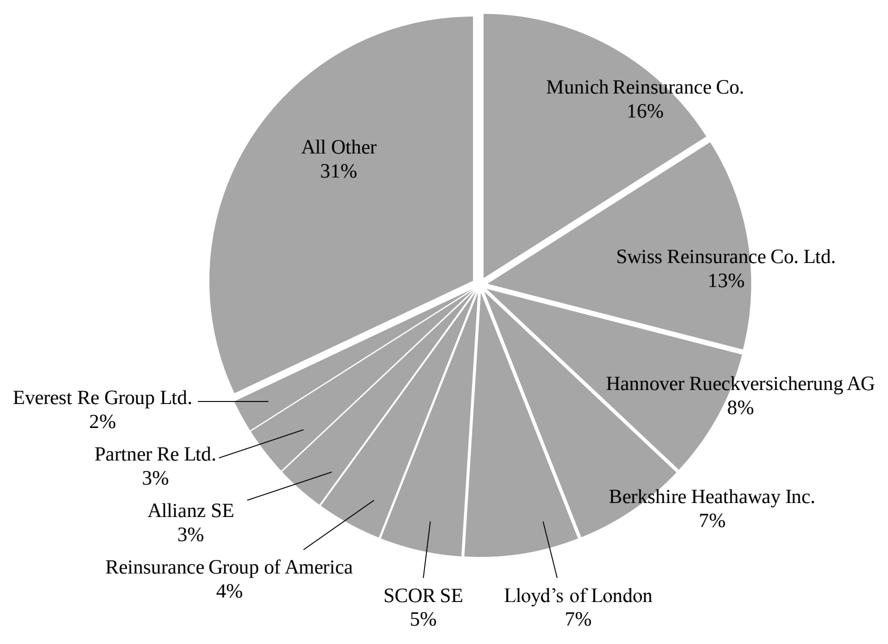
	Company Name	Country of Domicile	Reinsurance Premiums Written USD (millions) Life & Non-life	Reinsurance Premiums Written USD (millions) Non-life only
1.	Munich Reinsurance Co.	Germany	31,280	20,809
2.	Swiss Reinsurance Co. Ltd.	Switzerland	24,756	13,783
3.	Hannover Rueckversicherung AG	Germany	15,147	8,401
4.	Berkshire Hathaway Inc.	U.S.	14,374	9,171
5.	Lloyd's of London	UK	12,977	12,977
6.	SCOR SE	France	8,872	4,849
7.	Reinsurance Group of America	U.S.	7,201	0
8.	Allianz SE	Germany	5,736	5,320
9.	PartnerRe Ltd.	U.S.	4,881	4,132
10.	Everest Re Group Ltd.	U.S.	4,201	4,201
11.	Transatlantic Holdings Inc.	U.S.	4,133	4,133
12.	Korean Reinsurance Company	Korea	4,114	4,114
13.	China Reinsurance Group Inc.	China	3,796	2,526
14.	London Reinsurance Group Inc.	UK	3,266	0
15.	MAPFRE RE Companies de Reaseguros SA	Spain	3,143	2,766
16.	General Insurance Corporation of India	India	2,573	2,566
17.	Assicurazioni Generali S.p.A.	Italy	2,463	776
18.	AEGON N.V.	Netherlands	2,391	0
19.	QBE Insurance Group Ltd.	Australia	2,280	2,280
20.	XL Group plc	UK	2,255	1,843
21.	MS&AS Insurance Group Holdings Inc.	Japan	2,206	2,206
22.	The Toa Reinsurance Company Ltd.	U.S.	2,021	2,021
23.	Axis Capital Holdings Ltd.	Bermuda	1,834	1,834
24.	Caisse Centrale de Reassurance	France	1,814	1,682
25.	Odyssey Re Holdings Co.	U.S.	1,625	1,625

Notes: Reinsurance premiums include both life and non-life business and are from A.M. Best (2012).

Against the background that the global reinsurance premium income in 2010 accounted for only $200 billion, Table 2-2 shows that the global reinsurance market is dominated by a few large reinsurance firms. To illustrate this fact, Figure 2-12 reports the market share of the ten largest reinsurance firms (in terms of reinsurance premium income in 2010). In doing so it becomes apparent that, while the three largest reinsurance firms account for more than one third of global reinsurance premiums, the ten largest reinsurance firms account for more than two thirds. It is estimated that the remaining 31% are shared globally among another 190 different reinsurance firms.

In sum, the reinsurance industry is relatively smaller (in terms of premium income) and much more concentrated as compared to the insurance industry. Yet, the reinsurance industry faces similar difficulties as the insurance industry, as it has recently struggled to generate significant premium growth in advanced markets.

Figure 2-12
Market Share Based on Reinsurance Premium Written 2010



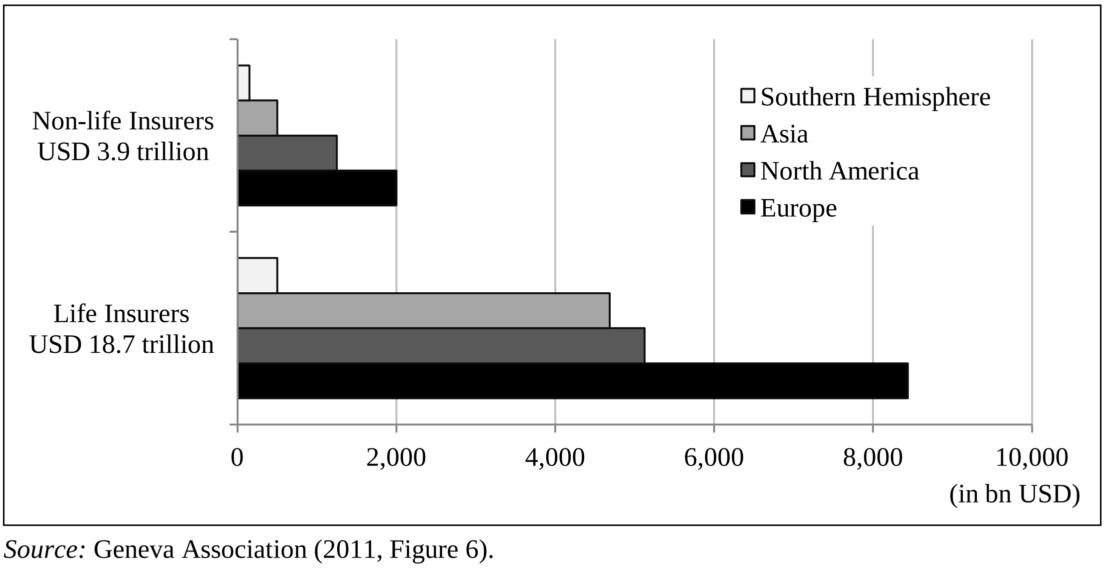
Notes: Reinsurance premiums include both life and non-life business and are from A.M. Best (2012).

2.3.4 The Importance of Investment Income

Insurance and reinsurance firms usually have substantial funds at their disposal for investments. The main reason is that insurance and reinsurance firms usually collect premiums from policyholders in advance of paying claims on the corresponding policies. Depending on the type of insurance policy, the time lag between collecting the premiums and paying off claims to policyholders can be significant. Especially in the case of life insurance contracts this time period can last up to several decades.

Figure 2-13 shows that in 2010 global insurance and reinsurance investments totaled $22.6 trillion. This is equal to 12% of global financial assets in 2010 according to the Geneva Association (2011). The vast majority of funds is held by life insurers and reinsurers who account for $18.7 trillion or nearly 83% of global insurance investments. Non-life insurers and reinsurers, on the contrary, only account for $3.9 trillion or less than 18% of global insurance investments. Geographically, Europe and North America are the largest investors in 2010 accounting for $10.5 trillion and $6.4 trillion in insurance investments, respectively.

Figure 2-13
Insurance and Reinsurance Investments by Region in 2010

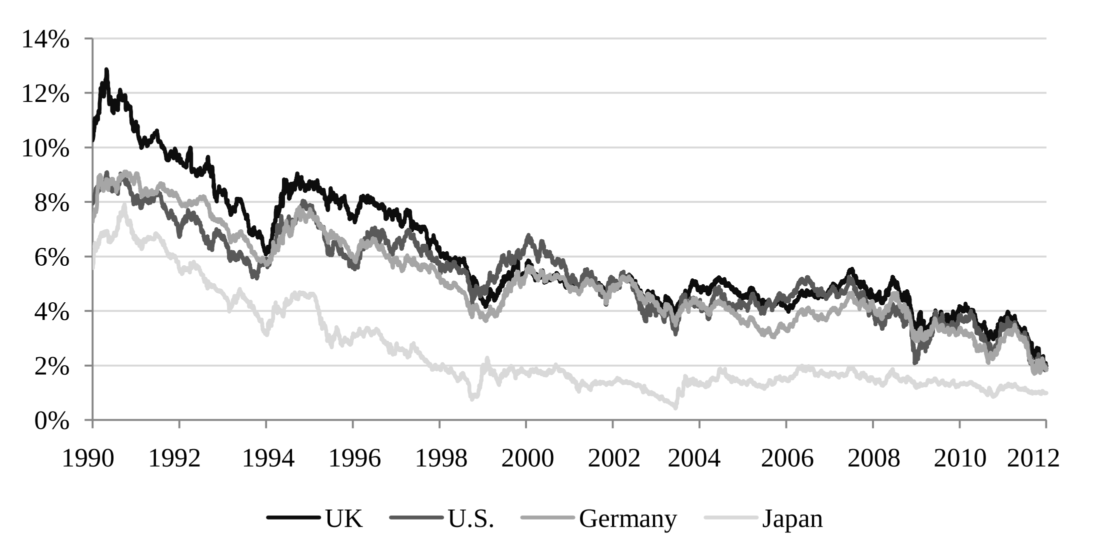


Source: Geneva Association (2011, Figure 6).

The income from investment activities is crucial for insurance firms in order to remain profitable. This is because most insurance and reinsurance firms do not generate profits from their underwriting operations. For example, according to several Swiss Re sigma reports (dating from 2000 to 2011), the insurers' combined ratio (which is a commonly used measure for underwriting performance, defined as the percentage of the premium dollar spent on claims and expenses) in North America has only been below 100% in 2004, 2006 and 2007 since 2000. This means that in the other nine years for the average of North American insurers, claims and expenses exceeded premium income, i.e. North American insurers produced underwriting losses. However, insurance and reinsurance firms usually offset these underwriting losses with the income from their investment activities.

Since most of the collected premiums by insurance and reinsurance firms need to be available at some future time (which us unknown in most cases) to reimburse policyholders for the insured losses, insurance firms are restricted in their investment opportunities by insurance regulation. As a result, two-thirds of global insurance investments are in bonds (Geneva Association, 2011). Stocks are less popular as an investment class as they are less liquid (in a case of a major insurance or market disaster) and exhibit more market risk as compared to bonds. However, long-term interest rates on bonds have been declining in the past decades and have reached a historical low at the beginning of 2012. Figure 2-14 illustrates this trend by showing the historical interest rates on ten-year government bonds for the UK, the U.S., Germany as well as Japan during the time period 1990 to the beginning of 2012. In the UK, for example, long-term interest rates declined from nearly 13% in 1990 to less than 2% at the beginning of 2012.

Figure 2-14
Long-term Interest Rates

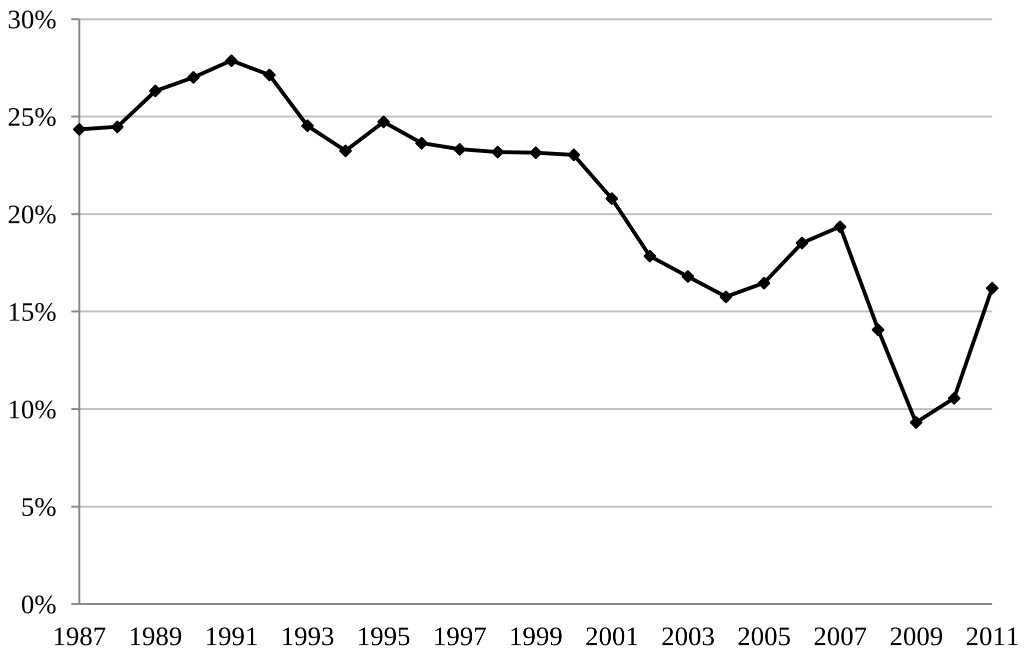


Notes: The figure shows the historical interest rates on ten-year government bonds for selected countries during the period 1990 to 2012 (March). The data are from Datastream.

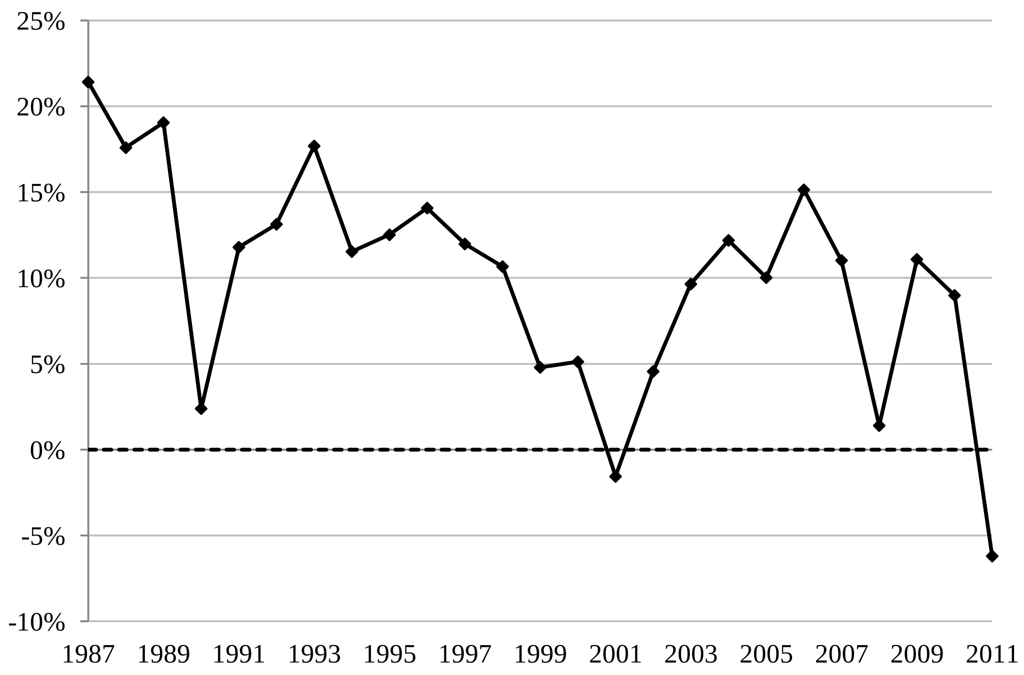
As a result of the declining long-term interest rates in the past decades, insurance and reinsurance firms increasingly face difficulties in maintaining their high levels of investment incomes. This becomes evident when the investment income is expressed as a % of premium income as in Figure 2-15 (Panel A). Thus, while the investment income for the sample of all listed insurance and reinsurance firms on Datastream accounted for more than 28% of premium income in 1991, it dropped to nearly 9% in 2009. Since then, the ratio has slightly recovered but still remains at a relatively low level (as compared to historical values) of 16%. As mentioned above, lower investment incomes are critical for insurance firms' profitability as insurers can no longer rely on this source of income to offset underwriting losses. This is illustrated in Figure 2-15 (Panel B) which shows the return on equity of all listed insurance and reinsurance firms on Datastream for the period 1987 to 2011. Though the return on equity is highly volatile (ranging from 21% in 1988 to -6% in 2011) the overall historical trend is clearly downward facing.

Figure 2-15
Investment Income and Return on Equity

Panel A: Investment Income as a % of Premiums Income



Panel B: Return on Equity



Notes: The figure reports the investment income as a % of premium income (Panel A) as well as the return on equity (Panel B) for all insurance and reinsurance firms listed on Datastream for the period 1987 to 2011.

2.4 Summary and Conclusions

As the first of two background chapters to the thesis (Chapters 2 and 3), this chapter started off by explaining the fundamentals of risk and insurance, which was followed by a discussion of the institutional setting for the private insurance and reinsurance industry.

By explaining the fundamentals of risk and insurance, it could be shown that insurance can be interpreted as a risk management tool which belongs to the group of risk financing techniques. Also, the two fundamental characteristics of insurance (i.e. the transfer of risk and pooling of losses) were explained and it was argued that (due to the law of large numbers and pooling thousands of homogeneous risk exposure units) insurance firms are better able to predict future losses within rather narrow limits as compared to individuals and business firms. Finally, it was shown that insurance provides a more optimal utilization of capital, and that individuals and business firms are best off purchasing insurance against those risks which rarely happen but, if they do, usually cause substantial financial losses.

The discussion of the institutional setting revealed that global insurance and reinsurance markets have been struggling to generate significant premium growth in recent years. At the same time, historically low interest rates have caused the investment income of both insurance and reinsurance firms to significantly decline. This means that insurance and reinsurance firms can no longer rely on their investment income to offset underwriting losses. As a result, insurance and reinsurance firms are increasingly put at risk of suffering major financial losses in the event of large underwriting losses. This requires insurance and reinsurance firms to manage their exposure to large underwriting losses more carefully than ever before.

3
The Market for Catastrophe Risk and Insurance Securitization[5]

3.1 Introduction

The previous chapter shows that for insurance and reinsurance firms the management of their exposure to large underwriting losses (i.e. their exposure to catastrophe risk) has become more important than ever before in order to remain profitable. This chapter (the second of two background chapters to this thesis) now provides an overview of the market for catastrophe risk, including both the development in economic and insured losses from catastrophe risks as well as the problems faced by individuals, business firms and insurers in transferring catastrophe risks through insurance and reinsurance. Further, and following the overview of the market for catastrophe risk, an alternative approach of transferring catastrophe risk is discussed, namely the securitization of catastrophe risk. This discussion consists of the concept of insurance securitization in general (and of Cat bonds in particular), as well as a brief overview of the development of the Cat bond market.

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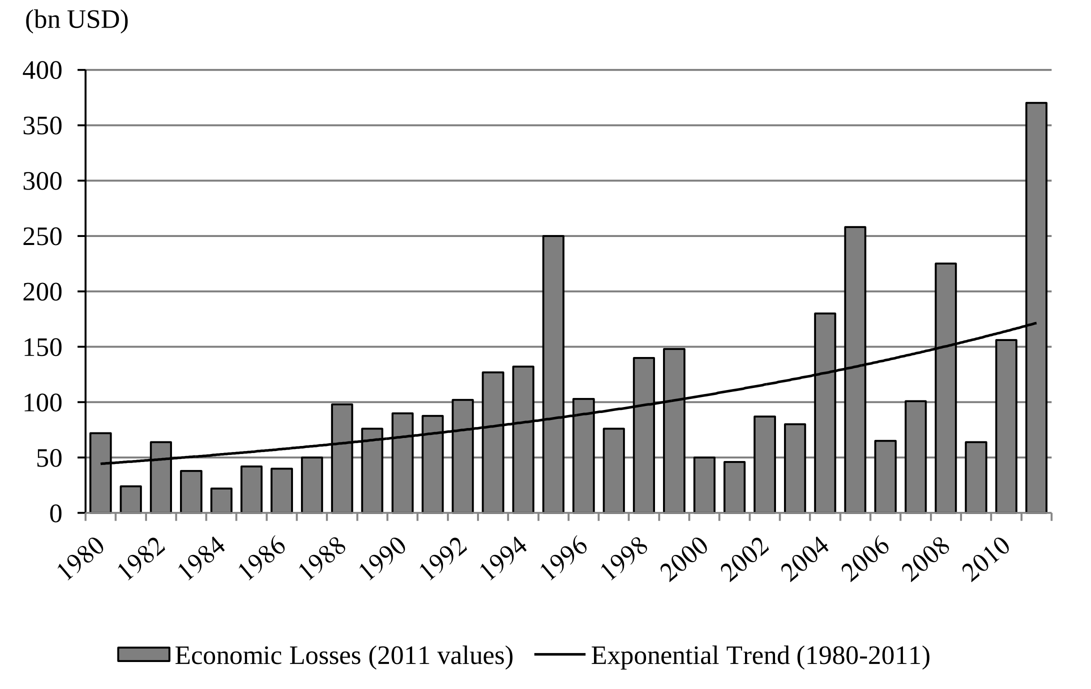
[5] Parts of this chapter have been published in Hagendorff, B., Insurance-linked Securities – Here to Stay? (Master thesis, 2009, Chapter 2).

From the discussion below, it will become evident that capacity constraints in the market for catastrophe risk prevent an efficient sharing of catastrophe risk among market participants (leaving individuals, business firms and insurers no choice but to retain the vast majority of their catastrophe risk exposure) and that insurance securitization could ease the markets' constraints by providing additional underwriting capacity for firms exposed to catastrophe risk. However, while the market for insurance securitization has undergone rapid growth in response to a general increase in the amount of catastrophe-related underwriting losses, global volumes of insurance securitization still lag behind expectations. This raises questions about the general need of insurance and reinsurance firms for additional risk-financing capacity and casts doubt on the usefulness and effectiveness of insurance securitization as a risk management tool.

3.2 The Market for Catastrophe Risk

The past decades have seen a remarkable increase in economic losses from catastrophe risks (i.e. mainly losses from natural catastrophes such as hurricanes, earthquakes, wind and ice storms, floods, etc). This trend becomes evident in Figure 3-1 which shows global economic losses associated with natural catastrophes for the period 1980 to 2011. Especially low-frequency but high-severity events, such as the recent tsunami in Japan (or Hurricane Katrina in 2005) which caused more than $200 billion ($100 billion) of economic losses, have contributed to the increase in catastrophe losses from natural catastrophes. This trend is expected to continue, given the growth rates in both physical asset values as well as population in high-risk zones (Froot, 2001).

Figure 3-1
Economic Losses from Natural Catastrophes with Trend



Source: Munich Re (2012).

To avoid large and unexpected losses from natural catastrophes, owners of physical capital (i.e. mainly individuals and business firms) can share their catastrophe risk exposure with others through the purchase of insurance (as explained in Chapter 2). As a result of this risk transfer and the increase in economic losses from natural catastrophes, insurance firms too have experienced a dramatic increase in both the magnitude as well as frequency of underwriting losses linked to natural catastrophes in recent years. For example, Table 3-1 reveals that eight out of the ten most expensive natural catastrophes for insurance firms (in terms of insured losses) have occurred in the past ten years.

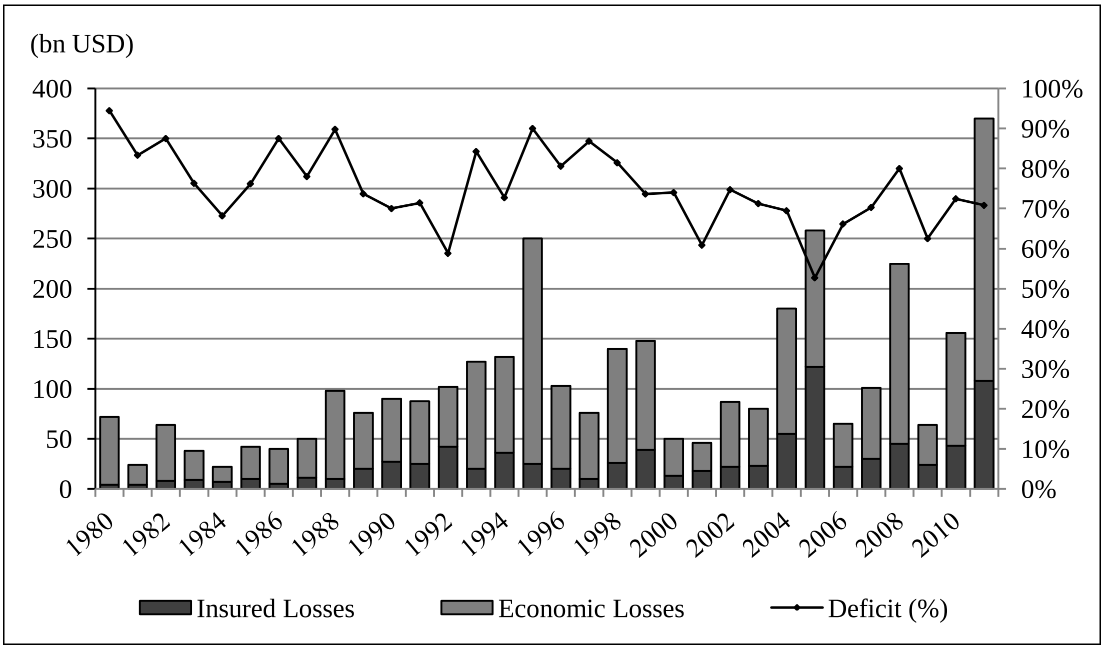
Table 3-1
Ten Most Costly Natural Catastrophes in Terms of Insured Losses

Insured Loss (bn USD)	**Date** (start)	**Event**	**Country**
74,686	25.08.2005	Hurricane Katrina	U.S., Gulf of Mexico, Bahamas
35,000	11.03.2011	Earthquake triggers tsunami	Japan
25,641	23.08.1992	Hurricane Andrew	U.S., Bahamas
21,239	17.01.1994	Northridge earthquake	U.S.
21,141	06.09.2008	Hurricane Ike	U.S., Caribbean, et al.
15,350	02.09.2004	Hurricane Ivan	U.S., Caribbean, Barbados, et al.
14,468	19.10.2005	Hurricane Wilma	U.S., Mexico, Jamaica, Haiti, et al.
12,000	27.07.2011	Flood	Thailand
12,000	22.02.2011	Earthquake	New Zealand
11,625	20.09.2005	Hurricane Rita	U.S., Gulf of Mexico, Cuba

Notes: Losses are in constant 2011-USD terms based on the Consumer Price Index (All Urban Consumers) and are from Swiss Re (2012b).

One of the main problems associated with the recent increase in underwriting losses from natural catastrophes for insurance firms is that the global risk-financing capacity of natural catastrophes in the insurance industry has remained limited to date. For example, in case of a $200 billion catastrophe the U.S. P&L insurance industry could only pay 78.6% of losses (based on 1997 capitalization), leaving open the prospect of insolvencies and instability in global insurance markets in the event of a severe natural catastrophe (Cummins et al., 2002). Owing to the limited risk-financing capacity, insurance firms have been willing to insure only fractions of the economic losses caused by natural catastrophes, while the great bulk of economic losses is retained by individuals and business firms (see also D’Agostino, 2002). To illustrate this behavior, Figure 3-2 shows the deficit of insurance cover for natural catastrophes as a percentage of total economic losses from natural catastrophes for the period 1980 to 2011. It becomes evident that the deficit of insurance cover for natural catastrophes has ranged between 53% and 94% during this time period.

Figure 3-2
Deficit of Insurance Cover for Natural Catastrophes

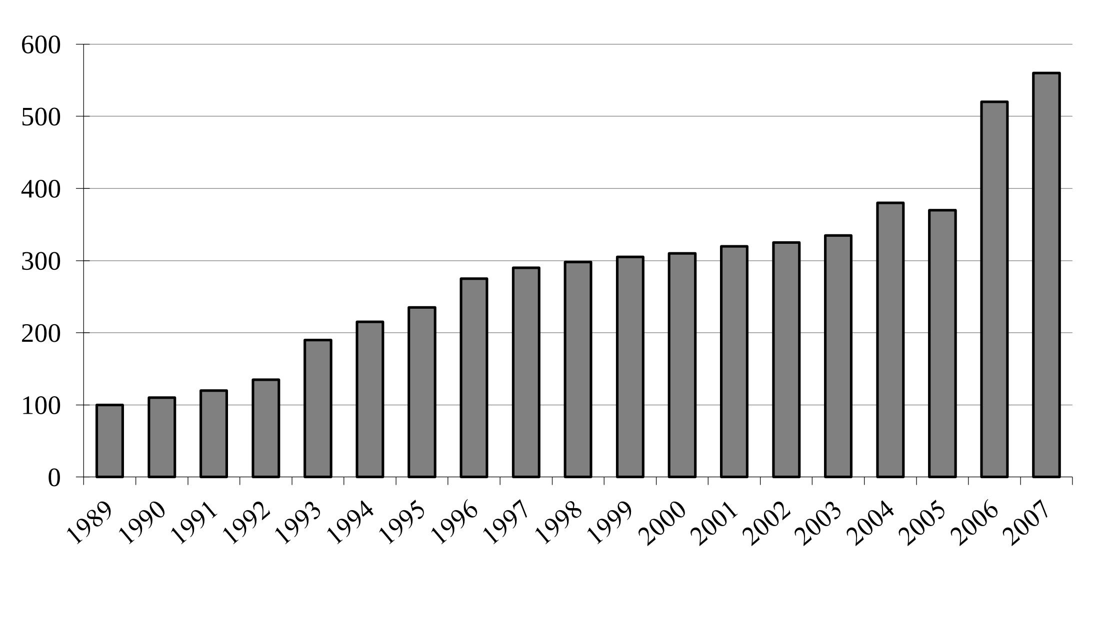


Notes: Figures are in constant 2011-USD terms based on the Consumer Price Index (All Urban Consumers) and are from various Swiss Re Sigma Reports dating from 1998 to 2012 as well as Munich Re (2012). The deficit of insurance cover for natural catastrophes is calculated as the percentage of uninsured losses to total economic losses from natural catastrophes.

In order to increase the risk-financing capacity of natural catastrophes, insurance firms can purchase reinsurance to share their exposure to catastrophe risk with reinsurance firms. However, Froot (2001) finds that insurance firms purchase relatively little reinsurance against catastrophe losses, even though risk management theory suggests protection against the losses of large catastrophe events is most valuable (Froot et al., 1993).

Figure 3-3 shows the retention rate for natural catastrophe risks of U.S. insurance firms for the period 1989 to 2007 and illustrates that insurance firms have continuously been retaining more natural catastrophe risks, especially in recent years. This is problematic as the limited ability to share catastrophe risks with reinsurance firms increases the risk of major financial losses and potential insolvencies in insurance markets in the event of a severe natural catastrophe (Froot, 2001).

Figure 3-3
Retention Rate for Natural Catastrophe Risk of U.S. Insurers

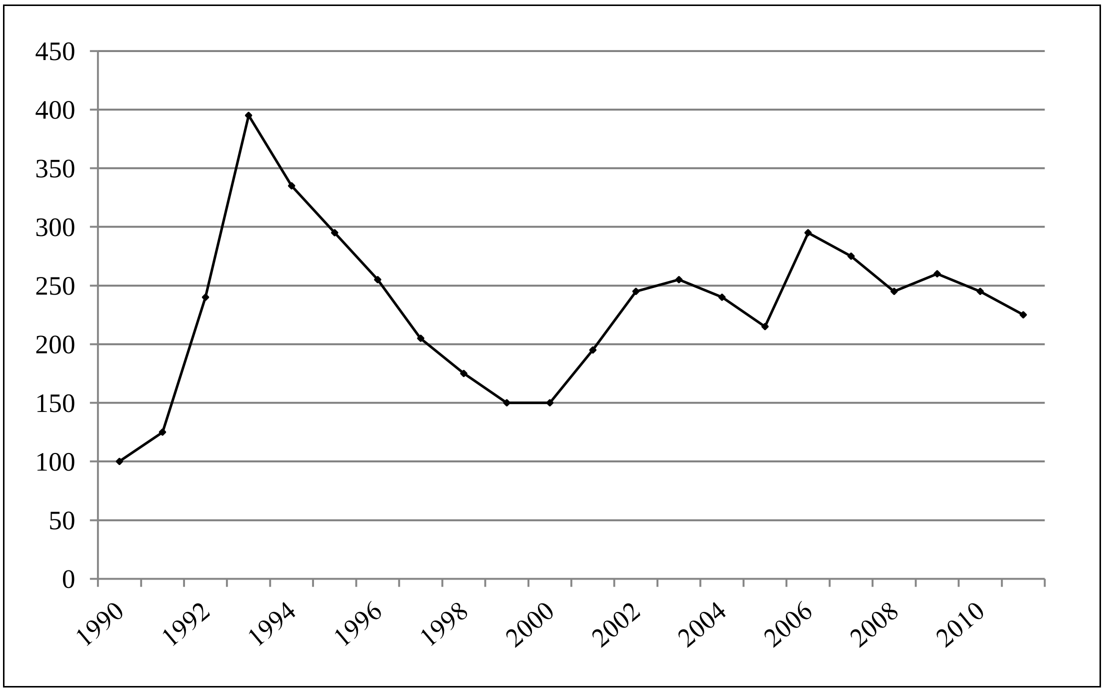


Source: Approximation of Guy Carpenter (2007). 1989 = base year set to 100. Figures for 2008 to 2011 were not available at the point this thesis was completed.

One of the main reasons as to why insurance firms make only little use of catastrophe reinsurance is that the reinsurance industry is also subject to capacity constraints (Weiss and Chung, 2004; Cummins, 2007). As a result, insurance firms too face difficulties in transferring their exposure to catastrophe risk. For example, due to capacity constraints in the reinsurance market, catastrophe reinsurance proves to be relatively expensive (with premiums for catastrophe cover being usually a multiple of expected losses, see Froot, 2001 or Froot and O'Connell, 2008). Also, the capacity constraints cause severe price instability for catastrophe reinsurance, a phenomenon known as the underwriting cycle, which poses difficulties in accurately predicting the costs of risk management via reinsurance. The underwriting cycle is characterized by periods when reinsurance prices are relatively low and coverage is readily available (soft markets) and periods when reinsurance prices are high and coverage supply is restricted (hard markets).

Figure 3-4 shows the global Guy Carpenter catastrophe reinsurance rate on line (ROL) index for the period 1990 to 2011. The index is calculated by dividing the contractual reinsurance premium by the reinsurance limit and converting the results into a percentage. Figure 3-4 reveals two important findings. First, prices for catastrophe coverage have varied substantially (up to 400 per cent) during the period 1990 to 2011. Second, it becomes evident that hard markets are usually triggered by large natural catastrophes. Thus, the ROL index spiked dramatically in response to Hurricane Andrew in 1992, the World Trade Centre terrorist attacks in 2001 as well as Hurricane Katrina in 2005. Similar evidence for price cycles can also be found in insurance markets (see Gron, 1994).

Figure 3-4
Catastrophe Reinsurance Rate on Line Index



Source: Guy Carpenter (2012a). 1990 = base year set to 100.

In sum, the past decades have seen a remarkable increase in economic and underwriting losses from natural catastrophes. This poses great risks to owners of physical capital and insurance firms, as evidence shows that the current market for catastrophe risk is subject to capacity constraints which prevent an efficient sharing of the exposure to catastrophe risk among market participants. As a result, individuals and business firms have no choice but to retain most of their exposure to catastrophe risk and face the possibility of major financial losses in the event of a severe natural catastrophe. In the same vein, insurance firms are increasingly put at risk of becoming concentrated warehouses of catastrophe exposure (leading to the increasing possibility of catastrophe-induced insolvencies) as the capacity to transfer catastrophe risk to reinsurance firms is limited and causes prices for catastrophe reinsurance to remain at relatively high levels.

3.3 Insurance Securitization: The Case of Catastrophe Bonds

Capital markets can draw on a larger, more liquid and more diversified pool of capacity than the equity of insurance and reinsurance firms (Durbin, 2001). Consequently, capital markets seem to be a viable source for insurance and reinsurance firms to markedly increase the global risk-financing capacity of natural catastrophes and to establish a more efficient sharing of the exposure to catastrophe risk among the participants in the market for catastrophe risk.

Insurance securitization has long been hailed as a promising vehicle for accessing capital markets for providing additional risk-financing capacity (e.g. Jaffee and Russell, 1997; Froot, 2001). Insurance securitization is a general term that covers various instruments designed to transfer both non-life as well as life insurance risks to capital markets. Depending on how strictly the term insurance securitization is defined, instruments range from pure financial instruments to so called *hybrid* *products*, which combine features of financial instruments and traditional insurance and reinsurance.[6] Cat bonds are pure financial instruments and, irrespective of which insurance securitization definition is applied, have been by far the most successful securitization vehicle (as measured by total issued risk capital) for transferring insurance-related underwriting risks to capital markets to date (Cummins and Trainar, 2009).

Cat bonds are sometimes referred to as insurance-linked securities (ILS). Strictly speaking, however, the term ILS serves as a subordinate for bonds whose coupons and principal payments are contingent on the performance of a pool or index of insurance-related risks. Based on the underlying risk type of these bonds, ILS can be categorized into either catastrophe bonds and non-catastrophe bonds, or into property and casualty (P&C) bonds and life bonds. Until recently, Cat bonds had solely been used to transfer extreme P&C risks such as hurricanes and earthquakes to the capital markets, whereas life bonds had preliminarily provided financing backed by future premium flows (life securitization). During that time literature used the terms Cat bonds and P&C bonds synonymously which could be clearly defined to life bonds. Meanwhile, some life bonds have been issued to purely transfer catastrophe mortality risk (Cowley and Cummins, 2005).[7] Cat bonds and life bonds are, therefore, no longer mutually exclusive terms given that *"some life bonds are now Cat bonds"* (Helfenstein and Holzheu 2006, pg. 4).

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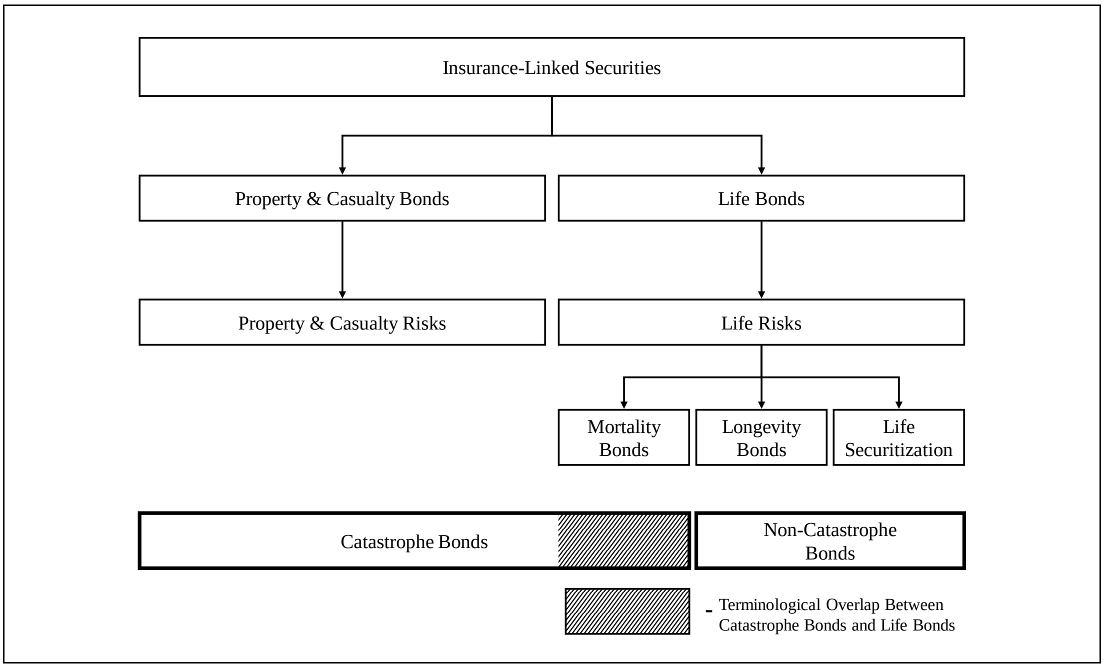
[6] Pure financial instruments are amongst others catastrophe swaps and options, as well as contingent capital. Examples of hybrid products include sidecars, industry loss warranties and finite reinsurance. For more details on financial instruments and hybrid products refer to Cummins and Weiss (2009).

[7] The first such bond was the Swiss Re mortality bond known as *VITA I* which came to market in December 2003 (see Helfenstein and Holzheu, 2006).

To avoid any confusion over terminology, this thesis uses the following categorization of Cat bonds as shown in Figure 3-5. The term Cat bond comprises all bonds which are designed to transfer catastrophe risks to capital markets. This includes all P&C bonds as well as those life bonds which are based on catastrophe mortality risks (morality bonds). All other life bonds which do not refer to the transfer of catastrophe risks (i.e. longevity bonds and life securitizations) are not subsumed under the term Cat bond and are not further examined in this thesis.

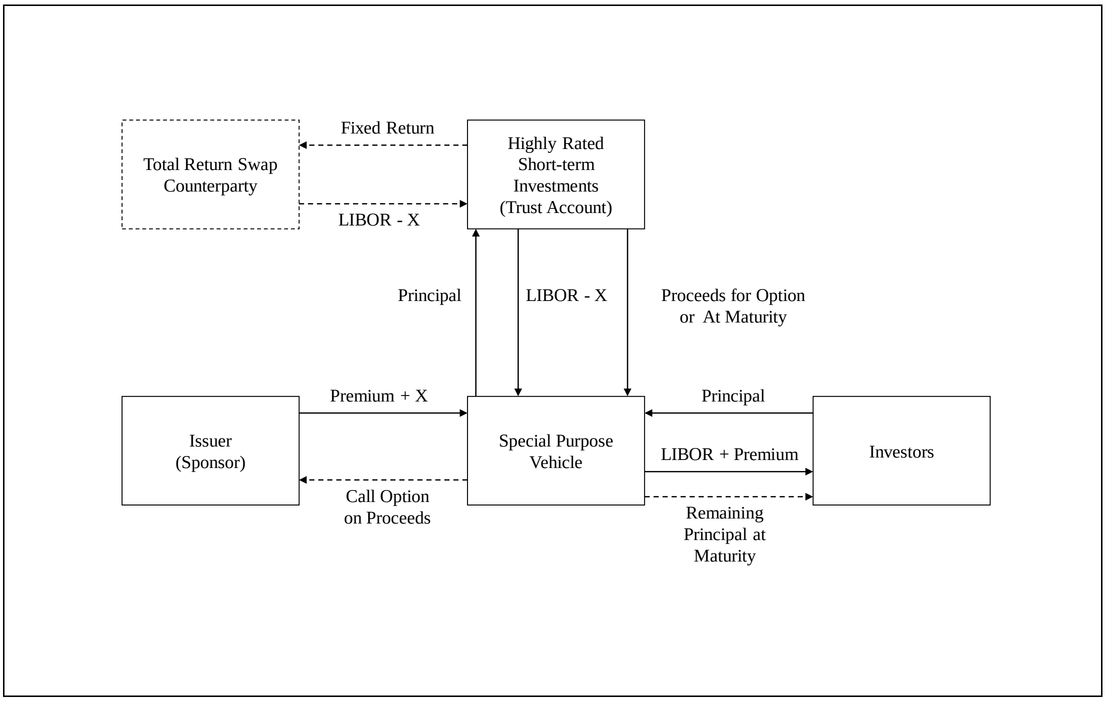
Figure 3-5
Terminology Used in the Thesis



3.3.1 A Typical Catastrophe Bond Structure

The unique characteristic of Cat bonds is that coupons and principal payments are contingent on the performance of a pool or index of insurance-related risks. Consequently, Cat bonds are insurance derivatives whose payoffs depend on the occurrence of a catastrophe loss event. Most of the Cat bonds issued to date have been linked to natural catastrophes such as hurricanes and earthquakes, although some bonds have also been linked to mortality events. A typical Cat bond structure is shown in Figure 3-6. The transaction usually involves an issuer (sometimes referred to as sponsor), a special purpose vehicle (SPV), a total return swap (TRS) counterparty and several investors.

Figure 3-6
Typical Catastrophe Bond Structure



Based on Cummins and Weiss (2009).

The first step in the transaction is the formation of the SPV which issues the Cat bonds to investors and invests the proceeds in low risk, short-term securities such as government bonds which are held in a trust account. Embedded in the bonds is a call option that is triggered by a defined event (trigger event), which can for example be the occurrence of a specific magnitude of an earthquake in the case of P&C bonds, or the occurrence of a certain attachment point of a mortality index in the case of mortality bonds.

On the occurrence of the trigger event, the proceeds are released from the SPV and passed on to the issuer leading to a partial or total loss of principal to investors, and/or future coupons to investors are reduced. If no trigger event occurs during the term of the bonds - which on average is between three to four years - the principal is returned to the investors upon the bonds' expiration. In return for taking the risk of losing principal and/or coupon payments, investors receive a risk premium - also referred to as 'spread' - from the issuer. In addition, investors are compensated for the time value of their money by receiving the fixed returns on the securities held in the trust account. Originally, these fixed returns were swapped for floating returns based on London interbank offered rate (LIBOR) or some other widely accepted index by a TRS counterparty in order to minimize interest rate risk.

However, the TRS counterparty gave rise to counterparty risk. This was revealed when Lehman Brothers - acting as the TRS counterparty on four Cat bonds - went bankrupt which caused the impairment of the collaterals behind.[8] This is why more recent Cat bond issuances have been structured without any TRS counterparties ('pass trough approach') or with the intervention of a clearing house between the issuer and the repurchase counterparty ('three party repurchase approach').

[8] The four Cat bonds where Lehman Brothers acted as the TRS counterparty were Ajax, Carillon, Newton Re and Wilow Re. Investors incurred a loss of 80 points on Ajax and around 40 points on the other three deals.

3.3.2 The Trigger Event: Basis Risk vs. Moral Hazard

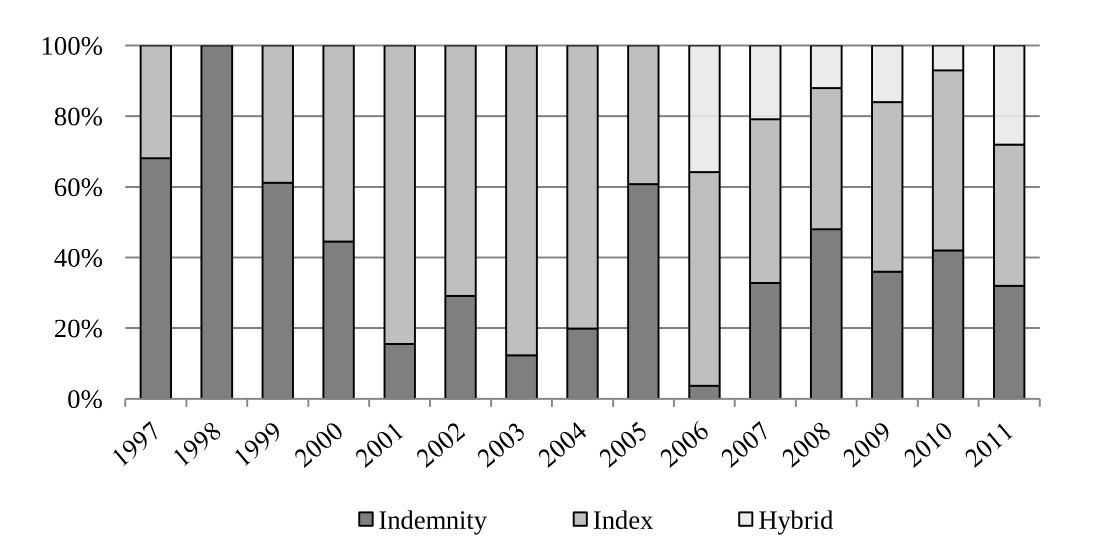
A crucial issue in the design of a Cat bond is the choice of the trigger event. The trigger event is stated in the contract between the issuer and the SPV and, eventually, defines the conditions under when payouts to investors are made.

The features of the different trigger events (i.e. mainly the degree of basis risk and moral hazard associated with each trigger event) play an important role in understanding the risk implications and performance implications of insurance securitization in Chapter 5 and Chapter 6 of this thesis. Consequently, this subsection explains the features of the different trigger events in detail, including their pros and cons for issuers and investors.

There are basically three types of trigger events: (i) *indemnity based triggers*, where payouts are based on the actual loss experience of the issuer's own book of business, (ii) *index based triggers*, where payouts are based on an index which is not directly tied to the issuer's own book of business and (iii) *hybrid triggers*, which blend more than one trigger in a single bond.

The issuers' choice of the trigger type from 1997 through 2011 is illustrated in Figure 3-7. It shows that, for the period as a whole, index and hybrid triggers accounted for 60% of total issue volume. However, an observable trend in the use of a particular trigger cannot be exposed.

Figure 3-7
Catastrophe Bond Issues by Trigger Type



Notes: The relative use of the different trigger types are expressed in percentage of total issue volume. Figures are taken from Swiss Re (2012d).

Doherty (1997) explains that the choice between indemnity and index based triggers is shaped by the trade-off between the relative cost of moral hazard and basis risk. As defined by the American Academy of Actuaries[9],

"B*asis risk is the risk that there may be a difference between the performance of the hedge and the losses sustained from the hedged exposure. It is the risk that the value of the underlying or index used and/or structure of the settlement (in cash) of the derivative may not provide the desired offset to the insurer's loss*."

While basis risk is resolved via the use of indemnity based indices, this gives rise to moral hazard. Moral hazard could cause the issuer failing to take actions to reduce future losses (ex ante moral hazard) or relaxing settlement practices (ex post moral hazard). Index based triggers on the other hand, reduce moral hazard but

[9] Kist and Meyers (1999).

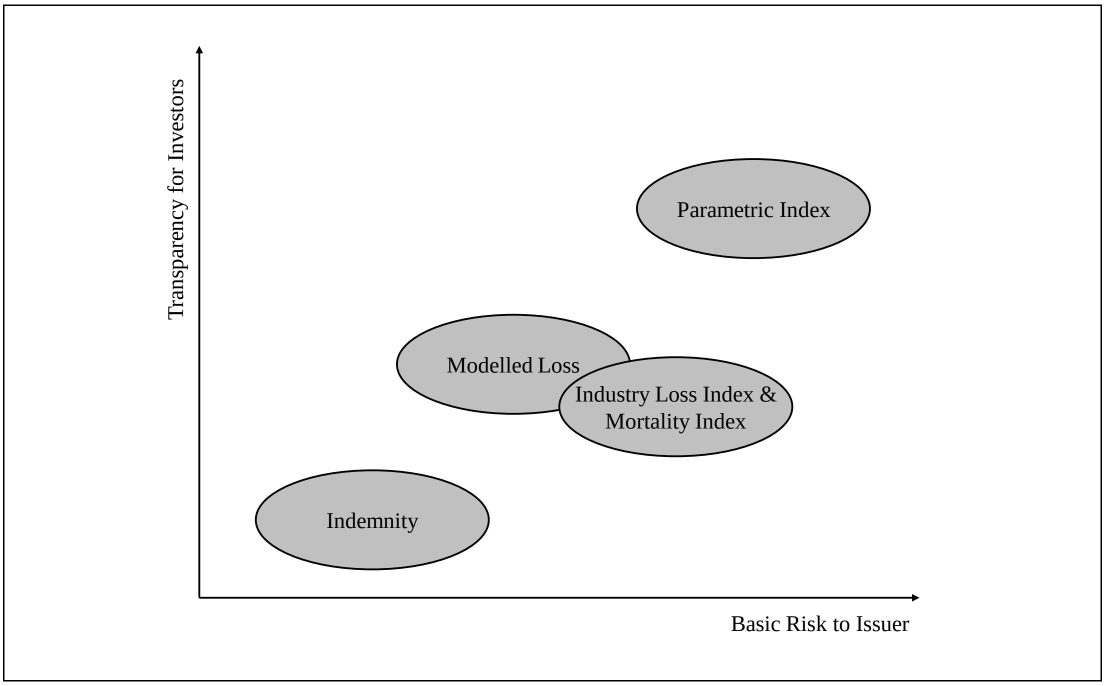
increase basis risk. Therefore, when choosing an index based trigger, it is favorable for issuers when the index is highly correlated with the actual loss experience of their own books of business to minimize basis risk, while it is favorable for investors when the issuer has little or no control over the index which increases the transparency of the transaction by reducing moral hazard.

There are three broad types of indices which can be used as Cat bond triggers: (i) industry loss indices in the case of non-life bonds, or mortality indices in the case of mortality bonds, (ii) modelled-loss indices, and (iii) parametric indices (Cummins, 2008).

Industry loss indices are based on industry-wide indices of losses, e.g. the Property Claim Service index, where payoffs on the bonds are triggered when estimated industry-wide losses from an event exceed a specified threshold. Similarly, mortality indices are based on a particular index of mortality rates, e.g. the LifeMetrics index, which is usually broken down by age and gender for different countries. Payoffs on mortality indices are triggered when events such as major natural catastrophes or avian flu pandemics cause the index to exceed a specified rate. Payoffs on modelled-loss indices, however, are determined by inputting actual physical parameters into an agreed-upon, fixed model to calculate losses (Helfenstein and Holzheu, 2006). Finally, parametric indices determine the payoffs on the bond on actual reported physical events such as the magnitude of an earthquake or the wind speed of a hurricane.

Both industry loss indices and mortality indices, as well as modelled-loss indices are considered to have a moderate degree of basis risk and transparency (Helfenstein and Holzheu, 2006). Parametric indices, on the contrary, are regarded to involve the highest degree of basis risk for issuers but also the highest degree of transparency for investors. These characteristics are summarized in Figure 3-8. It becomes evident that there is no such thing as a superior trigger type.

Figure 3-8
Transparency and Basis Risk for Various Types of Triggers



Source: Helfenstein and Holzheu (2006, Figure 2).

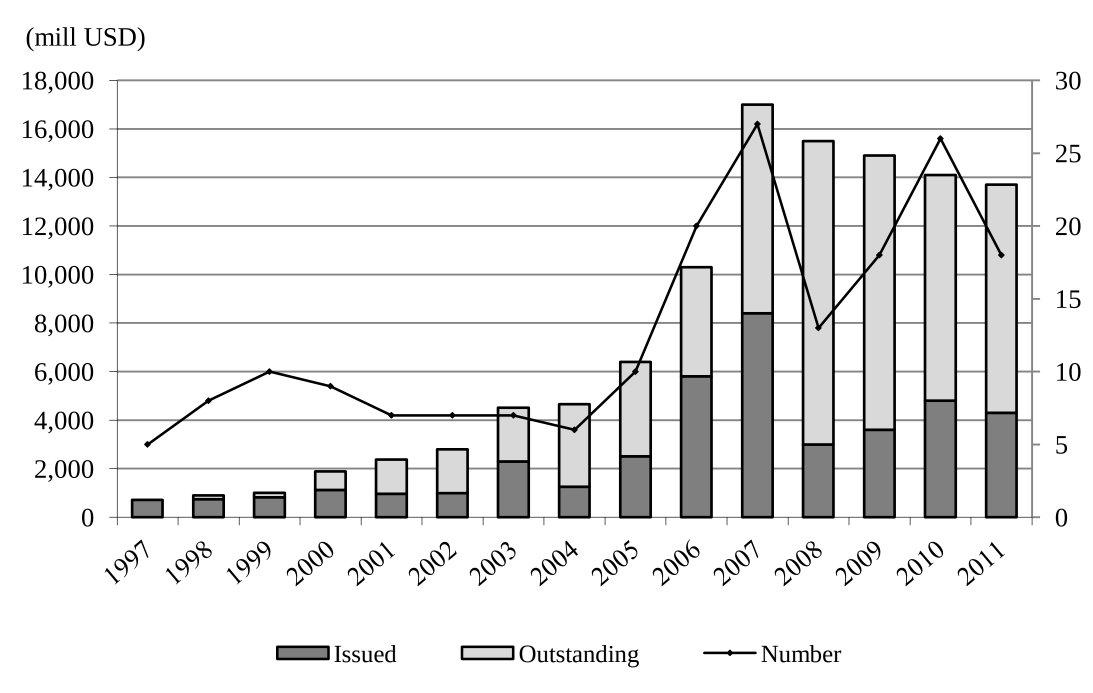
3.3.3 The Catastrophe Bond Market

The idea of accessing capital markets by issuing Cat bonds was borne out of the desire to increase reinsurance capacity in the aftermath of Hurricane Andrew in 1992. However, the first ever successful Cat bond issuance - named *KOVER* initialized by Hannover Re - was not performed until 1994.[10]

[10] The first Cat bonds are sometimes referred to as 'Act of God' bonds.

The development of the Cat bond market is reflected in Figure 3-9 which shows the total Cat bond risk capital issued and outstanding from 1997 through 2011.[11] It becomes evident that the Cat bond market has grown steadily from less than $1 billion of total risk capital outstanding and issued in 1997 to its record-high of nearly $17 billion in 2007, whereupon the market stagnated at around $14 billion in the following years.

Figure 3-9
Outstanding and Issued Catastrophe Bond Volume



Source: Swiss Re (2012c, Figure 6)

The significant market growth is mostly ascribed to the heavily accelerating volume of new Cat bond issuances throughout the 2004 to 2007 period, during which the volume quadrupled to reach $8 billion in 2007. The main reason for this increase

[11] Amount of risk capital outstanding represents the face value of all bonds still in effect in each year.

in the new issue volume were severe capacity constraints in the insurance and reinsurance industry following the 2005 losses of hurricanes Katrina, Rita and Wilma in excess of $100 billion. Hereafter, however, the volume of new issued Cat bonds collapsed to nearly $3 billion in 2009 and, since then, has not really recovered. Thus, the total outstanding risk capital of Cat bonds issued between 1997 and 2011 corresponds to only 8% of insured catastrophe losses during that period (according to calculations based on various Swiss Re Sigma Reports dating from 1997 to 2011).

In theory, each party with catastrophe risk exposure could issue Cat bonds. However, as shown in Figure 3-10 which illustrates the risk capital by issuer type from 1997 through 2011, the market is dominated by insurers and reinsurers. As only a small fraction of risk capital accounts for corporate/government, this thesis focuses on insurance and reinsurance firms only.[12] Since the first successful Cat bond issuance in 1994, there have been approximately 70 different issuers participating in the market. An important characteristic of these issuers is that they are all particularly large relative to their market competitors. One explanation is that only large companies possess the financial sophistication and adequate mass to produce transactions of sufficient size to amortize the high costs of structuring, and that larger companies are more likely to have easier access to a broader pool of investors due to their own asset management entities (see Cummins and Trainar, 2009).

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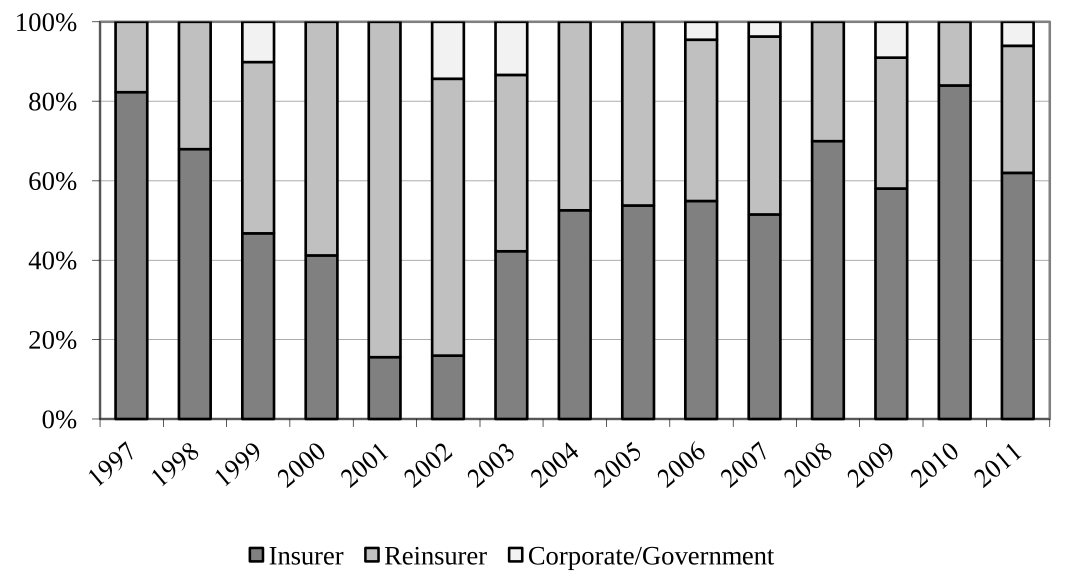
[12] The first Cat bond issued by a non-insurance company was in 1999 by Oriental Land Company, Ltd., the owner of Tokyo Disneyland, which covered earthquake losses.

Figure 3-10
Catastrophe Bond Issues by Issuer Type



Source: Guy Carpenter (2008) and Swiss Re (2012d).

The motivation for investors to engage in the Cat bond market is simple. Aside from earning potentially higher investment returns as compared to assets having the same risk profile, investors expect Cat bonds *"as a new asset class"* (Litzenberger et al. 1996) to show no or little correlation with traditional asset classes and, therefore, to offer attractive risk/return opportunities when included in diversified stock and bond portfolios. Investments in Cat bonds are restricted to qualified institutional investors as defined in rule 144A of the U.S. Securities Act.[13] Also, Cat bonds are not publicly traded and, therefore, not subject to the SEC's full registration and disclosure requirements. As a result, there is only limited data available regarding the different investor types.

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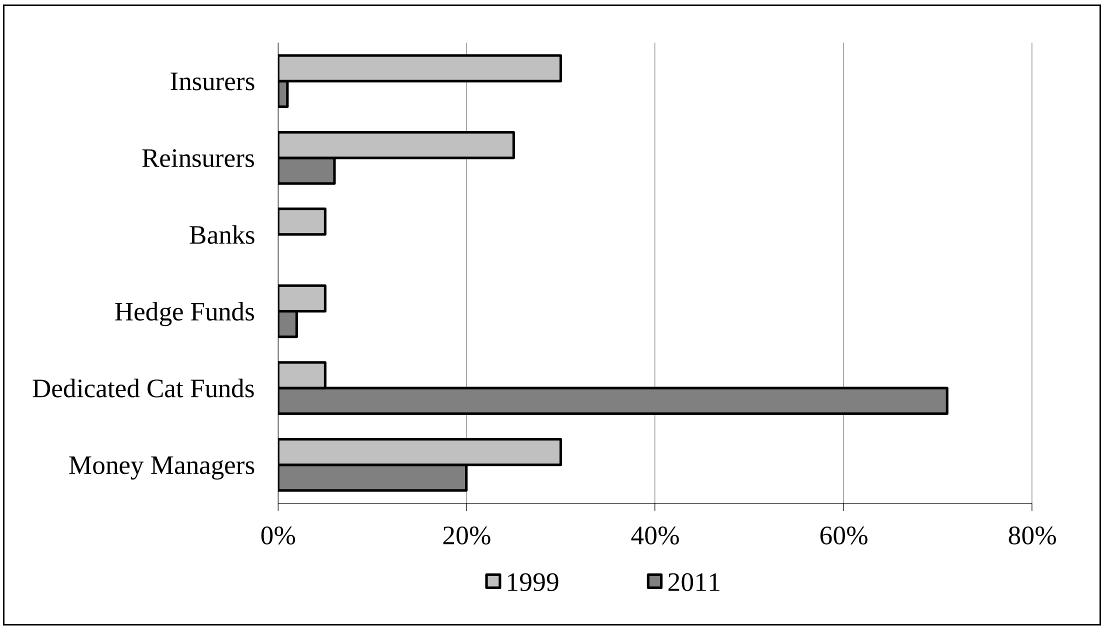
[13] The only opportunity for private investors to indirectly invest in Cat bonds is to use the two public funds managed by Switzerland's Bank Leu, which solely invest into Cat bonds.

Figure 3-11 compares the issue volume purchased by investor type of the years 1999 and 2011. It becomes apparent that, unlike in 1999, the Cat bond market is now able to attract new capital from outside the insurance market into the financing of catastrophe risk. Thus, in 2011 insurers and reinsurers accounted for only 7% of supply, as compared to 55% in 1999. Specialized catastrophe-oriented funds (dedicated Cat funds) make up the vast majority of investments in Cat bonds in 2011, accounting for 71% of the market, followed by money managers (20%), and hedge funds (2%).

Figure 3-11
Catastrophe Bond Issues by Investor Type



Source: Swiss Re (2012d).

3.4 Concluding Remarks

This chapter (i.e. the second of two background chapters to this thesis) argues that insurance securitization in general (and Cat bonds in particular) which are designed to access capital markets for additional underwriting capacity can ease the current capacity constraints in the market for catastrophe risk and can help to establish a more efficient sharing of catastrophe risk among market participants. However, the chapter also reveals that, while the market for insurance securitization has undergone rapid growth in response to a general increase in the amount of catastrophe-related underwriting losses, global volumes of insurance securitization have lagged behind expectations.

This raises various questions including whether insurance and reinsurance firms would actually benefit from additional underwriting capacity or whether insurance securitization is effective in transferring catastrophe risks to capital markets as argued in various, largely theoretical, studies (e.g. Niehaus, 2002; Harrington and Niehaus, 2003; Cummins et al., 2004).

In order to provide answers to these questions, the following chapters empirically examine the performance implications of natural catastrophes (Chapter 4), the performance implications of insurance securitization (Chapter 5), and the risk implications of insurance securitization (Chapter 6) for insurance and reinsurance firms.

4
The Performance Implications of Natural Catastrophes: Insurer Stock Returns around Mega-Catastrophes

4.1 Introduction

Chapter 3 demonstrates a remarkable increase in both the frequency and magnitude of underwriting losses from natural catastrophes. Also, it shows that capacity constraints in the market for catastrophe risk prevent an efficient sharing of catastrophe risk among market participants. As a result, insurance firms face difficulties in transferring their catastrophe risk exposure to reinsurance firms and are increasingly put at risk of becoming concentrated warehouses of catastrophe exposure.

Various commentators argue that large natural catastrophes pose the risk of causing severe instability and insolvencies in global insurance and reinsurance markets (e.g. Cummins et al., 2002 or Cummins and Trainar, 2009). It is, therefore, surprising to find that insurance and reinsurance firms have been rather reluctant in making use of insurance securitization which could provide additional underwriting capacity and ease the catastrophe markets' constraints. One possible explanation for this might be the fact that the demand for additional underwriting capacity is limited, because the performance implications of natural catastrophes for insurance and reinsurance firms are not as severe as suggested.

Natural catastrophes pose great financial risks to insurance firms (Cummins et al., 2002 or Kunreuther and Heal, 2012). Mega-catastrophes, such as Hurricane Katrina in 2005 or the recent earthquake and tsunami in Japan, are high-severity and low-frequency events which can be particularly costly to insurance firms. The high-severity nature of mega-catastrophes causes large underwriting losses, while the low frequency nature of mega-catastrophes means they are difficult to predict and incorporate into the premium pricing for catastrophe coverage.

If insurers are likely to pay substantial amounts to reimburse policyholders for the insured losses caused by a mega-catastrophe, it appears obvious that mega-catastrophes should have negative performance implications for insurance firms. However, mega-catastrophes may equally improve the performance of insurers. For instance, in the aftermath of a catastrophe event, mega-catastrophes can heighten demand for catastrophe risk coverage (Zanjani, 2002; Froot and O’Connel, 2008), thus, boosting insurance rates and insurer profitability in the catastrophe risk market (Born and Viscusi, 2006). Additionally, supply side factors such as insurers updating their catastrophe risk models (Winter, 1994; Cummins and Danzon, 1997) or softening regulatory attitudes towards price increases (Angbazo and Narayanan, 1996) may also lead to higher prices and improved insurer performance. The overall effect of mega-catastrophes on insurance firms is, therefore, uncertain ex ante.

The purpose of this chapter is to provide an analysis of the expected performance implications of mega-catastrophes on U.S. P&L insurance firms. Using detailed data on homeowners’ insurance coverage by state, firm and year, the market revaluation effects realized by P&L insurers with at least some relevant risk exposure to mega-catastrophes in response to nineteen U.S. mega-catastrophes are computed.

Against the background of the remarkable increase in both the magnitude and frequency of underwriting losses from catastrophe events in recent years, the performance implications of mega-catastrophes on insurance firms are an important issue. However, empirical work that studies the performance effects of catastrophe events on the market valuations of insurers tends to focus on a single catastrophe event. For instance, studies have analyzed the market revaluation effects linked to the San Francisco earthquake in 1989 (Shelor et al., 1992; Aiuppa et al., 1993), the Northridge earthquake in 1994 (Lamb and Kennedy, 1997), Hurricane Hugo in 1989 (Cagle, 1996) or Hurricane Andrew in 1992 (Lamb, 1995; 1998). Cummins and Lewis (2003) study Hurricane Andrew, the Northridge earthquake and the World Trade Centre attacks in 2001 in a single study, but their study analyzes the performance implications of each event separately.

The main challenge faced by an analysis of the performance effects of catastrophe events that is based on a single event is to distinguish effects that are unique about a particular event from the more general effects of mega-catastrophes on insurers. It is, therefore, not surprising that the extant literature has been unable to draw general inferences about the performance effect of mega-catastrophes on insurers. By means of illustration, Lamb (1995; 1998), Cagle (1996), and Cummins and Lewis (2003) find that insurers realize negative abnormal returns on average for the specific catastrophe events they study, while Shelor et al. (1992), Aiuppa et al. (1993) as well as Lamb and Kennedy (1997) find positive equity valuation effects linked to the specific events they study.

For these reasons, the present investigation is based on a sample of nineteen large catastrophes (mega-catastrophes) and their impact on the equity valuations of U.S. insurance firms. The sample of insurers used in this chapter is substantial and includes the near population of publicly traded U.S. P&L insurers with loss exposure to homeowner's business during 1996 to 2010. The empirical design is meant to help better understand the expected performance effect of catastrophes on insurers. By doing so, it is also examined which theoretical explanation—the *pessimistic theory* which predicts a decline in market valuations following a mega-catastrophe or the *market hardening theory* which predicts an increase in market valuations—best describes the observed empirical relationships (see Marlett et al., 2000).

The analysis starts by demonstrating that across the series of nineteen U.S. mega-catastrophes examined, shareholders in U.S. P&L insurers realize wealth losses on average. However, the relatively small magnitude of share price losses suggests that the expected performance effects of mega-catastrophes are by no means devastating. Next, detailed information on the geographic and business line origin of insurers' premium income is used to understand the loss exposure of insurers to each catastrophe. If the negative stock returns reflect expected increases in underwriting losses, the value losses should be largely confined to insurance firms with loss exposure. This is what the analysis finds and this is interpreted as consistent with the pessimistic theory. While some evidence is found that insurers benefit from the prospect of market hardening in the aftermath of a mega-catastrophe, results show that this is only the case when insurers have no loss exposure and predominantly operate in states with low competition (i.e., when insurers benefit from the prospect of higher premium income without facing underwriting losses).

This chapter makes two important contributions. First, it provides the first comprehensive analysis of the market performance effect of a series of natural catastrophes on the U.S. P&L insurance industry. Critically, the present analysis differs from previous empirical works which are limited to the analysis of a single catastrophe event (e.g. Lamb, 1995; 1998; Cagle, 1996; Cummins and Lewis 2003). Overall, results of this chapter provide empirical support for the pessimistic theory. Since the results also demonstrate that factors such as the type of catastrophe event and competition in the geographic region insurers operate in shape the market valuation effects of an event, the results highlight the importance of analyzing a cross-section of catastrophe events rather than a single event.

Second, and related to the first point, the equity revaluation effects vary significantly across P&L insurers and this chapter helps to indentify some of the event-specific and time-specific factors that explain the expected performance changes for insurers linked to a catastrophe event. The empirical design of previous work (which studies a single catastrophe event) is unable to do so. For instance, the cross-sectional analysis shows that hurricanes have less negative value implications for insurers than other catastrophe events. Further, catastrophes that occurred after Hurricane Katrina in 2005 receive a less negative market reaction than catastrophes which occurred before Katrina. The latter finding is in line with explanations that Hurricane Katrina caused the insurance industry to upwardly revise its expectations of the potential magnitude and frequency of mega-catastrophes. Put differently, post-Katrina, the insured losses caused by mega-catastrophes have been better anticipated by insurers (and have been reflected in the premium income of P&L insurers).

The remainder of the chapter is organized as follows. The next section discusses the data and empirical strategy used to gauge changes in insurers' firm values in response to mega-catastrophes. Sections 4.3 and 4.4 present the results of the univariate and multivariate analysis, respectively. Finally, Section 4.5 reports the results of several tests to evaluate the robustness of the results before Section 4.6 concludes.

4.2 Data and Methodology

4.2.1 Data

Two main types of data are used to analyze the impact of mega-catastrophes on the performance of publicly traded P&L insurers during the period 1996 to 2010: data on the magnitude and geographic spread of mega-catastrophes as well as financial data on P&L insurers.

To collect data on mega-catastrophes, statistics on insured property losses are obtained from Property Claims Service (PCS), a division of the Insurance Services Office (ISO). The PCS data include information about the date, value of first insured loss estimates, and the states affected by catastrophe events that cause $25 million or more in direct insured losses to property.[14] Since this study is concerned with homeowners' exposure, the sample of catastrophe events is restricted to natural catastrophes, i.e. events which are caused by natural forces. Terrorism attacks or man-made disasters (such as aviation accidents and explosions) are not

[14] The threshold of $25 million of insured losses applies to the total event, i.e. insured losses at the state level can be (much) smaller than $25 million.

included in the sample, because these disasters are more likely to impact on commercial (rather than homeowners') lines and because they only affect a small number of policies. Further, only catastrophe events with first insured loss estimates in excess of $1 billion are included and these events are called mega-catastrophes.[15]

From an initial sample of 24 mega-catastrophes, five catastrophes are excluded to avoid overlaps in the examination period of up to 20 trading days after the event occurred.[16] The final sample, therefore, consists of nineteen mega-catastrophes which can be broken down into 191 state-level catastrophes.[17] This sample is substantial. It covers more than $80 billion in first insured loss estimates (which corresponds to nearly 40 % of total first insured loss estimates) during 1996 to 2010 according to the PCS data.[18]

Table 4-1 provides descriptives on the mega-catastrophes included in this analysis. The data presented in Panel A include the catastrophe date, the peril type (hurricane, storm, etc.), the affected states as well as first insured loss estimates for all nineteen mega-catastrophes. Panel B presents the number of mega-catastrophes broken down by state. With a total of nine events, hurricanes make up the majority of the sample of mega-catastrophes. Further, Florida and Massachusetts are the states most frequently hit by mega-catastrophes in the sample (i.e. eleven times each).

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[15] First insured loss estimates are adjusted for inflation using the All Urban Consumer Price Index for the United States (CPI-U) for a base year 2010.

[16] The omitted mega-catastrophes are Hurricane France (04.09.2004), Hurricane Jeanne and Ivan (both 15.09.2004), as well as Hurricane Gustav (31.08.2008) and Hurricane Ike (12.09.2008).

[17] The number of state-level catastrophes is obtained by summing up the number of states which are affected by a mega-catastrophe. For example, if a hurricane affects four states, four state-level catastrophes are counted.

[18] The PCS database holds record on 414 individual natural catastrophe events during the period 1996 to 2010 which have caused total first insured loss estimates of nearly $215 billion.

Table 4-1
Sample of Mega-Catastrophes during 1996-2010

Panel A: Mega-Catastrophe Characteristics

Date	Peril	States Affected	First Insured Loss Estimate (in million USD)
25.08.2005	Hurricane Katrina	AL, FL, GA, LA, MS, TN	38,360
13.08.2004	Hurricane Charley	FL, NC, SC	7,850
24.10.2005	Hurricane Wilma	FL	6,809
20.09.2005	Hurricane Rita	AL, AR, FL, LA, MS, TN, TX	5,243
25.10.2003	Wildland Fire	CA	2,412
05.09.1996	Hurricane Fran	MD, NC, OH, PA, SC, VA, WV	2,224
03.05.1999	Wind/Thunderstorm Event	AL, AR, FL, GA, IL, IN, KS, KY, LA, MO, MS, NC, NE, OH, OK, SC, TN, TX	1,944
02.05.2003	Wind/Thunderstorm Event	AL, AR, CO, GA, IA, IL, IN, KS, KY, MO, MS, NC, NE, OH, OK, SC, SD, TN	1,837
14.09.1999	Hurricane Floyd	CT, DE, FL, GA, MA, MD, ME, NC, NH, NJ, NY, PA, RI, SC, VA, VT	1,734
05.06.2001	Tropical Storm Allison	FL, LA, MS, NJ, PA, TX	1,502
04.04.2003	Winter Storm	AL, IL, IN, LA, MI, MO, MS, NY, TN, TX	1,440
18.09.2003	Hurricane Isabel	DE, MD, NC, NJ, NY, PA, VA, WV	1,387
21.10.2007	Wildland Fire	CA	1,262
12.05.2010	Wind/Thunderstorm Event	IL, MD, OK, PA; TX	1,065
31.01.1996	Winter Storm	AL, AR, CT, DE, FL, GA, IA, IL, IN, KS, KY, LA, MA, MD, MI, MN, MO, MS, NC, NE, NJ, NY, OH, OK, PA, SC, TN, TX, VA, WI, WV	1,021
01.01.1999	Winter Storm	AL, AR, CT, DE, FL, GA, IL, IN, LA, MA, MD, ME, MO, MS, NC, NJ, NY, OH, OK, PA, RI, SC, TN, TX, VA, WV	1,014
13.04.2007	Wind/Thunderstorm Event	CT, DE, GA, LA, MA, MD, ME, MS, NC, NH, NJ, NY, PA, RI, SC, TX, VA, VT	1,013
09.07.2005	Hurricane Dennis	AL, FL, GA, MS	1,005
21.09.1998	Hurricane Georges	AL, FL, LA, MS	1,003

Panel B: Total Number of Mega-Catastrophes broken down by State, 1996-2010

State	Events	State	Events	State	Events	State	Events	State	Events
AK	-	HI	-	ME	3	NJ	6	SD	1
AL	9	IA	3	MI	2	NM	-	TN	7
AR	5	ID	-	MN	1	NV	-	TX	8
AZ	-	IL	6	MO	5	NY	6	UT	-
CA	2	IN	4	MS	11	OH	5	VA	6
CO	1	KS	3	MT	-	OK	5	VT	2
CT	4	KY	3	NC	9	OR	-	WA	-
DE	5	LA	8	ND	-	PA	9	WI	1
FL	11	MA	4	NE	3	RI	3	WV	4
GA	9	MD	7	NH	2	SC	8	WY	-

Notes: The sample consists of nearly all U.S. natural catastrophes during 1996 to 2010 with first insured loss estimates exceeding 1 billion USD (mega-catastrophes). According to the Property Claims Service (PCS) database this sample of mega-catastrophes makes up nearly 40% of total first insured loss estimates during 1996 to 2010. Insured losses are in constant 2010-USD terms based on the Consumer Price Index (All Urban Consumers). An explanation of the state abbreviations can be found in the Appendix to this chapter on pg. 107.

To build the sample of publicly traded P&L insurers in the U.S., first a list of firms is downloaded which both the Center for Research in Security Prices (CRSP) and Datastream classify as P&L insurers (based on a SIC code of 6330 or 6331). This yields an initial sample of 142 publicly traded P&L insurers. In cases where only one database identifies a firm as a P&L insurer, the firm's website is checked to confirm its specialization. This way, an additional 26 P&L insurers are identified.

The sample of P&L insurers is then matched with data on premium earnings compiled from the State Pages of insurers' annual filings with the National Association of Insurance Commissioners (NAIC). The NAIC filings provide detailed state-level data on the composition of an insurer's premium income. To ensure that sample firms are P&L insurers with at least some relevant risk exposure to mega-catastrophes, insurers are only included in the sample if the NAIC filings show that insurers have homeowners' loss exposure at the time of a mega-catastrophe. That is, insurers need to have positive premiums *earned* in the homeowners' line in the year the catastrophe occurred.[19] Finally, sample firms are required to have accounting and share price information on COMPUSTAT and CRSP, respectively. The final sample consists of 57 publicly traded P&L firms. A list of the sample insurers is provided in Table 4-2.

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[19] As insurance premiums are usually paid in advance, it is common to classify premiums into premiums written and premiums earned. While premiums written are equal to the revenues from insurance policies sold in a given period, earned premiums are equal to the portion of premiums written which is actually exposed to loss. For example, if an annual policy begins on July 1, the written premium is equal to the total revenue of that policy (usually the price of the policy), while premiums earned would only make up half the policy's total revenue. Since this analysis is interested in the actual loss exposure of individual insurers, earned premiums are used as in Born and Viscusi (2006).

Table 4-2
Sample Firms

21st Century Insurance Group	EMC Insurance Group	National Security Group Inc.
Ace Ltd.	Erie Indemnity	North Pointe Group
Acceptance Insurance Corp.	Everest Re Group	Ohio Casualty Insurance Group
Affirmative Insurance Holdings	Farm Family Holdings Inc.	Old Republic International Corp.
Alfa Corp.	First Acceptance Corp.	Progressive Corp. (The)
Allstate Corp. (The)	Frontier Insurance Group Inc.	Renaissance Re Holdings
Alterra Capital Holdings Group	Hallmark Financial Service Inc.	Royal and Sun Alliance
American Country Holdings	Hanover Insurance Group (The)	Safeco Corp.
American Financial Group	Harleysville Group Inc.	Safety Insurance Group
American International Group	Hartford Financial Services	Seibels Bruce Group Inc.
Argonaut Group Inc.	Homeowners Choice Inc.	Selective Insurance Group
Aspen Insurance Holdings Group	Horace Mann Educators Corp.	Tower Group Inc.
AXIS Capital Group	Kemper Corp.	Travelers Corp.
Berkshire Hathaway Inc.	Markel Corp Group	Trenwick Group Inc.
Chubb Corp.	Meadowbrook Insurance Group	United Fire and Casualty Group
Cincinnati Financial Corp.	Mercer Insurance Group Inc.	Universal Insurance Holdings
CNA Insurance Group	Merchants Group Inc.	VESTA Insurance Group
Commerce Group Inc.	Mercury General Corp.	White Mountains Insurance Group
Donegal Group Inc.	Meridian Insurance Group Inc.	W.R. Berkley Corp.

Notes: The sample consists of all publicly traded property-liability (P&L) insurers during the period 1996 to 2010 with positive premiums earned in the homeowners' line from the State Pages of insurers' annual filings with the National Association of Insurance Commissioners (NAIC) as well historical accounting and stock price information on COMPUSTAT and CRSP, respectively.

4.2.2 Methodology

To estimate the impact of mega-catastrophes on the stock price performance of P&L insurers during the period 1996 to 2010, market-adjusted abnormal returns (AR) are used as employed by Fuller et al. (2002), Faccio et al. (2006) and others:

$$AR_{it} = r_{it} - r_{mt}, \tag{4.1}$$

where r_{it} is the return for insurer i on day t and r_{mt} is the CRSP-equally-weighted market index return for day t.[20] Equity return data are from CRSP. Abnormal returns

[20] The CRSP-equally-weighted market index is used for market returns. This return index is more dominated by returns on smaller firms (relative to a value-weighted index). This is appropriate for the present sample of small and medium sized P&L insurers (the median sample firm is smaller than the

are averaged across days and firms to yield cumulative abnormal returns (CAR). To test for the statistical significance of cumulative abnormal returns, a two tailed *t*-test as well as the non-parametric Mann-Whitney-Wilcoxon test (which is robust to the effects of outliers) are employed. With the exception of hurricanes, the event date is defined as the trading day on which the mega-catastrophe took place (if the event occurs on a non-trading day, the next trading day is used instead). For hurricanes, two calendar days before the event are used as the event date. This is because hurricanes can be tracked with a fair amount of accuracy and, consequently, some information leakage prior to the hurricane hitting land is expected.

The analysis does not estimate market model-adjusted returns (which yield risk-adjusted returns) for two reasons. First, the market model approach assumes that the estimation period over which market model parameters are estimated is free of the type of event whose value effects are being investigated. If risk-adjusted abnormal returns were computed using contaminated estimation periods, the resulting estimates would be unreliable. Since the sample of insurers contains firms that are hit by more than a single mega-catastrophe in close succession, the clean time series of return data necessary to implement this approach is not available. Second, Brown and Warner (1980) show that over short-time periods risk-adjusted return values do not significantly improve estimation results as compared to the type of market-adjusted values employed in this study.

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median firm included in the CRSP indices). Further, the vast majority of previous studies on the performance implications of catastrophe events for insurers have also employed the CRSP-equally-weighted index (e.g., Cummins and Lewis, 2003, Lamb 1998, 1995 or Angbazo and Narayanan, 1996).

4.3 Univariate Results

4.3.1 The Shareholder Wealth Effects of Mega-Catastrophes

In this section, changes in the market value of P&L insurers in response to mega-catastrophes are examined. In doing so, this section provides new insights into the validity of the two opposing (yet not mutually exclusive) theories, i.e. the pessimistic and hardening theories, as regards the expected performance implications for insurers in response to mega-catastrophes.

If the pessimistic theory dominates (as found in Lamb, 1995, 1998; Cagle, 1996; Cummins and Lewis, 2003), a negative stock price response is expected. Under the pessimistic theory, investors price in the payments to reimburse policyholders for insured losses. Contrarily, if the hardening theory is an accurate portrayal of the expected performance implications of insurers following mega-catastrophes, positive returns linked to mega-catastrophes are expected (as found in Shelor et al., 1992; Aiuppa et al., 1993; Lamb and Kennedy, 1997). Under the hardening theory, investors expect that a mega-catastrophe leads to additional premium earnings (e.g., from increased consumer and institutional demand for catastrophe insurance) and that this additional demand will more than offset the insured loss payments linked to a catastrophe event.

Table 4-3 reports insurers' market adjusted abnormal returns linked to the sample of mega-catastrophes for selected event windows. The results provide clear support for the pessimistic theory. Thus, for all event windows after the catastrophe event date, cumulative abnormal returns are negative and statistically significant at the 1%-level (for both *t*-tests and *z*-tests), ranging from -0.279% on day one to

-1.393% 20 days after the event date. For the five-day period immediately preceding the catastrophe event date [-5;-1], no statistically significant stock price reaction is found at all. Based on the results, it is concluded that the prospect of potentially substantial loss reimbursements to policyholders outweigh any expected benefits of potential premium increases in the aftermath of a catastrophe event.

However, Table 4-3 also shows that the sample is nearly split in half as regards firm observations experiencing value gains and value losses from mega-catastrophes. This points towards some heterogeneity in the market valuation effects linked to mega-catastrophes. The next sections, therefore, identify some of the factors which determine the market reaction to catastrophe events.

Table 4-3
Cumulative Abnormal Returns for Selected Event Windows

Event window (days)	N	mean (%) (*t*-stat)	median (%) (*z*-stat)	CAR<0% N	CAR<0% %
CAR[-5;-1]	716	-0.179 (-1.154)	-0.422 (-1.112)	398	55.6
CAR[0;+1]	716	-0.279*** (-2.840)	-0.401*** (-5.050)	419	58.5
CAR[0;+5]	716	-0.671*** (-3.723)	-0.686*** (-4.411)	413	57.7
CAR[0;+10]	716	-1.105*** (-4.539)	-0.930*** (-5.035)	414	57.8
CAR[0;+15]	716	-1.161*** (-3.532)	-0.698*** (-3.604)	394	55.0
CAR[0;+20]	716	-1.393*** (-3.777)	-1.292*** (-4.037)	408	57.0

Notes: The table reports cumulative abnormal returns (CAR) for different event windows before and after the catastrophe event date for the period 1996 to 2010. Abnormal returns are estimated using an adjusted market model ($AR_{it} = r_{it} - r_{mt}$), where r_{it} is the observed arithmetic return for firm *i* at day *t* and r_{mt} is the CRSP-equally-weighted market index return for day *t*. Also included are *t*-statistics (two tailed) and the non-parametric Mann–Whitney–Wilcoxon *Z*-scores. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

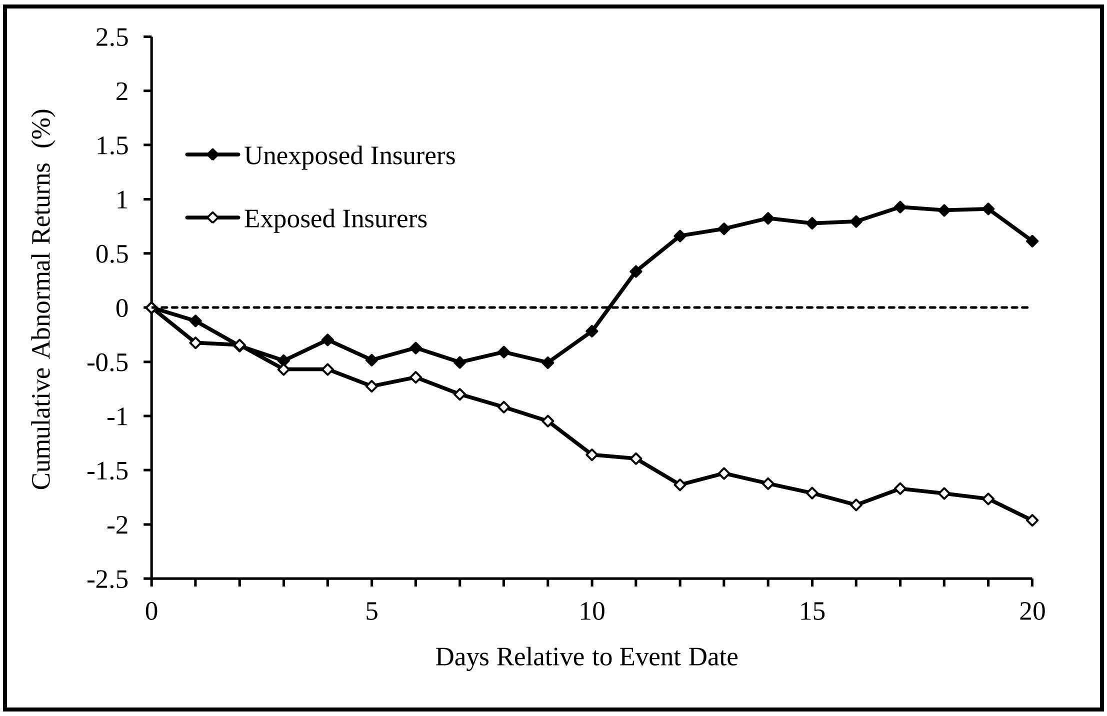
4.3.2 Value Effects and Insurers' Loss Exposure

In this subsection, it is investigated how an insurer's loss exposure impacts upon changes in the insurer market value in response to a mega-catastrophe. Loss exposure is captured using the homeowners' premium income earned in the states affected by a mega-catastrophe. The rationale behind this test is to further probe the validity of the pessimistic versus the hardening theory. It is expected that if the pessimistic theory is a valid description of the expected performance effects linked to catastrophe events, insurers with higher loss exposure to an event should experience a stronger negative stock price reaction.

By contrast, if mega-catastrophes lead to additional demand for insurance (as advocated by the hardening theory), it could be argued that such benefits will mainly be accrued by insurance firms with little or no loss exposure. This is because unexposed insurers would benefit from any additional insurance demand following a catastrophe event without having to indemnify existing policyholders for insured losses. Therefore, under the hardening theory, unexposed insurers are expected to experience revaluation gains around mega-catastrophes. For exposed insurers, however, no expectations are held as the overall valuation effect for this group of insurers depends on the relative magnitude of expected losses and additional insurance demand in the years following an event.

Figure 4-1 presents a graphical comparison of CAR for both unexposed and exposed insurers up to 20 days following a mega-catastrophe. Firms are classified as either exposed or unexposed based on whether or not they have positive premiums earned in the homeowners' line of business in any affected state(s).

Figure 4-1
Value Effects by Existence of Loss Exposure



Notes: The figure shows market adjusted cumulative abnormal returns (CAR) for both unexposed and exposed insurers for the 20 days following a mega-catastrophe. Exposed insurers are firms which have positive premiums earned in the homeowners' line of business in the state(s) affected by the sample catastrophes. Unexposed insurers are firms which have also positive premiums earned in the homeowners' line of business but only in the state(s) which are not affected by the sample catastrophes. Source: National Association of Insurance Commissioners (NAIC).

Two important conclusions can be drawn from Figure 4-1. First, mega-catastrophes have different performance implications for exposed and unexposed insurers. While exposed insurers experience negative CAR throughout the 20 days following a mega-catastrophe, CAR for unexposed insurers become positive 11 days after the catastrophe event. Second, Figure 4-1 provides graphical evidence for a delay in the market response to mega-catastrophes. The return difference between exposed and unexposed insurers widens around 10 days after the catastrophe event. Shelor et al. (1992) note that a delay in the market response may be attributable to a lack of data on expected loss estimates, the degree to which damaged property was insured or effects on the demand for insurance.

To more formally test these propositions, Table 4-4 reports CAR for different event windows following mega-catastrophes by whether or not insurers had loss exposure (Panel A). In addition, the level of loss exposure (defined as the ratio of direct earned homeowner premiums in the affected states to nationwide direct earned homeowner premiums in the year the catastrophe struck) is examined in Panel B. Also in Panel B, CAR are reported for insurers in the lowest (Q_1) and highest quartile (Q_4) of the distribution of loss exposure and the differences in CAR between the two groups are computed.

Table 4-4 reports two important findings. First, and in line with Figure 4-1, Panel A shows that the expected performance of an insurer in response to a mega-catastrophe is highly dependent on whether or not the insurer has earned premium in the affected states. Thus, for insurers with earned premium in the affected states (exposed insurers), CAR for all event windows are negative (and statistically significant at the 1%-level for both *t*-tests and *z*-tests), while insurers with no earned premium in the affected states (unexposed insurers) are not (statistically and significantly) affected by mega-catastrophes. Second, Panel B shows that the level of loss exposure also significantly impacts upon the stock price performance of insurers. For four out of the five event windows tested, the differences between firms in the highest and lowest quartile of the distribution of loss exposure ($\Delta CAR_{HIGH\text{-}LOW}$) are negative and statistically significant at the 1%-level for both *t*-tests and *z*-tests. Finally, Table 4-4 confirms that insurers' wealth losses in response to mega-catastrophes are rather modest, indicating that mega-catastrophes do not have devastating performance effects on insurers. Thus, on average, even insurers located in the highest quartile (Q_4) of the distribution of loss exposure experience share price losses of less than 5% during the event period (Panel B), while the share price losses for the subsample of exposed insurers is less than 2% (Panel A).

Table 4-4
Cumulative Abnormal Returns by Loss Exposure

		CAR[0;+1]	CAR[0;+5]	CAR[0;+10]	CAR[0;+15]	CAR[0;+20]
Panel A: Existence of Loss Exposure (Yes/No)						
EXPOSED Insurers	mean	-0.324***	-0.724***	-1.357***	-1.710***	-1.961***
N=558	(*t*-stat)	(-2.855)	(-3.610)	(-4.768)	(-4.507)	(-4.655)
	median	-0.414***	-0.707***	-1.021***	-0.993***	-1.629***
	(*z*-stat)	(-4.770)	(-4.321)	(-5.217)	(-4.575)	(-4.991)
UNEXPOSED Insurers	mean	-0.121	-0.484	-0.217	0.779	0.614
N=158	(*t*-stat)	(-0.623)	(-1.186)	(-0.481)	(1.239)	(0.828)
	median	-0.388*	-0.517	-0.411	0.052	0.202
	(*z*-stat)	(-1.806)	(-1.228)	(-0.883)	(0.997)	(0.886)
$\Delta CAR_{EXPOSED-UNEXPOSED}$	mean	-0.203	-0.241	-1.140*	-2.489***	-2.575***
	(*t*-stat)	(-0.854)	(-0.554)	-(1.950)	(-3.160)	(-2.911)
	median	-0.026	-0.190	-0.610*	-1.045***	-1.831***
	(*z*-stat)	(-0.856)	(-1.007)	(-1.910)	(-3.039)	(-3.134)
Panel B: Level of Loss Exposure (for Insurers with Some Loss Exposure)						
HIGH Exposure(Q_4)	mean	-0.459*	-2.073***	-3.307***	-4.192***	-4.969***
N=139	(*t*-stat)	(-1.695)	(-3.840)	(-4.586)	(-4.182)	(-4.530)
	median	-0.895***	-1.755***	-2.703***	-2.994***	-3.443***
	(*z*-stat)	(-2.807)	(-4.638)	(-4.945)	(-4.661)	(-4.998)
LOW Exposure(Q_1)	mean	-0.374**	-0.247	-0.922**	-0.376	-0.233
N=140	(*t*-stat)	(-2.234)	(-0.880)	(-2.063)	(-0.614)	(-0.330)
	median	-0.411***	-0.439	-0.913***	-0.493	-0.988
	(*z*-stat)	(-2.854)	(-1.136)	(-2.787)	(-1.169)	(-0.909)
$\Delta CAR_{HIGH-LOW}$	Δmean	-0.085	-1.826***	-2.385***	-3.817***	-4.736***
	(*t*-stat)	(-0.267)	(-3.014)	(-2.816)	(-3.7546)	(-3.635)
	Δmedian	-0.484	-1.316***	-1.790***	-2.501***	-2.455***
	(*z*-stat)	(-1.212)	(-3.401)	(-2.735)	(-3.382)	(-3.747)

Notes: The table reports market adjusted cumulative abnormal returns (CAR) for different event windows following the sample of mega-catastrophes by an insurer's loss exposure (defined as the ratio of homeowners' premium earned in the affected states to total homeowners' premium earned). Both the results for exposed and unexposed insurers (Panel A) as well as for exposed insurers in the highest (Q_4) and lowest (Q_1) quartile of the distribution of loss exposure are shown (Panel B). Also, the differences in CAR between exposed and unexposed firms ($\Delta CAR_{EXPOSED-UNEXPOSED}$) as well as firms in the highest and lowest quartile of the distribution of loss exposure are reported ($\Delta CAR_{HIGH-LOW}$). To test for the statistical significance of CAR, a two tailed *t*-test as well as the non-parametric Mann–Whitney–Wilcoxon test are employed. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Overall, the finding that exposed insurers realize return losses, but unexposed insurers do not realize return gains around catastrophe events, further corroborates the pessimistic theory. It is also important to note that the delay in the market response to insurers' loss exposure (which is also evident in Figure 4-1) is confirmed in Table 4-4. Thus, differences in CAR between exposed and unexposed insurers are not statistically significant until at least 10 (5) days after the catastrophe event in Panel A (B).

4.3.3 Value Effects and Competition in the Homeowners' Insurance Market

An additional factor that may influence an insurer's stock price reaction and help determine the applicability of the pessimistic versus the hardening theory is the level of competition at the state level in the homeowners' insurance market. The hardening theory relies on the ability of insurers, when faced with additional demand for insurance coverage, to enforce premium increases for catastrophe coverage (e.g. Zanjani, 2002; Born and Viscusi, 2006). It is expected that insurers face more difficulty raising premiums when operating in highly competitive states as compared to insurers operating in states with little competition in the homeowners' insurance market.

For example, it could be argued that premium increases after a mega-catastrophe will be smaller in highly competitive states (which will make it more difficult to offset initial reimbursements paid to policyholders and capital depletions) as compared to states with low levels of competition, because premium increases in more competitive states are likely to result in a permanent loss of market share. Under the hardening theory, it is expected that insurers without loss exposure will experience valuation gains when they predominantly write business in states with low levels of competition.

The measure of competition is calculated in two steps. In a first step, a yearly Herfindahl index is computed based on homeowners' premiums in each state to measure the state-level degree of competition in the homeowners' insurance market. Specifically, a state-level Herfindahl index is calculated as the sum of the squared percentages of homeowners' insurance premiums earned by each insurer to the total homeowners' insurance premium earned by all insurers in a given state and year. In a second step, the Herfindahl index is weighted by the proportion of homeowners' insurance premiums earned in a state relative to the nationwide total of direct homeowner premiums earned by an insurer. To ease the interpretation of the results, the 1-Herfindahl index is used. The resulting measure of competition ranges from 0 to 1, with higher values indicating increased competition for an insurer.

Table 4-5 reports market-adjusted cumulative abnormal returns for different event windows after a mega-catastrophe for the highest (Q_4) and lowest quartile (Q_1) of the distribution of the 1-Herfindahl index and shows the differences in abnormal returns between the highest and lowest quartile ($\Delta CAR_{HIGH\text{-}LOW}$). This analysis is performed for the full sample (Panel A), exposed insurers (Panel B) and unexposed insurers (Panel C) to test for any differences among these groups.

Table 4-5
Cumulative Abnormal Returns by Competition

		CAR[0;+1]	CAR[0;+5]	CAR[0;+10]	CAR[0;+15]	CAR[0;+20]
Panel A: All Insurers						
HIGH Competition	mean	0.017	-0.032	-0.854*	-1.447**	-1.756*
Q_4 (N=155)	(*t*-stat)	(0.085)	(-0.091)	(-1.786)	(-1.975)	(-1.935)
	median	-0.032	0.093	-0.302	-1.036**	-1.299**
	(*z*-stat)	(-0.666)	(0.372)	(-1.363)	(-2.010)	(-2.158)
LOW Competition	mean	-0.076	0.507	0.694	1.188**	0.941*
Q_1 (N=186)	(*t*-stat)	(-0.399)	(1.385)	(1.459)	(2.206)	(1.674)
	median	-0.366**	-0.259	0.231	0.844*	0.364
	(*z*-stat)	(-2.075)	(-0.082)	(0.640)	(1.861)	(1.174)
$\Delta CAR_{HIGH-LOW}$	mean	0.093	-0.539	-1.548**	-2.635***	-2.697***
	(*t*-stat)	(0.336)	(-1.054)	(-2.277)	(-2.955)	(-2.613)
	median	0.334	0.352	-0.533	-1.880***	-1.663**
	(*z*-stat)	(0.895)	(0.361)	(-1.467)	(-2.740)	(-2.436)
Panel B: Exposed Insurers						
HIGH Competition	mean	-0.199**	-0.139	-1.217***	-2.380***	-2.851***
Q_4 N=117	(*t*-stat)	(-2.075)	(-1.338)	(-2.910)	(-3.542)	(-3.557)
	median	-0.133**	-0.091	-0.573**	-1.186***	-1.425***
	(*z*-stat)	(-2.396)	(-0.414)	(-2.231)	(-3.231)	(-3.682)
LOW Competition	mean	-0.055	0.450	0.665	1.005	0.632
Q_1 (N=153)	(*t*-stat)	(-0.243)	(1.056)	(1.189)	(1.609)	(0.965)
	median	-0.397*	-0.353	0.307	0.622	0.111
	(*z*-stat)	(-1.762)	(-0.480)	(0.396)	(1.207)	(0.236)
$\Delta CAR_{HIGH-LOW}$	mean	-0.144	-0.589	-1.882**	-3.385***	-3.483***
	(*t*-stat)	(-0.443)	(-1.043)	(-2.350)	(-3.332)	(-2.944)
	median	0.264	0.262	-0.880*	-1.808***	-1.536**
	(*z*-stat)	(0.180)	(0.451)	(-1.690)	(-2.604)	(-2.126)
Panel C: Unexposed Insurers						
HIGH Competition	mean	0.684	0.301	0.263	1.425	1.613
Q_4 (N=38)	(*t*-stat)	(1.646)	(0.299)	(0.276)	(0.955)	(0.936)
	median	0.196	0.276	0.182	0.761	0.106
	(*z*-stat)	(1.066)	(0.558)	(0.123)	(0.036)	(-0.007)
LOW Competition	mean	-0.174	0.773	0.829	2.035**	2.374**
Q_1 (N=33)	(*t*-stat)	(-0.784)	(1.276)	(1.185)	(2.237)	(2.662)
	median	-0.264	0.408	0.080	2.536**	2.852**
	(*z*-stat)	(-1.099)	(1.027)	(0.634)	(1.974)	(2.332)
$\Delta CAR_{HIGH-LOW}$	mean	0.858*	-0.472	-0.566	-0.610	-0.761
	(*t*-stat)	(1.744)	(-0.387)	(-0.466)	(-0.336)	(-0.375)
	median	0.460	-0.132	0.102	-1.775	-2.746
	(*z*-stat)	(1.430)	(-0.173)	(-0.565)	(-1.280)	(-1.579)

Notes: The table reports market adjusted cumulative abnormal returns (CAR) for different event windows following the sample of mega-catastrophes by state-level competition in the homeowners' insurance market (as measured by 1-homeowners' premium-based Herfindahl index at the state level which is value weighted by the individual insurer's proportion of homeowners' insurance premiums earned in the state to nationwide direct earned homeowner premiums in the year the catastrophe struck). CAR in the highest (Q_4) and lowest (Q_1) quartile of the distribution of competition are shown for all sample firms (Panel A), exposed insurers (Panel B) as well as unexposed insurers (Panel C). Also, the differences in CAR between firms in the highest (Q_4) and lowest (Q_1) quartile ($\Delta CAR_{HIGH-LOW}$) are shown. To test for the statistical significance of CAR, a two tailed *t*-test as well as the non-parametric Mann–Whitney–Wilcoxon test are employed. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 4-5 confirms the initial proposition that competition in the homeowners' insurance market affects the expected performance of insurers. For the sample as a whole (Panel A) as well as for the subsample of exposed insurers (Panel B), evidence is presented that CAR are lower (statistically significant at the 5% level for both *t*-tests and *z*-tests) when insurers predominantly operate in the most competitive states as compared to insurers operating in the least competitive states. Further, results show that unexposed insurers (Panel C) benefit from mega-catastrophes if they write business in the least competitive states. For this group of insurers, CAR are positive and statistically significant over [0; +15] and [0; +20].

Overall, the findings provide some evidence consistent with the hardening theory as proposed by Shelor et al. (1992) and Aiuppa et al. (1993). While the previous section has demonstrated that having no loss exposure does not cause positive market revaluation effects for insurers, the results in this section show that insurers with no loss exposure experience positive returns, but only when they predominantly write insurance business in states which exhibit low levels of competition. Presumably, low levels of competition create additional opportunities for insurers to enforce premium increases in the aftermath of a mega-catastrophe.

4.4 Multivariate Results

4.4.1 The Model

Next, multivariate regression analyses are used to assess the robustness of the findings in the univariate analysis and to jointly estimate the various factors which affect the market reaction of insurers to mega-catastrophes. Specifically, the following model is estimated via OLS with robust standard errors.

$$\mathbf{CAR}[0;+15] = \alpha + \gamma' \mathbf{IC} + \theta' \mathbf{CC} + \varepsilon\,, \tag{4.2}$$

where:

- **CAR**[0;+15] is the market-adjusted mean cumulative abnormal return over [0;+15] days relative to the catastrophe event date,
- **IC** is a vector of insurer characteristics in the fiscal quarter before the catastrophe event, and
- **CC** is a vector of catastrophe event characteristics.

In line with Cummins and Lewis (2003) and Chen et al. (2008), a multi-week event window is used. A multi-week event window is required to ensure that the event window coincides with the disclosure of important information about a catastrophe event to market investors. For example, the PCS catastrophe database used shows that, on average, a catastrophe lasts for 3 to 4 days and that it takes another 9 to 10 days before the first estimate of insured losses are published. In line with this, both Figure 4-1 and Table 4-4 showed that it takes around ten days for a more substantial market response to a mega-catastrophe to materialize. Finally, to control for the effect of unobserved variables that are constant over years and insurers, firm and year fixed effects are also included into the model.

Table 4-6 includes descriptions and summary statistics for the vector of variables described below. All accounting data (unless stated differently) refer to one fiscal quarter prior to the catastrophe event date and are from COMPUSTAT. Premium income data refer to the current fiscal year of the catastrophe event and are from NAIC insurer filings. Loss estimates are from the PCS database.

Table 4-6
Summary Statistics

	Variable	Definition	N	Mean	Median	Std. Dev	1 Pctile	99 Pctile
Value effect	CAR[0;+15]	Market-adjusted mean cumulative abnormal return over[0;+15] days relative to the mega-catastrophe event date (%)	716	-1.161	-0.698	8.796	-25.905	25.049
Insurer characteristics	FIRMSIZE	Log of total assets (millions of USD)	716	8.656	8.566	2.025	5.175	13.500
	TOBQ	Tobin's Q measured as the market value of equity plus the book value of liabilities divided by the book value of assets	716	1.103	1.049	0.229	0.689	1.955
	ROA	The ratio of pre-tax profits to total assets (%)	716	1.047	0.879	1.628	-2.721	4.407
	LOSSRATIO	Log of loss ratio which is defined as losses incurred to premiums earned in the homeowners' line of business	716	4.161	4.107	0.932	3.377	7.158
	EXPOSURE	The ratio of homeowners' premium earned in the affected state(s) to total homeowners' premium earned (%)	716	29.707	14.749	34.165	0.000	100.000
	EXPOSED	Dummy which equals 1 if the insurer has positive homeowners' premium earned in the affected state (and 0 otherwise)	716	0.779	1.000	0.415	0.000	1.000
	LOWCOMPETITION	Dummy which equals 1 if the insurer is located in the lowest quartile of the competition measure defined as 1-Herfindahl index by state-level homeowners' premium earned multiplied by the individual insurer's proportion of homeowners' insurance premiums earned in the state to nationwide direct earned homeowner premiums in the year the catastrophe struck	716	0.259	0.000	0.438	0.000	1.000
	HIGHRATING	Dummy which equals 1 if the insurer's financial rating assigned by Standard & Poor's is AA or better (and 0 otherwise)	716	0.056	0.000	0.229	0.000	1.000
	LINEDIVERS	A measure of line diversification defined as 1-Herfindahl index by line of business which is calculated as the sum of the squared percentage of insurance premium earned in each business line to the total premium earned in all property-liability lines (%)	716	74.622	79.463	12.625	36.641	89.214
Catastrophe characteristics	POSTKATRINA	Dummy which equals 1 if the catastrophe took place after hurricane Katrina (and 0 otherwise)	716	0.208	0.000	0.406	0.000	1.000
	relCATSIZE	The ratio of first insured loss estimate to total liabilities (%)	716	14.901	0.545	193.696	0.003	93.310
	CATSIZE	Log of first insured loss estimate (millions of USD) in constant 2010-USD terms based on the Consumer Price Index (All Urban Consumers)	716	0.743	0.407	0.917	0.003	3.647
	HURRICANE	Dummy which equals 1 if the catastrophe is a hurricane (and 0 otherwise)	716	0.474	0.000	0.499	0.000	1.000

Notes: Accounting data (apart from premium income data) refer to one fiscal quarter prior to the catastrophe event date and are from COMPUSTAT. Premium income data refer to the fiscal year of the catastrophe event and are from the State Pages of insurers' annual filings with the National Association of Insurance Commissioners (NAIC). Loss estimates are compiled using data from Property Claim Services (PCS).

Insurer Characteristics:

The vector of insurer characteristics contains the following variables. Firm size is included because larger firms are expected to be less susceptible to mega-catastrophes. Firm size (**FIRMSIZE**) is measured as the logarithm of the total assets in the financial quarter preceding the mega-catastrophe and it is expected to find a positive relationship between FIRMSIZE and the market revaluation effect following a mega-catastrophe.[21]

Further, the insurer's Tobin's Q is included (**TOBQ**, measured as the market value of equity plus the book value of liabilities divided by the book value of assets), a commonly used proxy for a firm's growth opportunities. Cummins et al. (2006) demonstrate that operational loss events that lead to internal capital depletion cause larger losses in market value for insurers with higher growth opportunities. The authors argue this is because having capital for new investments is more important for growth-orientated firms. Since mega-catastrophes typically lead to internal capital depletion, TOBQ is expected to enter the regressions with a negative coefficient.

Next, the model also controls for the general insurer performance as well as the insurer performance in the homeowners' market segment. For general performance, return on assets is used (**ROA**, defined as pre-tax profits over the book value of total assets), while the performance in the homeowners' insurance business

[21] As alternative measures to FIRMSIZE, the number of states where an insurer writes business as well as the annual total premium earned as a proxy for the firm's size are employed. Regression results, however, do not change by using these measures instead of FIRMSIZE.

is measured using the log of the loss ratios (**LOSSRATIO**, defined as the log of the sum of claim and loss expenses scaled by premium income).[22] Both performance measures are expected to enter the model with positive coefficients, as more profitable insurers should be in a better position to quickly recover from any capital depletions caused by a mega-catastrophe.

In line with the univariate tests, the model also controls for both the existence as well as the level of an insurers' loss exposure to a mega-catastrophe. To capture the existence of loss exposure, a dummy variable (**EXPOSED**) is included which is one when an insurer has earned homeowners' premium in the state(s) affected by an event (and 0 otherwise). To capture the level of loss exposure, the ratio of homeowners' premiums earned in the affected state(s) to total homeowners' premium earned is included **(EXPOSURE)**. Both measures of exposure are expected to be highly correlated with insured losses and, therefore, to enter the model with a negative coefficient.

The model also includes a variable to control for the level of competition in the homeowners' insurance market. For this purpose, **LOWCOMPETITION** is used, a dummy which equals one if the insurer is located in the lowest quartile of the competition measure (which is defined as the 1-Herfindahl index by state-level homeowners' premium earned; see Section 4.3.3 for a more detailed description of how the competition measure is calculated). In line with the univariate results above, LOWCOMPETITION is expected to have a positive effect on insurers' abnormal

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[22] The log of loss ratios is used as the loss ratios in the homeowners' line of business are usually highly skewed.

returns. This is because firms can more readily increase insurance premiums in states with little competition, leading to more profitable insurance business in the future.

Next, the insurer's financial rating is included to compute **HIGHRATING**, a dummy variable which equals one if the insurer's financial rating assigned by Standard&Poor's is AA or better (and 0 otherwise) when a mega-catastrophe occurs. Mega-catastrophes are likely to give insurers with superior financial ratings a competitive advantage. These firms are in a better position to quickly replenish external capital at relatively lower costs as compared to insurers with lower financial ratings (which have to rely on slower capital recovery using internal capital as external capital is too costly for them). This is supported by Cummins and Lewis (2003) and Chen et al. (2008) who find evidence that insurers with superior financial ratings were better able to recover from the financial losses associated with the World Trade Center attacks in 2001. Consequently, HIGHRATING is expected to have a positive impact on insurers' abnormal returns following mega-catastrophes as those firms can raise capital more cheaply.

Finally, the model controls for the product (or line) diversification within the firm by including the 1-Herfindahl index of business diversity (**LINEDIVERS)**. LINEDIVERS is calculated as the sum of the squared percentage of insurance premiums earned in each business line reported in NAIC filings to the total premium earned in all property and-liability lines. Higher values of this variable denote a more diversified firm. As more diversified firms are expected to be better able to handle losses from mega-catastrophes, LINEDIVERS is expected to enter the models with positive coefficients.

Catastrophe Characteristics:

The vector of catastrophe characteristics includes a dummy variable which is one if the catastrophe event occurred after Hurricane Katrina **(POSTKATRINA)** and zero otherwise. It is hypothesized that Hurricane Katrina (the most expensive catastrophe in insurance history) has caused insurers to revise their probabilistic catastrophe models by increasing both the probability of loss occurrence and the magnitude of mega-catastrophe induced losses. For example, Cummins (2007, pg. 182) refers to Hurricane Katrina as a '*truly paradigm shifting event*' for insurance markets as regards the revision of databases and predictive techniques in modelling natural catastrophes. Consequently, POSTKATRINA is expected to be positively related to insurer valuations as the losses caused by mega-catastrophes should be more anticipated by insurers after Hurricane Katrina.

Further, the size of the first estimate of insured losses (**CATSIZE)** is included. For this purpose, preliminary estimates of insured losses are used instead of final estimates, because the final estimates were only available after the examination period. CATSIZE is expected to enter the model with a negative coefficient as larger losses are associated with larger reimbursements to policyholders. Since catastrophe losses which are small in absolute terms may still yield similar performance effects than large catastrophes for smaller insurers, a measure of relative loss size is also included as the ratio of the first insured loss estimate to the insurer's total liabilities **(relCATSIZE)** in the regressions. First loss estimates are scaled by total liabilities, because the liabilities of P&L insurers typically comprise of insurance reserves for future loss payments.

Finally, the model includes a dummy variable which is equal to one if the mega-catastrophe is a hurricane and zero otherwise (**HURRICANE**). It is argued that since losses from hurricanes account for the lion's share of total catastrophe losses in the sample (approximately 82% of total losses are caused by hurricanes), insurers should be able to more precisely anticipate losses from mega-catastrophes caused by hurricanes in premium pricing. Consequently, HURICANE is expected to be positively related to insurance firm values.

4.4.2 Regression Results

Table 4-7 presents the results of the regressions on market-adjusted cumulative abnormal returns (CAR[0;+15]) in response to mega-catastrophes. The results confirm the main findings from the univariate tests above. First, capital markets distinguish among firms based on the existence as well as the magnitude of an insurer's loss exposure. Thus, EXPOSED and EXPOSURE both enter with a negative and statistically significant coefficients at the 1%-level.[23] This is consistent with arguments that investors devalue those insurers in the aftermath of catastrophe events which face potential reimbursements to policyholders and that higher loss exposures (which are associated with higher depletions of internal capital) lead to less favourable stock price performance around a mega-catastrophe.

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[23] EXPOSED and EXPOSURE are not simultaneously included in one model as they have a high correlation between them.

Table 4-7
Regressions on Insurers' Cumulative Abnormal Returns [0;+15], All Sample Insurers

	(A)	(B)	(C)	(D)	(E)	(F)
FIRMSIZE	-0.109	-0.102	-0.231	-0.110	-0.062	-0.178
	(0.11)	(0.10)	(0.23)	(0.11)	(0.06)	(0.17)
TOBQ	-8.109**	-8.185**	-8.065**	-7.547**	-7.567**	-7.611**
	(2.35)	(2.31)	(2.39)	(2.21)	(2.15)	(2.24)
ROA	1.036	1.035	0.912	1.038	1.030	0.940
	(1.42)	(1.41)	(1.23)	(1.42)	(1.39)	(1.26)
LOSSRATIO	0.073	0.099	0.096	0.143	0.158	0.141
	(0.27)	(0.33)	(0.32)	(0.52)	(0.52)	(0.46)
EXPOSURE				-0.043***	-0.045***	-0.039***
				(3.52)	(3.69)	(3.13)
EXPOSED	-3.267***	-3.455***	-3.248***			
	(3.43)	(3.65)	(3.48)			
LOWCOMPETITION	4.999***	5.826***	7.157***	4.862***	5.793***	6.799***
	(5.88)	(5.64)	(6.59)	(5.69)	(5.56)	(6.20)
HIGHRATING		0.034	0.032		0.014	0.014
		(0.43)	(0.40)		(0.18)	(0.17)
LINEDIVERS			4.051			4.377
			(1.35)			(1.51)
POSTKATRINA	9.222***	9.886***	10.755***	9.335***	10.088***	10.769***
	(6.63)	(6.86)	(7.36)	(6.75)	(7.02)	(7.39)
relCATSIZE	-0.253	-0.241	-0.198	-0.277	-0.253	-0.217
	(0.45)	(0.42)	(0.35)	(0.49)	(0.44)	(0.38)
CATSIZE		-0.960**	-1.427***		-1.089**	-1.413***
		(2.11)	(3.11)		(2.42)	(3.11)
HURRICANE			3.226***			2.512**
			(3.07)			(2.34)
Intercept	12.490	10.736	10.013	11.894	11.242	10.485
	(1.53)	(1.16)	(1.09)	(1.45)	(1.20)	(1.12)
Observations	716	716	716	716	716	716
Year fixed effects	YES	YES	YES	YES	YES	YES
Insurer fixed effects	YES	YES	YES	YES	YES	YES
Adjusted R^2	0.196	0.198	0.210	0.201	0.203	0.210

Notes: The table reports the results of OLS regression with robust standard errors for CAR [0;+15] relative to the mega-catastrophe event. The independent variables are the log of total assets (FIRMSIZE), the insurers' Tobin's Q (TOBQ) measured as the market value of equity plus the book value of liabilities divided by the book value of assets, the ratio of pre-tax profits to total assets (ROA), the log of the loss ratio which is defined as losses incurred to premiums earned in the homeowners' line of business (LOSSRATIO), the ratio of homeowners' premium earned in affected state(s) to total homeowners' premium earned (EXPOSURE), a dummy which equals 1 if the insurer has positive homeowners' premium earned in the affected states (EXPOSED), a dummy which equals 1 if the insurer is located in the lowest quartile of the competition measure defined by 1-Herfindahl index by state-level homeowners' premium (LOWCOMPETITION), 1-Herfindahl index by line of business (LINEDIVERS) which is calculated as the sum of the squared percentage of insurance premium earned in each business line to the total premium earned in all property and-liability lines, a dummy which equals 1 if the insurer's financial rating assigned by Standard &Poor's is AA or better (HIGHRATING), a dummy which equals 1 if the catastrophe took place after hurricane Katrina (POSTKATRINA), the ratio of total insured loss to total liabilities (relCATSIZE), the total insured loss (billions USD) in constant 2010-USD terms based on the Consumer Price Index (CATSIZE) and a dummy which is equal to one if the mega-catastrophe is a hurricane (HURRICANE). Accounting data (apart from premium income data) refer to one fiscal quarter prior to the catastrophe event and are from COMPUSTAT. Premium income data refer to the current fiscal year of the catastrophe event and are from the State Pages of insurers' annual filings with the National Association of Insurance Commissioners (NAIC). Loss estimates are compiled using data from Property Claim Services. The *t*-statistics (two tailed) of the coefficients are reported in the parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Second, LOWCOMPETITION enters the regression models with a positive and statistically significant coefficient (at the 1%-level) which shows that firms are more likely to benefit from mega-catastrophes when they write homeowners' insurance in the least competitive states. This is consistent with the argument that firms can more easily increase premiums in response to mega-catastrophes in states with lower competition as compared to states with higher competition where premium increases are likely to result in a permanent loss of market share.

In addition to the results at the univariate level, further variables are identified which significantly impact on the stock price response of insurers. TOBQ, for example, is negatively related with abnormal returns at the 5% level. In line with Cummins et al. (2006), it is argued that loss events, such as mega-catastrophes, which lead to internal capital depletion are more severe for firms with strong growth prospects than for firms whose market value is more dependent on assets in place, as capital for new investments is more important for growth-orientated firms.

Also, a negative relationship (at the 5% level) is reported between the amount of first insured loss estimates (CATSIZE) and insurers' stock price reaction. This result was anticipated, as more expensive catastrophes (in terms of insured losses) lead to higher loss payments. Finally, results report that mega-catastrophes which are caused by hurricanes as well as catastrophes which occurred after Hurricane Katrina have positive value implications for insurers. Thus, both HURRICANE and POSTKATRINA are positive and statistically significant (at the 5%-level and 1%-level, respectively). This is in line with the arguments that the risk models for hurricanes are amongst the most advanced and most accurate ones (as regards the estimation of the probability of potential losses of future hurricanes) and that Hurricane Katrina caused the insurance industry to upwardly revise its expectations regarding the potential magnitude of all natural disaster losses (and not only windstorm events) which resulted in a smaller ‘shock effect’ for mega-catastrophes following Katrina as large-scaled losses by natural catastrophes were better anticipated by capital markets (Cummins and Lewis, 2003).

In a next step, it is tested whether the results observed for the sample as a whole (Table 4-7) also apply for the two subgroups of exposed and unexposed firm level observations. The rationale behind this test is that some of the variables are expected to turn (in)significant when applied to the sample of (un)exposed firm level observations only. For example, it could be argued that variables such as the absolute and relative size of first insured loss estimates (CATSIZE and relCATSIZE) which relate to the level of capital depletions (following reimbursements to policyholders) should only impact upon the stock price performances of exposed insurers.

Table 4-8 presents the results of regressions on market-adjusted cumulative abnormal returns (CAR[0;+15]) in response to mega-catastrophes for exposed and unexposed firm level observations, respectively. For the sample of exposed firm level observations it is reported, in addition to the results for the sample as a whole (Table 4-7), that the relative size of first loss estimates (relCATSIZE) enters the model with a negative and statistically significant coefficient. This provides further evidence that more expensive catastrophes (this time in relative terms) lead to higher loss payments. For the sample of unexposed insurers, only LOWCOMPETITION and POSTKATRINA remain significant while all variables which are related to the effect of underwriting losses (TOBQ, CATSIZE and relCATSIZE, HURRICANE) turn out to be insignificant.

Table 4-8
Regressions on Insurers' Cumulative Abnormal Returns [0;+15], Exposed and Unexposed Insurers

	Exposed Insurers			Unexposed Insurers		
	(A)	(B)	(C)	(D)	(E)	(F)
FIRMSIZE	-0.782	-0.660	-0.782	-4.144	-3.739	-3.967
	(0.84)	(0.70)	(0.82)	(1.06)	(1.00)	(1.05)
TOBQ	-7.848**	-7.842**	-7.592**	-2.217	-2.199	-1.590
	(2.17)	(2.12)	(2.15)	(0.31)	(0.31)	(0.22)
ROA	-0.123	-0.104	-0.236	0.880	0.801	0.746
	(0.16)	(0.13)	(0.30)	(0.79)	(0.72)	(0.67)
LOSSRATIO	0.050	0.047	0.002	-0.695	-0.722	-0.736
	(0.14)	(0.13)	(0.01)	(1.34)	(1.39)	(1.45)
EXPOSURE	-0.032**	-0.035**	-0.026*			
	(2.25)	(2.41)	(1.70)			
LOWCOMPETITION	5.289***	6.267***	7.422***	5.276**	6.730**	7.450**
	(5.51)	(5.41)	(5.94)	(2.46)	(2.17)	(2.41)
HIGHRATING		-0.013	-0.009		0.004	0.004
		(0.18)	(0.12)		(0.02)	(0.02)
LINEDIVERS			3.913			2.648
			(1.30)			(1.15)
POSTKATRINA	8.227***	9.061***	9.803***	10.350***	11.354***	11.810***
	(5.39)	(5.57)	(5.91)	(3.76)	(3.62)	(3.75)
relCATSIZE	-1.458***	-1.378***	-1.393***	-0.614	-0.532	-0.532
	(3.23)	(2.92)	(3.03)	(0.77)	(0.67)	(0.67)
CATSIZE		-1.217**	-1.630***		-1.101	-1.175
		(2.40)	(3.05)		(1.09)	(1.15)
HURRICANE			2.722**			2.789
			(2.15)			(1.05)
Intercept	17.983**	18.694*	17.320*	35.895	33.966	32.332
	(2.06)	(1.90)	(1.74)	(1.16)	(1.09)	(1.02)
Observations	558	558	558	158	158	158
Year fixed effects	YES	YES	YES	YES	YES	YES
Insurer fixed effects	YES	YES	YES	YES	YES	YES
Adjusted R^2	0.237	0.240	0.248	0.118	0.109	0.108

Notes: The table reports the results of OLS regression with robust standard errors for CAR [0;+15] relative to the mega-catastrophe event. The independent variables are the log of total assets (FIRMSIZE), the insurers' Tobin's Q (TOBQ) measured as the market value of equity plus the book value of liabilities divided by the book value of assets, the ratio of pre-tax profits to total assets (ROA), the log of the loss ratio which is defined as losses incurred to premiums earned in the homeowners' line of business (LOSSRATIO), the ratio of homeowners' premium earned in affected state(s) to total homeowners' premium earned (EXPOSURE), a dummy which equals 1 if the insurer is located in the lowest quartile of the competition measure defined by 1-Herfindahl index by state-level homeowners' premium (LOWCOMPETITION), 1-Herfindahl index by line of business (LINEDIVERS) which is calculated as the sum of the squared percentage of insurance premium earned in each business line to the total premium earned in all property and-liability lines, a dummy which equals 1 if the insurer's financial rating assigned by Standard &Poor's is AA or better (HIGHRATING), a dummy which equals 1 if the catastrophe took place after hurricane Katrina (POSTKATRINA), the ratio of total insured loss to total liabilities (relCATSIZE), the total insured loss (billions USD) in constant 2010-USD terms based on the Consumer Price Index (CATSIZE) and a dummy which is equal to one if the mega-catastrophe is a hurricane (HURRICANE). Accounting data (apart from premium income data) refer to one fiscal quarter prior to the catastrophe event and are from COMPUSTAT. Premium income data refer to the current fiscal year of the catastrophe event and are from the State Pages of insurers' annual filings with the National Association of Insurance Commissioners (NAIC). Loss estimates are compiled using data from Property Claim Services. The *t*-statistics (two tailed) of the coefficients are reported in the parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

4.5 Robustness

Several tests are conducted to evaluate the robustness of the results. First, it is assessed whether the results are sensitive to the event window used. For this purpose, the analysis of market-adjusted mean cumulative abnormal return is re-run using [0;+1], [0;+5] [0;+10] and [0;+20] days relative to the catastrophe event date as event windows. The results of this test are provided in Table 4-9 (models A-H). It becomes apparent that, with the exception of CAR(0;+1), all event windows confirm the main conclusions as the regression results remain qualitatively unaffected. However, the insignificance of nearly all variables during [0;+1] confirms the rationale for using multi-week event windows. After all, key information relating to expected losses which are crucial for market investors to assess potential performance implications of mega-catastrophes are usually not available one day after the event date.

Next, the stability of the results are examined after excluding Hurricane Katrina from the sample of mega-catastrophes. This is done, because Hurricane Katrina is still the most expensive natural catastrophe in insurance history (in terms of insured losses) and, as such, might have influenced the results reported. Consequently, all firm level observations are excluded that relate to Hurricane Katrina and the analysis of market-adjusted mean cumulative abnormal returns over [0;+15] days relative to the catastrophe event date is re-run. The results are shown in Table 4-9 (models I-J). Apart from the absolute size of first insured loss estimates (CATSIZE), which turns out to be insignificant, all other conclusions remain unaffected.

Table 4-9
Regressions on Insurers' Cumulative Abnormal Returns for different Event Windows and Without Hurricane Katrina

	CAR(0;+1)		CAR(0;+5)		CAR(0;+10)		CAR(0;+20)		Excluding Katrina CAR (0;+15)	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
FIRMSIZE	0.003	0.005	0.330	0.345	0.044	0.079	-0.819	-0.759	-0.256	-0.191
	(0.01)	(0.02)	(0.74)	(0.77)	(0.06)	(0.11)	(0.83)	(0.75)	(0.25)	(0.19)
TOBQ	-0.069	-0.068	0.327	0.334	-3.892**	-3.553**	-6.937**	-6.407*	-7.802**	-7.353**
	(0.46)	(0.45)	(1.16)	(1.18)	(2.32)	(2.14)	(2.03)	(1.81)	(2.38)	(2.22)
ROA	0.039	0.068	-0.154	0.015	0.705*	0.723*	0.646	0.677	0.954	0.987
	(0.04)	(0.08)	(0.12)	(0.01)	(1.90)	(1.94)	(1.08)	(1.13)	(1.28)	(1.31)
LOSSRATIO	-0.108	-0.105	-0.220	-0.200	-0.020	0.017	0.021	0.075	0.045	0.084
	(1.22)	(1.19)	(1.24)	(1.12)	(0.08)	(0.07)	(0.05)	(0.18)	(0.15)	(0.27)
EXPOSURE		-0.003		-0.015**		-0.029***		-0.045***		-0.038***
		(0.70)		(2.57)		(3.44)		(2.82)		(3.00)
EXPOSED	-0.145		-0.972*		-2.161***		-3.677***		-3.345***	
	(0.47)		(1.79)		(3.16)		(3.19)		(3.46)	
LOWCOMPETITION	1.081***	1.062***	4.233***	4.116***	5.855***	5.606***	7.098***	6.688***	6.517***	6.222***
	(2.65)	(2.62)	(6.36)	(6.15)	(7.45)	(7.06)	(5.53)	(5.19)	(5.50)	(5.22)
HIGHRATING	-0.008	-0.009	-0.002	-0.008	0.007	-0.005	0.010	-0.010	0.029	0.012
	(0.40)	(0.44)	(0.06)	(0.22)	(0.13)	(0.10)	(0.08)	(0.09)	(0.37)	(0.14)
LINEDIVERS	0.744	0.756	2.612	2.700	3.151	3.357	2.044	2.408	4.108	4.444
	(0.75)	(0.77)	(1.21)	(1.26)	(1.06)	(1.14)	(0.65)	(0.79)	(1.36)	(1.51)
POSTKATRINA	0.801	0.794	5.290***	5.266***	8.499***	8.477***	9.279***	9.283***	8.217***	8.529***
	(1.49)	(1.46)	(4.96)	(4.93)	(7.56)	(7.52)	(5.70)	(5.62)	(4.23)	(4.34)
relCATSIZE	0.024	0.023	-0.221	-0.228	-0.367	-0.382	-0.219	-0.241	-0.264	-0.287
	(0.16)	(0.15)	(1.21)	(1.24)	(1.41)	(1.47)	(0.44)	(0.48)	(0.45)	(0.49)
CATSIZE	-0.089	-0.091	-0.659***	-0.667***	-1.248***	-1.252***	-1.126**	-1.116**	0.189	0.033
	(0.53)	(0.55)	(2.63)	(2.67)	(3.85)	(3.90)	(2.02)	(2.01)	(0.20)	(0.03)
HURRICANE	0.579*	0.528	2.363***	2.075***	2.441***	1.884**	3.603***	2.762**	2.743**	2.094*
	(1.73)	(1.54)	(4.71)	(4.11)	(3.35)	(2.47)	(3.08)	(2.30)	(2.56)	(1.93)
Intercept	1.635	1.719	-2.871	-2.496	4.698	5.272	12.322	12.962	9.867	10.245
	(0.61)	(0.63)	(0.68)	(0.59)	(0.76)	(0.84)	(1.04)	(1.06)	(1.06)	(1.07)
Observations	716	716	716	716	716	716	716	716	680	680
Year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Insurer fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Adjusted R^2	0.023	0.023	0.178	0.181	0.203	0.207	0.179	0.180	0.222	0.221

Notes: The table reports the results of OLS regression with robust standard errors for cumulative abnormal returns (CAR) for different event windows following the sample of mega-catastrophes (models A-H) as well as for CAR[0;+15] without any observations that relate to the effects of Hurricane Katrina. The independent variables are the log of total assets (FIRMSIZE), the insurers' Tobin's Q (TOBQ) measured as the market value of equity plus the book value of liabilities divided by the book value of assets, the ratio of pre-tax profits to total assets (ROA), the log of the loss ratio which is defined as losses incurred to premiums earned in the homeowners' line of business (LOSSRATIO), the ratio of homeowners' premium earned in affected state(s) to total homeowners' premium earned (EXPOSURE), a dummy which equals 1 if the insurer has positive homeowners' premium earned in the affected states (EXPOSED), a dummy which equals 1 if the insurer is located in the lowest quartile of the competition measure defined by 1-Herfindahl index by state-level homeowners' premium (LOWCOMPETITION), 1-Herfindahl index by line of business (LINEDIVERS) which is calculated as the sum of the squared percentage of insurance premium earned in each business line to the total premium earned in all property and-liability lines, a dummy which equals 1 if the insurer's financial rating assigned by Standard &Poor's is AA or better (HIGHRATING), a dummy which equals 1 if the catastrophe took place after hurricane Katrina (POSTKATRINA), the ratio of total insured loss to total liabilities (relCATSIZE), the total insured loss (billions USD) in constant 2010-USD terms based on the Consumer Price Index (CATSIZE) and a dummy which is equal to one if the mega-catastrophe is a hurricane (HURRICANE). Accounting data (apart from premium income data) refer to one fiscal quarter prior to the catastrophe event and are from COMPUSTAT. Premium income data refer to the current fiscal year of the catastrophe event and are from the State Pages of insurers' annual filings with the National Association of Insurance Commissioners (NAIC). Loss estimates are compiled using data from Property Claim Services. The *t*-statistics (two tailed) of the coefficients are reported in the parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

4.6 Summary and Conclusions

Mega-catastrophes are low-frequency but high-severity events which pose great financial risks to insurance firms. Underwriting losses from mega-catastrophes are often large relative to capital reserves. Further, mega-catastrophes are extremely difficult to predict which means they cannot be fully anticipated in premium pricing. However, mega-catastrophes may also lead to an increase in consumer and institutional demand for catastrophe risk insurance and lead to premium increases in the catastrophe risk market. Previous empirical work tends to focus on a single catastrophe event and reports results that are consistent with either of these explanations. In this chapter, a cross-section of nineteen mega-catastrophes between 1996 and 2010 is examined to shed light on a simple question: what are the expected performance effects of mega-catastrophes on insurance firms?

The rationale behind this question is to assess whether the rather limited use of insurance securitization can (to some extent) be explained by the fact that the expected losses from natural catastrophes (as reflected in equity losses) despite the capacity constraints in the market for catastrophe risk do not pose as much of a risk to insurance and reinsurance firms as proposed by several authors (e.g., Froot, 2001 or Cummins et al., 2002). For example, if the expected losses associated with natural catastrophes are only little, insurance and reinsurance firms may not have much to gain from additional underwriting capacity provided by insurance securitization.

The results show that P&L insurers with homeowners' exposure realize value losses around the time that a mega-catastrophe occurs. Since this value effect is primarily driven by insurers with loss exposure to the type of event which occurs, this indicates that market investors are concerned about underwriting losses associated with a mega-catastrophe. Further, no evidence is found that insurers without loss exposure experience valuation gains, unless they operate in the least competitive geographic markets. However, and most importantly, the magnitude of share price losses during the examination period is only moderate on average. This is interpreted as evidence that the expected performance implications of mega-catastrophes are by no means devastating for insurers. Consequently, the results challenge the view that firms exposed to catastrophe risks have much to gain from additional underwriting capacity and, therefore, put a ceiling on the potential benefits of insurance securitization to firms. Arguably, this finding provides a possible explanation for the underwhelming use of insurance securitization as a tool for increasing the underwriting capacity for catastrophe risks.

4.7 Appendix

Table 4-10
Explanation of State Abbreviations

AK	Alaska	LA	Louisiana	OH	Ohio
AL	Alabama	MA	Massachusetts	OK	Oklahoma
AR	Arkansas	MD	Maryland	OR	Oregon
AZ	Arizona	ME	Maine	PA	Pennsylvania
CA	California	MI	Michigan	RI	Rhode Island
CO	Colorado	MN	Minnesota	SC	South Carolina
CT	Connecticut	MO	Missouri	SD	South Dakota
DE	Delaware	MS	Mississippi	TN	Tennessee
FL	Florida	MT	Montana	TX	Texas
GA	Georgia	NC	North Carolina	UT	Utah
HI	Hawaii	ND	North Dakota	VA	Virginia
IA	Iowa	NE	Nebraska	VT	Vermont
ID	Idaho	NH	New Hampshire	WA	Washington
IL	Illinois	NJ	New Jersey	WI	Wisconsin
IN	Indiana	NM	New Mexico	WV	West Virginia
KS	Kansas	NV	Nevada	WY	Wyoming
KY	Kentucky	NY	New York		

5
The Performance Implications of Insurance Securitization: The Case of Catastrophe Bonds and Issuing Firms[24]

5.1 Introduction

The previous chapter demonstrates that, despite the recent increase in underwriting losses from natural catastrophes and capacity constraints in the market for catastrophe risk, insurance and reinsurance firms are (on average) able to cope rather well with the losses associated with natural catastrophes. This raises questions about the usefulness and value of insurance securitization as a risk management tool for insurance and reinsurance firms to provide additional underwriting capacity.

This chapter empirically analyzes the performance implications of insurance securitization for insurance and reinsurance firms in order to find out about the perceptions of capital markets about the use of insurance securitization and to provide new empirical evidence which can help to explain the limited use of

[24] A version of this chapter has been accepted for publication as Hagendorff, B., J. Hagendorff, K. Keasey, The Shareholder Wealth Effects of Insurance Securitization: Preliminary Evidence from the Catastrophe Bond Market, *Journal of Financial Services Research* (forthcoming in 2013).

insurance securitization by insurance and reinsurance firms. Specifically, for a unique sample which consists of the near population of Cat bond issues by listed companies up to May 2010, changes in the market value realized by firms which announce their intention to issue a Cat bond are computed. As illustrated in Chapter 3, Cat bonds have been the most successful insurance securitization vehicles to date (in terms of total risk capital issued). Basically, Cat bonds are insurance derivatives whose payoffs depend on the occurrence of a catastrophe loss event. As such, the issuing firm may forfeit on principal and/or coupon payments when a specified catastrophe loss event occurs.

This chapter makes two important contributions. First, it presents the first empirical investigation into the wealth benefits of Cat bonds. Given the relatively low number of Cat bond issues to date, previous work on Cat bonds has been mostly theoretical (e.g. Bantwal and Kunreuther, 2000; Lakdawalla and Zanjani, 2006) with empirical work lagging behind. This has led to considerable uncertainty as to the actual effects of Cat bonds on the issuing firm. While the low number of Cat bond issues to date also means that the results of the following analysis have to be interpreted with suitable care, the analysis is the first to show that, even though Cat bonds do not lead to strong wealth gains for shareholders in the issuing firm, there are large variations in the market revaluation effects linked to Cat bonds.

Second, this chapter helps to understand the motivations as to why firms issue Cat bonds. While the motivations for banks to engage in asset securitization have previously been analyzed (e.g. Ambrose et al., 2005; Lockwood et al., 1996, Martin-Oliver and Saurina, 2007), much less is empirically known about the reasons why firms engage in insurance securitization. Jointly, the results of this chapter support the notion that firms issue Cat bonds less as a means to hedge catastrophe risks and more as a means to realize cost efficiencies relative to other forms of catastrophe risk management. For instance, the analysis reveals that the value effects linked to Cat bond issues are particularly pronounced for firms with less volatile losses from their insurance business. It is argued that this group of firms is likely to benefit from lower information acquisition costs in financial markets when they substitute reinsurance coverage using Cat bonds (see Gibson et al. 2011). In the same vein, since Cat bond prices are fixed over a multi-year period and remain unaffected by future price increases in the market for catastrophe coverage, issuer abnormal returns are particularly high during periods of low catastrophe reinsurance prices when the costs of raising capital via Cat bonds are relatively low.

The remainder of this chapter is organized as follows. Section 5.2 surveys the previous literature on why firms may benefit from issuing Cat bonds and develops the propositions to be tested in this chapter. Section 5.3 discusses the data and empirical strategy. Sections 5.4 and 5.5 then present the results of the univariate and multivariate analysis, respectively. Finally, Section 5.6 concludes and discusses the implications of the findings.

5.2 Theory and Literature: Do Firms Benefit from Issuing Catastrophe Bonds?

Most of the reasons as to why firms may benefit from issuing Cat bonds can be summarized into two main arguments. First, Cat bonds allow firms to hedge against catastrophe-related underwriting losses. Second, Cat bonds can help firms with catastrophe exposure to realize costs savings on catastrophe-related risk management.

The first argument is that Cat bonds allow the issuer to hedge against catastrophe-related underwriting losses by transferring catastrophe risks to capital markets (e.g. Niehaus, 2002; Harrington and Niehaus, 2003; Cummins et al., 2004). The argument is based on the rationale that Cat bonds typically let the issuing firm forfeit on principal and/or coupon payments subject to a catastrophe event occurring. Cat bonds can, therefore, be viewed as a form of subordinated debt which, once forgiven, free up funds to absorb underwriting losses caused by a specified catastrophe.

In practice, however, the payoff structure of Cat bonds rarely makes them a perfect hedge against underwriting losses. This is because the triggers, which permit forfeiture, do not necessarily match the specific loss experience of the issuer. Instead, triggers tend to be defined in terms of industry losses (e.g. via loss indices). While index-based triggers are meant to keep issuers from transferring their highest portfolio risks to unsuspecting investors (Doherty, 1997), any mismatch between the payoffs from issuing Cat bonds and the losses experienced by the issuer in a catastrophe event gives rise to so-called basis risk. Simulation analyses conducted by Harrington and Niehaus (1999) and Cummins et al. (2004) show that the basis risk linked to index-based triggers is manageable for U.S. homeowner insurers and large Hurricane insurers in Florida, respectively. Nonetheless, it is important to bear in mind that these results are based on simulations. The risk that the payoffs from index-based Cat bonds do not cover the issuer's catastrophe losses remains a valid concern for issuing firms. However, regarding basis risk and Cat bonds, it is also important to bear in mind that the payoffs in a classical insurance setup may also be inefficient. Some insurance and reinsurance contracts include a cap on the losses which may be indemnified, which means that insurance coverage may not fully indemnify an insurer's losses either in the event of a natural catastrophe.

While the presence of basis risk diminishes the effectiveness of Cat bonds as a perfect hedge, there are also questions over the extent to which Cat bonds help diversify catastrophe exposures more generally. Commonly, insurers economize on capital and realize diversification gains by protecting insured value in excess of the capital held against it. However, in contrast to insurance agreements, Cat bonds frequently offer full collateralization of risk exposures. This is because the funds reserved for principal payment are placed in special trusts and cannot be used to offset losses caused by events other than the trigger event (Niehaus, 2002; Lakdawalla and Zanjani, 2006). In that respect, it could be argued that capital provision via Cat bonds is inefficient, because it precludes the type of capital diversification benefits linked to traditional insurance and reinsurance.

The second argument as to why firms could benefit from issuing Cat bonds is based on issuing firms realizing costs savings on catastrophe-related risk management (e.g. Jaffee and Russell, 1997; Niehaus, 2002; Kunreuther and Heal, 2012). Traditionally, catastrophe risk management for underwriting firms involves either raising capital (to absorb losses) or purchasing reinsurance (to seek indemnity from all or part of the losses caused by a catastrophe event). The cost of purchasing reinsurance coverage for catastrophe risks is expensive since reinsurance premiums are high relative to actuarial loss estimates (see Lane and Mahul, 2008). This is why especially higher layers of protection (i.e. protection against events with a very low probability of occurrence) often go unreinsured by insurers (Froot, 2001). Therefore, insurers that seek to increase their catastrophe underwriting capacity will typically have to rely on raising capital. However, raising capital to absorb catastrophe losses is costly for both insurance and reinsurance companies (e.g. Jaffee and Russell, 1997; Froot, 2001; Niehaus, 2002). For insurance companies, raising equity capital is costly because it is tax-inefficient, while raising debt capital to finance catastrophe risks increases the probability of financial distress of the insurer (Niehaus, 2002). For reinsurance companies, raising capital to increase their capacity to underwrite catastrophe risks is costly, as it is likely to lead to higher costs of capital. This is because catastrophes are large correlated loss events which reinsurers cannot fully diversify (Froot and Stein, 1998; Froot and O'Connell, 2008).

Against this background, Cat bonds could provide a cost-efficient substitute for risk management via reinsurance. Froot and O'Connell (2008) argue that because catastrophe risks are both quantifiable and diversifiable for investors, the required rate of return from holding Cat bonds should equal the risk-free rate. This argument stands in contrast to the findings of applied work which shows that, while spreads on Cat bonds have fallen in recent years, they remain well above risk-free levels (Lane and Mahul, 2008) and are comparable to reinsurance premiums for catastrophe coverage (Cummins et al., 2004).[25] However, comparing the pricing of Cat bonds with reinsurance premiums is unlikely to convey an accurate picture of the net costs and benefits linked to insurance securitization as compared with reinsurance coverage. Among other things, such comparisons do not take into account that Cat bonds (vis-à-vis reinsurance contracts) carry lower counterparty risk (Cat bond

[25] One frequently advanced explanation for the high spreads on Cat bonds is that investors are still unfamiliar with the concept of insurance securitization and, therefore, demand a return premium (see Bantwal and Kunreuther, 2000; Habib and Ziegler, 2007; Barrieu and Louberge, 2009).

principals are fully collateralized), provide liquidity benefits for the issuer (Cat bond premiums are paid at the end of each quarter rather than upfront as in the case of reinsurance) and result in more predictable cost management for the issuer (Cat bonds fix the costs of coverage at the time of issue for a multiyear period).

Nonetheless, there remain good reasons to argue that some issuers should realize cost savings from issuing Cat bonds compared with obtaining reinsurance. Gibson et al. (2011) compare the information-gathering incentives of traders in financial markets (Cat bonds) with the incentives of reinsurers and develop a model where it is relatively more cost efficient for insurers which face low levels of loss uncertainty to securitize catastrophe risks. They argue that lower levels of loss uncertainty reduce the information acquisition costs in financial markets (which are ultimately borne by the issuer via a discount on the price of the securities issued[26]). Therefore, insurance securitization may be a less costly alternative to either reinsurance or to raising equity for insurers facing low levels of loss uncertainty.

5.3 Data and Methodology

5.3.1 Data

The data on insurance securitizations before May 2010 are obtained from Hannover Re. All Cat bonds are selected which are defined as bonds where coupons and/or principal payments are contingent on the occurrence of catastrophe-related property

[26] In Gibson et al. (2011), the discount which insurers with high loss uncertainty offer serves as compensation to uninformed traders for the losses they are likely to experience when dealing with informed market traders. The discount also equals the information production costs of informed market traders.

and casualty risks or catastrophe-related mortality risks.[27] Both types of risks are pooled, because the bonds' structures are (apart from the trigger event) identical (Cowley and Cummins, 2005) and because the issuing firms in the sample do not operate in distinct markets (i.e. all sample firms issuing mortality-related bonds have at some point also issued property and casualty-related bonds). Further, the findings presented in this chapter remain unaffected when mortality-related Cat bonds are excluded from the sample (the results of the analysis without mortality-related Cat bonds can be found in the Appendix to this chapter on pgs. 142 to 145). Finally, it is stipulated that Cat bond issuers need to be listed firms which have equity and accounting data available on the Datastream-Worldscope database and that issuers are the ultimate beneficiary of the Cat bond coverage.[28]

For an initial sample of 143 Cat bond issues, the Cat bond data from Hannover Re is verified by matching them with public information on insurance securitizations in AON Capital Markets (2010) and Guy Carpenter (2008). Where discrepancies between proprietary and public data are identified (e.g., as regards the issue date, value and risks underlying an issue), further searches on various news sources available on LexisNexis and Factiva are conducted. Where the discrepancies remain unresolved, the issue is omitted from the sample (this affects a total of eight issues).

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[27] Catastrophe mortality risks result from events which lead to sharp increases in mortality rates such as natural catastrophes or pandemics. Bonds which securitize such risks are referred to as 'mortality (Cat) bonds'. By contrast, longevity bonds are not included in the sample, because these securitize longevity risk (due to increased life expectancy) and are not linked to catastrophe events (for more details, see Cowley and Cummins, 2005).

[28] Transactions where the Cat bond coverage was sold by the issuer to a third party (i.e. Calabash Re Ltd. I-III by Swiss Re) are not included to avoid convoluted interpretations of the results.

In a next step, issues are omitted for any of the following reasons. First, so-called follow-up transactions from shelf offering programs are dropped. Shelf offering programs allow firms to issue further Cat bonds at any time. Follow-up transactions tend to be very small and have only a limited amount of information available. This affects 29 issues. Second, when a firm issues more than one Cat bond on the same trading day, the transactions are consolidated into a single issue. This leads to 15 individual transactions being consolidated into three deals.[29] Third, a further 14 transactions were excluded because the news coverage indicates that confounding events such as earnings announcements, dividend payments or equity and debt issues occurred around the event date.

The final sample used in this chapter consists of 80 Cat bond issues undertaken by 25 issuing firms. The data from Hannover Re indicate that the sample corresponds to 80% of the total Cat bond risk capital (i.e. the total of bond principal and coupon payments at risk) issued by listed companies up to May 2010.

Table 5-1 provides sample descriptives by year (Panel A), trigger type (Panel B), country (Panel C), and issuing firm (Panel D). It is evident from Panel A that the majority of Cat bond transactions (by both number and total risk capital) took place in 2006 and 2007. Panel B reveals that the vast majority of Cat bonds exhibits an index-based trigger (meaning that Cat bond payoffs are independent of the underwriting losses of the issuing firm). Finally, Panel C and D illustrate that most Cat bonds were issued in Switzerland by Swiss Reinsurance Company.

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[29] When Cat bond transactions are consolidated, the risk capital of the individual transactions is summed up. For all cases where Cat bonds are consolidated, the trigger types of the individual transactions are identical across constituent issues.

Table 5-1
Sample Characteristics

Panel A: Cat Bond Issues by Year

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Number	1	1	3	4	6	3	2	1	5	12	17	10	9	6	80
Risk capital $ (millions)	112	45	322	604	797	356	605	248	1,007	3,344	4,043	1,638	1,290	850	15,261
% Value	0.73	0.29	2.11	3.95	5.21	2.33	3.95	1.62	6.58	21.86	26.42	10.71	8.43	5.56	100.00

Panel B: Cat Bond Issues by Trigger Type

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Indemnity	0	1	1	0	0	0	0	0	1	2	2	3	1	0	11
Index	1	0	2	4	6	3	2	1	3	9	12	5	6	5	59
Hybrid	0	0	0	0	0	0	0	0	1	1	3	2	2	1	10

Panel C: Cat Bond Issues by Country

	France	Germany	Japan	Switzerland	UK	U.S.	Total
Number	9	18	3	24	3	23	80
Risk capital $ (millions)	2,164	2,944	748	5,215	408	3,782	15,261
% Value	14.15	19.24	4.89	34.08	2.67	24.72	100.00

Panel D: Cat Bond Issues by Issuing Firm

Firm	No.	Firm	No.	Firm	No.
Allianz SE	5	Flagstone Reinsurance Holdings Ltd.	2	PXRE Group Ltd.	2
Allstate Corp.	2	Hannover Re	3	Scor SE	4
Aspen Insurance Holdings	1	Hartford Financial Service Group Inc.	3	Swiss Reinsurance Company Ltd.	18
Assurances Generales De France (AGF)	1	Hiscox Ltd.	1	Tokio Marine Holdings Inc.	1
Assurant Inc.	2	Mitsui Sumitomo Insurance Group Holdings Inc.	1	Travelers Companies Inc.	4
AXA S.A.	4	Montpelier Re Holdings Ltd.	1	Vesta Insurance Group Inc.	1
Catlin Group Ltd.	2	Munich Re Group	10	Zurich Financial Services AG	6
Chubb Corp.	3	Nissay Dowa General Insurance Company Ltd.	1		
Endurance Specialty Holdings Ltd.	1	Platinum Underwriters Holdings Ltd.	1		

5.3.2 Methodology

In this chapter, the stock market valuation effects linked to a firm's announcement to issue a Cat bond are analyzed. In an efficient capital market, changes in the market valuation of the issuing firm provide an assessment of the net benefits which issuers will realize from a Cat bond issue. Market-adjusted abnormal returns (AR) are estimated as employed by Fuller et al. (2002), Faccio et al. (2006) and others:

$$AR_{it} = r_{it} - r_{mt}\,, \tag{5.1}$$

where r_{it} is the return for issuer i on day t and r_{mt} is the return on a Datastream insurance index (which also includes reinsurers) for the country of the issuing firm.[30] The Datastream insurance index is computed as the value-weighted AR of all insurance and reinsurance companies listed on Datastream in the issuer's country which have not issued Cat bonds.[31] AR are summed across days and firms to yield cumulative abnormal returns (CAR). To test for the statistical significance of cumulative abnormal returns, a two tailed t-test as well as the non-parametric Mann-Whitney-Wilcoxon test (which is robust to the effects of outliers) is employed.

The analysis does not estimate market model-adjusted returns (which effectively yield risk-adjusted returns) for two reasons. First, the market model approach assumes that the estimation period over which market model parameters are estimated is free of the type of event whose value effects are being investigated.

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30 This market return index is appropriate given the composition of the sample which consists of insurance and reinsurance firms.

31 The results are qualitatively identical if an European insurance index (by aggregating all insurance and reinsurance companies in France, Germany, Switzerland and the UK) is used instead of the individual return index at country level.

If the analysis was to compute risk-adjusted abnormal returns using contaminated estimation periods, the resulting estimates would be unreliable. Since the sample contains a number of repeat issues by the same firm, the clean time series of return data necessary to implement this approach cannot be provided.[32] Second, Brown and Warner (1980) show that over short-time periods risk-adjusted return values do not significantly improve estimation results as compared to the type of market-adjusted values employed in this study.

The lack of an official announcement date presents a difficulty when determining the market reaction to Cat bond issues. The issue date of a Cat bond is unsuitable as an announcement date, because Cat bonds are sold on a book-building basis where investment banks contact potential investors in advance of an issue to gauge their interest as regards the size and structure of a new issue. It is, therefore, highly likely that market investors are informed about a firm’s intention to issue a Cat bond before the issue date. Following Thomas (1999), the event date is defined as the announcement date, unless the issue date precedes the announcement date, in which case the issue date is used as the event date. For each Cat bond, the day that an issue was first announced is identified by conducting news searches on LexisNexis and Factiva, as well the issuing firm’s website and ARTEMIS (www.artemis.bm) an online practitioner portal for insurance securitization. For 80% of sample observations, press announcements of Cat bond issues precede the issue date (on

[32] When overlaps in the estimation period are allowed and the regression models are re-run using a single index market model ($AR_{it}=r_{it}-\alpha_i-\beta_i r_{mt}$) and an estimation period of 200 trading days (*t*-226 to *t*-26 trading days relative to the announcement date *t* of a Cat bond issue), the main conclusions are not affected. The results of these regressions are displayed in the Appendix to this chapter on pg. 146.

average by 13 days). This highlights the importance of employing hand collected announcement dates (rather than the issue dates) as event dates.

5.4 Univariate Results

5.4.1 The Shareholder Wealth Effects of Issuing Catastrophe Bonds

In this section, the changes in the market value of firms which announce their engagement in insurance securitization by issuing Cat bonds are examined. Given the rather underwhelming contribution of Cat bonds to global catastrophe coverage to date, it is not expected to find strong performance gains for shareholders in the issuing firms.

Table 5-2 reports abnormal returns linked to new Cat bond issues for selected event windows. Panel A shows that CAR[-15;+15] and CAR[-20;+20] are positive and statistically significant above the 10%-level (yet only according to the *t*-test).[33] While Cowan and Sergeant (1996) argue that non-parametric tests may struggle to detect small levels of abnormal share price performance, the insignificant *z*-statistic means that explanations according to which the finding of value gains is driven by outliers cannot be excluded.

Panel B reports abnormal returns around the issue date of Cat bonds. Since any press coverage has preceded the issue date for the vast majority of Cat bond issues, it is not expected to find any statistically significant valuation effects around

[33] The use of multi-week event periods is consistent with studies examining the shareholder wealth effects of asset securitization in the banking sector. For instance, Thomas (1999, 2001) uses a 50-day event window.

the issue. The results in Panel B are consistent with this expectation and confirm the rationale for centering the event study around announcement dates rather than issue dates.

Table 5-2
Abnormal Returns for Selected Event Windows

	N	mean (%) (*t*-stat)	median (%) (*z*-stat)	CAR>0% N	CAR>0% %
Panel A: Distribution by Announcement Date					
CAR[-5;+5]	80	0.38	-0.20	37	46.3
		(0.77)	(-0.11)		
CAR[-10;+10]	80	1.01	0.20	42	52.5
		(1.50)	(0.56)		
CAR[-15;+15]	80	1.55	0.85	43	53.8
		(2.00)**	(1.25)		
CAR[-20;+20]	80	1.45	0.11	43	53.8
		(1.67)*	(0.93)		
CAR[-25;+25]	80	0.78	0.41	44	55.0
		(0.94)	(0.47)		
Panel B: Distribution by Issue Date					
CAR[-5; +5]	80	0.08	-0.20	39	48.8
		(0.14)	(-0.10)		
CAR[-10;+10]	80	0.97	0.52	44	55.0
		(1.39)	(1.26)		
CAR[-15;+15]	80	0.93	-0.33	39	48.8
		(1.10)	(-0.47)		
CAR[-20;+20]	80	0.88	-0.02	40	50.0
		(0.96)	(-0.08)		
CAR[-25;+25]	80	0.41	0.05	41	51.3
		(0.47)	(0.33)		

Notes: The table reports cumulative abnormal returns (CAR) for both the announcement date (Panel A) and the issue date (Panel B) of Cat bond issues during the period 1997 to May 2010 for different event windows. In both cases, abnormal returns are estimated using a market model ($AR_{it} = r_{it} - r_{mt}$), where r_{it} is the observed arithmetic return for issuing firm *i* at day *t* and r_{mt} is the value-weighted market index return for day *t*. Also included are *t*-statistics (two tailed) and the non-parametric Mann–Whitney–Wilcoxon *Z*-scores. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

In sum, no evidence is found that Cat bond issues, on average, lead to strong performance gains for shareholders in the issuing firm. However, Table 5-2 also reports that the sample is nearly split in half as regards sample firms experiencing value gains and value losses from Cat bond issues. This points towards large variations in the distribution of Cat bond effects. The next sections, therefore, identify some of the factors which determine the market reaction to Cat bonds. This will lead to a better understanding of the motivations as to why firms engage in insurance securitization. Based on the two main sources for firm gains from issuing Cat bonds identified in Section 5.2, these factors are grouped into hedging benefits and cost benefits.

5.4.2 Value Effects and Hedging Benefits

As previously noted, one reason why firms could benefit from Cat bond issues is that Cat bonds allow firms to hedge against catastrophe-related underwriting losses by transferring catastrophe risks to capital markets. Since very few Cat bonds have been triggered by a natural catastrophe to date, it is not possible to measure the hedge efficiency of Cat bonds by matching Cat bond payoffs with insurer losses. Instead, two proxies are used to gauge the hedging benefits likely to be realized by the issuer: the trigger types underlying Cat bonds and the initial bond rating.

The first proxy which is used to measure any hedging benefits realized by the issuers is the trigger type. The sample contains three types of triggers. (i) Indemnity based triggers, where the conditions for principal and/or coupon forfeiture are defined in terms of the underwriting losses of the issuer, (ii) index based triggers, where payouts are based on a loss index, and (iii) hybrid triggers, which combine more than one trigger in a single Cat bond. Indemnity-based triggers provide a perfect hedge against catastrophe-related losses of the issuing firm and should, therefore, provide the greatest hedging benefits to firms issuing Cat bonds.

However, indemnity-based Cat bonds suffer from a well-defined moral hazard problem. Since issuers are better informed about the loss functions linked to particular risks than market investors, they may issue high-risk bonds to unsuspecting investors (Doherty, 1997). Furthermore, indemnity-based Cat bonds display higher transaction costs resulting from higher disclosure requirements on the part of the issuer over the securitized risks. While index-linked and hybrid triggers are subject to a lower degree of moral hazard (and, thus, carry lower transaction costs for issuers), they both involve substantial basis risk when Cat bond payoffs are independent of the losses realized by the issuer. A priori it is, therefore, not obvious which trigger type will bring larger benefits to the issuer. It is proposed, however, that if the main benefit of Cat bonds lies in hedging catastrophe-related risks, indemnity-based Cat bonds should lead to higher abnormal returns.

Table 5-3 examines the market valuation effects linked to Cat bond issues by trigger type for different event windows. The sample is split into indemnity-based triggers as well as non-indemnity triggers. Overall, the results show that abnormal returns surrounding the announcement to issue Cat bonds do not differ by the type of trigger. Differences in the abnormal returns for indemnity-based Cat bonds as compared with non indemnity-based Cat bonds are not statistically significant at customary levels (based on either a *t*-test or the non-parametric Mann-Whitney-Wilcoxon test). While statistically significant abnormal returns according to a *t*-test for non indemnity-based Cat bonds over [-15,+15] (at 10%-level of significance) are presented, Table 5-3 provides no further evidence that the value effects linked to Cat bond issues differ by the type of trigger event underlying an issue.

Table 5-3
Value Effects by Trigger Event

		CAR[-5;+5]	CAR[-10;+10]	CAR[-15;+15]	CAR[-20;+20]	CAR[-25;+25]
Indemnity	mean	-0.42%	-0.04%	1.03%	1.27%	-0.58%
N=11	(*t*-stat)	(-0.37)	(-0.02)	(0.43)	(0.37)	(-0.14)
	median	-0.47%	-0.14%	-0.37%	-0.44%	-0.31%
	(*z*-stat)	(-0.46)	(-0.05)	(-0.15)	(-0.26)	(-0.25)
Other	mean	0.50%	1.16%	1.62%	1.47%	0.97%
N=69	(*t*-stat)	(0.91)	(1.58)	(1.91)*	(1.64)	(1.26)
	median	-0.13%	0.20%	1.13%	0.27%	0.41%
	(*z*-stat)	(-0.06)	(0.64)	(1.36)	(0.85)	(0.64)
$\Delta \mathbf{CAR}_{\mathbf{INDEM\text{-}OTHER}}$	mean	-0.92%	-1.20%	-0.59%	-0.20%	-1.55%
	(*t*-stat)	(-0.61)	(-0.59)	(-0.24)	(-0.08)	(-0.62)
	median	-0.34%	-0.06%	-1.50%	-0.77%	-0.72%
	(*z*-stat)	(-0.46)	(-0.21)	(-0.62)	(0.10)	(-0.53)

Notes: The table reports market adjusted cumulative abnormal returns (CAR) for different event windows surrounding the announcement to issue Cat bonds for indemnity based and non-indemnity based Cat bonds, respectively. Also, the differences in CAR between indemnity based and non-indemnity based Cat bonds are displayed ($\Delta CAR_{INDEM\text{-}OTHER}$). The sample consists of 80 Cat bonds issued in the period 1997 to May 2010. All firms are publicly traded. To test for the statistical significance of CAR, a two tailed *t*-test as well as the non-parametric Mann–Whitney–Wilcoxon test are employed. * indicates significance at the 10 % level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

The second proxy which is used to measure any hedging benefits realized by the issuers is the initial Cat bond rating by Standard & Poor's (or, if unavailable, by Moody's).[34] Since Cat bonds involve no credit risk (as their principals are fully collateralized), lower ratings indicate that the catastrophe loss event underlying the bond is more likely to occur. Given capacity constraints in reinsurance markets due to the inability of reinsurers to fully diversify underwriting losses caused by catastrophe events (see Froot and Stein, 1998; Froot and O'Connell, 2008), issuers will find it particularly difficult to obtain coverage in reinsurance markets for the type of loss events underlying Cat bonds with low ratings. Therefore, if the main benefit of Cat bonds lies in hedging catastrophe-related risks, it is expected that for high-risk catastrophes (i.e. for Cat bonds with low ratings), Cat bonds should result in higher revaluation gains for the issuing firm.

Table 5-4 examines the market valuation effects linked to Cat bond issues by bond rating. Specifically, it reports abnormal returns for different event windows surrounding the announcement to issue Cat bonds for both the ten highest and lowest rated bonds. Bond ratings are converted into a numerical scale where higher numbers indicate a lower rating.[35] The results in Table 4 show that Cat bond ratings do not impact on abnormal returns surrounding the issue announcement. Thus, differences between the ten highest and lowest rated Cat bonds are all statistically insignificant at customary levels (based on either a *t*-test or the Mann-Whitney-Wilcoxon test).

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[34] Since Cat bonds often consist of several tranches with separate ratings, the rating assigned in this chapter to an issue is an average weighted rating by the risk capital underlying each tranche.

[35] The numerical conversion applied to Cat bond ratings is as follows. The value of one is assigned to an issue which is rated AAA (or Aaa rated by Moodys), two to an AA+ (or Aa1) bond issue, and so on down to 17 for a CCC+ (or Caa) and 18 for 'Not Rated'. In ther sample, nearly 60% of observations attract a rating between BB+ (or Ba1) and BB (or Ba2), i.e. between the values 11 and 12.

Table 5-4
Value Effects by Credit Rating

		CAR[-5;+5]	CAR[-10;+10]	CAR[-15;+15]	CAR[-20;+20]	CAR[-25;+25]
High Rating	mean	0.17%	2.13%	0.44%	-0.59%	-0.38%
N=10	(*t*-stat)	(0.37)	(0.93)	(0.31)	(-0.35)	(-0.31)
	median	0.40%	-0.78%	-0.50%	-2.94%	-1.26%
	(*z*-stat)	(0.36)	(0.25)	(-0.25)	(-1.27)	(-0.66)
Low Rating	mean	0.67%	0.79%	0.15%	0.47%	0.08%
N=10	(*t*-stat)	(0.72)	(0.76)	(0.13)	(0.37)	(0.11)
	median	-0.13%	0.46%	0.35%	-0.56%	0.22%
	(*z*-stat)	(0.56)	0.76	(0.25)	(0.05)	(0.25)
$\mathbf{\Delta CAR_{HIGH\text{-}LOW}}$	Δmean	-0.50%	1.33%	0.29%	-1.07%	-0.45%
	(*t*-stat)	(-0.49)	(0.53)	(0.16)	(-0.49)	(-0.33)
	Δmedian	0.53%	-1.24%	-0.85%	-2.38%	-1.48%
	(*z*-stat)	(-0.23)	(-0.61)	(-0.23)	(-1.05)	(-0.75)

Notes: The table reports market adjusted cumulative abnormal returns (CAR) for different event windows surrounding the announcement to issue Cat bonds for both the ten highest and lowest rated bonds. The bond rating is applied by Standard &Poor's or Moody's with 1 being the highest rated bond and 18 being not rated Also, the differences in CAR between the ten highest and lowest rated bonds are displayed ($\Delta CAR_{HIGH\text{-}LOW}$). The sample consists of 80 Cat bonds issued in the period 1997 to May 2010. All firms are publicly traded. To test for the statistical significance of CAR, a two tailed *t*-test as well as the non-parametric Mann–Whitney–Wilcoxon test are employed. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5.4.3 Value Effects and Cost Benefits

Next to hedging benefits, firms may also benefit from Cat bonds by realizing cost savings on catastrophe-related risk management. To analyze whether firms issue Cat bonds to realize cost savings on catastrophe-related risk management, this section examines how loss uncertainty and the prices of catastrophe coverage via reinsurance markets affect the market reaction to a Cat bond issue.

First, loss uncertainty facing the issuer may prove costly to the issuer of Cat bonds. Gibson et al. (2011) develop a theoretical model where loss uncertainty gives rise to increased information acquisition costs which are borne by insurers that seek catastrophe coverage via financial markets. These additional costs arise because insurers which face greater loss uncertainty need to offer a discount on the price of any securities issued to uninformed market participants. This discount is designed to compensate uninformed market participants for the likely losses they will experience when dealing with more informed traders under high loss uncertainty.

Table 5-5 tests this proposition. To capture loss uncertainty, the volatility of the issuer's loss ratio in the four fiscal years before the announcement date is used as in De Haan and Kakes (2010).[36] Table 5-5 reports abnormal returns for different event windows surrounding the announcement to issue Cat bonds in the lowest (Q_1) and highest (Q_5) quintile of the distribution of issuers' loss uncertainty.

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[36] Loss ratios are defined as the sum of claim and loss expenses and long-term insurance reserves scaled by premium income as in Browne and Hoyt (1995) and Cummins and Xie (2008). To address concerns that loss ratios are not comparable across property/casualty and life insurers, both univariate as well as multivariate tests are re-run after excluding life insurers. The main conclusions remain unaffected.

Table 5-5
Value Effects by the Issuer's Loss Uncertainty

		CAR[-5;+5]	CAR[-10;+10]	CAR[-15;+15]	CAR[-20;+20]	CAR[-25;+25]
Low (Q_1)	mean	4.43%	7.02%	7.98%	6.77%	2.84%
N=16	(*t*-stat)	(1.09)	(1.75)*	(1.38)	(1.24)	(0.55)
	median	1.26%	3.19%	4.37%	2.92%	2.61%
	(*z*-stat)	(1.15)	(2.31)**	(1.36)	(1.36)	(0.52)
High (Q_5)	mean	0.35%	1.04%	1.30%	1.29%	1.00%
N=16	(*t*-stat)	(0.68)	(1.45)	(1.50)	(1.26)	(1.04)
	median	0.14%	0.45%	0.97%	-0.10%	0.30%
	(*z*-stat)	(0.58)	(0.26)	(1.27)	(0.60)	(0.51)
$\Delta CAR_{Q1\text{-}Q5}$	Δmean	4.08%	5.97%	6.68%	5.49%	1.84%
	(*t*-stat)	(2.07)**	(2.38)**	(2.11)**	(1.56)	(0.56)
	Δmedian	1.12%	2.74%	3.40%	3.02%	2.31%
	(*z*-stat)	(0.98)	(1.80)*	(1.16)	(1.13)	(0.27)

Notes: The table reports market adjusted cumulative abnormal returns (CAR) for different event windows surrounding the announcement to issue Cat bonds for the lowest (Q_1) and highest quintiles (Q_5) for the standard deviation of the loss ratio in the four fiscal years before the announcement date. The loss ratio is defined as claim and loss expenses plus long-term insurance reserves scaled by premium income (all in *t*-1). Also, the differences in CAR between the lowest and highest quintile are reported ($\Delta CAR_{Q1\text{-}Q5}$). The sample consists of 80 Cat bonds issued in the period 1997 to May 2010. All firms are publicly traded. To test for the statistical significance of CAR, a two tailed *t*-test as well as the non-parametric Mann–Whitney–Wilcoxon test are employed. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

In line with the proposition and Gibson et al.'s (2011) arguments, Table 5-5 documents that issuers with lower loss uncertainty benefit more from issuing Cat bonds than issuers with more volatile loss ratios. Over most event windows, issuers with low loss uncertainty realize higher abnormal returns than issuers with high loss uncertainty (significant at 10% for both *t*-test and *z*-test).

Second, the pricing of catastrophe coverage is examined. Since the pricing of catastrophe coverage varies across the reinsurance underwriting cycle, the extent to which the gains from issuing Cat bonds vary across the reinsurance underwriting cycle provides an additional indicator of whether firms issue Cat bonds to realize costs savings on catastrophe-related risk management.

The reinsurance underwriting cycle is characterized by periods when reinsurance prices are relatively low and coverage is readily available (soft markets) and periods when reinsurance prices are high and coverage supply is restricted (hard markets). Hard markets tend to follow time periods in the aftermath of natural catastrophes (Froot and O'Connell, 2008). Lane and Mahul (2008) show that Cat bond spreads are positively related to the reinsurance underwriting cycle. Consequently, when the costs of reinsurance are high, the costs of catastrophe coverage via Cat bonds are high as well. The critical cost advantage of Cat bonds lies in the fact that the costs of catastrophe coverage are fixed over a multiyear period (of usually three to four years) at the time of the issue. Therefore, Cat bonds issued during soft markets effectively lock in low catastrophe pricing and may result in substantial cost savings should reinsurance markets harden in the following years. By the same token, issues during hard markets mean that the issuer is likely to pay a high price for catastrophe coverage when reinsurance markets soften again. If the costs of obtaining catastrophe coverage are an important driver of the benefits linked to Cat bond issues, it is proposed that the value effects linked to issuing Cat bonds during hard reinsurance markets will be lower than the value effects generated by issuing Cat bonds during soft reinsurance markets.

In order to distinguish between soft markets and hard reinsurance markets, the Guy Carpenter (2010) World Catastrophe Rate On Line Index is used. The index values essentially equate to the average premium per dollar of reinsurance coverage (defined as global catastrophe reinsurance premiums divided by the global policy limits of catastrophe reinsurance). Table 5-6 reports abnormal returns for different event windows surrounding the announcement to issue Cat bonds for the lowest (Q_1) and highest quintile (Q_5) of the distribution of the Rate On Line index.

Table 5-6 confirms the propositions. Over all event windows examined, Cat bond issues during soft markets lead to higher abnormal returns for issuing firms compared with issues during hard markets. These results are statistically significant according to the *t*-test for all event windows and also according to a z-test (for [-20; +20] and [-25; +25]). This suggests that lowering the costs of catastrophe coverage is an important source of gains for the issuers of Cat bonds.

Table 5-6
Value Effects by Reinsurance Prices

		CAR[-5;+5]	CAR[-10;+10]	CAR[-15;+15]	CAR[-20;+20]	CAR[-25;+25]
Guy Carpenter Rate On Line Index						
Low (Q_1)	mean	3.78%	4.04%	6.34%	6.91%	3.11%
N=20	(*t*-stat)	(0.98)	(0.99)	(1.29)	(1.23)	(0.67)
	median	0.55%	3.42%	4.15%	7.85%	6.25%
	(*z*-stat)	(0.28)	(0.70)	(1.12)	(1.26)	(0.70)
High (Q_5)	mean	-0.46%	-1.08%	-0.93%	-1.58%	-2.17%
N=13	(*t*-stat)	(-0.97)	(-1.70)*	(-1.17)	(-2.17)**	(-2.77)***
	median	-1.04%	-0.95%	-0.61%	-1.12%	-1.70%
	(*z*-stat)	(-1.07)	(-1.48)	(-0.92)	(-1.85)*	(-2.41)**
ΔCAR_{Q1-Q5}	Δmean	4.25%	5.11%	7.27%	8.48%	5.28%
	(*t*-stat)	(1.96)*	(2.14)**	(2.50)**	(2.69)**	(1.91)*
	Δmedian	1.59%	4.37%	4.76%	8.97%	7.95%
	(*z*-stat)	(0.55)	(0.92)	(0.85)	(1.77)*	(2.04)**

Notes: The table reports market adjusted cumulative abnormal returns (CAR) for different event windows surrounding the announcement to issue Cat bonds for the lowest (Q_1) and highest quintiles (Q_5) for the Guy Carpenter Rate On Line Index (Source: Guy Carpenter, 2010). This index is used as a measure of the reinsurance price level. Also, the differences in CAR between the lowest and highest quintile are reported (ΔCAR_{Q1-Q5}). The sample consists of 80 Cat bonds issued in the period 1997 to May 2010. All firms are publicly traded. To test for the statistical significance of CAR, a two tailed *t*-test as well as the non-parametric Mann–Whitney–Wilcoxon test are employed. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Overall, the wealth effects in response to the issue announcement of Cat bonds appear to be driven by explanations according to which Cat bonds offer cost savings versus other forms of catastrophe risk management (and less by their potential to hedge exposure to catastrophe risk). To test whether additional factors impact upon the shareholder wealth effects of insurance securitization, multivariate regression analyses are employed in the next section.

5.5 The Determinants of the Wealth Effects of Issuing Catastrophe Bonds

5.5.1 The Model

Multivariate regression analyses is used to assess the robustness of the findings in the univariate analysis and to jointly estimate the various factors which affect the market reaction to firms issuing Cat bonds. Specifically, the following model is estimated via OLS with robust standard errors.

$$\mathbf{CAR}[-20;\ +20] = \alpha + \gamma'\mathbf{IC} + \theta'\mathbf{BC} + \delta'\mathbf{MC} + \varepsilon, \qquad (5.2)$$

where:

- **CAR**[-20;+20] is the market-adjusted mean cumulative abnormal return over [-20;+20] days relative to the announcement date;
- **IC** is a vector of issuer characteristics in the fiscal year before the issue;
- **BC** is a vector of Cat bond characteristics, and
- **MC** is a vector of market specific characteristics.

To control for the effect of unobserved variables that are constant over time, year fixed effects are included into the model. Also, because observations for specific issuers are unlikely to be independent (possibly leading to within correlation issues), cluster-robust standard errors are computed and each issuing firm is treated as a cluster.

Table 5-7 presents descriptions and summary statistics for the vector of variables described below. All accounting data (unless stated differently) refer to one fiscal year prior to the announcement of the Cat bond issue (*t*-1) and are from Worldscope.

Issuer Characteristics:

The vector of issuer characteristics contains firm size (**SIZE**) which is measured by the logarithm of issuer total assets. Firm size is expected to enter the model with a positive coefficient for three reasons. First, large companies should possess the financial sophistication and adequate mass to produce transactions of sufficient scale to amortize the high structuring costs of Cat bonds (Cummins and Trainar, 2009). Second, it is conceivable that larger firms are more likely to boast sizable asset management divisions which facilitate access to potential Cat bond investors. Third, basis risk involved in the transaction is likely to decrease with the size of the issuing firm (Harrington and Niehaus, 1999).

Another issuer characteristic is the issuer’s leverage (**LEV**; defined as total liabilities over total assets) which measures a firm’s exposure to financial distress. Firms with higher leverage are expected to generate positive announcement returns, because securitization is a means to free up capital that can then be used to absorb losses and avoid financial distress following a catastrophe event (Cummins and Trainar, 2009).

Table 5-7
Summary Statistics

	Variable	Definition	N	Mean	Median	Std. Dev	5 Pctile	95 Pctile
Value effect	CAR[-20;+20]	Market-adjusted mean cumulative abnormal return over [-20; +20] days relative to the announcement date (%)	80	1.45	0.11	7.90	-8.92	17.48
Issuer characteristics	SIZE	Log of total assets	80	18.36	18.87	1.62	14.94	20.84
	LEV	Total liabilities to total assets (%)	80	85.47	89.43	13.03	61.86	95.93
	ROE	The ratio of pre-tax profits to equity (%)	80	16.18	17.59	10.61	-3.19	31.70
	PREPERF	Buy and hold abnormal return from -252 to -20 days relative to the announcement date (%)	80	0.25	-2.52	22.25	-27.40	34.72
	LOSSVOL	Standard deviation of loss ratios (defined as claim and loss expenses plus long-term insurance reserves scaled by premium income) over a four-year period prior to the announcement date	80	6.45	4.62	6.08	1.24	18.02
	FREQUENT	Dummy which equals 1 if the issuer has issued five or more Cat bonds during the observation period (and 0 otherwise)	80	0.49	0.00	0.51	0.00	1.00
Cat bond characteristics	ISSUESIZE	Value of Cat bond issue scaled by the book value of equity (%)	80	2.61	1.45	3.25	0.31	10.60
	INDEM	Dummy which equals 1 if the Cat bond has an indemnity trigger (and 0 otherwise)	80	0.13	0.00	0.33	0.00	1.00
	BONDRATING	The bond rating applied by Standard &Poor's or Moody's with 1 being the highest rated bond and 18 being not rated	80	11.39	11.43	2.55	5.39	14.91
	MORTALITY	Dummy which equals 1 if the Cat bond securitizes mortality-related risks (and 0 otherwise)	80	0.07	0.00	0.27	0.00	1.00
Market characteristics	SOFTMARKET	Dummy which equals 1 if the announcement to issue a Cat bond took place during the lowest quintile for the Guy Carpenter Rate On Line Index (and 0 otherwise). Source: Guy Carpenter (2010).	80	0.25	0.00	0.30	0.00	1.00

Notes: Accounting data (unless stated differently) refer to one fiscal year prior to the announcement of the Cat bond issue and are from Worldscope.

Also, the model controls for accounting and market performance before the time period of an issue. For accounting performance, the return on equity is used (**ROE**; defined as pre-tax profits over book value of equity). For pre-issue market performance, the issuers' buy and hold abnormal returns (**PREPERF**) over [-252; -20] days relative to the announcement date net of the return for the Datastream insurance index at country-level over the same time period is used. Against the background that shareholders may be unfamiliar with the concept of Cat bonds, it is expected to find a positive association between both performance measures and announcement returns. This would indicate that shareholders place more confidence in the performance effects of Cat bonds issued by highly performing firms.

The vector of issuer characteristics also includes the issuers' loss volatility (**LOSSVOL**). In line with the univariate tests above, loss volatility is defined as the standard deviation of the loss ratio (which is the sum of claim and loss expenses as well as long-term insurance reserves scaled by premium income) in the four fiscal years before the announcement date. LOSSVOL is expected to have a negative effect on abnormal returns, meaning that issuers with more stable loss ratios will benefit more from issuing Cat bonds, as insurance securitization offers them relatively greater cost savings as compared to reinsurance coverage (see Gibson et al. 2011).[37]

FREQUENT is a proxy for the experience of the issuing firm in the Cat bond market. This variable is defined as a dummy variable which equals one if the

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[37] The model also controls for the type of issuer, by including a dummy variable which is equal to one when the issuer is a reinsurance firm and 0 otherwise (REINSURER). REINSURER enters the model with a statistically insignificant coefficient while the results remain the same. Nevertheless, as REINSURER is highly correlated with the size of the issuer (SIZE), the variable is excluded from the model.

issuer has issued five or more Cat bonds during the observation period (and zero otherwise).[38] Evidence from the banking sector shows that frequent securitizations are rewarded with higher excess shareholders returns (Thomas, 2001). These findings are explained by potential knowledge and reputation gains as well as greater bargaining power vis-à-vis investors when structuring follow-up issues. As a result, the announcement by a firm which has already issued five or more Cat bonds is expected to be associated with positive abnormal returns.

Catastrophe Bond Characteristics:

The vector of Cat bond controls contains the following variables. The size of the issue (**ISSUESIZE**) is computed as the ratio of total risk capital issued to the book value of equity. Since Cat bond issues display a high proportion of fixed transaction costs, larger issues should be more cost efficient (Cummins and Trainar, 2009) and should, therefore, generate higher abnormal returns.

In line with the univariate tests, the model further controls for the type of trigger event underlying Cat bonds. **INDEM** is a dummy variable which is equal to one when an indemnity trigger is used (and zero otherwise). As explained in Section 4.2, if the main benefit of Cat bonds lies in hedging catastrophe-related risks, INDEM to enter the model with a positive coefficient. Also in line with the univariate tests, the model controls for the initial Cat bond rating (**BONDRATING**) by Standard & Poor's (or, if unavailable, by Moody's) with 1 being the highest rated

[38] As an alternative measure to FREQUENT, the number of previous Cat bond issues as a proxy for the issuer's experience is employed, as suggested by Thomas (2001). However, regression results did not change by using this measure instead of FREQUENT.

bond and 18 being not rated. If the main benefit of Cat bonds lies in hedging catastrophe-related risks, it is expected that the coefficient on BONDRATING enters the model with a positive sign, indicating that Cat bonds with a lower rating (meaning the catastrophe loss event underlying the bond is more likely to occur) lead to higher abnormal returns.

Since Cat bonds can be used to securitize either catastrophe-related property and casualty risks or catastrophe-related mortality risks, the model also controls for the securitized type of risk by adding **MORTALITY** to the model. MORTALITY takes a value of one if the bond securitizes catastrophe-related mortality risks (and zero otherwise). Against the background that mortality bonds are much less frequently used, shareholders are expected to be more uncertain about mortality bonds' potential performance effects. Consequently, MORTALITY should have negative value implications for the issuing firms.

Market Characteristics:

Finally, moving on to the vector of market characteristics, the Guy Carpenter Rate On Line Index is used to compute **SOFTMARKET**, a dummy variable which equals one if the issue announcement takes place during particular soft reinsurance markets (defined as the lowest quintile of the sample distribution of the Guy Carpenter Rate On Line Index). In line with the univariate tests, a positive association between SOFTMARKET and announcement returns is expected, as Cat bond spreads are positively related to the reinsurance underwriting cycle (Lane and Mahul, 2008).

5.5.2 Regression Results

Table 5-8 presents the results of regressions on the announcement period returns (CAR[-20;+20]) around the announcement of a Cat bond issue. The results confirm the main findings from the univariate tests above. First, INDEM and BONDRATING do not enter with a statistically significant coefficient, suggesting that the hedging potential of Cat bonds do not impact on the value effects linked to insurance securitization. Second, LOSSVOL enters the model with negative coefficients (significant at the 1% level). This is consistent with issuers with more stable loss ratios realizing larger cost savings from Cat bonds vis-à-vis reinsurance coverage. This is in line with Gibson et al. (2011) who argue that insurance securitization involves lower information acquisition costs as compared to traditional reinsurance when expected losses can be predicted involving little uncertainty.

Third, reinsurance prices affect the benefits that issuers expect to extract from the issue of a Cat bond. SOFTMARKET enters with a positive and statistically significant coefficient (significant at the 5% level), indicating that Cat bond issues during periods of particularly low reinsurance prices lead to higher abnormal returns for issuing firms. As argued earlier, this can be ascribed to the fact that Cat bond prices are locked in for a multi-year period and, consequently, Cat bond prices remain unaffected by future price increases in the market for catastrophe coverage. By and large, these results confirm that market investors take the view that the source of performance gains for firms engaging in insurance securitization lies in these firms realizing cost efficiencies compared with reinsurance coverage.

Table 5-8
Regressions on Abnormal Issuer Announcement Returns

	(A)	(B)	(C)	(D)	(E)	(F)
SIZE	0.813	0.385	0.391	0.854	0.836	
	(0.45)	(0.26)	(0.27)	(0.58)	(0.57)	
LEV	-0.217**	-0.180**	-0.180**	-0.189**	-0.189**	-0.172***
	(2.65)	(2.23)	(2.20)	(2.23)	(2.22)	(5.27)
ROE	0.021	0.003	0.001	-0.014	-0.012	
	(0.28)	(0.04)	(0.02)	(0.18)	(0.16)	
PREPERF	0.083**	0.074**	0.074**	0.077**	0.077**	0.073**
	(2.24)	(2.25)	(2.24)	(2.31)	(2.36)	(2.36)
LOSSVOL	-0.391***	-0.351***	-0.351***	-0.364***	-0.368***	-0.323***
	(3.04)	(3.08)	(2.97)	(3.13)	(3.06)	(3.51)
FREQUENT	-1.720	-0.808	-0.744	-1.674	-1.793	
	(0.71)	(0.70)	(0.52)	(1.17)	(1.02)	
ISSUESIZE	0.093	0.172	0.174	0.258	0.247	
	(0.13)	(0.31)	(0.32)	(0.46)	(0.46)	
INDEM	-1.595		-0.148		-0.484	
	(0.53)		(0.06)		(0.18)	
BONDRATING	0.360			0.363	0.375	
	(1.48)			(1.67)	(1.68)	
MORTALITY	1.179		-0.791	1.122	1.168	
	(0.56)		(0.70)	(0.60)	(0.61)	
SOFTMARKET	1.555**	1.491**	1.494**	1.424**	1.419**	1.611***
	(2.25)	(2.42)	(2.36)	(2.25)	(2.20)	(3.00)
Intercept	0.803	9.187	9.025	-1.630	-1.307	14.802***
	(0.03)	(0.44)	(0.45)	(0.08)	(0.06)	(5.31)
Observations	80	80	80	80	80	80
Year fixed effects	YES	YES	YES	YES	YES	YES
Country fixed effects	NO	NO	NO	NO	YES	NO
Adjusted R^2	0.321	0.381	0.360	0.367	0.356	0.416

Notes: The table reports the results of ordinary least squares regression for CAR[-20;+20] relative to the announcement date (*t*=0). The model is estimated with Huber-White corrected standard errors clustered by the issuing firm. The independent variables are: SIZE = logarithm of total assets; LEV = ratio of total assets to total liabilities; ROE = return on equity; PREPERF = one year buy and hold abnormal return before the issue announcement net of the same return computed for the market index; LOSSVOL = standard deviation of loss ratios (defined as claim and loss expenses plus long-term insurance reserves scaled by premium income) over a four-year period prior to the announcement date; FREQUENT = dummy variable which equals 1 if the issuer has issued 5 or more Cat bonds during the observation period (and 0 otherwise); ISSUESIZE = ratio of total risk capital issued to total shareholders' equity; INDEM = dummy variable which equals 1 if the Cat bond has an indemnity trigger (and 0 otherwise); BONDRATING = the bond rating applied by Standard &Poor's or Moody's with 1 being the highest rated bond and 18 being not rated; MORTALITY = dummy variable which equals 1 if the securitized risk is linked to mortality risk (and 0 otherwise); SOFTMARKET = dummy variable which equals 1 if the bond is issued during the lowest quintile for the Guy Carpenter Rate On Line Index (Source: Guy Carpenter, 2010). All accounting data (unless stated differently) refer to one fiscal year prior to the announcement of the Cat bond issue (*t*-1) and are from Worldscope. The *t*-statistics (two tailed) of the coefficients are reported in the parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Further, the control variables show that firms which are less exposed to financial distress (LEV), as well as firms with higher pre-issue market performances (PREPERF) realize higher abnormal returns (significant at the 5% level). These findings are jointly interpreted as consistent with explanations according to which investors are uncertain about the performance implications of Cat bonds. It could be argued that investors focus on measures of the issuer's recent performance and financial stability to gauge the expected performance effects of a Cat bond on the issuing firm.

Also, and consistent with the last point, it is interesting to note a general absence of control variables linked to the Cat bond design which enter the regressions with a statistically significant sign. Consequently, it could be argued that shareholders are either indifferent about the Cat bond design or, alternatively, they are uncertain over the performance effects of Cat bond design on the issuing firm.

5.6 Summary and Conclusions

The recent earthquake and tsunami in Japan is estimated to be the second most costly insurance loss after Hurricane Katrina in 2005. These and similar catastrophe loss events bear testimony to a remarkable increase in catastrophe-related underwriting losses over the past decade. Against the background of capacity constraints in the market for catastrophe risk, firms exposed to catastrophe-related underwriting losses can use alternative risk transfer solutions, most prominently in the form of Cat bonds, which are designed to transfer catastrophe-related risks to capital markets. However, the total outstanding risk capital of Cat bonds has been lagging behind expectations to date. This raises questions about the usefulness of Cat bonds for insurers.

For firms with catastrophe-related underwriting exposures, issuing Cat bonds should offer a number of potential benefits. However, many of the arguments made in favor of Cat bonds do not take into account supply-side or demand-side frictions in the market for catastrophe risks. Over the years, this has led to considerable uncertainty over whether Cat bonds actually benefit the firms which issue them. This chapter empirically examines the shareholder wealth effects for a unique data set consisting of the near population of Cat bond issues by listed companies up to May 2010.

Consistent with the underwhelming contribution which Cat bonds make to global catastrophe coverage to date, evidence of strong performance gains for the shareholders of firms which issue Cat bonds cannot be provided. However, further examination reveals that the value effects linked to insurance securitization appear to be driven by explanations according to which Cat bonds offer cost savings versus other forms of catastrophe risk management and less by their potential to hedge exposure to catastrophe risk. Thus, issues by firms facing low levels of loss uncertainty (which reduces the information acquisition costs in financial markets) as well as issues during time periods in which the premiums for catastrophe coverage are particularly low (and coverage via Cat bonds is inexpensive) experience large value gains linked to Cat bond issues.

As a result, this chapter offers another possible explanation for the underwhelming use of insurance securitization by firms exposed to catastrophe risks. This is because the analysis casts doubt on the effectiveness of insurance securitization in general (and Cat bonds in particular) in hedging underwriting risks.

5.7 Appendix

Table 5-9
Abnormal Returns for Selected Event Windows, Excluding Catastrophe Mortality Bonds

	N	mean (%) (*t*-stat)	median (%) (*z*-stat)	CAR>0% N	CAR>0% %
Panel A: Distribution by Announcement Date					
CAR[-5;+5]	74	0.40	-0.20	34	45.9
		(0.74)	(-0.10)		
CAR[-10;+10]	74	1.11	0.33	40	53.3
		(1.53)	(0.70)		
CAR[-15;+15]	74	1.62**	1.13	41	54.7
		(2.01)	(1.46)		
CAR[-20;+20]	74	1.55*	0.27	41	54.7
		(1.68)	(1.09)		
CAR[-25;+25]	74	0.81	0.46	42	56.0
		(0.93)	(0.62)		
Panel B: Distribution by Issue Date					
CAR[-5; +5]	74	0.09	(-0.21)	36	48.7
		(0.15)	(0.12)		
CAR[-10;+10]	74	1.04	(0.63)	42	56.76
		(1.38)	(1.29)		
CAR[-15;+15]	74	0.94	(0.19)	37	50.0
		(1.09)	(0.57)		
CAR[-20;+20]	74	0.88	(0.05)	38	51.4
		(0.90)	(0.11)		
CAR[-25;+25]	74	0.41	(0.09)	38	51.4
		(0.45)	(-0.22)		

Notes: The table reports cumulative abnormal returns (CAR) for both the announcement date (Panel A) and the issue date (Panel B) of Cat bond issues during the period 1997 to May 2010 for different event windows. In both cases, abnormal returns are estimated using a market model ($AR_{it} = r_{it} - r_{mt}$), where r_{it} is the observed arithmetic return for issuing firm *i* at day *t* and R_{mt} is the value-weighted market index return for day *t*. Also included are *t*-statistics (two tailed) and the non-parametric Mann–Whitney–Wilcoxon *Z*-scores. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5-10
Value Effects by Trigger Event, Excluding Catastrophe Mortality Bonds

		CAR[-5;+5]	CAR[-10;+10]	CAR[-15;+15]	CAR[-20;+20]	CAR[-25;+25]
$\Delta CAR_{INDEM\text{-}OTHER}$	mean	-0.94%	-1.33%	-0.68%	-0.32%	-1.61%
	(*t*-stat)	(0.60)	(0.62)	(0.28)	(0.12)	(0.63)
	median	-0.34%	-0.19%	-1.74%	1.03%	-0.77%
	(*z*-stat)	(-0.47)	(-0.28)	(-0.74)	(0.03)	(-0.55)

Notes: The table reports market adjusted cumulative abnormal returns (CAR) for different event windows surrounding the announcement to issue Cat bonds for indemnity based and non-indemnity based Cat bonds, respectively. Also, the differences in CAR between indemnity based and non-indemnity based Cat bonds are displayed ($\Delta CAR_{INDEM\text{-}OTHER}$). The sample consists of 80 Cat bonds issued in the period 1997 to May 2010. All firms are publicly traded. To test for the statistical significance of CAR, a two tailed *t*-test as well as the non-parametric Mann–Whitney–Wilcoxon test are employed. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5-11
Value Effects by Catastrophe Bond Rating, Excluding Catastrophe Mortality Bonds

		CAR[-5;+5]	CAR[-10;+10]	CAR[-15;+15]	CAR[-20;+20]	CAR[-25;+25]
$\Delta CAR_{HIGH\text{-}LOW}$	Δmean	-0.45%	2.68%	1.92%	1.00%	1.10%
	(*t*-stat)	(-0.36)	(0.87)	(0.94)	(0.33)	(0.51)
	Δmedian	0.25%	0.32%	0.23%	-0.27%	1.63%
	(*z*-stat)	(0.00)	(0.35)	(0.81)	(0.12)	(0.69)

Notes: The table reports market adjusted cumulative abnormal returns (CAR) for different event windows surrounding the announcement to issue Cat bonds for both the ten highest and lowest rated bonds. The bond rating is applied by Standard &Poor’s or Moody’s with 1 being the highest rated bond and 18 being not rated Also, the differences in CAR between the ten highest and lowest rated bonds are displayed ($\Delta CAR_{HIGH\text{-}LOW}$). The sample consists of 80 Cat bonds issued in the period 1997 to May 2010. All firms are publicly traded. To test for the statistical significance of CAR, a two tailed *t*-test as well as the non-parametric Mann–Whitney–Wilcoxon test are employed. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5-12
Value Effects by the Issuer’s Loss Uncertainty, Excluding Catastrophe Mortality Bonds

		CAR[-5;+5]	CAR[-10;+10]	CAR[-15;+15]	CAR[-20;+20]	CAR[-25;+25]
$\Delta CAR_{Q1\text{-}Q5}$	Δmean	4.12%	5.91%	6.72%	5.45%	1.87%
	(*t*-stat)	(2.01)**	(2.27)**	(2.10)**	(1.52)	(0.55)
	Δmedian	1.07%	2.68%	3.11%	2.92%	2.28%
	(*z*-stat)	(1.00)	(1.73)*	(1.16)	(1.08)	(0.27)

Notes: The table reports market adjusted cumulative abnormal returns (CAR) for different event windows surrounding the announcement to issue Cat bonds for the lowest (Q_1) and highest quintiles (Q_5) for the standard deviation of the loss ratio in the four fiscal years before the announcement date. The loss ratio is defined as claim and loss expenses plus long-term insurance reserves scaled by premium income (all in *t*-1). Also, the differences in CAR between the lowest and highest quintile are reported ($\Delta CAR_{Q1\text{-}Q5}$). The sample consists of 80 Cat bonds issued in the period 1997 to May 2010. All firms are publicly traded. To test for the statistical significance of CAR, a two tailed *t*-test as well as the non-parametric Mann–Whitney–Wilcoxon test are employed. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5-13
Value Effects by Reinsurance Prices, Excluding Catastrophe Mortality Bonds

		CAR[-5;+5]	CAR[-10;+10]	CAR[-15;+15]	CAR[-20;+20]	CAR[-25;+25]
Guy Carpenter Rate On Line Index						
ΔCAR_{Q1-Q5}	Δmean	4.17%	5.01%	7.06%	8.36%	5.20%
	(*t*-stat)	(1.86)*	(2.03)*	(2.35)**	(2.55)**	(1.81)*
	Δmedian	1.53%	3.34%	4.37%	8.70%	7.64%
	(*z*-stat)	(0.51)	(0.86)	(0.82)	(1.73)*	(2.00)**

Notes: The table reports market adjusted cumulative abnormal returns (CAR) for different event windows surrounding the announcement to issue Cat bonds for the lowest (Q_1) and highest quintiles (Q_5) for the Guy Carpenter Rate On Line Index (Source: Guy Carpenter, 2010). This index is used as a measure of the reinsurance price level. Also, the differences in CAR between the lowest and highest quintile are reported ($\Delta CARQ1_{-Q5}$). The sample consists of 80 Cat bonds issued in the period 1997 to May 2010. All firms are publicly traded. To test for the statistical significance of CAR, a two tailed *t*-test as well as the non-parametric Mann–Whitney–Wilcoxon test are employed. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5-14
Regressions on Abnormal Issuer Announcement Returns, Excluding Catastrophe Mortality Bonds

	(A)	(B)	(C)	(D)	(E)	(F)
SIZE	0.567	0.398	0.362	0.699	0.676	
	(0.29)	(0.25)	(0.23)	(0.43)	(0.41)	
LEV	-0.216**	-0.178*	-0.178*	-0.184*	-0.184*	-0.170***
	(2.50)	(1.98)	(1.97)	(2.01)	(1.99)	(4.76)
ROE	0.076	0.048	0.051	0.039	0.043	
	(1.04)	(0.66)	(0.72)	(0.51)	(0.57)	
PREPERF	0.092**	0.080**	0.081**	0.082**	0.083**	0.079**
	(2.21)	(2.19)	(2.24)	(2.25)	(2.33)	(2.31)
LOSSVOL	-0.395**	-0.360**	-0.363**	-0.368**	-0.374**	-0.338***
	(2.73)	(2.72)	(2.71)	(2.76)	(2.77)	(3.12)
FREQUENT	-1.129	-0.930	-1.018	-1.586	-1.789	
	(0.76)	(0.79)	(0.69)	(0.99)	(0.87)	
ISSUESIZE	0.062	0.232	0.219	0.281	0.266	
	(0.08)	(0.38)	(0.37)	(0.47)	(0.45)	
INDEM	-1.958		-0.480		-0.733	
	(0.66)		(0.19)		(0.28)	
BONDRATING	0.244			0.234	0.258	
	(0.68)			(0.86)	(0.87)	
SOFTMARKET	1.584***	1.712***	1.676***	1.785***	1.738***	1.633***
	(4.82)	(7.43)	(5.79)	(6.93)	(5.91)	(14.72)
Intercept	5.918	7.945	8.630	1.077	1.404	14.659***
	(0.20)	(0.35)	(0.39)	(0.05)	(0.06)	(4.80)
Observations	74	74	74	74	74	74
Year fixed effects	YES	YES	YES	YES	YES	YES
Country fixed effects	NO	NO	NO	NO	YES	NO
Adjusted R^2	0.322	0.380	0.368	0.370	0.359	0.415

Notes: The table reports the results of ordinary least squares regression for CAR[-20;+20] relative to the announcement date (t=0). The model is estimated with Huber-White corrected standard errors clustered by the issuing firm. The independent variables are: SIZE = logarithm of total assets; LEV = ratio of total assets to total liabilities; ROE = return on equity; PREPERF = one year buy and hold abnormal return before the issue announcement net of the same return computed for the market index; LOSSVOL = standard deviation of loss ratios (defined as claim and loss expenses plus long-term insurance reserves scaled by premium income) over a four-year period prior to the announcement date; FREQUENT = dummy variable which equals 1 if the issuer has issued 5 or more Cat bonds during the observation period (and 0 otherwise); ISSUESIZE = ratio of total risk capital issued to total shareholders' equity; INDEM = dummy variable which equals 1 if the Cat bond has an indemnity trigger (and 0 otherwise); BONDRATING = the bond rating applied by Standard &Poor's or Moody's with 1 being the highest rated bond and 18 being not rated; SOFTMARKET = dummy variable which equals 1 if the bond is issued during the lowest quintile for the Guy Carpenter Rate On Line Index (Source: Guy Carpenter, 2010). All accounting data (unless stated differently) refer to one fiscal year prior to the announcement of the Cat bond issue (t-1) and are from Worldscope. The t-statistics (two tailed) of the coefficients are reported in the parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5-15
Regressions on Abnormal Issuer Announcement Returns Using Risk Adjusted Abnormal Returns

	(A)	(B)	(C)	(D)	(E)	(F)
SIZE	0.749	0.644	0.607	1.118	1.087	
	(0.36)	(0.41)	(0.39)	(0.67)	(0.65)	
LEV	-0.274**	-0.219**	-0.220**	-0.229**	-0.230**	-0.175***
	(2.65)	(2.24)	(2.23)	(2.19)	(2.22)	(3.69)
ROE	0.034	-0.006	-0.003	-0.020	-0.017	
	(0.30)	(0.06)	(0.03)	(0.18)	(0.15)	
PREPERF	-0.004	-0.019	-0.019	-0.017	-0.016	-0.014
	(0.09)	(0.40)	(0.40)	(0.36)	(0.34)	(0.32)
LOSSVOL	-0.439**	-0.423*	-0.427*	-0.440*	-0.446*	-0.500**
	(2.06)	(1.88)	(1.87)	(1.91)	(1.94)	(2.59)
FREQUENT	-1.021	1.204	1.090	0.156	-0.041	
	(1.39)	(0.81)	(0.65)	(0.08)	(0.02)	
ISSUESIZE	0.094	0.260	0.245	0.341	0.324	
	(0.12)	(0.41)	(0.40)	(0.53)	(0.52)	
INDEM	-2.419		-0.437		-0.800	
	(0.75)		(0.17)		(0.30)	
MORTALITY	0.335			0.384	0.404	
	(0.78)			(0.97)	(1.03)	
BONDRATING	2.422		0.299	2.334	2.410	
	(0.64)		(0.18)	(0.70)	(0.72)	
SOFTMARKET	1.782**	1.641**	1.637**	1.565**	1.557**	1.622***
	(2.26)	(2.47)	(2.43)	(2.26)	(2.21)	(2.90)
Intercept	4.173	5.103	5.863	-5.810	-5.276	14.278***
	(0.13)	(0.23)	(0.28)	(0.24)	(0.22)	(3.50)
Observations	80	80	80	80	80	80
Year fixed effects	YES	YES	YES	YES	YES	YES
Country fixed effects	NO	NO	NO	NO	YES	NO
Adjusted R^2	0.223	0.262	0.237	0.245	0.232	0.299

Notes: The table reports the results of ordinary least squares regression for CAR[-20;+20] relative to the announcement date (t=0) using a standard market model ($AR_{it}=r_{it}-\alpha_i-\beta_i r_{mt}$) with risk adjusted abnormal returns. The model is estimated with Huber-White corrected standard errors clustered by the issuing firm. The independent variables are: SIZE = logarithm of total assets; LEV = ratio of total assets to total liabilities; ROE = return on equity; PREPERF = one year buy and hold abnormal return; LOSSVOL = standard deviation of loss ratios (defined as claim and loss expenses plus long-term insurance reserves scaled by premium income) over a four-year period prior to the announcement date; FREQUENT = dummy variable which equals 1 if the issuer issued more than 5 Cat bonds during the observation period (and 0 otherwise); ISSUESIZE = ratio of total risk capital issued to total shareholders' equity; INDEM = dummy variable which equals 1 if the Cat bond has an indemnity trigger (and 0 otherwise); MORTALITY = dummy variable which equals 1 if the securitized risk is linked to mortality risk (and 0 otherwise); BONDRATING = the bond rating applied by Standard &Poor's or Moody's with 1 being the highest rated bond and 18 being not rated; SOFTMARKET = dummy variable which equals 1 if the announcement to issue a Cat bond took place during the highest quintile for the Guy Carpenter Rate On Line Index (Source: Guy Carpenter, 2010). All accounting data (unless stated differently) refer to one fiscal year prior to the announcement of the Cat bond issue (t-1) and are from Worldscope. The t-statistics (two tailed) of the coefficients are reported in the parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

6
The Risk Implications of Insurance Securitization: Do Catastrophe Bonds Lower the Default Risk of Issuers?

6.1 Introduction

The previous chapter casts doubt on the effectiveness of insurance securitization in general (and Cat bonds in particular) in hedging underwriting risks. Potentially, this could provide another explanation for the hitherto underwhelming use of insurance securitization, as one of the key characteristics of insurance securitization is the transfer of catastrophe risks from insurers to capital markets.

Therefore, the purpose of this chapter is to analyze the effectiveness of insurance securitization in hedging underwriting risks by assessing how effective Cat bonds are in reducing the default risk of the firms which issue them. The investigation focuses on default risk, because the underwriting losses linked to catastrophe events may prove large enough to cause distress and, consequently, have an effect on the default-likelihood of an insurer (Cummins et al., 2002; Harrington and Niehaus, 2003). If Cat bonds are effective in transferring catastrophe underwriting risk from issuers to market investors, they should lead to a commensurate reduction in the issuers' default risk.

Default risk is calculated by using a default likelihood indicator derived from the Merton (1974) option pricing model. This default risk measure has recently been applied to both insurance firms (Bernoth and Pick, 2011) and to financials more generally (e.g. Akhigbe et al., 2007; Vallascas and Hagendorff, 2011). The Merton default risk measure has several critical advantages over other risk measures. First, because it draws on both accounting and market data, the Merton default risk measure picks up the expected risk benefits at the time of the issue even though these benefits will only materialize at a future point in time. Consistent with this, evidence from the banking sector shows that the Merton default risk measure outperforms pure market measures of default risk over most time horizons (Gropp et al., 2006). Second, the Merton default risk measure can be computed for all listed insurers. By contrast, data on credit default swap spreads and other market measures of default risk are not widely available.[39]

The main intuition behind this analysis is that if Cat bonds transfer catastrophe-related underwriting risk, their issue should cause a reduction in the default risk of the issuer. Next to this argument, there are additional explanations as to why Cat bonds may exhibit risk reducing benefits. First, unlike reinsurance, Cat bonds involve no counterparty risk. Reinsurance claims may not be indemnified if large losses force reinsurers into default. By contrast, the pay-offs from Cat bonds for insurers are independent of the counterparty remaining solvent, because Cat bond principals are fully collateralized (Lakdawalla and Zanjani, 2006). Second, Cat bonds

[39] Less than half of the issuers of Cat bonds have credit default swap (CDS) contracts outstanding which are traded on an exchange and for which spreads can be calculated at a high frequency. Also, the data on CDS contracts are rarely available before 2004.

have a maturity of typically three to four years. This makes the costs of risk management via Cat bonds more predictable as compared with reinsurance contracts which have a typical risk period of only one year. Consequently, the costs of coverage via Cat bonds are fixed for the issuer until the bond's maturity and remain fixed irrespective of underwriting losses realized by either the issuer or the industry. Since large loss events typically cause reinsurance markets to 'harden', leading to higher prices and restrictions in the supply of catastrophe coverage (Froot and O'Connell, 2008; Cummins and Weiss, 2009), the multi-year maturity of Cat bonds may insulate insurers from unexpected hikes in the pricing of catastrophe risk management (or a loss of coverage if reinsurance pricing becomes too unattractive).

However, there remain doubts over whether Cat bonds entail a transfer of catastrophe-related underwriting risk which is sufficiently large to lead to observable changes in the default risk of the issuing firm. These doubts are founded on two reasons. First, the triggers which permit issuers of Cat bonds to forfeit do not necessarily match the specific loss experience of the issuer. Instead, triggers are frequently defined in terms of industry-wide losses (e.g. via loss indices). Few Cat bonds use so-called indemnity triggers where payoffs are defined in terms of the issuer's realized losses. As a result, non-indemnity triggers give rise to basis risk which may leave insurers which have issued Cat bonds facing default in the event of high individual losses but low index losses (see Harrington and Niehaus, 1999; Cummins et al., 2004).[40]

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[40] Both Harrington and Niehaus (1999) and Cummins et al. (2004) use simulation analyses to show that the basis risk linked to index-based triggers is manageable for U.S. homeowner insurers and large

Second, it is unknown whether the risks which insurers securitize via Cat bonds actually pose substantial underwriting risks to them (in the sense that the underlying catastrophe event is likely to occur). Evidence from the banking sector shows that banks tend to securitize assets with low ex-post default rates and retain assets with high ex-post default rates on their balance sheets (see Ambrose et al., 2005; Keys et al., 2010). The fact that only four Cat bonds have been triggered by a catastrophe event to date raises the point whether, similar to banks, the issuers of Cat bonds are mindful of any reputational damage which could result from allegations that they had issued high-risk bonds to unsuspecting investors.

This chapter makes three important contributions. First, and most importantly, it presents the first empirical investigation into the realized risk implications of insurance securitization and shows that Cat bonds are effective in reducing the default risk of the firms which issue them as insurers experience a statistically and economically significant reduction in default risk around the issue of a Cat bond. Consequently, this chapter can diminish the concerns regarding the effectiveness of insurance securitization in hedging catastrophe risk which originated from results in Chapter 5.

Second, this chapter presents new insights into the nexus between basis risk and the effectiveness of risk transfers via Cat bonds (see Harrington and Niehaus, 1999; Cummins et al., 2004). Results show that even Cat bond issues with index triggers (which involve basis risk because payouts are largely independent of the

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Hurricane insurers in Florida, respectively. However, it is important to bear in mind that these results are based on simulations. The risk that the payoffs from index-based Cat bonds do not cover the issuer's catastrophe losses remains a concern for issuing firms.

catastrophe losses experienced by the issuer) lead to a reduction in default risk. This shows that the basis risk underlying Cat bonds is not sufficiently large as to thwart the hedging benefits linked to Cat bonds from materializing.

Third, the results also identify some of the drivers of the risk reduction benefits of Cat bond issues. Thus, Cat bonds are particularly risk reducing for issuers that are more exposed to either catastrophe or default risk. Further, the risk reduction benefits associated with insurance securitization are more pronounced during time periods when the supply of reinsurance as a substitute to catastrophe risk management is restricted.

The remainder of this chapter proceeds as follows. The next section describes the Cat bond sample and explains the methodology used to gauge changes in the issuer's default risk in response to the issue of a Cat bond. Sections 6.3 and 6.4 present the results of the univariate and multivariate analysis, respectively. Finally, Section 6.5 concludes.

6.2 Data and Methodology

6.2.1 Sample

The data on insurance securitization are obtained from Hannover Re and include all Cat bond issues before May 2010. Cat bonds are defined as bonds where coupons and/or principal payments are contingent on the occurrence of catastrophe-related property and casualty risks or catastrophe-related mortality risks.[41] In all cases, the issuer is the ultimate beneficiary of the Cat bond coverage.[42] Issuing firms are insurance and reinsurance firms—most of them large and well-known firms such as Travelers Companies, Axa and Swiss Reinsurance. All issuing firms included in the sample are publicly listed firms with equity returns available on Datastream and accounting data on Worldscope.

For an initial sample of 143 Cat bond issues, the Cat bond data from Hannover Re is verified by matching them with publicly available information on insurance securitizations in AON Capital Markets (2010) and Guy Carpenter (2008). Where discrepancies between proprietary and public data (as regards the issue date, value and risks underlying an issue) are identified, further searches on various news sources available on LexisNexis and Factiva were conducted. Where the discrepancies remain unresolved, the affected issue was omitted from the sample (this affects a total of seven issues).

In a next step, issues were omitted for any one of the following reasons. First, to avoid confounding events, there need to be more than 122 trading days between separate issue announcements by the same issuer to Cat bonds.[43] As a result

[41] Catastrophe mortality risks result from catastrophe events which generate spikes in mortality rates (e.g. natural catastrophes or pandemics). While these so-called mortality (Cat) bonds are included in the sample, longevity bonds are excluded. This is because longevity bonds securitize longevity risk (due to increased life expectancy) and are not linked to catastrophe events (for more details, see Cowley and Cummins, 2005).

[42] Transactions where the Cat bond coverage is sold by the issuer to a third party (i.e. Calabash Re Ltd. I-III by Swiss Re) are not included in the sample to avoid convoluted interpretations of the results.

[43] There needs to be at least 122 trading days between separate events since this chapter analyses the issuers' default risk for a period ranging from -61 days to +61 days relative to the announcement date. For more details regarding the methodology in this chapter, see Section 6.2.2.

of this criterion, 14 Cat bond issues were omitted. Second, all so-called follow-up transactions from shelf offering programs were dropped. Shelf offering programs allow firms to issue further Cat bonds at any time. Follow-up transactions tend to be very small and have only a limited amount of information available. This affects 29 issues. Finally, when a firm issues more than one Cat bond on the same trading day, the transactions are consolidated into a single issue. This leads to 15 individual transactions being consolidated into three deals.[44]

The final sample used in this study consists of 81 Cat bond issues. When comparing the sample with the data from Hannover Re, it becomes evident that the sample corresponds to 75% of the total Cat bond risk capital issued by listed firms up to May 2010. Table 6-1 provides sample descriptives by year (Panel A), trigger type (Panel B) and country (Panel C). It shows that the majority of Cat bond transactions (by both number and total risk capital) took place in 2006 and 2007 (Panel A). Also, the vast majority of Cat bonds exhibits an index-linked trigger where Cat bond payoffs are largely independent of the losses realized by the issuer (Panel B). Finally, most Cat bonds were issued by firms listed in Switzerland, the U.S. and Germany (Panel C).

[44] When Cat bond transactions are consolidated, the risk capital of the individual transactions was summed up. For all cases where Cat bonds are consolidated, the trigger types of the individual transactions are identical.

Table 6-1
Sample Characteristics

Panel A: Distribution of Cat bond Issues by Year

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Number	1	4	3	5	4	4	1	1	5	13	16	8	12	4	81
Risk capital ($ millions)	112	251	322	804	564	506	205	248	1,007	3,064	3,663	1,220	1,710	630	14,306
% Value	0.78	1.76	2.25	5.62	3.94	3.54	1.44	1.73	7.04	21.42	25.60	8.53	11.95	4.40	100.00
Panel B: Distribution of Cat bond Issues by Trigger Type															
Indemnity	0	4	1	1	0	0	0	0	1	0	2	2	1	0	12
Non-indemnity	1	0	2	4	4	4	1	1	4	13	14	6	11	4	69

Panel C: Distribution of Cat bond Issues by Country

	France	Germany	Japan	Switzerland	UK	U.S.	Total
Number	11	18	4	23	2	23	81
Risk Capital ($ millions)	2,565	2,705	468	4,424	258	3,886	14,306
% Value	17.92	18.91	3.27	30.93	1.81	27.16	100.00

Notes: The sample consists of 81 Cat bond issues in the period 1997 to May 2010. This is approximately 75% of total Cat bond risk capital (defined as the total of bond principal and coupon payments at risk) issued by listed firms during that time period.

6.2.2 Methodology

To estimate the effect of Cat bonds on the issuers' default risk, this chapter applies the Merton (1974) option pricing method as in Akhigbe et al. (2007) and Vassalou and Xing (2004). The daily default risk of issuing firms is estimated using the following default likelihood indicator (DLI):

$$\mathrm{DLI}_t = N\left(-\frac{\ln(V_{A,t}/L_t) + \left(r_f - 0.5\sigma^2{}_{A,t}\right)T}{\sigma_{A,t}\sqrt{T}} \right), \tag{6.1}$$

where $V_{A,t}$ is the market value of assets on day t, L_t is the book value of total liabilities and, r_f is the risk-free rate (proxied by the annualized yield on two-year government bonds in the issuer's country), $\sigma_{A,t}$ is the annualized asset volatility on day t, T is the time to maturity (conventionally set to one year), and N is the cumulative density function of the standard normal distribution.

The computation of DLI requires estimates of $V_{A,t}$ and $\sigma_{A,t}$, neither of which are directly observable. Following Akhigbe et al. (2007) and Hillegeist et al. (2004), the values of $V_{A,t}$ and $\sigma_{A,t}$ are simultaneously estimated through an iterative process based on the Black-Scholes-Merton option pricing method. Specifically, the market value of a firm's equity ($V_{E,t}$) is viewed as a call option on the value of the firm's assets by solving the following system of nonlinear equations:

$$V_{E,t} = V_{A,t}N(d_1) - L_t e^{-rfT} N(d_{2,t}), \tag{6.2}$$

$$\sigma_{E,t} = \left(V_{A,t}N(d_{1,t})\sigma_{A,t}\right) / V_{E,t}\ , \tag{6.3}$$

where,

$$d_{1,t} = \frac{\ln(V_{A,t}/L_t) + \left(r_f + 0.5\sigma^2{}_{A,t}\right)T}{\sigma_{A,t}\sqrt{T}},\quad d_{2,t} = d_{1,t} - \sigma_{A,t}\sqrt{T} \tag{6.4}$$

Equation (6.3) is the optimal hedge equation that relates the standard deviation of a firm's equity value to the standard deviation of a firm's total asset value (both on an annualized basis).

To solve the system of nonlinear equations, this chapter first employs as starting values for $\sigma_{A,t}$ the historical volatility of equity (computed daily on the basis of a 90-trading day rolling window) multiplied by the square root of the number of trading days in the year. The chapter then uses the daily values of $\sigma_{E,t}$ and $V_{E,t}$ to compute the initial value of $\sigma_{A,t}$ as $\sigma_{A,t} = \sigma_{E,t} V_{E,t} / (V_{E,t} + L_t)$. Finally, a Newton search algorithm identifies the daily values of $V_{A,t}$ and $\sigma_{A,t}$ which are then employed to compute the default likelihood for each issuer per day as in (6.1).

To measure the risk effects linked to the issue of a Cat bond, the differences in DLI during a 60-day trading period ending 2 days before the issue announcement (the pre-issue period [α-61, α-2]) and DLI during a 60-day trading period starting two days after the issue announcement (the post-issue period [α+2, α+61]) are computed.[45] The analysis measures changes in risk around the announcement date of a Cat bond, because press announcements of Cat bond issues precede the issue date for 64 issues in the sample (by 13 days on average).[46] In cases where the issue date precedes the announcement date, the issue date is employed as the announcement date. Since the default risk measure used in this chapter captures expected changes in

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[45] Akhigbe et al. (2007) use an identical examination period when analyzing the effects of Fed policy actions on the default likelihood of commercial banks.

[46] To assess whether the results are sensitive to the event period used, the analysis is re-run using a time window of identical length but around the issue date rather than the date the issue was first announced. The main implications of both the univariate and regression results remain unaffected. The tables to this test can be found in the Appendix to this chapter on pgs. 179 and 180.

risk (via the inclusion of market valuations), changes in risk due to securitization will be most reliably measured around the announcement date. The dates on which Cat bond issues were first announced in the press are hand-collected by searching various news sources on LexisNexis and Factiva, as well as the issuing firms' websites and ARTEMIS (www.artemis.bm), an online practitioner portal for insurance securitization.

The analysis follows Vallascas and Hagendorff (2011) and eliminates general industry and time trends in risk by computing a daily default likelihood index at country level. For every issue, the market risk index is calculated as the value-weighted DLI of all insurance and reinsurance companies listed on Datastream in the issuer's country which have not issued Cat bonds.[47] The industry-adjusted change in default likelihood (ΔIADL) which can be attributed to Cat bonds can, therefore, be expressed as:

$$\begin{aligned}\Delta\text{IADL} &= \overline{\text{DLI}}_{(\alpha+2;\alpha+61)} - \overline{\text{DLI}}_{(\alpha-61;\alpha-2)} - \left(\overline{\text{DLI}}_{index(\alpha+2;\alpha+61)} - \overline{\text{DLI}}_{index(\alpha-61;\alpha-2)}\right) \\ &= \Delta\text{DLI}_{issuer} - \Delta\text{DLI}_{index}\end{aligned} \qquad (6.5)$$

Some researchers argue that the Merton default risk measure as applied in this chapter underestimates the true probability of default as it assumes that corporate assets follow a diffusion process. They propose, given that the diffusion process makes a sudden drop in the firm value impossible, to add a jump component to the firm value process as a potential remedy to the underestimation of default risk (e.g. Zhou, 1997). However, Chapter 4 of this thesis as well as previous work has

[47] The results are qualitatively identical if an European default likelihood index (by aggregating all insurance and reinsurance companies in France, Germany, Switzerland and the UK) is used instead of the individual default likelihood index at country level.

demonstrated that even extreme catastrophe events (such as Hurricane Andew in 1992, the World Trade Centre Attacks in 2001 or Hurricane Katrina in 2005) do not cause extreme plunges in the market value of insurers (Lamb, 1995; Cummins and Lewis, 2003). Therefore, and in line with published work in the insurance area (e.g. Bernoth and Pick, 2011), this study applies the Merton default risk measure in its original form.[48]

6.3 Univariate Results

6.3.1 Catastrophe Bonds and Issuers' Default Risk

In this section, the risk effects that Cat bond issues exert on the issuers' default risk are examined. Table 6-2 reports the industry-adjusted default likelihood (IADL) during the pre-issue period [α-61; α-2] and post-issue [α+2; α+61] period relative to the issue announcement date (α). To analyze whether insurance securitization exerts a statistically significant impact on the issuers' default likelihood, Table 6-2 reports *t*-statistics (z-statistics) which evaluate the hypothesis that mean (median) changes in the issuers' default likelihood (ΔIADL) are equal to zero. If Cat bonds are effective in transferring catastrophe risks from insurers to capital markets (as suggested by Niehaus, 2002; Harrington and Niehaus, 2003; Cummins et al., 2004), the issuing

[48] To test whether the results are influenced by any large-scale catastrophe events which occurred during the examination period (*t*-61; *t*+61), issues which coincide with the ten most costly catastrophe events in terms of insured losses (identified in the annual Swiss Re Sigma Reports from 1996 to 2010) during the examination period are excluded and both univariate and multivariate tests are re-run. This affects 23 observations and reduces the total sample size to 58. The univariate results as well as the regression results remain unaffected. The tables to this test can be found in the Appendix to this chapter on pgs. 181 and 182.

firm’s default likelihood is expected to decrease in response to the issue of a Cat bond.

Table 6-2 shows that the mean (median) IADL declines in response to Cat bond issues. The reduction in the default likelihood (ΔIADL) is statistically significant at the 1% level according to the *t*-test (and 5% level according to the *z*-test). Further, the risk reduction benefits of Cat are widespread in the sample. More than 60% of issuers in the sample exhibit a reduction in default likelihood after the Cat bond issue.

The results reported in Table 6-2 indicate that insurance securitization is an effective vehicle to reduce the issuers’ default risk. However, the risk profile of the issuing firm may play an important factor in determining the risk effects of an issue. Equally, because only indemnity-based triggers do not involve any basis risk and, hence, serve as a perfect hedge against catastrophe-related underwriting losses, it is conceivable that the risk reductions reported above are driven by this type of trigger. Consequently, the next subsections analyze if the risk benefits of Cat bonds are moderated by the risk profile of the issuing firm or the trigger type underlying the Cat bond.

Table 6-2

Effect of Catastrophe Bonds on the Issuers' Industry-Adjusted Default Likelihood (IADL)

	N	**mean (%)**	**median (%)**	**ΔIADL<0%**	
		(t-stat)	**(z-stat)**	***N***	**%**
IADL: Pre-Issue Period (α-61;α-2)	81	1.305 (1.906)*	-0.040 (-0.963)		
IADL: Post-Issue Period (α+2;α+61)	81	-0.047 (-0.120)	-0.066** (-2.305)		
ΔIADL	81	-1.352*** (-2.727)	-0.019** (-2.135)	50	61.7

Notes: The table reports the mean (median) industry-adjusted default likelihood for a sample of Cat bond issuing firms. Both the default likelihood in the pre-issue period (computed as the default likelihood over the period from -61 days to -2 days relative to the announcement date α) as well as the default likelihood in the post-issue period (computed as the average of the default likelihood over the period from +2 days to +61 days relative to the announcement date α) are displayed. The effect of Cat bonds on the issuers' industry-adjusted default likelihood (ΔIADL) is the difference between the post-issue and pre-issue period. Also included are *t*-statistics (two tailed) and the non-parametric Mann–Whitney–Wilcoxon *Z*-scores to evaluate if the mean and median IADL and ΔIADL are equal to zero. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

6.3.2 Risk Effect and Issuers' Exposure to Catastrophe Risk

In this subsection, it is investigated how the exposure to catastrophe risk impacts upon changes in the default risk of the issuing firm around insurance securitizations. If Cat bonds are effective in transferring catastrophe underwriting risks from the issuer, it would be expected that issuers which are more exposed to catastrophe risk experience a more pronounced reduction in default risk. Table 6-3 tests this proposition.

To measure an insurer's exposure to catastrophe risk, the correlation between the issuing firms' mean quarterly IADL and quarterly global insured catastrophe losses (as published in Swiss Re Sigma Reports dating from 1994 to 2010) over a three-year period prior to the issue is used. Insurers are ranked into quartile portfolios according to their exposure to catastrophe risk and the changes in ΔIADL for the lowest (Q_1) and highest (Q_4) catastrophe risk portfolio are reported.[49] Also, the changes in default risk in response to the Cat bond issue are assessed for insurers among the two quartiles ($\Delta IADL_{Q4}$- $\Delta IADL_{Q1}$).

[49] There is little overlap between the quartile portfolio of issuing firms which are most exposed to Cat risk (Q4 in Table 6-3) and the quartile portfolio of firms which are most exposed to default (Q4 in Table 6-4). Out of the 20 issues contained in both portfolios, six issues are present in both portfolios.

Table 6-3
Risk Effects of Catastrophe Bonds, by the Issuers' Exposure to Catastrophe (Cat) Risk

		N	**mean (%)**	**median (%)**	**ΔIADL<0%**	
			(t-stat)	**(z-stat)**	***N***	**%**
Low Cat Exposure (Q1)	IADL: Pre-Issue Period (α-61;α-2)	21	0.242	-0.050		
			(0.365)	(-0.299)		
	IADL: Post-Issue Period (α+2;α+61)	21	-0.040	-0.037		
			(-0.084)	(-0.299)		
	$\Delta IADL_{Q1}$	21	-0.282	-0.123	12	57.1
			(-0.453)	(-0.672)		
High Cat Exposure (Q4)	IADL: Pre-Issue Period (α-61;α-2)	20	6.129**	0.628**		
			(2.679)	(2.133)		
	IADL: Post-Issue Period (α+2;α+61)	20	1.918	-0.023		
			(1.660)	(0.765)		
	$\Delta IADL_{Q4}$	20	-4.211**	-0.364***	17	85.0
			(-2.471)	(-2.777)		
	$\Delta IADL_{Q4}$- $\Delta IADL_{Q1}$		-3.930**	-0.241*		
			(2.211)	(1.69)		

Notes: The table reports the mean (median) industry-adjusted default likelihood for a sample of Cat bond issuing firms for the lowest (Q1) and highest (Q4) quartile of pre-issue exposure to catastrophe risk based on the correlation between quarterly IADL values and quarterly insured catastrophe losses (as published in Swiss Re Sigma Reports dating from 1994 to 2010) over a three-year period prior to the issue of a Cat bond. Both the default likelihood in the pre-issue period (computed as the average of the default likelihood over the period from -61 days to -2 days relative to the announcement date α) as well as the default likelihood in the post-issue period (computed as the average of the default likelihood over the period from +2 days to +61 days relative to the announcement date α) are displayed. Also, the differences in IADL between the highest and lowest quartile are reported ($\Delta IADL_{Q4-Q1}$). The effect of Cat bonds on the issuers' industry-adjusted default likelihood (*ΔIADL*) is the difference between the post-issue and pre-issue period. Also included are *t*-statistics (two tailed) and the non-parametric Mann–Whitney–Wilcoxon *Z*-scores to evaluate if the mean and median *IADL* and *ΔIADL* are equal to zero. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 6-3 confirms the expectations that issuers which are more exposed to catastrophe risk exhibit a larger reduction in default risk. Thus, issuers with the highest exposure to catastrophe risk (Q_4) experience a larger reduction in default likelihood around the issue of a Cat bond as compared to issuers with the lowest exposure to catastrophe risk (Q_1). This finding is statistically significant at the 5% level according to the *t*-test (and 10% level according to the *z*-test).

6.3.3 Risk Effect and Issuers' Exposure to Default Risk

It is expected that the risk reduction benefits linked to Cat bond issues will be larger for insurers which are more exposed to default risk. This expectation is based on two arguments. First, insurers which are more exposed to default risk should see a larger reduction in default risk when issuing Cat bonds, because Cat bonds collateralize coverage of specific loss events. While insurers may also hedge catastrophe risks using reinsurance contracts, coverage via reinsurance is not collateralized and, therefore, involves counterparty risk. This means that insurer losses will not be indemnified in the event the reinsurance counterparty defaults. Since the default likelihood of insurers which are more exposed to default risk will be more sensitive to the counterparty risk inherent in reinsurance contracts (Lakdawalla and Zanjani, 2006), it is expected that this type of insurer should realize higher risk reduction benefits from issuing Cat bonds.

Second, the pricing of the risk transfer underlying Cat bonds is fixed over the multi-year maturity of the bond. This is in contrast to reinsurance contracts with a typical risk period of only one year. Therefore, reinsurance premiums may increase sharply following large loss experiences either by the industry or individual insurers (see Froot and O'Connell, 2008; Cummins and Weiss, 2009). To the extent that insurers which are more exposed to default risk will be more vulnerable to the liquidity shocks caused by volatile reinsurance premiums, this type of insurer should see a larger reduction in their default risk when issuing Cat bonds. Cat bonds effectively insulate insurers which are more exposed to default risk from potential liquidity shocks caused by volatile reinsurance premiums.

Table 6-4 tests if the risk reduction benefits in response to the issue of Cat bonds are more pronounced for insurers which are more exposed to default risk. Issuers are ranked into quartile portfolios according to their default risk values in the pre-issue period and the changes in the industry-adjusted default risk for the lowest ($\Delta IADL_{Q1}$) and highest ($\Delta IADL_{Q4}$) default risk portfolio are reported. It can then be examined whether the changes in default risk in response to the Cat bond issue are different among the two quartiles ($\Delta IADL_{Q4}$- $\Delta IADL_{Q1}$). In line with expectations, Table 6-4 documents that when issuers are located in the highest-default risk portfolio (Q_4), they realize a larger reduction in default risk in response to the Cat bond issue (significant at 1% according to both *t*-test and *z*-test) as compared to issuers which are located in the lowest-default risk portfolio (Q_1).

Table 6-4
Risk Effects of Catastrophe Bonds, by the Issuers' Exposure to Default Risk

		N	**mean (%)**	**median (%)**	**ΔIADL<0%**	
			(t-stat)	**(z-stat)**	***N***	**%**
Low Default Risk (Q1)	IADL: Pre-Issue Period (α-61;α-2)	21	-2.752	-1.331		
			(-4.737)***	(-4.015)***		
	IADL: Post-Issue Period (α+2;α+61)	21	-2.612	-1.080		
			(-3.066)***	(-3.841)***		
	$\Delta IADL_{Q1}$	21	0.136	0.213	10	47.6
			(0.233)	(0.574)		
High Default Risk (Q4)	IADL: Pre-Issue Period (α-61;α-2)	20	8.320	6.035		
			(4.201)***	(3.920)***		
	IADL: Post-Issue Period (α+2;α+61)	20	2.744	1.046		
			(2.712)**	(2.576)**		
	$\Delta IADL_{Q4}$	20	-5.576	-3.22	17	85.0
			(-3.484)***	(-3.248)***		
	$\Delta IADL_{Q4}$- $\Delta IADL_{Q1}$		-5.712***	3.433***		
			(3.146)	(3.391)		

Notes: The table reports the mean (median) industry-adjusted default likelihood for a sample of Cat bond issuing firms for the lowest (Q1) and highest (Q4) quartile of pre-issue exposure to catastrophe risk based on the correlation between quarterly IADL values and quarterly insured catastrophe losses (as published in Swiss Re Sigma Reports dating from 1994 to 2010) over a three-year period prior to the issue of a Cat bond. Both the default likelihood in the pre-issue period (computed as the average of the default likelihood over the period from -61 days to -2 days relative to the announcement date α) as well as the default likelihood in the post-issue period (computed as the average of the default likelihood over the period from +2 days to +61 days relative to the announcement date α) are displayed. Also, the differences in IADL between the highest and lowest quartile are reported ($\Delta IADL_{Q4\text{-}Q1}$). The effect of Cat bonds on the issuers' industry-adjusted default likelihood (*ΔIADL*) is the difference between the post-issue and pre-issue period. Also included are *t*-statistics (two tailed) and the non-parametric Mann–Whitney–Wilcoxon *Z*-scores to evaluate if the mean and median *IADL* and *ΔIADL* are equal to zero. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

6.3.4 Risk Effect and Trigger Type

As previously noted, Cat bonds can be designed using either indemnity-based or non-indemnity based triggers. For indemnity-based triggers, Cat bond payoffs depend on the actual loss experience of the issuer's own book of business. By contrast, the payoffs from Cat bonds linked to non-indemnity-based triggers are defined in terms of industry-wide losses (via loss indices) which may vary substantially from the underwriting losses realized by the issuer. As a result, non-indemnity-based triggers give rise to basis risk which rises the more the insured losses of the issuer and the index losses diverge. It is, therefore, expected that the risk reduction benefits linked to Cat bonds are higher for the group of indemnity-based triggers which involve no basis risk for the issuing firm.

Table 6-5 examines the risk effects that Cat bond issues exert on the issuers' default risk by type of trigger. Both the changes in the issuers' default likelihood for indemnity-based triggers ($\Delta IADL_{INDEM}$) and non-indemnity triggers ($\Delta IADL_{NONINDEM}$) are displayed, as well as the difference in changes in the issuers' default risk among these two groups ($\Delta IADL_{INDEM}$ -$\Delta IADL_{NONINDEM}$).

Table 6-5
Risk Effects of Catastrophe Bonds, by Trigger Type

		N	**mean (%)**	**median (%)**	**ΔIADL<0%**	
			(t-stat)	**(z-stat)**	***N***	**%**
Indemnity	IADL: Pre-Issue Period (α-61;α-2)	12	-1.007	-0.011		
			(-0.907)	(-943)		
	IADL: Post-Issue Period (α+2;α+61)	12	-1.850	-0.037		
			(-1.319)	(-1.013)		
	$\Delta IADL_{INDEM}$	12	-0.843*	-0.195*	10	83.3
			(-1.676)	(-1.782)		
Non-Indemnity	IADL: Pre-Issue Period (α-61;α-2)	69	1.747**	-0.044		
			(2.244)	(-0.703)		
	IADL: Post-Issue Period (α+2;α+61)	69	0.298	-0.085**		
			(0.796)	(-2.096)		
	$\Delta IADL_{NONINDEM}$	69	-1.449**	-0.016*	40	58.0
			(-2.488)	(-1.674)		
	$\Delta IADL_{NONINDEM}$- $\Delta IADL_{INDEM}$		0.606	-0.179		
			(0.447)	-(0.495)		

Notes: The table reports the mean (median) industry-adjusted default likelihood for a sample of Cat bond issuing firms for the lowest (Q1) and highest (Q4) quartile of pre-issue exposure to catastrophe risk based on the correlation between quarterly IADL values and quarterly insured catastrophe losses (as published in Swiss Re Sigma Reports dating from 1994 to 2010) over a three-year period prior to the issue of a Cat bond. Both the default likelihood in the pre-issue period (computed as the average of the default likelihood over the period from -61 days to -2 days relative to the announcement date α) as well as the default likelihood in the post-issue period (computed as the average of the default likelihood over the period from +2 days to +61 days relative to the announcement date α) are displayed. Also, the differences in IADL between the highest and lowest quartile are reported ($\Delta IADL_{Q4\text{-}Q1}$). The effect of Cat bonds on the issuers' industry-adjusted default likelihood (*ΔIADL*) is the difference between the post-issue and pre-issue period. Also included are *t*-statistics (two tailed) and the non-parametric Mann–Whitney–Wilcoxon *Z*-scores to evaluate if the mean and median *IADL* and *ΔIADL* are equal to zero. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

The results presented in Table 6-5 do not confirm the expectation that indemnity-based Cat bonds generate larger risk effects than non-indemnity based Cat bonds. However, the results show that the risk reduction benefits in response to the issue of a Cat bond are not limited to issues with indemnity-based triggers. Both the changes in the issuers' default likelihood for indemnity-based triggers ($\Delta IADL_{INDEM}$) and non-indemnity triggers ($\Delta IADL_{NONINDEM}$) are negative and statistically significant (at the 10% level according to the *t*-test and *z*-test, respectively). The presence of risk reduction benefits linked to Cat bonds without an indemnity-based trigger is interpreted as an indication that the potential basis risk underlying these issues is not sufficiently large as to prevent the risk-reducing effects of Cat bonds from materializing.

In summary, the univariate tests in this section show that Cat bonds lower the default risk of issuing firms. This risk reduction is higher for insurers which are riskier in the sense that they are more exposed to either catastrophe risk or default risk more generally. Finally, a risk reduction is observable irrespective of the type of trigger underlying the Cat bond. The last results are interpreted as indicting that the basis risk underlying Cat bonds which do not have an indemnity trigger does not prevent insurers from realizing some hedging benefits via the issue of Cat bonds.

In the next section, multivariate regression analyses are used to examine whether these findings hold and whether additional factors (e.g. issuer characteristics, Cat bond characteristics or market characteristics) shape the default risk benefits of Cat bonds.

6.4 The Determinants of Changes in Default Risk

6.4.1 The Model

The multivariate model, estimated via GLS with robust standard errors, assumes the following specification:

$$\mathbf{\Delta IADL}_i = \alpha_0 + \gamma'\mathbf{IC}_i + \theta'\mathbf{BC}_i + \delta'\mathbf{MC}_i + \varepsilon_i \qquad (6.6)$$

where:

- $\mathbf{\Delta IADL_i}$ is the Cat bond-related change in industry-adjusted default likelihood (see Section 6.2.2);
- $\mathbf{IC_i}$ is a vector of issuer characteristics at the end of the fiscal year before the issue announcement;
- $\mathbf{BC_i}$ is a vector of Cat bond characteristics, and
- $\mathbf{MC_i}$ is a vector of market specific characteristics.

To control for the effect of unobserved variables that are constant over countries and years, country and year fixed effects are included into the model.[50] Also, because the observations for one specific issuer are unlikely to be independent (possibly leading to within–correlation issues), cluster-robust standard errors are computed and each issuing firm is treated as a cluster.

Table 6-6 provides descriptions and summary statistics for the variables described below. All accounting data (unless stated differently) are from Worldscope and refer to the last accounting year prior to the announcement of the Cat bond issue.

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[50] When the models are re-estimated without fixed effects, the results are qualitatively identical. The tables to this test can be found in the Appendix to this chapter on pg. 183.

Table 6-6
Summary Statistics

	Variable	Definition	*N*	Mean	Median	Std. Dev	5 Pctile	95 Pctile
Default likelihood measures	IADL: Pre-Issue Period (α-61;α-2)	Industry-adjusted default likelihood during the pre-issue period (%)	81	1.305	-0.040	6.163	-4.101	10.820
	IADL: Post-Announcement (α+2;α+61)	Industry-adjusted default likelihood during the post-issue period (%)	81	-0.047	-0.066	3.525	-3.972	5.603
	ΔIADL	Cat bond-related change in industry-adjusted default likelihood (%)	81	-1.352	-0.019	4.464	-8.007	2.184
Issuer characteristics	HIGHCATEXPOSURE	Dummy which equals 1 if the issuer is in the highest pre-announcement Cat exposure quartile (and 0 otherwise)	81	0.247	0.000	0.434	0.000	1.000
	HIGHDEFAULT	Dummy which equals 1 if the issuer is in the highest pre-announcement default probability quartile (and 0 otherwise)	81	0.247	0.000	0.434	0.000	1.000
	ROA	The ratio of pre-tax profits to total assets (%)	81	1.241	1.036	2.493	-0.379	5.599
	CAR	Cumulative abnormal return between -20 days to +1 day relative the issue announcement (%)	81	1.573	0.492	7.538	-6.953	16.312
	SIZE	Log of total assets (thousands of USD)	81	18.205	18.623	1.70	14.833	20.690
	LEVERAGE	Total liabilities to total assets (%)	81	84.408	89.439	14.841	60.313	95.799
	LOSSRATIO	Loss ratio (%). Defined as (claims and loss expenses + long-term insurance reserves) / premiums earned	81	78.919	80.000	18.813	51.000	117.000
	UWRISK	Standard deviation of loss ratios over a four-year period prior to the issue announcement	81	8.821	5.551	9.641	1.299	35.514
	PREV	Number of previous Cat bond transactions undertaken by the issuer	81	3.753	2.000	4.157	1.000	14.000
Cat bond characteristics	INDEM	Dummy which equals 1 if the Cat bond has an indemnity trigger (and 0 otherwise)	81	14.814	0.000	0.357	0.000	1.000
	ISSUESIZE	Value of Cat bond issue scaled by the book value of equity (%)	81	3.128	1.620	3.964	0.308	12.170
	BONDRATING	The bond rating applied by Standard &Poor's or Moody's with 1 being the highest rated bond and 18 being not rated	81	11.395	11.447	2.453	6.833	14.400
Market characteristics	REPRICES	Reinsurance cycle. Guy Carpenter World Catastrophe Rate On Line Index. Source: Guy Carpenter (2010)	81	241.667	260.000	42.278	155.000	295.000
	GDP	Real GDP growth rate (%)	81	1.483	2.140	2.207	-2.440	4.070

Notes: This table reports summary statistics for the measure of default likelihood, issuer characteristics, Cat bond characteristics and market characteristics. The sample consists of 81 Cat bond issues announced over the period from 1997 to May 2010. Accounting data (unless stated differently) refer to the last accounting year prior to the announcement of the Cat bond issue and are from Worldscope. Cat bond data (PREV, INDEM, ISSUESIZE, BONDRATING, USRISK) are provided by private records by Hannover Re and public records by AON Capital Markets (2010). GDP data are from IMF – International Financial Statistics database.

Issuer Characteristics:

Amongst other variables, the vector of issuer characteristics contains two dummy variables which control for the pre-issue riskiness of the issuers. These variables are used to assess the robustness of the univariate tests above. Specifically, **HIGHCATEXPOSURE** equals one if the issuer is located in the highest pre-issue catastrophe exposure quartile (and zero otherwise), while **HIGHDEFAULT** equals one if the issuer is located in the highest pre-issue default probability quartile (and zero otherwise). In line with the results of the univariate analysis, both variables are expected to enter the models with a negative coefficient (i.e. to reduce the default likelihood). Also, the models control for issuers' profitability using return on assets (**ROA**; defined as pre-tax profits scaled by total assets). De Haan and Kakes (2010) suggest that more profitable insurers are less exposed to default risk as they tend to have more internal funds that can be used to absorb losses. As a result, ROA is expected to be inversely related to changes in issuers' default risk.

To evaluate whether the performance gains which issuers are expected to realize from Cat bond issues explain the risk implications of insurance securitization, the market adjusted announcement returns are modeled (**CAR**) and averaged from day -20 to +1 relative to the issue announcement date. CAR is expected to exert a negative impact on the issue-related changes in default risk. This is because reductions in the default risk of the issuer (suggesting Cat bonds are effective in hedging catastrophe-related underwriting risk) should be associated with higher expected performance gains.

Further, the models control for issuer size (**SIZE**) which is measured by the logarithmic transformation of the U.S. dollar value of the issuers' total assets.

Harrington and Niehaus (1999) argue that basis risk (which arises when Cat bond payoffs depend on industry rather than on insurer losses) is likely to decrease with the size of the issuing firm. Since larger insurers pool a wider range of catastrophe risks, their losses will be more aligned with industry-wide losses which means that basis risk will become more manageable.

The issuing firm's leverage (**LEVERAGE)** is also included in the models. LEVERAGE is defined as total liabilities over total assets. Given the liquidity benefits of Cat bonds to issuing firms (which are largely due to the predictability of the costs of Cat risk management), the risk reduction benefits of insurance securitization should increase with issuer leverage. Highly leveraged firms will have low excess cash flows which could raise default risk when the costs of reinsurance coverage rise unexpectedly. Therefore, a negative relationship between insurer leverage and industry-adjusted changes in the default likelihood around the issue of Cat bonds is expected.

Further, the models include two variables which capture the risk of the issuer's insurance portfolio. First, **LOSSRATIO** is the sum of claim expenses, loss expenses and long-term insurance reserves scaled by premium income. Cummins and Weiss (2011) demonstrate that loss ratios are an appropriate risk measure in the insurance industry. The authors show that loss ratios correlate highly with ex post default rates in the U.S. insurance sector. Second, underwriting risk (**UWRISK)** is the standard deviation of LOSSRATIO over a four-year period before the issue announcement (as employed in de Haan and Kakes, 2010). Both LOSSRATIO and UWRISK are expected to enter the models with negative coefficients based on the rationale that issuers with riskier insurance portfolios will benefit more from catastrophe risk transfers than insurers with less risky insurance portfolios.

PREV counts the number of previous Cat bond transactions undertaken by an issuer.[51] Against the background of how novel insurance securitization is and how unfamiliar many investors are with Cat bonds, it could be argued that issuers are only able to engineer effective risk transfers with growing expertise and reputation in the Cat bond market. Thus, the number of previous Cat bond transactions is expected to be associated with a negative change in industry-adjusted default likelihood (ΔIADL), meaning that issuers realize higher reductions in default risk with a higher number of completed issues.

Catastrophe Bond Characteristics:

The vector of Cat bond controls contains the following variables. **INDEM** is a dummy variable which is equal to one if the Cat bond exhibits an indemnity trigger (and 0 otherwise). Indemnity triggers define the conditions for principal and/or coupon forfeiture in terms of the underwriting losses of the issuer rather than catastrophe index losses. Since Cat bonds with indemnity-based triggers allow issuers to fully (rather than partially) hedge against catastrophe underwriting losses, INDEM is expected to enter with a negative sign.

ISSUESIZE measures the ratio of risk capital issued to the market value of the issuers' equity at the end of the fiscal year prior to the announcement. Larger

[51] As an alternative measure to PREV the model also used a dummy variable which is equal to one in the case of the issuer's first Cat bond and 0 for follow-up issues. No qualitative changes to the regression results are found when this definition of PREV is used instead of the count variable.

issues are expected to provide the issuers with more diversification benefits and, as a result, to reduce the issuers' default risk. Also, the models control for the initial Cat bond rating (**BONDRATING**) by Standard & Poor's (or, if unavailable, by Moody's).[52] BONDRATING is based on a numerical conversion of bond ratings where higher numbers indicate a lower rating.[53] Since Cat bonds involve no credit risk (as their principals are fully collateralized), higher Cat bond ratings indicate that the catastrophe loss event underlying the bond is more likely to occur. As a result, lower Cat bond ratings are expected to lead to larger reductions in the industry-adjusted changes in the default likelihood.

<u>Market Characteristics:</u>

Finally, moving on to the vector of market characteristics, the Guy Carpenter (2010) Rate On Line Index (**REPRICES**) is used as a measure of reinsurance prices. This yearly index is calculated by dividing global catastrophe reinsurance premiums by global catastrophe reinsurance limits. REPRICES, therefore, measures average reinsurance prices per unit of catastrophe risk underwritten.

Reinsurance markets tend to follow cycles which are characterized by periods when reinsurance prices are relatively low and coverage is readily available (soft markets), and periods when reinsurance prices are high and coverage supply is restricted (hard markets) (see Jaffee and Russell, 1997; Niehaus, 2002). During hard

[52] Cat bonds usually consist of several tranches with different ratings. The rating assigned to an issue is an average weighted by the risk capital of each tranche.

[53] The numerical conversion applied to Cat bond ratings is as follows. The value of one is assigned to issues rated AAA (or Aaa by Moodys), two to AA+ (Aa1) bond issues, and so on up to 17 for CCC+ (Caa) and 18 for bonds which are not rated. In the sample, nearly 60% of issues are rated between BB+ (or Ba1) and BB (Ba2), i.e. BONDRATING lies between 11 and 12.

reinsurance markets, insurers will only be able to make limited use of catastrophe reinsurance and are more reliant on Cat bonds. For some types of catastrophe events, no reinsurance capacity may be available during hard reinsurance markets which means that Cat bonds will be the only vehicle for insurers to hedge their catastrophe-related underwriting risk. Owing to the lack of reinsurance capacity during hard reinsurance markets, Cat bond issues during hard reinsurance markets (when REPRICES is high) are expected to be designed with a view to maximize the potential risk transfer. Consequently, REPRICES is expected to enter the models with a negative sign.

Finally, the models control for the influence of economic growth on the risk implications of insurance securitization by including the inflation-adjusted national GDP growth rates (**GDP**).

6.4.2 Regression Results

Table 6-7 reports the results of the regressions on Cat bond-related changes in industry-adjusted default likelihood (ΔIADL). The results confirm the main findings from the univariate tests. Issuers which are most exposed to catastrophe risk (HIGHCATEXPOSURE) as well as issuers which are most exposed to default risk (HIGHDEFAULT) reduce their default likelihood after the issue (significant at the 5% levels). Further, INDEM enters the model with a statistically significant coefficient (significant for most models at the 10% level). Accordingly, reductions in default likelihood in response to a Cat bond issue are more pronounced for issuers when indemnity-based Cat bonds are used. This is consistent with expectations as indemnity triggers do not involve basis risk and, thus, serve as a perfect hedge against catastrophe-related underwriting risk (Harrington and Niehaus, 1999; Cummins et al., 2004).

In addition, cumulative abnormal returns (CAR) exert a negative impact on issue-related changes in default risk. This implies that reductions in the default risk of the issuer (suggesting a transfer of catastrophe-related underwriting risks away from the issuer) are associated with higher expected shareholder returns. The remaining issuer characteristics do not enter the regressions with statistically significant coefficients.

Finally, and also in line with expectations, reinsurance prices affect changes in default likelihood in response to Cat bond issues. REPRICES enters with a negative and statistically significant coefficient (significant at the 5% levels). This indicates that Cat bond issues during periods of high reinsurance prices lead to larger reductions in the default likelihood of issuing firms. It is argued that hard reinsurance markets (when the supply of catastrophe coverage via traditional reinsurance is restricted) make insurers more reliant on Cat bonds as vehicle to hedge catastrophe risk and that this is likely to incentivize insurers to design Cat bonds such that they maximize the potential hedging benefits to them.

Table 6-7
Regressions on the Effect of Catastrophe Bonds on the Issuers' Industry-Adjusted Default Likelihood (IADL)

	(A)	(B)	(C)	(D)	(E)	(F)
HIGHCATEXPOSURE	-3.623**	-3.538**	-3.468**	-3.582**	-3.643**	-3.480**
	(2.51)	(2.30)	(2.29)	(2.41)	(2.36)	(2.21)
HIGHDEFAULT	-2.880**	-2.827**	-2.900**	-3.255**	-3.143**	-2.881**
	(2.12)	(2.09)	(2.08)	(2.10)	(2.07)	(2.10)
ROA	0.612	0.583	0.570	0.594	0.595	0.566
	(1.49)	(1.51)	(1.55)	(1.51)	(1.66)	(1.59)
CAR	-0.202**	-0.204**	-0.207**	-0.194**	-0.186**	-0.204**
	(2.39)	(2.45)	(2.39)	(2.33)	(2.32)	(2.47)
SIZE	0.413	0.231	0.086	0.237	0.292	0.079
	(0.58)	(0.31)	(0.12)	(0.32)	(0.36)	(0.10)
LEVERAGE			0.019		0.008	0.017
			(0.31)		(0.12)	(0.29)
LOSSRATIO		0.004		0.004	0.008	0.002
		(0.16)		(0.17)	(0.36)	(0.10)
UWRISK		0.045	0.048	0.068		0.047
		(1.20)	(1.33)	(1.64)		(1.29)
PREV				0.215	0.134	
				(1.33)	(0.84)	
INDEM	-2.421*	-2.221*	-2.248*	-1.945	-2.196*	-2.227*
	(1.98)	(1.78)	(1.87)	(1.48)	(1.70)	(1.78)
ISSUESIZE	0.272	0.172	0.157	0.177	0.247	0.151
	(0.85)	(0.56)	(0.51)	(0.56)	(0.75)	(0.48)
BONDRATING		0.014				0.009
		(0.09)				(0.06)
REPRICES	-0.032**	-0.048**	-0.028**	-0.049**	-0.032**	-0.028**
	(2.68)	(2.54)	(2.54)	(2.64)	(2.52)	(2.43)
GDP	-0.042	-0.065	-0.103	-0.072	-0.094	-0.109
	(0.12)	(0.19)	(0.32)	(0.19)	(0.28)	(0.35)
Constant	0.669	8.482	4.231	8.307	1.578	4.180
	(0.05)	(0.55)	(0.35)	(0.54)	(0.12)	(0.34)
Observations	81	81	81	81	81	81
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Country Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.506	0.488	0.499	0.503	0.487	0.479

Notes: The dependent variable is the change in the issuers' industry-adjusted default likelihood calculated as the difference between the post-issue (α-61, α-2) and pre-issue period (α+2, α+61) relative to the issue announcement date α. The model is estimated with country- and year-fixed effects and Huber-White corrected standard errors clustered by the issuing firm. *t*-Statistics are in parentheses. Issuer characteristics include a dummy indicating if the issuer is listed in the highest quartile of the distribution of pre-announcement exposure to catastrophe risk (HIGHCATEXPOSURE), a dummy indicating if the issuer is listed in the highest quartile of the distribution of pre-announcement industry-adjusted default likelihood (HIGHDEFAULT), the ratio between pre-tax profit and total assets (ROA), the market-adjusted mean cumulative abnormal return over -20 to +1 days relative to the announcement date (CAR), the log of the issuer total assets (SIZE), the ratio of total liabilities to total assets (LEVERAGE), the loss ratio of the issuer (LOSSRATIO) defined as claim and loss expenses plus long-term insurance reserves scaled by premium income, the standard deviation of loss ratios over a four-year period prior to the issue announcement (UWRISK), and the number of previous Cat bond transactions undertaken by the issuer (PREV). Cat bond characteristics include a dummy which equals 1 if the Cat bond has an indemnity trigger (INDEM), the value of the Cat bond issue scaled by the book value of equity (ISSUESIZE), and the bond rating applied by Standard &Poor's or Moody's with 1 being the highest rated bond and 18 being not rated (BONDRATING). Market characteristics include reinsurance prices (REPRICES), estimated by the Guy Carpenter world catastrophe rate on line index (Guy Carpenter, 2010), as well as the real GDP growth rate (GDP). Accounting data (unless stated differently) refer to the last accounting year prior to the issue announcement of the Cat bond. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

6.5 Summary and Conclusions

This chapter assesses how effective Cat bonds are in transferring catastrophe-related underwriting risk away from issuers by analyzing the impact of Cat bonds on the issuers' default risk. The chapter was partly motivated by findings in Chapter 5 which cast doubt on the effectiveness of insurance securitization in general (and Cat bonds in particular) to hedge catastrophe risks.

Using the Merton distance to default model, this chapter provides the first empirical evidence that Cat bonds are effective tools for hedging catastrophe-related underwriting risk by showing that the issuers' default risk decreases in response to the Cat bond issue. Consequently, the results can diminish the concerns regarding the effectiveness of insurance securitization in hedging catastrophe risk which became evident in the last chapter. It is also shown that issuers which are more exposed to either catastrophe or default risk benefit from Cat bonds by realizing larger reductions in default risk. It is argued that these insurers are placed to reap the benefits of lower catastrophe exposure as well as of lower counterparty and lower liquidity risk which Cat bonds offer vis-a-vis traditional reinsurance. Further, results show that while basis risk matters, it is not so large as to prevent Cat bonds with non-indemnity triggers from lowering the default risk of the issuer. Finally, this chapter finds that changes in the issuers' default risk are more pronounced during hard reinsurance markets (when the supply of catastrophe coverage via traditional reinsurance is restricted).

6.6 Appendix

Table 6-8
Effect of Catastrophe Bonds on the Issuers' Industry-Adjusted Default Likelihood (IADL) Using the Issue Date Instead of the Announcement Date

	N	mean (%) (*t*-stat)	median (%) (*z*-stat)	ΔIADL<0% N	ΔIADL<0% %
IADL: Pre-Issue Period (α-61;α-2)	81	1.145* (1.701)	-0.048 (-1.165)		
IADL: Post-Issue Period (α+2;α+61)	81	-0.196 (-0.535)	-0.067*** (-2.590)		
ΔIADL	81	-1.342*** (-2.671)	-0.047*** (-2.513)	51	63.7

Notes: The table reports the mean (median) industry-adjusted default likelihood for a sample of Cat bond issuing firms. Both the default likelihood in the pre-issue period (computed as the default likelihood over the period from -61 days to -2 days relative to the issue date α) as well as the default likelihood in the post-issue period (computed as the average of the default likelihood over the period from +2 days to +61 days relative to the issue date α) are displayed. The effect of Cat bonds on the issuers' industry-adjusted default likelihood (ΔIADL) is the difference between the post-issue and pre-issue period. Also included are *t*-statistics (two tailed) and the non-parametric Mann–Whitney–Wilcoxon *Z*-scores to evaluate if the mean and median IADL and ΔIADL are equal to zero. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 6-9
Regressions on the Effect of Catastrophe Bonds on the Issuers' Industry-Adjusted Default Likelihood (IADL) Using the Issue Date Instead of the Announcement Date

	(A)	(B)	(C)	(D)	(E)	(F)
HIGHCATEXPOSURE	-4.908**	-4.904**	-4.506**	-4.804**	-4.597**	-4.653**
	(2.55)	(2.63)	(2.29)	(2.45)	(2.34)	(2.44)
HIGHDEFAULT	-4.049**	-3.914**	-4.270**	-4.030**	-4.170**	-4.125**
	(2.41)	(2.27)	(2.46)	(2.35)	(2.42)	(2.37)
ROA	0.605	0.555	0.531	0.549	0.515	0.517
	(1.36)	(1.37)	(1.36)	(1.35)	(1.37)	(1.38)
CAR	-0.087	-0.071	-0.107	-0.066	-0.068	-0.082
	(0.72)	(0.55)	(0.83)	(0.51)	(0.57)	(0.67)
SIZE	0.367	0.169	-0.192	0.066	-0.182	-0.155
	(0.48)	(0.22)	(0.28)	(0.09)	(0.25)	(0.22)
LEVERAGE			0.051		0.037	0.039
			(0.79)		(0.54)	(0.62)
LOSSRATIO		0.020		0.019	0.018	0.016
		(0.93)		(0.91)	(0.85)	(0.79)
UWRISK		0.017	0.037	0.025		0.023
		(0.36)	(0.76)	(0.52)		(0.50)
PREV				0.074	0.018	
				(0.44)	(0.10)	
INDEM	-2.723**	-2.511*	-2.587**	-2.317	-2.467*	-2.524*
	(2.13)	(1.80)	(2.06)	(1.61)	(1.79)	(1.87)
ISSUESIZE	0.326	0.217	0.191	0.191	0.184	0.171
	(0.97)	(0.66)	(0.60)	(0.59)	(0.61)	(0.53)
BONDRATING		0.110				0.096
		(0.66)				(0.56)
REPRICES	-0.034*	-0.031*	-0.032*	-0.030*	-0.035*	-0.032**
	(1.68)	(1.86)	(2.03)	(1.79)	(1.68)	(2.08)
GDP	-0.312	-0.381	-0.499	-0.355	-0.460	-0.495
	(0.60)	(0.76)	(1.06)	(0.66)	(0.92)	(1.06)
Constant	2.707	3.022	8.392	5.798	9.075	6.683
	(0.15)	(0.20)	(0.66)	(0.40)	(0.57)	(0.50)
Observations	81	81	81	81	81	81
Year Dummies	YES	YES	YES	YES	YES	YES
Country Dummies	YES	YES	YES	YES	YES	YES
Adjusted R^2	0.441	0.427	0.435	0.425	0.429	0.422

Notes: The dependent variable is the change in the issuers' industry-adjusted default likelihood calculated as the difference between the post-issue (α-61, α-2) and pre-issue period (α+2, α+61) relative to the issue date α. The model is estimated with country- and year-fixed effects and Huber-White corrected standard errors clustered by the issuing firm. *t*-Statistics are in parentheses. Issuer characteristics include a dummy indicating if the issuer is listed in the highest quartile of the distribution of pre-announcement exposure to catastrophe risk (HIGHCATEXPOSURE), a dummy indicating if the issuer is listed in the highest quartile of the distribution of pre-issue industry-adjusted default likelihood (HIGHDEFAULT), the ratio between pre-tax profit and total assets (ROA), the market-adjusted mean cumulative abnormal return over -20 to +1 days relative to the announcement date (CAR), the log of the issuer total assets (SIZE), the ratio of total liabilities to total assets (LEVERAGE), the loss ratio of the issuer (LOSSRATIO) defined as claim and loss expenses plus long-term insurance reserves scaled by premium income, the standard deviation of loss ratios over a four-year period prior to the issue announcement (UWRISK), and the number of previous Cat bond transactions undertaken by the issuer (PREV). Cat bond characteristics include a dummy which equals 1 if the Cat bond has an indemnity trigger (INDEM), the value of the Cat bond issue scaled by the book value of equity (ISSUESIZE), and the bond rating applied by Standard &Poor's or Moody's with 1 being the highest rated bond and 18 being not rated (BONDRATING). Market characteristics include reinsurance prices (REPRICES), estimated by the Guy Carpenter world catastrophe rate on line index (Guy Carpenter, 2010), as well as the real GDP growth rate (GDP). Accounting data (unless stated differently) refer to the last accounting year prior to the issue announcement of the Cat bond. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 6-10
Effect of Catastrophe Bonds on the Issuers' Industry-Adjusted Default Likelihood (IADL) without the ten Most Costly Catastrophes during the Examination Period

	N	**mean (%)** (***t*-stat**)	**median (%)** (***z*-stat**)	**ΔIADL<0%** N	**ΔIADL<0%** %
IADL: Pre-Issue Period (α-61;α-2)	58	1.362 (1.509)	-0.069 (-1.157)		
IADL: Post-Issue Period (α+2;α+61)	58	0.083 (0.160)	-0.122** (-2.280)		
ΔIADL	58	-1.278** (-2.005)	-0.014* (-1.721)	33	56.9

Notes: The table reports the mean (median) industry-adjusted default likelihood for a sample of Cat bond issuing firms. Both the default likelihood in the pre-issue period (computed as the default likelihood over the period from -61 days to -2 days relative to the announcement date α) as well as the default likelihood in the post-issue period (computed as the average of the default likelihood over the period from +2 days to +61 days relative to the announcement date α) are displayed. The effect of Cat bonds on the issuers' industry-adjusted default likelihood (ΔIADL) is the difference between the post-issue and pre-issue period. Also included are *t*-statistics (two tailed) and the non-parametric Mann–Whitney–Wilcoxon *Z*-scores to evaluate if the mean and median IADL and ΔIADL are equal to zero. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 6-11
Regressions on the Effect of Catastrophe Bonds on the Issuers' Industry-Adjusted Default Likelihood (IADL) without the ten Most Costly Catastrophes during the Examination Period

	(A)	(B)	(C)	(D)	(E)	(F)
HIGHCATEXPOSURE	-3.322*	-2.891*	-3.556*	-3.765*	-3.529*	-4.628*
	(1.75)	(1.79)	(1.77)	(1.89)	(1.80)	(2.02)
HIGHDEFAULT	-3.353*	-4.567*	-3.288*	-4.337*	-4.112*	-3.018
	(1.98)	(2.03)	(1.84)	(1.82)	(1.70)	(1.43)
ROA	0.692	0.639	0.599	0.667	0.703*	0.607
	(1.51)	(1.56)	(1.50)	(1.58)	(1.81)	(1.65)
CAR	-0.211**	-0.145	-0.190*	-0.166	-0.184	-0.139
	(2.10)	(1.32)	(1.86)	(1.60)	(1.60)	(1.20)
SIZE	1.028	1.230	0.605	0.739	0.964	1.035
	(1.34)	(1.46)	(0.67)	(0.90)	(1.05)	(1.17)
LEVERAGE			0.030		-0.005	0.023
			(0.44)		(0.06)	(0.35)
LOSSRATIO		0.021		0.008	0.013	0.019
		(0.84)		(0.31)	(0.59)	(0.72)
UWRISK		0.058	0.077	0.109		0.068
		(0.71)	(0.97)	(1.07)		(0.78)
PREV				0.392	0.285	
				(1.30)	(1.03)	
INDEM	-4.213**	-4.292**	-3.869**	-3.837**	-4.261**	-4.351**
	(2.61)	(2.15)	(2.24)	(2.47)	(2.71)	(2.14)
ISSUESIZE	0.446	0.422	0.321	0.330	0.421	0.398
	(1.37)	(1.29)	(0.99)	(1.02)	(1.31)	(1.22)
BONDRATING		0.406				0.409
		(1.43)				(1.45)
REPRICES	-0.033*	-0.047*	-0.052**	-0.053**	-0.033	-0.048*
	(1.72)	(1.95)	(2.28)	(2.21)	(1.42)	(1.96)
GDP	-0.066	-0.300	-0.334	-0.145	0.024	-0.377
	(0.15)	(-0.54)	(0.76)	(0.27)	(0.04)	(0.75)
Constant	-11.467	-16.910	0.125	-1.396	-11.779	-15.043
	(0.84)	(0.76)	(0.01)	(0.07)	(0.76)	(0.71)
Observations	58	58	58	58	58	58
Year Dummies	YES	YES	YES	YES	YES	YES
Country Dummies	YES	YES	YES	YES	YES	YES
Adjusted R^2	0.490	0.472	0.473	0.505	0.476	0.466

Notes: The dependent variable is the change in the issuers' industry-adjusted default likelihood calculated as the difference between the post-issue (α-61, α-2) and pre-issue period (α+2, α+61) relative to the issue announcement date α. The model is estimated with country- and year-fixed effects and Huber-White corrected standard errors clustered by the issuing firm. *t*-Statistics are in parentheses. Issuer characteristics include a dummy indicating if the issuer is listed in the highest quartile of the distribution of pre-announcement exposure to catastrophe risk (HIGHCATEXPOSURE), a dummy indicating if the issuer is listed in the highest quartile of the distribution of pre-announcement industry-adjusted default likelihood (HIGHDEFAULT), the ratio between pre-tax profit and total assets (ROA), the market-adjusted mean cumulative abnormal return over -20 to +1 days relative to the announcement date (CAR), the log of the issuer total assets (SIZE), the ratio of total liabilities to total assets (LEVERAGE), the loss ratio of the issuer (LOSSRATIO) defined as claim and loss expenses plus long-term insurance reserves scaled by premium income, the standard deviation of loss ratios over a four-year period prior to the issue announcement (UWRISK), and the number of previous Cat bond transactions undertaken by the issuer (PREV). Cat bond characteristics include a dummy which equals 1 if the Cat bond has an indemnity trigger (INDEM), the value of the Cat bond issue scaled by the book value of equity (ISSUESIZE), and the bond rating applied by Standard &Poor's or Moody's with 1 being the highest rated bond and 18 being not rated (BONDRATING). Market characteristics include reinsurance prices (REPRICES), estimated by the Guy Carpenter world catastrophe rate on line index (Guy Carpenter, 2010), as well as the real GDP growth rate (GDP). Accounting data (unless stated differently) refer to the last accounting year prior to the issue announcement of the Cat bond. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 6-12

Regressions on the Effect of Catastrophe Bonds on the Issuers' Industry-Adjusted Default Likelihood (IADL) without Country- and Year-Fixed Effects

	(A)	(B)	(C)	(D)	(E)	(F)
HIGHCATEXPOSURE	-2.766**	-2.933**	-2.720**	-2.819**	-2.637*	-2.801*
	(2.05)	(2.07)	(2.06)	(2.07)	(2.01)	(2.04)
HIGHDEFAULT	-4.211***	-4.204***	-4.442***	-4.344***	-4.395***	-4.390***
	(3.67)	(3.56)	(3.68)	(3.62)	(3.89)	(3.77)
ROA	0.547	0.569	0.561	0.567	0.547	0.571
	(1.28)	(1.41)	(1.39)	(1.42)	(1.33)	(1.42)
CAR	-0.126*	-0.130*	-0.124	-0.135*	-0.125*	-0.129*
	(1.69)	(1.82)	(1.58)	(1.80)	(1.76)	(1.80)
SIZE	0.214	0.258	-0.041	0.206	-0.033	0.068
	(0.44)	(0.52)	(0.09)	(0.44)	(0.06)	(0.12)
LEVERAGE			0.025		0.024	0.025
			(0.44)		(0.40)	(0.44)
LOSSRATIO		-0.002		-0.004	0.002	-0.004
		(0.08)		(0.20)	(0.09)	(0.19)
UWRISK		0.068*	0.066	0.072*		0.069*
		(1.91)	(1.65)	(1.95)		(1.92)
PREV				0.086	0.064	
				(1.18)	(0.90)	
INDEM	-1.448*	-1.772*	-1.735*	-1.663*	-1.386*	-1.821**
	(1.74)	(2.01)	(1.95)	(1.93)	(1.68)	(2.10)
ISSUESIZE	0.172	0.177	0.120	0.187	0.147	0.152
	(0.66)	(0.72)	(0.53)	(0.74)	(0.57)	(0.63)
BONDRATING		0.093				0.081
		(0.70)				(0.60)
REPRICES	-0.029***	-0.028***	-0.028***	-0.030***	-0.030***	-0.028***
	(3.17)	(2.89)	(3.00)	(2.94)	(2.93)	(2.91)
GDP	0.264	0.293	0.257	0.284	0.246	0.273
	(1.35)	(1.46)	(1.27)	(1.40)	(1.15)	(1.31)
Constant	2.319	-0.208	4.170	1.999	4.776	1.495
	(0.26)	(0.02)	(0.60)	(0.26)	(0.65)	(0.19)
Observations	81	81	81	81	81	81
Year Dummies	No	No	No	No	No	No
Country Dummies	No	No	No	No	No	No
Adjusted R^2	0.495	0.498	0.505	0.501	0.480	0.493

Notes: The dependent variable is the change in the issuers' industry-adjusted default likelihood calculated as the difference between the post-issue (α-61, α-2) and pre-issue period (α+2, α+61) relative to the issue announcement date α. The model is estimated with Huber-White corrected standard errors clustered by the issuing firm. *t*-Statistics are in parentheses. Issuer characteristics include a dummy indicating if the issuer is listed in the highest quartile of the distribution of pre-announcement exposure to catastrophe risk (HIGHCATEXPOSURE), a dummy indicating if the issuer is listed in the highest quartile of the distribution of pre-announcement industry-adjusted default likelihood (HIGHDEFAULT), the ratio between pre-tax profit and total assets (ROA), the market-adjusted mean cumulative abnormal return over -20 to +1 days relative to the announcement date (CAR), the log of the issuer total assets (SIZE), the ratio of total liabilities to total assets (LEVERAGE), the loss ratio of the issuer (LOSSRATIO) defined as claim and loss expenses plus long-term insurance reserves scaled by premium income, the standard deviation of loss ratios over a four-year period prior to the issue announcement (UWRISK), and the number of previous Cat bond transactions undertaken by the issuer (PREV). Cat bond characteristics include a dummy which equals 1 if the Cat bond has an indemnity trigger (INDEM), the value of the Cat bond issue scaled by the book value of equity (ISSUESIZE), and the bond rating applied by Standard &Poor's or Moody's with 1 being the highest rated bond and 18 being not rated (BONDRATING). Market characteristics include reinsurance prices (REPRICES), estimated by the Guy Carpenter world catastrophe rate on line index (Guy Carpenter, 2010), as well as the real GDP growth rate (GDP). Accounting data (unless stated differently) refer to the last accounting year prior to the issue announcement of the Cat bond. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

7
Conclusions

7.1 Background to the Thesis

Insurance and reinsurance firms have experienced a remarkable increase in both the frequency and magnitude of underwriting losses associated with natural catastrophes in the past decade. At the same time, historically low interest rates have caused the investment income of insurance and reinsurance firms to significantly decline which means that insurance and reinsurance firms have increasingly been facing difficulties in relying on their investment income to offset underwriting losses.

Yet, capacity constraints in the market for catastrophe risk prevent insurance and reinsurance firms from sharing their exposure to catastrophe losses efficiently among each other. Given the recent growth rates in physical asset values and in populations living in high-risk zones, it has, therefore, become a widely accepted view that a single natural catastrophe could result in very substantial financial losses for insurance and reinsurance firms and cause insurer insolvencies and disruptions in insurance and reinsurance markets.

Insurance securitization is a tool for insurance and reinsurance firms to access capital markets for additional underwriting capacity. Insurance securitization could be particularly useful to finance the mounting losses from natural catastrophes. While the market for insurance securitization has undergone rapid growth in response to the general increase in the amount of catastrophe-related underwriting losses, the overall volume of insurance securitization (as compared to traditional insurance and reinsurance) has remained surprisingly low to date. The extant literature on insurance securitization provides various, but mostly theoretical, explanations for the relatively limited use of insurance securitization by insurance and reinsurance firms to date. Inter alia, these explanations include relatively high transactions costs (Gibson et al. 2011) and the involvement of basis risk for insurance and reinsurance firms (e.g. Harrington and Niehaus, 1999; Froot, 2001; Cummins et al., 2004), as well as behavioral factors such as ambiguity and loss aversion by investors (Bantwal and Kunreuther, 2000).

The purpose of this thesis is to provide empirical evidence which can help to explain the hitherto underwhelming use of insurance securitization by insurance and reinsurance firms. For this purpose, this thesis analyses the performance and risk implications of natural catastrophes and insurance securitization for insurance and reinsurance firms. In doing so, it is possible to study the following three research questions: (i) What are the expected losses associated with natural catastrophes? (ii) What are the reasons for insurance and reinsurance firms to engage in insurance securitization? (iii) How effective is insurance securitization in transferring catastrophe risk?

The results in Chapter 4 show that insurance firms realize valuation losses when a natural catastrophe occurs. Consequently, the results show that insurance securitization vehicles such as Cat bonds may have a role to play in mitigating the effects of natural catastrophes on the firms which underwrite catastrophe risks. However, at the same time, the market valuation losses are only small in absolute terms and, thus, cast some doubt on the need of insurance and reinsurance firms for additional underwriting capacity.

Chapters 5 and 6 of this thesis draw a more positive picture on insurance securitization in general and advocate a more widespread use of Cat bonds by insurance and reinsurance firms. Thus, while Chapter 5 reveals that insurance securitization can provide insurance and reinsurance with potential cost advantages (as compared to other forms of catastrophe risk management), Chapter 6 shows that insurance securitization is an effective tool for transferring catastrophe risk to capital markets.

As a result, while the potential benefits of insurance securitization to firms exposed to catastrophe risk are limited ex ante, the results presented in this thesis show that insurance and reinsurance firms still benefit from issuing Cat bonds. It could be argued that the ex ante limited potential for firms to benefit from Cat bonds provides a possible explanation for the hitherto reluctance of insurance and reinsurance firms to make more extensive use of insurance securitization.

7.2 Summary of Findings

7.2.1 Insurance and Reinsurance Firms Can Cope with Underwriting Losses from Natural Catastrophes

Chapter 4 of this thesis gauges the expected losses linked to mega-catastrophes as reflected in equity markets. For this purpose, Chapter 4 uses a large dataset on homeowners' insurance coverage by state, firm, and year, and examines the stock returns of U.S. property-liability (P&L) insurers in response to a series of nineteen large U.S. natural catastrophes (mega-catastrophes) spanning from 1996 to 2010.

The rationale is to provide new empirical insights into the ability of insurance and reinsurance firms to financially cope with the underwriting losses from natural catastrophes. This is an important factor which can help to explain the limited use of insurance securitization as a vehicle to increase global underwriting capacity. Insurance and reinsurance firms may not have made extensive use of insurance securitization if the capacity constraints and financial losses associated with natural catastrophes are not severe enough. In fact, firms with underwriting exposure may benefit from the capacity constraints in the market for catastrophe risk.

For example, capacity constraints may permit premium increases in the catastrophe risk market in response to a catastrophe event as both the consumer and institutional demand for catastrophe risk insurance increase (Zanjani, 2002 or Froot and O'Connel, 2008). In line with this argument, the use of insurance securitization and the provision of additional underwriting capacity could, therefore, be (at best) redundant for insurance and reinsurance firms.

The results presented in Chapter 4 provide evidence that mega-catastrophes cause negative market returns for insurance firms. Further, the results also reveal that this finding is driven by insurers with loss exposure to mega-catastrophes. Nevertheless, the relatively small magnitude of share price losses during the event period suggests that insurance and reinsurance firms are (on average) able to cope rather well with the financial losses of mega-catastrophes. This finding provides a possible explanation for the underwhelming use of insurance securitization as a tool for increasing the underwriting capacity for catastrophe risks, as it challenges the view that firms exposed to catastrophe risks have much to gain from additional underwriting capacity and, therefore, puts a ceiling on the potential benefits of insurance securitization for insurance and reinsurance firms.

7.2.2 Insurance Securitization Offers Cost Advantages

Chapter 5 further examines possible explanations as to why the use of insurance securitization has been limited to date. Specifically, it analyzes the perception of equity market investors as regards the engagement of insurance and reinsurance firms in insurance securitization. Chapter 5 assesses the validity of the two most prominent arguments proposed by the literature as to why firms may benefit from insurance securitization, namely, that (i) insurance securitization allows firms to hedge against catastrophe-related underwriting losses (e.g. Niehaus, 2002; Harrington and Niehaus, 2003; Cummins et al., 2004) and that (ii) insurance securitization can help firms with catastrophe exposure to realize costs savings on catastrophe-related risk management (e.g. Jaffee and Russell, 1997; Niehaus, 2002). For this purpose Chapter 5 examines the changes in the market value of insurance and reinsurance firms which announce their engagement in insurance securitization by issuing Cat bonds.

Consistent with the hitherto underwhelming contribution of Cat bonds to global catastrophe coverage, Chapter 5 does not provide evidence that Cat bonds lead to strong wealth gains for shareholders in the issuing firm. More importantly, results show large variations in the distribution of wealth effects in response to the issue announcement. The analysis of these variations show that the wealth effects for shareholders in firms which issue Cat bonds appear to be driven by explanations according to which Cat bonds offer cost savings relative to other forms of catastrophe risk management (and less by the potential of Cat bonds to hedge catastrophe risk). Thus, abnormal returns are particularly large for issues by firms which face low levels of loss uncertainty (which reduces the information acquisition costs in financial markets) as well as for issues during periods when prices for catastrophe coverage (including Cat bonds) are low.

As a result, Chapter 5 reveals that insurance securitization can offer potential cost advantageous to insurance and reinsurance firms (as compared to other forms of catastrophe risk management). However, the chapter casts doubt on the ability of insurance securitization as a tool for efficiently transferring catastrophe risk to capital markets.

7.2.3 Insurance Securitization Provides an Effective Transfer of Catastrophe Risk

In the final empirical chapter of this thesis, the effectiveness of insurance securitization in transferring catastrophe risk is examined. Arguably, the hitherto limited use of insurance securitization can be explained by its inefficiency in transferring catastrophe risk to capital markets. To gauge the effectiveness of insurance securitization in transferring catastrophe risk, Chapter 6 analyzes the impact of Cat bonds on the default risk of insurance and reinsurance firms which issue them.

Using the Merton distance to default model to gauge default risk, Chapter 6 shows that Cat bonds lower the default risk of the issuer. Further, and consistent with explanations according to which insurance securitization reduces exposure to catastrophe risk and to default risk more generally, results reveal that Cat bonds lead to larger risk reductions for issuers with higher exposures to either catastrophe or default risk. Finally, the results show that basis risk does not prevent issuers from realizing risk benefits. Consequently, the results in Chapter 6 can diminish the concerns regarding the effectiveness of insurance securitization in hedging catastrophe risk (which emerged in the preceding chapter) and advocate a more widespread use of insurance securitization as a vehicle to finance catastrophe risks.

7.3 Policy Implications

Insurance serves an important purpose. It enables policyholders to share their exposure to financial losses linked to unexpected events with other parties. For this purpose, policyholders usually have to buy insurance coverage in advance, but the value of the insurance lies in the future performance of the various contingent obligations such as the reimbursements of insured property. If insurance firms become insolvent and cannot meet their obligations, the consequences for the insured and their beneficiaries can be devastating. As a result, insurance is a highly regulated industry.

The threat of insurer insolvencies caused by natural catastrophes and the alternative ways of sharing catastrophe risks has increasingly come under regulatory scrutiny in recent years (Klein and Wang, 2009). Insurance regulators have an important impact on future volumes of insurance securitization, because they can impose constraints or bar insurers from using certain instruments as well as facilitate or inhibit catastrophe risk financing by affecting the rules governing accounting and financial reporting of catastrophe risk transactions. Also, regulators define the amount of capital which insurance and reinsurance firms are required to hold in order to maintain solvent. Consequently, the results of this thesis have three main policy implications for regulators.

First, Chapter 4 of this thesis shows that mega-catastrophes only have marginal negative performance implications for insurance and reinsurance firms and that, consequently, insurance and reinsurance firms are in a position to absorb the losses caused by mega-catastrophes. Even though these findings apply to the U.S. insurance market only (and it remains to be tested whether these result hold for other countries too), they provide some evidence that the capital reserves held by insurance and reinsurance firms in the sample are sufficiently large to absorb the financial losses caused by mega-catastrophes. Therefore, the results challenge the appropriateness of regulatory initiatives (such as the NAIC's Solvency Modernization Initiative or Solvency II) which will require insurance and reinsurance firms to hold much higher capital reserves in order to remain solvent following a catastrophe event. While the results reported in this thesis have little to say about the desirability of higher capital holdings against other types of underwriting risk, the results show that the expected financial losses linked to natural catastrophes for U.S. insurers do not appear of the magnitude to justify substantially higher capital holdings against catastrophe underwriting risk.

Second, Chapter 5 and Chapter 6 show that insurance securitization can provide insurance and reinsurance firms with potential cost advantageous (as compared to other forms of catastrophe risk management) and that insurance securitization is an effective tool for transferring catastrophe risk to capital markets, respectively. Therefore, the use of insurance securitization should be encouraged by regulators. This is particularly important given the increasing systemic relevance of a number of large insurance firms (Billio et al, 2010; Cummins and Weiss, 2011). Due to their increasing interconnectedness with other financial firms (including banks), the failure of a large insurance or reinsurance firm is likely to cause financial distress beyond insurance markets.

Third, and related to the previous point, the results in Chapter 6 of this thesis imply that the adoption of Cat bonds should be encouraged irrespective of the underlying trigger type. Presently, solvency regulations only permit issuers of Cat bonds with indemnity triggers to treat Cat bonds like reinsurance (and hold lower reserves against the associated underwriting risks). This is because regulators are concerned that non-indemnity triggers involve basis risk which thwarts risk transfers which are sufficiently large to warrant lower capital holdings. The results of Chapter 6 are at odds with the present regulatory treatment of Cat bonds because the results show that non-indemnity based Cat bonds also reduce the default risk of the issuer. Therefore, insurance regulators should extend some form of favorable solvency treatment to non-indemnity based Cat bonds.

7.4 Constraints of the Thesis

A number of shortcomings of this thesis can be identified.

First, throughout this thesis, the focus of the analysis is on the issuers of Cat bonds, that is insurance or reinsurance firms. Thus, Chapter 4 looks at the performance implications of natural catastrophes on insurance and reinsurance firms, and Chapters 5 and 6 look into the risk and performance effects of Cat bonds on the firms which issue them. However, as well as the effects on issuers, the future development of the market for insurance securitization will equally depend on the willingness of investors to purchase Cat bonds. The attractiveness of Cat bonds to investors will depend on whether insurance securitization provides attractive risk-adjusted returns as well as on the risk and return effects resulting when investors combine Cat bonds with more standard financial assets in a single portfolio. In so far, as this dissertation tries to generalize why the development of the market for insurance securitization has lagged behind expectations, it has to be pointed out that the analysis performed in this thesis does not consider the investor perspective.

Second, while the results of this thesis draw a positive picture on insurance securitization from the perspective of a firm issuing Cat bonds, insurance securitization may well have additional and more universal positive effects on firms with catastrophe-related risks which the empirical approach used in this thesis is unable to detect. For instance, insurance securitization may have increased competition for catastrophe reinsurance and, thereby, lowered catastrophe reinsurance premiums for all insurers, including those which have not been engaged in insurance securitization at all (see Froot, 2001). In the same vein, it is likely that the risk benefits of insurance securitization reported in Chapter 6 go beyond individual insurers. For instance, the global insurance and financial industry may have become less vulnerable to systemic distress as a result of more insurers engaging in insurance securitization.

Third, due to the lack of data the results of this thesis have to be interpreted with suitable caution. For instance, the results presented in Chapter 4 (which show that the expected losses linked to natural catastrophes are not as severe as often expected) refer to the U.S. insurance market only. Arguably, results would differ when the same analysis is applied to gauge the impact of mega-catastrophes in other countries. Relatively, the market for insurance securitization is still a young market and, consequently, the number of successful insurance securitizations is relatively low. Thus, even though Chapters 5 and 6 examine the near population of Cat bonds ever issued by listed insurance and reinsurance firms up to May 2010, the results should be seen as suggestive rather than compelling.

Finally, all results presented in this thesis refer to listed companies only. As a result, it remains to be tested whether natural catastrophes and insurance securitization have similar performance and risk implications for non-listed insurance and reinsurance firms. This is especially important, given that non-listed firms play a large role in the market for insurance securitization (e.g., approximately half of the risk capital issued through insurance securitization is associated with catastrophe risks borne by non-listed firms).

7.5 Directions for Further Research

The constraints identified above indicate that further research in the area of natural catastrophes and insurance securitization is warranted in order to provide a more comprehensive analysis of the risk and performance implications of insurance securitization. Three possible extension of the work reported in this thesis are discussed here.

First, future empirical research needs to be directed towards the investor's perspective to identify other reasons which might influence the future success of insurance securitization. For example, one commonly used argument for investing into Cat bonds is that they offer attractive risk/return opportunities when included in diversified stock and bond portfolios as the returns from Cat bonds are believed to show no or little correlation with traditional asset classes (Litzenberger et al., 1996). However, no empirical study has yet examined whether Cat bonds have actually lived up to this expectation. Especially the more recent years (including the financial crisis commencing in 2008) are exceptionally suitable to test whether the returns of Cat bonds indeed show very little correlation with other (more traditional) asset classes.

Second, future research should examine whether the impact of insurance securitization is limited to firms which engage in insurance securitization (i.e. firms which issue Cat bonds). As argued above, insurance securitization might have had (universal) systemic stability effects or, alternatively, it may have increased competition for catastrophe reinsurance and, thereby, lowered catastrophe reinsurance premiums for all insurers (see Froot, 2001). Relatively, while the employed default likelihood approach in Chapter 6 picks up expected changes in default risk around the time that a Cat bond is issued, it would equally be useful to understand the realized default risk implications of a large natural catastrophe. For instance, future research could examine the default risk effects of the recent Japanese earthquake on firms with underwriting exposure to this catastrophe and gauge if the risk effects were mitigated for insurers which have issued Cat bonds. By the time of completing this thesis, the data to implement such an approach was not readily available.

Third, future research should turn to qualitative data to complement the quantitative results presented in this study. For this purpose, future studies on insurance securitization could collect more primary data through interviews and questionnaires targeted at insurance and reinsurance firms as well as (potential) investors. Especially the reasons for insurance and reinsurance firms to engage in insurance securitization are well suited for this approach. Also, this approach can provide a better understanding of the effects of insurance securitization on non-listed insurance and reinsurance firms.□

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