Catastrophic Events, Parameter Uncertainty and the Breakdown of Implicit Long-Term Contracting in the Insurance Market: The Case of Terrorism Insurance*

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J. David Cummins
The Wharton School
University of Pennsylvania
3641 Locust Walk
Philadelphia, PA 19104
215-898-5644
Cummins@wharton.upenn.edu

Christopher M. Lewis
Managing Director
Fitch Risk Management, Inc.
500 West Putnam Avenue
Greenwich, CT 06830
203-618-5132
Chris.Lewis@fitchrisk.com

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Abstract

This paper examines the reaction of the stock prices of U.S. property-casualty insurers to the World Trade Center (WTC) terrorist attack of September 11, 2001. Theories of insurance market equilibrium and theories of long-term contracting predict that large loss events which deplete capital and increase parameter uncertainty will affect weakly capitalized insurers more significantly than stronger firms. The empirical results are consistent with this prediction. Insurance stock prices generally declined following the WTC attack. However, the stock prices of insurers with strong financial ratings rebounded after the first post-event week, while those of weaker insurers did not, consistent with the flight-to-quality hypothesis.

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Following Hurricane Andrew (1992) and the Northridge earthquake (1994), insurance companies expended considerable resources on the measurement and management of the risk of natural catastrophes. Unfortunately, the next major "catastrophic loss" that the industry would face would be a man made event. After all losses are accounted for, the terrorist attacks on the World Trade Center (WTC) on September 11th, 2001 will be the costliest insured property loss in history, with current estimates of insured losses ranging from $40-$70 billion.[1]

Although the insurance industry appears to have the financial resources to absorb the WTC losses, this event has placed enormous stress on the insurance industry, created structural changes in how the market evaluates risk and return, and exposed fissures within the industry structure. Faced with a significant increase in uncertainty about the frequency and severity of future terrorist events, international reinsurers responded to the event by excluding or significantly restricting terrorism coverage from most reinsurance policies. This in turn motivated primary insurers to exclude terrorism coverage from most commercial lines insurance policies or forced primary insurers to cover terrorism risk without the benefit of reinsurance for some regulated insurance lines.[2]

At first glance, the response of insurance and reinsurance markets to the World Trade Center attacks seems to parallel the industry's response to earlier unanticipated loss shocks, including natural disasters such as Andrew and Northridge as well as the 1980s crisis in commercial liability insurance (see, for example, Berger, Cummins, and Tennyson 1992, Cummins and Danzon 1997, Froot and O'Connell 1999, and Cummins and Weiss 2000). Following those unexpected loss events, insurance prices rose sharply and supply was restricted, an outcome that is generally attributed to probability updating and capital market imperfections

(Winter 1994, Cummins and Danzon 1997, and Froot and O'Connell 1997).

Although the insurance market response to the WTC attacks exhibits similarities with the market disruptions caused by earlier large loss events, there are also indications that the WTC response may not represent merely a temporary market disequilibrium. The tendency of insurers and reinsurers to exclude terrorism coverage altogether rather than offering coverage at higher prices hints at least at a quantitative difference between this and previous catastrophic events. The nature of the event, a deliberate attack by terrorists, suggests that it will be more difficult to reduce parameter uncertainty through scientific and statistical modeling than in the case of natural catastrophes. Moreover, the mitigation of terrorism does not lend itself to domestic legal and contractual reform as in the case of the U.S. tort system.[3]

The objective of this paper is to provide evidence regarding the similarities between terrorist attacks and other types of catastrophic events by comparing the response of the U.S. equity markets to the WTC attack and earlier large loss shocks. Specifically, we conduct an event-study analysis of the response of equity markets to three large loss events – the WTC attack, Hurricane Andrew, and the Northridge earthquake.[4] We differentiate the impact of event-induced uncertainty (e.g., parameter uncertainty) and flight to quality in determining the market's valuation of different insurance companies in an attempt to better understand the process by which the industry moves towards a new market equilibrium following a crisis.

The remainder of the paper is organized as follows: Section 1 develops hypotheses based on a theoretical explanation of the relationship between loss shocks and insurance market disequilibria, drawing upon the prior literature on insurance market disequilibria. Section 2 presents an historical review of prior terrorism losses to shed light on the nature of the information communicated to the market from the WTC attacks. Section 3 discusses the sample of insurers used in the analysis and our event-study methodology. The empirical results are presented in section 4, and section 5 concludes with a discussion of implications of our findings for proposed Federal intervention in the market for terrorism reinsurance.

1. Loss Shocks and Disequilibria In Insurance Markets

Since the liability insurance crisis of the 1980s, a significant literature has developed to explain the economics of insurance markets under conditions of adverse shocks to equity capital (e.g., Winter 1994, Cummins and Danzon 1997, and Froot and O'Connell 1997, 1999). The stylized facts that this literature attempts to explain are the tendency for insurance prices to rise sharply following a shock to capital simultaneously with a decline in the quantity of insurance supplied. This pattern seems to apply rather generally to the primary insurance market during the 1980s liability crisis, to the catastrophe reinsurance market following Andrew and Northridge, and perhaps also to the market for terrorism insurance following the WTC attacks.

Although the nuances differ, most of the literature is based on the argument that insurance market disequilibria in response to unexpected loss shocks are attributable to some combination of shifting probability distributions (parameter uncertainty), correlated losses, and capital market imperfections. Parameter uncertainty occurs because an unexpected spike in losses is likely to reveal new information about the frequency and severity of insured losses. An excellent example of such an effect is Hurricane Andrew, which caused insurers to drastically increase their expectations about the potential property losses from natural disasters. Although following past events the market converged on new estimates of expected losses in which insurers have confidence, the period immediately following a shock is usually characterized by significant parameter uncertainty, making it difficult for insurers to develop credible prices. This effect is exacerbated when losses are due to rare events such as large property catastrophes and terrorist attacks.

Most authors also agree that positively correlated losses also exacerbate insurance market disequilibria. Loss correlations are an especially serious problem for insurance markets because they violate the assumption of statistical independence across insured units that provides the mathematical foundation for insurance pricing theory. Positive correlations among insured units were characteristic of the 1980s liability insurance crisis, when frequency and severity of loss shifted unfavorably for many liability exposures, and are obviously present for property catastrophes, where a single event affects many insured exposures simultaneously.

The final major factor that is hypothesized to drive insurance market disequilibria is capital market imperfections. The imperfections usually discussed involve informational asymmetries between insurers and capital markets that cause external capital to be more costly than internal capital. In Winter's (1994) model, there is a significant positive "round trip cost" of paying dividends when capital is relatively high and raising capital again following a shock. Cummins and Danzon (1997) argue that the cost of capital is likely to increase following a loss shock because of asymmetric information between insurers and capital markets regarding the adequacy of loss reserves, future loss expectations, and/or levels of loss exposure in high risk geographical areas or industries. As a result of costly external capital, insurers are reluctant to raise significant new capital following a loss shock, and insurance prices rise as policyholders compete for the limited quantity of insurance that can be supported with the remaining internal capital (Winter 1994). Prices remain high and supply remains relatively low until prices are high enough to support the costs of external capital and/or internal capital is restored through retained earnings.

A model that is especially useful in analyzing the case of terrorism insurance is the model developed by Froot and O'Connell (1997).[5] In their model, insurers finance the production of insurance by investing some combination of internal and external capital. Reflecting the assumption of capital market imperfections, external capital is assumed to be costly, with the costs of capital increasing and convex in the amount of external capital raised. Costly external capital causes insurers to behave as if they were risk averse when determining insurance supply.

The Froot and O'Connell model implies that the supply of insurance by any given insurer is directly related to the insurer's internal net assets, i.e., other things equal, insurers with higher internal resources optimally supply more insurance. Intuitively, this is because such insurers have to place less reliance on costly external capital than do insurers with smaller internal capital relative to their investment opportunity sets. Thus, better-capitalized insurers are likely to gain following a loss shock that depletes capital throughout the industry. The model also predicts that the supply of insurance will be inversely related to the correlation among the risks in an insurer's portfolio. Intuitively, this is because correlated risks are more likely to expose the insurer to large loss shocks that deplete internal capital and require the insurer to raise costly external capital. Thus, the supply of insurance is expected to respond negatively to an event that causes insurers to increase their estimated cross-risk correlations for certain types of risks. E.g., the WTC attack probably caused insurers to increase their estimates of correlations for insurance buyers located in large, high-rise office buildings, leading to a reduction in supply for such risks.

A final important implication the Froot-O'Connell model is that the equilibrium price of insurance will be positively related to the insurer's estimate of the volatility of the buyer's loss distribution, because higher volatility increases the probability that the insurer will need to raise costly external capital. To the extent that large loss events increase parameter uncertainty, the insurer's estimates of buyer loss distributions are likely to become more diffuse and hence have higher estimated variances, leading to price increases following a loss shock.[6]

Although the existing models of insurance market equilibrium provide a number of important insights into the financing of catastrophic risk, these models typically apply only to single period decision-making. This misses an important dimension of reinsurance contracting, which often implicitly or explicitly covers multiple periods. Reinsurance is often purchased with the objective of smoothing the primary insurer's annual net income. The reinsurer makes payments to the primary insurer when losses are abnormally high with the expectation of recovering part of these losses during periods when losses are relatively low. This is often implicitly agreed upon and, increasingly, explicitly included in reinsurance contracts (Swiss Re 1999, Cummins 2002).

Lewis and Murdock (1996) analyze the role of implicit multi-period contracts in managing "distribution uncertainty" risk – the risk that information is revealed during the term of a contract that forces both parties to reassess the "fair premium" for the underlying insurance. Long-term contracts also are exposed to the risk of insolvency and non-performance by one of the parties in the transaction (i.e., the primary insurer or the reinsurance company).[7] The importance of these two factors – and their interdependence – is critical in the markets that are subject to significant catastrophe risk.

In the long-term contracting market, defection and credit risk are actually interdependent concepts. Clearly, an insurer or reinsurer will not be able to honor long-term commitments (explicit or implicit) if the company is insolvent. However, even if the company is solvent, its financial condition will be a major factor in influencing whether the other party defects on existing contracts. If the parties remain financially strong following a loss, the ability to balance the parties' long-term interests over time will remain feasible and the parties will continue to work together. However, if one party perceives that the financial condition of the other party is weak – as reflected in an increased counterparty credit risk – the stronger counterparty may defect on the contract in hopes of devoting its scarce internal capital to contracts with stronger counterparties. This may, in fact, push the weaker counterparty into bankruptcy.[8]

In the commercial lines business, similar long-term contracting arrangements often exist between the primary insurer and corporate insurance buyers, especially as insurance product offerings have been broadened to include alternative hedging instruments in addition to conventional insurance products. Even policies such as commercial liability policies that generally are issued for one-year periods, usually involve claim payments over multiple year periods. As in the case of reinsurance contracts, the financial weakness of the policyholder may provide an incentive for the insurer to delay or resist claim payments in order to divert costly capital to more profitable uses.[9] Again this suggests that increased parameter uncertainty and financial weakness are likely to lead to breakdowns in insurance coverage arrangements, so that firms with superior financial strength are less likely to suffer significant declines in their equity market valuations following catastrophic events.

2. Historical Background on Terrorism Losses

As suggested above, the degree of parameter uncertainty about terrorism loss distributions created by the WTC attacks may be significantly larger and more lingering than that generated by natural hazards such as hurricanes and earthquakes. This may significantly impede the development of adequate private market coverage for terrorist events in comparison with the market for insurance covering natural catastrophes, which rebounded following Hurricane Andrew and the Northridge earthquake. In order to shed some light on the potential for estimating the frequency and severity of potential terrorist events and to provide some information on the "uniqueness" of the WTC attacks, this section provides a statistical overview of terrorist events that have occurred over the past quarter century.

The strikes on the World Trade Center on September 11th, 2001 materially changed the way that the insurance industry in the United States views the risk of terrorist actions. The driving-force behind this change, however, was not attributable to a sudden surge in the frequency of terrorist events around the globe, but to the fact that foreign terrorists were explicitly targeting U.S. properties on U.S. soil. To understand the significance of this change, one only has to look to the historical record of terrorism activity.

The frequency of global terrorist attacks over the period 1977-2000 is shown in Figure 1. The figure reveals that more than 10,000 terrorist attacks took place during this period, averaging 456 attacks per year. Moreover, a significant percentage of these attacks were directed at U.S. properties overseas. For example, according to the U.S. Department of State, 40 percent of all terrorist attacks in 1997 and 1998 directly impacted U.S. properties (U.S. Department of State, 1999). Representative targets have included the foreign branches or affiliates of such well-known companies as McDonald's, IBM, Coca-Cola, and Citibank. In fact, each of these companies has suffered from multiple terrorist attacks during the course of the past decades years.

In response, U.S. companies operating overseas have taken action to insure themselves against terrorist attacks. Many companies purchased war/terrorism insurance from private insurers or the Overseas Private Investment Corporation (OPIC) to limit their exposure to loss. These strategies were generally effective. Over the period 1970-2000, OPIC stepped in to cover over 45 separate losses associated with war risk and terrorism events in foreign countries (OPIC, 2001). The average loss severity of attacks that penetrated the OPIC contract deductible was over 95 percent – demonstrating the binary aspect of terrorist attacks on property. If the attack is successful, the property damage is usually considerable.

Up until September 11th, however, terrorist attacks were a risk of doing business overseas, not a risk that companies had to address domestically. As shown in Figure 2, terrorist attacks in North America accounted for only one-half of 1 percent of all terrorist actions over the 1991-1998 period. Moreover, the attacks that did occur in the United States – the first World Trade Center bombing and the Oklahoma City bombing – were viewed as aberrations that could be discounted as non-recurring events.

As a result, insurers had assumed that the probability of terrorist attacks on private U.S. companies in the United States was effectively zero – an assumption confirmed by insurance executive comments following September 11th. Once this myth was shattered, however, insurance companies were left wondering just how frequently these attacks were likely to occur in the future and what would be the likely losses that would result. With insurers having to write-off between $40-70 billion in capital to cover the World Trade Center losses, the uncertainty associated with this risk created a tremendous financial stress within the industry.

In some ways, the destabilization of the insurance industry caused by the World Trade Center attacks is reminiscent the tumult following Hurricane Andrew and the Northridge earthquake. In all three of these events, insurers were aware of the potential hazard (i.e., hurricane, earthquake, and terrorist attack), but grossly underestimated the probability and/or severity associated with an event. Moreover, in the wake of each event, insurers were left struggling to adjust their grossly underpriced books of business, while simultaneously trying to replenish depleted capital resources. As a result, the insurance industry quickly turned to the Federal Government with pleas for assistance after each loss.

An important difference between Andrew, the Northridge earthquake, and the World Trade Center attacks, however, is that in the case of the former two events, insurers had sufficient information available to price their insurance more accurately, but failed to do so either due to mispricing or regulatory rate suppression (Cummins, Lewis, and Phillips 1999). In the case of the World Trade Center attacks, however, Figure 2 suggests that insurers did not have sufficient information to formulate robust prior probability distributions for terrorist attacks within the U.S.

Moreover, unlike the physical processes underlying hurricanes and earthquakes, the forces governing terrorist events are sociopolitical factors that are closely tied to the actions and policies of the Federal government – many of which are not observable. Thus, the WTC attacks arguably introduced both significant parameter uncertainty regarding terrorist attacks within the U.S. and an increased level of uncertainty (i.e., earnings volatility) concerning insurer profitability. We now turn to an examination of whether these factors were evident in the investor response to property-casualty insurers following September 11, 2001.

3. The Stock Market Reaction to The WTC Attack: Hypotheses and Methodology

To examine the U.S. stock market's reaction to insurer stocks in the wake of the WTC attacks, we conduct an event-study analysis of the impact of WTC on publicly traded insurance companies. To shed light on the issue of the uniqueness of September 11 relative to earlier catastrophic events, we also conduct analyses of insurer stock price reactions to Hurricane Andrew and the Northridge earthquake, the two largest insured catastrophe losses prior to WTC.

We estimate the market response to all three events rather than relying on prior literature for Andrew and Northridge for three major reasons: (1) Although there has been at least one previous study of Hurricane Andrew (Lamb 1995), we have not been able to find any prior research on the market valuation effects of the Northridge earthquake. (2) By applying precisely the same event-study methodology to all three events, we can ensure that any differences we find are due to the events themselves and not due to methodological differences with earlier research. And (3) our methodology improves on that used by Lamb for Hurricane Andrew and by other prior researchers who studied the Loma Prieta earthquake (Shelor, Anderson, and Cross 1990; and Aiuppa, Carney, and Krueger 1993) by adjusting for event-induced increases in stock price volatility following the events. Our approach is expected to provide a more complete and accurate analysis of stock market response to property catastrophes than has been presented in the prior literature.[10]

We next turn to the specification of the hypotheses that will be tested in the study. These are based upon the theoretical models discussed above as well as general information-based arguments about the effects of unexpected events on stock prices. This section concludes with the discussion of our event-study methodology.

3.1. Hypotheses

Based on our discussion in Section 2, we can identify two main reasons why the WTC attacks are likely to have an adverse effect on the market value of insurance companies. The first is that the attacks led to a loss estimated at $40-70 billion for which little or no premium was collected, as a result of insurers' implicitly valuing the expected loss from domestic terrorism at close to zero. Even if much of the loss ends up being borne by international reinsurers, domestic insurers still are exposed to significant losses due to deductibles and policy limits as well as participation in domestic reinsurance pools. Uncertainty about the collectability of claims from reinsurers also may have adversely affected insurer stock prices. And, of course, U.S. reinsurers such as Berkshire Hathaway (the parent corporation of General Reinsurance) would be expected to take a large direct hit from the event.

A second reason for a negative stock price reaction would be investor reevaluation of future cash flows on insurance stocks due to terrorism risk. As mentioned above, the market for reinsurance against terrorist events essentially disappeared in the months following the attack, whereas domestic insurers have been not been able to exclude terrorism coverage from personal insurance policies, non-workers' compensation commercial policies in several key states, and workers' compensation insurance policies in most states. The lines where terrorism coverage have not been excluded (personal lines such as homeowners and workers' compensation) are heavily price regulated in many states, casting doubt on the ability of insurers to collect sufficient premiums to offset the expected costs of terrorism. Third, to the extent that the market forecasts that insurers will continue to write terrorism coverage voluntarily but will under-price the coverage due to parameter uncertainty, an adverse impact on stock prices would be anticipated.

On the other hand, to the extent that the market anticipated that insurers could minimize their exposure to terrorism risk through policy exclusions or through the enactment of a Federal reinsurance backstop program that would shift much of the burden of terrorism losses to taxpayers, the market's reaction to September 11 would likely be moderated. The market's evaluation of the potential success of the Homeland Security program and the international war on terrorism also would have affected returns following the event date. Because the negative effects of the event seem to us to outweigh the mitigating effects, however, we hypothesize as follows:

> **Hypothesis 1:** *The market reaction to the WTC attacks will be strongly negative for insurers in the days immediately following the attacks.*

Further, to account for the fact that the companies directly exposed to the WTC are likely see a more adverse impact than non-impacted firms, we regress abnormal returns associated with the WTC attacks against variables to measure insurer exposure to the lines of insurance most exposed to loss.

We also expect the WTC event, and past catastrophic events, to have the effect of increasing the variance of stock returns. This expectation is based on prior theoretical literature establishing a positive relationship between the variance of stock prices and the variance of the flow of new information into the securities market (Ross 1989). Empirical evidence of event-induced increases in variance have been found in numerous prior studies, including Beaver's (1968) and Christie's (1982) examination of earnings announcements, Ohlson and Penman's (1985) and Dravid's (1987) work on stock splits, and an event study analysis of takeover rumors by Pound and Zeckhauser (1990). Consistent with these findings, we would expect the entry of information around the attacks to lead to an increase in the variance in stock returns for property-casualty insurers.

> **Hypothesis 2:** *The WTC attacks created a significant event-induced increase in the variance of insurer returns in the week immediately following the attacks.*

In addition to providing new information on the likelihood of terrorist attacks within the United States, we argue that the WTC attacks introduced considerable uncertainty into investor valuations of insurance companies. Clearly, the attacks verified that the probability of a loss due to terrorism is not zero within the United States. Insurers and their shareholders, however, were then forced to wrestle with the question of what is an appropriate assumption about the probability and severity of future attacks. This additional parameter uncertainty would be expected to contribute to a significant increase in the variance of insurer stock returns immediately following the attacks, but also to translate into a more persistent increase in return variance as both insurers and their shareholders attempt to update their assessment of the risk of terrorism events. These arguments suggest the following hypothesis:

> **Hypothesis 3:** *The significant increase in variance induced by the WTC attacks would persist in the month following the event.*

Theoretical arguments predict that a large catastrophic event should create a strong flight-to-quality within insurance markets. This flight to quality will emanate from several sources. First, a catastrophic event is expected to deplete the net internal capital of many insurers and reinsurers, resulting in price increases and supply restrictions, based on the Froot-O'Connell (1999) model. These changes will be moderated in well-capitalized insurers, giving such firms a competitive advantage following the catastrophe. Similarly, a catastrophic loss shock is likely to increase the perceived correlation among the policies in insurer and reinsurer portfolios. Large, international insurers and reinsurers will be less affected by such changes because they are better diversified geographically, again giving them a competitive advantage.

Secondly, according to the Lewis and Murdock (1996) model of implicit long-term contracting, a large catastrophic loss can create new incentives for primary insurers and reinsurance companies to break their relational contracts. A key influence of whether a primary insurer or reinsurer breaks these implicit contracts is the credit-quality of the relational counterparty. If a counterparty is viewed as weak by another (stronger) insurer, the latter insurer will have less incentive to maintain the relationship – potentially cutting that insurer/reinsurer off from existing payments and new business and materially reducing the counterparty's business opportunities. As mentioned above, following the September attacks, several reinsurers withheld reinsurance payables owed to Reliance and Mutual Risk Management due to 'credit quality concerns and the need to meet other WTC claims,' effectively pushing both companies into financial difficulty. As such, we would stipulate the following hypothesis:

> **Hypothesis 4:** *The market returns to individual insurers following the first week of the WTC attacks will be relatively high for insurers with strong financial ratings.*

To examine the legitimacy of these hypotheses, we conducted a classic "event-study" analysis to assess the market's reaction to insurer stock following the WTC attacks.

3.2. Event Study: Data and Methodology

To test the market impact of the WTC attacks, we examined the stock return performance of property-casualty insurance companies traded in the United States. In selecting our initial sample of 48 property-casualty insurers, we limited our sample to companies that were publicly-traded on the NYSE, AMEX, or NASDAQ stock exchange around the time of September 11th, that had a pre-September market capitalization greater than $500 million, and were classified as a property-casualty insurer under the Standard Industrial Classification (SIC) code system. The goal of restricting our sample to firms with a market capitalization greater than $500 million was to limit our attention to national and large regional carriers that are less constrained by local economy factors. Of the 48 companies in our initial sample, we had to discard 5 firms due to insufficient historical price information for estimating the market model parameters. In four of these cases, the insurance company was actually a subsidiary of a foreign insurer. The fifth discarded firm, Travelers Property Casualty Insurance Company, did not start trading until after the event window. The companies in the final sample are shown in Appendix Table A3.

We adopt a standard market model event-study methodology, where the returns of the underlying securities are assumed to be jointly multi-variate normal and independently and identically-distributed through time (MacKinlay 1997). The analysis involves computing the returns for each of the 43 firms in our sample using data from the Center for Research in Security Prices (CRSP) tapes and financial rating information for each firm as of September 11th from the A.M. Best Company. Using this approach, the expected return for any given insurer security can be defined as follows:

$$R_{jt} = \alpha_j + \beta_j R_{mt} + \varepsilon_{jt} \qquad \textbf{(1)}$$

where R_{jt} is the actual dividend-adjusted return on security j on day t [log((Price$_t$ + Dividend$_t$)/Price$_{t-1}$], R_{mt} is the natural log of the CRSP equally-weighted market return on day t, α_j is the idiosyncratic return on security j, β_j is the beta coefficient of security j, and ε_{jt} is the error term of the regression. Under the assumption of joint normality and independently and identically distributed returns, the error of the regression is well–behaved, i.e.,

$$E(\varepsilon_{jt}) = 0, \quad Var(\varepsilon_{jt}) = \sigma^2_{\varepsilon_j} \qquad \textbf{(2)}$$

Using this model, we estimated the market parameters for each of our companies based on the securities' returns over the 250 days leading up to the last week in August of 2001.[11] Security returns for the week of September 3rd are excluded from this analysis. Using the market parameters estimated from this market model and the movement of the market index during the event period, we then computed the daily unexpected or abnormal return (AR) for each security during the event period. The event period of interest for this study was the day of September 11th (the event date) and the 30 days following September 11th.

Thus, the abnormal return on day t in the event window for security j can be expressed as the estimated disturbance term of the market model calculated out-of-sample:

$$AR_{jt} = R_{jt} - \hat{\alpha}_j - \hat{\beta}_j \; R_{mt} \quad \textbf{(3)}$$

The distribution of the abnormal return, conditional on the market return, is jointly normal with a zero conditional mean and a conditional variance equal to the following:

$$\sigma^2(AR_{jt}) = \hat{\sigma}^2_{\varepsilon_j} + \frac{1}{L_1}[1 + \frac{(R_{mt} - \overline{R}_m)^2}{\hat{\sigma}^2_m}] \quad \textbf{(4)}$$

where $\hat{\sigma}^2_{\varepsilon_j}$ represents the sum of the squared residuals (i.e., abnormal returns) from the market model estimation divided by (L_1-2), and L_1 represents the number of non-missing daily periods over which the market model was estimated for firm j. Note that in equation (4) the variance of daily abnormal returns has two components – a disturbance term estimated from the market model residuals and a sampling error term. Thus, provided that the number of days in the estimation period is sufficiently large (e.g., greater than 30), the variance in abnormal returns converges to $\sigma^2_{\varepsilon_j}$ and $AR_{jt} \sim N(0, \sigma^2_{\varepsilon_j})$ (MacKinlay 1997).

Because the conditional abnormal returns for all N securities are assumed to be independent and normally distributed, we can aggregate the abnormal returns across securities within any given time period. The average abnormal return and the variance in average abnormal returns across all N securities in a given time period are computed as follows:

$$\overline{AR_t} = \frac{1}{N} \sum_{j=1}^{N} AR_{jt} \quad \textbf{(5)}$$

$$\hat{\boldsymbol{\sigma}}^2(\overline{AR}_t) = \frac{1}{N^2}\sum_{j=1}^{N}\hat{\boldsymbol{\sigma}}^2_{\boldsymbol{\varepsilon}_j} \qquad \textbf{(6)}$$

As expected, the average abnormal return within a given period is also normally distributed with a zero conditional mean and a conditional variance given by equation (6). Thus, under the null hypothesis of no market impact, we can draw inferences about the impact on the average abnormal returns across the N-securities in the portfolio by using a standard Z-score statistic, computed as the ratio of the average abnormal return divided by the standard deviation of average abnormal returns.

We compute the cumulative average abnormal returns (CAR) for the N securities across two time periods (τ_1 and τ_2), as well as the variance in the CAR, as follows.

$$\overline{CAR}(\boldsymbol{\tau}_1, \boldsymbol{\tau}_2) = \frac{1}{N}\sum_{j=1}^{N}\overline{AR}(\boldsymbol{\tau}_1, \boldsymbol{\tau}_2) \qquad \textbf{(7)}$$

$$Var[\overline{CAR}(\boldsymbol{\tau}_1, \boldsymbol{\tau}_2)] = \frac{1}{N^2}\sum_{j=1}^{N}\hat{\boldsymbol{\sigma}}^2_j(\boldsymbol{\tau}_1, \boldsymbol{\tau}_2) \qquad \textbf{(8)}$$

In looking at event studies focused on large shocks to the property-casualty industry, we need to make several additional adjustments in measuring of abnormal returns. First, following Patell (1976), we standardized the abnormal return for each security by dividing by the security's own estimate of variance. This standardization process helps ensure that no single firm in the sample dominates the results of the analysis and helps improve the power of the test statistics.

For any given security, we can compute the standardized abnormal return (SAR) within a given period by dividing the abnormal return by our estimate of the security's sample return standard deviation from the market model regression.

$$SAR_{jt} = \frac{AR_{jt}}{\hat{\boldsymbol{\sigma}}_{\boldsymbol{\varepsilon}_j}} \sim t(L_1 - 2) \qquad \textbf{(9)}$$

where $t(L_1–2)$ represents the t-distribution with $(L_1–2)$ degrees of freedom. To construct a test statistic of abnormal returns across the N firms in period t, we aggregate the standardized abnormal returns (SAR_{jt}) across all N securities to obtain the total standardized abnormal return ($TSAR_t$).

As discussed above, the occurrence of such a damaging terrorist attack on U.S. property clearly changed the information that most investors would use in evaluating the financial returns of the property-casualty industry. This increase in the rate of flow of information should translate into an increase in the variance of stock returns following September 11th. The failure to adjust for this event-induced increase in variance could lead to spurious rejections of the null hypotheses. Accordingly, we adjust the estimated variance in returns by the contemporaneous cross-sectional variance of the sample, by applying the standardized cross-sectional procedure developed by Boehmer, Musumeci and Poulsen (1991).[12] We incorporate the Boehmer, et al. (1991) variance adjustment by developing a new Z-statistics as follows:

$$Z_t = \frac{TSAR_t}{\sigma_{sar,t}\sqrt{N}} \qquad \textbf{(10)}$$

where the adjusted standard deviation is given as follows:

$$\hat{\sigma}^2_{sar,t} = \frac{1}{N-1}\sum_{j=1}^{N}[SAR_{jt} - \frac{1}{n}SAR_{jt}]^2 \qquad \textbf{(11)}$$

To construct a measure of the standardized cumulative abnormal returns across the portfolio, we start by defining the Standardized Cumulative Abnormal Return (SCAR) for any one security over the period (τ1, τ2) as its Cumulative Abnormal Return (CAR) divided by its corresponding asymptotic variance (for large L_1) as follows:

$$SCAR(\tau_1,\tau_2) = \frac{CAR_j}{\sigma^2_j(\tau_1,\tau_2)} = \frac{\sum_{t=\tau_1}^{\tau_2} AR_{jt}}{(\tau_2 - \tau_1 + 1)\sigma^2_{\varepsilon_j}} \qquad \textbf{(12)}$$

Finally, we average these standardized cumulative abnormal returns across all N securities and divide by an estimate of the standard deviation of standardized cumulative abnormal returns to obtain a test statistic for the standardized cumulative average abnormal returns for the portfolio. This modified Z-statistic is presented in equation (13).

$$Z_t = \frac{\sum_{j=1}^{N} SCAR_j(\tau_1, \tau_2)}{\sigma_{scar}\sqrt{N}} \qquad \textbf{(13)}$$

where $\hat{\sigma}^2_{scar}(\tau_1, \tau_2) = \frac{1}{N-1}\sum_{j=1}^{N}[SCAR(\tau_1, \tau_2) - \frac{1}{N} SCAR(\tau_1, \tau_2)]^2$. Using equation (13), we can construct tests of the significance of the WTC attacks on the stock returns of the property-casualty insurance companies in our sample.

4. Empirical Results

This section presents the empirical results. We first present tests designed to evaluate whether the standard deviations of abnormal returns changed following September 11 and present comparable statistics for Hurricane Andrew and the Northridge earthquake. We then discuss the results of the event study analysis, beginning with summary statistics on abnormal returns and then turning to an analysis of the relationship between abnormal returns, insurer financial ratings, and exposure to catastrophic risk.

4.1. Effects of the Events on Standard Deviations

To evaluate whether the standard deviation in abnormal returns changed following September 11th, we compared the standard deviation in abnormal returns for three time periods: (1) The 20-day period ending one week prior to the attack (i.e., Event Window (-27, -7)), (2) the period including the event day and the following 7 days (i.e., Event Window (0,7)), and (3) the period including the event day and the following 20 days (i.e., Event Window (0, 20).[13] The results of this comparison, which are shown in Table 1, clearly illustrate that the rate of flow of information did i n fact increase during the week of September 11^{th}, resulting in a near doubling of the standard deviation of abnormal returns, from 0.0648 in the (-27,-7) day event window to 0.1180 in the (0,7) day event window. Thus, the results support Hypothesis 2. Moreover, consistent with Hypothesis 3, the jump in return volatility was persistent (0.1280 in the (0,20) day event window) – indicating a high degree of continuing uncertainty concerning the risk of loss from terrorism events in the future.

Of course, one can question whether the persistence in stock return volatility following the WTC attacks is simply endemic to the nature of stock returns following a shock. To examine this possibility, we estimated the volatility in the stock returns for the broader market. Of interest, the returns of the overall market also experienced a statistically significant jump in volatility in the days surrounding September 11^{th} (from 0.0142 in the (-27,-7) day event window to 0.0251 in the (0,7) day event window. However, unlike the firms in our sample, this event-induced increase in variance was short-lived (overall market volatility was 0.0127 in the (0,20) day event window). Therefore, under our null hypothesis that the abnormal returns of the firms in our sample are conditionally orthogonal to the returns of the market index, we can conclude that the persistent uncertainty associated with the market valuation of property casualty firms following September 11 did not characterize the broader market.

Similar to the WTC attack, the standard deviation in abnormal returns increased significantly following Hurricane Andrew.[14] Moreover, this increase in return variance persisted, supporting the notion that Hurricane Andrew resulted in a considerable increase in uncertainty (e.g., parameter/process uncertainty) about the pricing of insurance for natural disaster exposures in the United States. This finding is consistent with the perception that Andrew marked a major reassessment by the insurance industry of its exposure to natural disaster events.

Unlike Hurricane Andrew and the WTC attack, however, there was no statistically significant jump in the standard deviation of returns around the event day of the Northridge earthquake. In fact, there was very little change at all in the variance of abnormal returns. Consistent with Ross (1989), this finding suggests that the Northridge earthquake may not have provided significant new information to the market about the *uncertainty* of pricing natural disaster coverage. After Hurricane Andrew, there is considerable evidence that the insurance industry revised upward its expectations regarding the potential magnitude of all natural disaster losses – not just windstorm events. As a result, a significant amount of time, money and effort was invested in understanding natural disaster risks. Thus, Northridge apparently did not have the same "shock effect" that was conveyed by the WTC attacks and Hurricane Andrew, i.e., by 1994, large earthquake losses were anticipated by the market.

4.2. Effect of the Events on Returns

The World Trade Center Attacks

Turning to insurer returns, the results of our analysis of daily abnormal returns from our market model event study for the WTC are shown in Table 2. Column 3 of Table 2 presents the average daily abnormal returns within our portfolio based on a straight computation of the market model (equation (5)). We also present 4 different test statistics for assessing the significance of these average abnormal returns in columns 4-7 of the table. Columns 4 and 5 present the standardized abnormal return (SAR) Z-Score, with and without making an adjustment for event–induced variance. While we believe it is important to make the variance adjustment to avoid incorrectly rejecting the null hypothesis of no market impact, both results are presented for completeness. We also present comparable Z-Score statistics based on the estimated generalized least squares (EGLS) approach (Sanders and Robins 1991) and the generalized sign test (GST) approach (Cowan 1992).

Each of the tests presented in Table 2 shows that the World Trade Center Attacks had a material impact on the stock returns of property-casualty insurers following September 11th. Moreover, unlike some other single-date studies, the impact of the event on stock returns persisted throughout the first 10 days and was followed by several additional periods of abnormal returns, probably as new information was released on the magnitude of insured losses.

To get a better sense of the scale of abnormal returns associated with this event, Table 3 examines the cumulative average abnormal returns for all 43 firms on September 11th, during the week of September 11th, and during the remainder of the month. In addition to reporting our standard z-scores, Table 3 reports an estimate of the precision-weighted cumulative average abnormal returns (PWCAAR). By adjusting the standardized cumulative returns for the relative weights used in the standardization process, the PWCAAR provides a measure of average standardized returns that is more comparable with the non-standardized measure of cumulative average abnormal returns (see Cowan 2002).

Table 3 shows that the attacks on the World Trade Center had a very strong negative impact on property-casualty insurance firms during the day of the attack and during the ensuing week. After adjusting for event-induced variance, the mean abnormal return across the sample was approximately minus 4 percent on September 11th and minus 5 percent during the first week – clearly supporting the large negative impact envisioned by Hypothesis 1.

It is also interesting that the large negative abnormal returns experienced by insurers in the immediate aftermath of the attacks were partially offset during the ensuing 25 days – with cumulative average abnormal returns of approximately 3 percent. Based on the theory discussed above as well as the studies by Lamb (1995) and Aiuppa et al (1993), this market reaction may reflect several factors:

- Positive reaction to the absence of immediate attacks following September 11th.

- Positive reaction to revised estimates of loss from the World Trade Center attacks.
- Investor expectation of a hardening market for insurance, which would lead to higher prices in commercial insurance markets.
- Investor expectations that insurers would succeed in excluding most terrorism coverage from commercial policies until uncertainty about the terrorism threat were significantly reduced.
- Investor beliefs that some form of Federal reinsurance back-stop would be established to shift the bulk of terrorism losses to taxpayers.

At this point, it is difficult to assess the extent to which the absence of additional attacks motivated the positive abnormal stock returns of insurers in the weeks following September 11th. Furthermore, the information published on property-casualty losses in the weeks following September 11th could hardly be classified as "good news."[15] On September 17th, Morgan Stanley published an impact analysis on the WTC attacks estimating total losses of $30 -$70 billion – the same day that our sample experienced statistically significant positive abnormal returns.

On the other hand, the property-casualty market was already hardening in advance of the September 11th attacks. In the wake of the losses associated with the World Trade Center, rates were clearly going to harden further. As such, it would be reasonable to expect investors to experience a positive reaction to insurance company returns – provided that the insurer was not so severely impacted by the events that its survival was in jeopardy. Thus, consistent with Hypothesis 4, we would expect to see highly rated insurance companies experiencing stronger positive abnormal earnings in the weeks following September 11th, with weaker insurers experiencing neutral or negative abnormal earnings.

To provide additional information on whether Hypothesis 4 is supported in the data, Table 4 shows the cumulative average abnormal returns for the insurers in our sample categorized into five A.M. Best financial rating groups. As seen in Table 4, the returns for all companies were decisively negative during the first week following September 11th. However, when we examined the abnormal returns for insurance companies during the ensuing 25 days, we see that highest-rated firms (with ratings of A++ or A+) actually experienced strong positive abnormal returns, while lower rated (A and A-) insurers continued to experience negative abnormal returns. Unrated insurers, which are largely offshore reinsurance companies, also experienced positive abnormal returns during the latter part of September.[16]

To provide a more formal test of Hypothesis 4, we conducted a regression analysis with cumulative abnormal returns as the dependent variable and financial ratings as the explanatory variable(s). Based on the results in Table 4, we classified insurers into three financial rating groups – high-rated (A++ or A+), low-rated (A or A-), and un-rated, with the companies in the later category dropped from the analysis.[17] We then regressed the standardized cumulative abnormal return (SCAR) for each firm against the firm ratings for the three aforementioned event windows (0,1 days), (0,4 days), and (6,30 days). Because the dependent variable has been standardized, we use weighted least squares with the weights computed as the reciprocal of each security's return variance to ensure the regression parameter estimates are best linear unbiased estimators (Cowan 2002).

The results of the regression analysis are presented in Table 5. Consistent with Table 4, our first cross-sectional regression (Panel A of Table 5) demonstrates that all firms experienced strong negative returns in the immediate aftermath of the WTC attacks regardless of their rating at the time of the attack. That is, firm financial ratings were not statistically significant in determining the impact of the WTC attacks on insurer stock returns in the week following September 11th. Comparable results hold for returns in the 1-day event window (not shown).

The second panel of Table 5, however, shows that financial ratings did play an important role in the return experience of insurers in the ensuing 3-4 weeks. Specifically, firms that had an A.M. Best rating of A or A- experienced significantly lower returns than insurers rated A+ or

A++. Moreover, this statistically significant relationship between financial ratings and abnormal returns holds at the 1.0 percent level of significance. This result thus provides additional evidence in support of Hypothesis 4.

Given the strength of our findings with respect to the World Trade Center attack, we wanted to evaluate whether this pattern also held for the market's reaction to Hurricane Andrew and the Northridge earthquake – clearly the other two major "unexpected" losses experienced by property-casualty insurers during the past 10 years. To do so, we replicated our analysis for both Andrew and Northridge.

Hurricane Andrew

In the case of Hurricane Andrew, we use the sample of insurers and event window as defined by Lamb (1995). Unlike Lamb, however, we standardized individual firm abnormal returns and adjusted our test statistics for event-induced increases in the standard deviation of returns. After making these adjustments, we confirmed Lamb's finding that property-casualty insurers experienced a statistically significant negative shock to returns on the day that Andrew hit the East Coast. However, unlike Lamb's analysis, our variance-adjusted measure of abnormal returns holds only at a 5% confidence level, whereas Lamb's result held at the 1% level. (Our results are presented in Appendix Table A1.) This lower level of significance signifies that Lamb's analysis – by not adjusting for a change in standard deviation – uses a test statistic that overstates the probability of rejecting the null hypothesis.

Using these results, we attempted to replicate Lamb's result showing a statistical relationship between abnormal returns and insurer exposure. Perhaps due to the lower significance of abnormal returns in general, these efforts proved unsuccessful. At the same time, we also failed to demonstrate any statistical relationship between an insurer's rating and abnormal returns. In many ways, this result is not surprising since investors appear to have incorporated the mean impact of Hurricane Andrew on insurance firms within a 1-day time period. Furthermore, personnel lines insurance tends to be considerably less sensitive to insurer credit-quality as compared to the commercial lines business impacted by the WTC attack. At the same time, however, Hurricane Andrew did result in persistent "uncertainty" as investors were left unsure of how to evaluated their exposure to future events.

Northridge Earthquake

Following the same approach, we also modeled the investor reaction to the Northridge earthquake. Table A2 in the Appendix presents our main results. By examining Table A2, we can see that insurers clearly experienced a large and statistically significant shock to market values resulting from the occurrence of the earthquake. Similar to Hurricane Andrew, the impact of the earthquake on returns was quickly incorporated into insurer returns, with only 2 other days in the event window demonstrating statistically-significant abnormal returns. Also like Hurricane Andrew, cross sectional regressions of cumulative abnormal returns over the event window did not support the importance of firm rating for this type of event. Again, this is consistent with the lower sensitivity to credit quality in the personnel lines business.

5. Conclusion

This paper examines the reaction of the stock prices of traded U.S. property-casualty insurers to the World Trade Center (WTC) terrorist attacks of September 11, 2001. We hypothesize that the WTC event caused insurers and reinsurers to dramatically increase their estimates of the potential frequency and severity of terrorist events in the U.S., leading to disruptions in insurance and reinsurance markets. Such a response is predictable considering the prior theoretical and empirical evidence on insurance market disequilibria resulting from loss events that increase parameter uncertainty and deplete insurer capital.

There are two strains of the theoretical literature on insurance that are relevant in interpreting the effects of the WTC attacks: (1) A significant body of literature evaluates insurance market disequilibria caused by loss shocks based on the assumptions of probability updating, correlated losses, and capital market imperfections that make external capital more costly than internal capital. This literature predicts that insurance prices will rise and supply will decline in response to events that increase parameter uncertainty and that deplete internal capital of insurers. These factors are predicted to affect strongly capitalized insurers less significantly than weaker insurers, leading to a "flight to quality" following a major event. (2) The literature on multi-period contracting in insurance suggests that the stronger counterparties in multi-period insurance and reinsurance relationships are likely to defect from relationships where counterparties are significantly weakened following a large loss event. This again leads to the prediction of a flight to quality following the WTC attack. The empirical implication of the flight to quality predictions is that stronger insurers should sustain a smaller negative impact from the WTC attacks than financially weaker insurers.

General informational theory regarding stock prices predicts a significant negative impact on insurer stock prices following September 11 and also predicts that insurers that with relatively higher exposure to the insurance coverages most affected by the attacks should show a stronger negative impact from WTC. Finally, information theory (Ross 1989) predicts that stock price volatility should increase to the extent that an event increases the volatility of information flow into the stock market.

The empirical analysis considers 43 U.S. property-casualty insurers during several event windows surrounding September 11. The empirical results are consistent with the hypotheses: (1) There was a strong negative impact of insurer stock prices in response to the WTC attacks that persisted for a relatively lengthy period of time following the event. (2) The volatility of abnormal returns increased significantly following the event, suggesting that the attacks increased the volatility of information flow into the market. Moreover, the volatility increase persisted during the month following the attack, providing additional support for the hypothesis that significant new information was provided by the event and that investors were left with an increase in parameter uncertainty associated with property-casualty risks. (3) The immediate effect of the attack was a general decline in insurance stock prices. However, during the period after the first post-event week the stock prices of insurers with strong financial ratings rebounded while those of weaker insurers did not, thus providing support for the flight to quality hypothesis.

The analysis implies that the stock market value for property-casualty insurers provides a fairly important barometer for assessing the impact of a given loss shock on the industry. Consistent with theory, large unexpected losses from "new" sources of risk translate into both negative abnormal stock returns and higher return volatility associated with parameter uncertainty in valuing insurer performance. This experience was demonstrated first with Hurricane Andrew for natural disasters and more recently with the WTC attacks for terrorism risks. Once the nature of the risk is more thoroughly examined, however, the impact of future events centers more on the impact to capital than on the uncertainty associated with future earnings. For commercial insurance, the impact on insurer stock returns is also likely to favor higher-rated, better capitalized firms that are positioned to gain from a hardening market following a loss event.

We also can draw some inferences regarding the "uniqueness" of the WTC attacks relative to other large loss events. As the largest insured loss event in history, WTC had a larger and more sustained impact on insurer stock prices than either Hurricane Andrew or the Northridge earthquake. It is difficult to say at this stage whether this effect was due to the magnitude of the event alone or to other factors that differentiate terrorist attacks from natural catastrophes. While the WTC event increased the volatility of insurer abnormal returns following September 11, this effect was very similar to the market response to Hurricane Andrew, which also introduced significant new information on loss distributions. Finally, although the WTC attacks led to significant restrictions on the supply of terrorism insurance coverage, prior events such as Andrew and the 1980s liability crisis have had similar effects. It is too early to say whether the terrorism coverage market will follow the traditional pattern of rebound and recovery that has characterized earlier market disequilibria. In short, while it is clear that WTC had a significant effect on insurers and insurance markets, the evidence for the uniqueness of the event is inconclusive.

From a public policy perspective, we believe that this demonstrates that the market, possibly in a second-best sense, is working fairly well – with risks effectively being transferred and diversified into the broader capital markets through insurer stock ownership. As such, we would expect the industry to follow a similar path in adjusting to the recognition of terrorism risk as was the case for natural disasters. If the Federal Government does pursue a program to facilitate the establishment of private market institutions for providing terrorism insurance in the United States, however, our analysis suggests several important factors that must be addressed.

First, the Government should devote resources to helping the industry better understand the nature of terrorism risk, especially in terms of understanding the likely long-term frequency of these events. Insurers can take responsibility for managing the hazard condition of properties within their portfolios with respect to terrorism risk, but given the interdependence between government policy and the occurrence of terrorism events, the Government can play a role in controlling/understanding the frequency of these attacks. These efforts will help reduce insurer uncertainty and thus moderate high, market-distorting risk loads for ambiguity averse insurers.

Secondly, the Government should allow the competitive marketplace to determine the financial prospects for any firm even in the face of large terrorism losses. The current flight-to-quality in the property-casualty market is a constructive manifestation of the competitive market equilibrium. Government intervention that distorts this adjustment process will only create a larger deadweight loss to society by rewarding rent seeking within the insurance industry. This means that the Government should not provide solvency protection for insurers, either directly or through reinsurance tied to firm surplus. Any assistance must be commercially-viable in contract design and execution.

Finally, the Government should look for every possible strategy for migrating any Federal program back to the private sector – either through mandatory coinsurance requirements for the federal insurance or exchange-traded terrorism securities. Graduation and sunset provisions in federal legislation are laudable, but subject to political pressure. Any government assistance must be designed and administered to support private market institutions.

Notes

[1] For a review of major natural and man-made catastrophic losses, see Swiss Re (2002).

[2] Although insurers were permitted by regulators in most states to exclude terrorism coverage from most commercial lines insurance policies, some important states such as California declined to approve the restrictions. Moreover, insurers typically have not been able to exclude terrorism coverage in one major commercial line, workers' compensation insurance, because workers' compensation statutes in the United States typically require that insurers cover workers for employment-related injuries regardless of cause.

[3] Tort reform in the U.S. contributed to stabilizing the liability insurance system in the years following the onset of the tort liability crisis in 1984 (see Viscusi, et al. 1993).

[4] Because the emergence of the 1980s liability crisis as well as the resolution of the crisis through contracting and legal reforms took place gradually over an extended period of time, the liability crisis does not lend itself to straightforward comparison with sudden unexpected events such as terrorism and natural disasters.

[5] Their paper in turn utilizes results developed in Froot, Scharfstein, and Stein (1993).

[6] The effect of volatility (σ_i^2) on the equilibrium quantity of insurance is ambiguous in this model because volatility also increases the demand for insurance.

[7] Both implicit and explicit contracts are subject to the risk of non-performance, although this risk is clearly significantly smaller for explicit contracts. Non-performance of explicit contracts can result from coverage disputes and other conflicts between the parties to the contract and can also result from opportunistic behavior by one of the parties.

[8] An example is the 2001 insolvency of Reliance Insurance Group, which was hastened by a slowdown in payments from its reinsurers in the aftermath of the WTC attacks. See Douglas McLeod, "Road Ends for Reliance," *Business Insurance*, October 8, 2001, pp. 3 ff. Another company, Mutual Risk Management, also encountered severe financial problems associated with the collectability of reinsurance receivables. See Michael Bradford, "MRM Plan Aims To Restore Investor Confidence, Profits," *Business Insurance*, May 13, 2002.

[9] Abraham (2002) argues that long-tail liability policies are implicitly subject to a "Big Claim Exclusion," whereby insurers tend to resist especially large claims such as mass torts even if they originate from events that are covered under the language of policy contracts. Insurers can be expected to be more likely to invoke this exclusion for financially weak policyholders, for which the prospects for future profitable business are relatively dim.

[10] The prior papers on Andrew and the Loma Prieta earthquake found that insurers with large exposures to the catastrophic event often faced negative market reactions. However, the papers also found that less exposed insurers operating in the affected region experienced favorable market valuations as investors expected the catastrophes would boost demand for insurance and lead to higher premiums.

[11]Given reports of possible Al Qaida insurance company stock transactions in the week prior to September 11th, we ended our estimation period for security market parameters on August 31st. Also, in the case of Odyssey Re Holdings, limited stock return data restricted our estimation of market parameters to the 54 days leading up to August 31st. We do not, however, believe that this materially impacted our overall results.

[12] The Boehmer, et al. (1991) procedure for estimating the cumulative abnormal returns also adjusts for any serial correlation of returns within the event window (i.e., forecast error) as suggested by Mikkelson and Partch (1988).

[13] Note, the comparison examines standardized abnormal returns before adjusting for changes in return variance due to the WTC attack.

[14] Our F-test of no event-induced change in variance after Hurricane Andrew (F=6.12) was rejected at α=.005.

[15] In contrast, life insurers did benefit from positive news associated with declining fatality estimates.

[16] The lack of ratings for the offshore firms may reflect the fact that they are less heavily regulated by U.S. state regulators and hence do not face the same data reporting requirements as on-shore insurers. Thus, Best's in many cases lacks the data to provide comparable ratings for these firms. Anecdotally, most of the off-shore reinsurers tend to be well-capitalized. Unrated on-shore insurers usually are viewed as somewhat suspect because they typically are very new firms or firms that are facing severe financial difficulties.

[17] Technically, A.M. Bests considers all insurers with an A++ or A+ rating to be "Superior" and insurers with ratings of A and A- to be "Excellent". Since we have no insurers in our sample with an initial rating below A-, we are effectively using a rating classification based on Best's superior and excellent categories.

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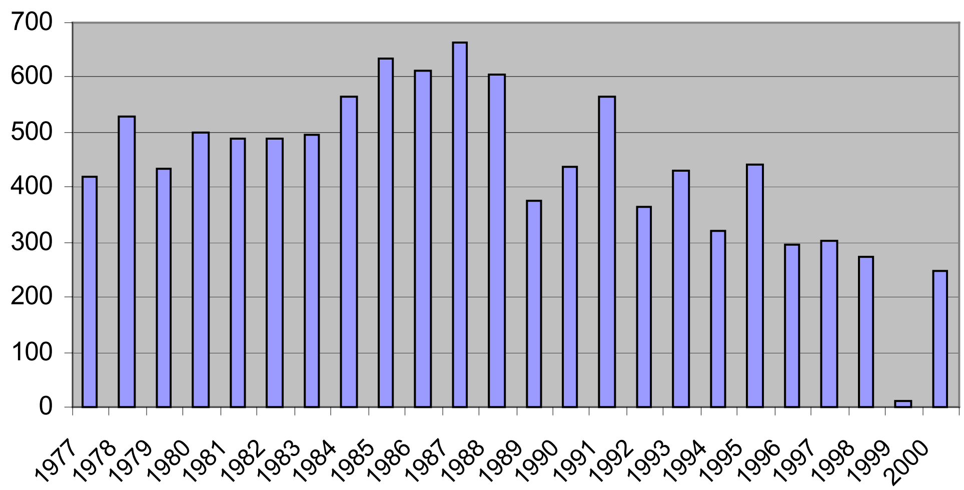
Figure 1: International Terrorist Attacks: 1977-2000



Source: U.S. Department of State, Patterns of Global Terrorism: 1993-2000

Figure 2: International Terrorism Attacks By Region:1991-1998

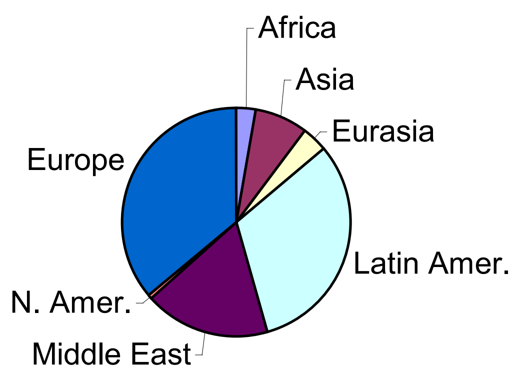


Table 1 **Standard Deviation in Standardized Cumulative Abnormal Returns (SCAR)**		
	Stand. Deviation	**F-Test**
WTC Attack:		
Window (-27, -7)	0.0648	N/A
Window (0, 7)	0.1180	3.32***
Window (0, 20)	0.1280	3.91***
Market Return		
Window (-27, -7)	0.0142	N/A
Window (0, 7)	0.0121	0.0029
Window (0, 20)	0.0127	0.5809
Hurricane Andrew (8/24/1992):		
Window (-27, -7)	0.0777	N/A
Window (0, 7)	0.1316	2.868***
Window (0, 20)	0.1599	4.239***
Northridge Earthquake (1/17/1994):		
Window (-27, -7)	0.0934	N/A
Window (0, 7)	0.0519	0.3096
Window (0, 20)	0.1016	1.1837

Note: *** indicates significant at α=.005

Table 2
Daily Average Abnormal Returns
Market Model, Equally-weighted Index

Day	N	Mean Abnormal Return	Patell Z-Score	Variance-adjusted Z-Score	Estimated GLS Z-Score	Generalized Sign Z
-5	43	-0.14	-0.611	-0.830	-0.806	0.36
-4	43	0.09	0.200	0.254	0.255	1.275
-3	43	-0.61	-1.858 *	-2.265 *	-2.311 *	-1.166
-2	43	-0.78	-1.971 *	-2.400 **	-2.466 **	-1.776 *
-1	43	0.88	2.544 **	2.576 **	2.673 **	2.496 **
0	43	-4.74	-14.781 ***	-4.657 ***	-4.771 ***	-5.133 ***
1	43	0.10	0.044	0.035	0.033	-1.166
2	43	-0.96	-3.085 **	-2.157 *	-2.039 *	-0.861
3	43	-2.06	-6.215 ***	-4.513 ***	-4.456 ***	-2.997 **
4	43	-1.90	-6.455 ***	-3.678 ***	-4.069 ***	-2.692 **
5	43	2.65	7.905 ***	4.028 ***	3.995 ***	3.411 ***
6	43	1.51	4.585 ***	3.351 ***	3.406 ***	2.496 **
7	43	1.11	3.507 ***	2.092 *	2.222 *	2.801 **
8	43	2.90	8.658 ***	5.795 ***	5.915 ***	4.937 ***
9	43	2.92	8.831 ***	6.141 ***	6.043 ***	4.327 **
10	43	-0.73	-2.091 *	-2.420 **	-2.343 *	-1.776 *
11	43	0.78	2.315 *	1.551	1.58	2.496 **
12	43	2.41	7.412 ***	4.474 ***	4.656 ***	3.411 ***
13	43	-0.67	-1.657 *	-1.798 *	-1.728 *	-2.387 **
14	43	-1.13	-3.391 ***	-3.409 ***	-3.289 **	-2.387 **
15	43	-1.24	-3.519 ***	-4.757 ***	-4.588 ***	-2.692 **
16	43	0.64	2.074 *	1.642	1.618	2.191 *
17	43	0.62	1.671 *	1.100	1.038	-0.251
18	43	-0.76	-1.749 *	-1.260	-1.231	-1.471
19	43	-0.78	-2.208 *	-2.379 **	-2.294 *	-2.082 *
20	43	0.63	1.603	1.824 *	1.758 *	2.191 *
21	43	0.69	1.892 *	2.136 *	2.119 *	1.275
22	43	-1.96	-5.446 ***	-4.874 ***	-4.555 ***	-3.912 ***
23	43	-1.14	-3.482 ***	-3.745 ***	-3.539 ***	-2.997 **
24	43	-0.37	-1.759 *	-1.773 *	-1.699	-2.387 **
25	43	2.37	7.075 ***	6.320 ***	6.054 ***	3.411 ***
26	43	-1.68	-4.906 ***	-3.786 ***	-3.743 ***	-2.997 **
27	43	0.54	2.307 *	0.765	0.757	-0.251
28	43	-0.24	-1.091	-1.147	-1.106	-1.166
29	43	-0.19	-0.453	-0.518	-0.484	-0.861
30	43	-1.11	-3.142 ***	-3.650 ***	-3.522 ***	-2.997 ***

Note: The symbols *, **, *** denote statistical significance at the 5%, 1%, and 0.1% level.

Table 3
Cumulative Average Abnormal Returns (CAAR) Across Event Window
Market Model, Equally-weighted Index

Window (Days)	N	Mean Cumulative Abnormal Return	Precision-Weighted CAAR	Patell Z-Score	Variance-adjusted Z-Score	Estimated GLS Z-Score	Generalized Sign Z-Score
(0,1)	43	-4.65	-4.880	-10.58***	-4.12***	-4.187***	-3.912***
(0,4)	43	-9.56	-10.010	-13.084***	-5.121***	-5.298***	-3.912**
(5,30)	43	7.8	8.110	4.594***	3.107***	3.088*	1.886*

Note: The symbols *, **, *** denote statistical significance at the 10%, 5%, 1%, and 0.1% level.

Table 4: Cumulative Average Abnormal Returns (CAAR) By Rating				
AmBest Rating	**N**	**Days (0,1)**	**Days (0,4)**	**Days (5,30)**
A++	6	-2.95	-2.62	7.80
A+	17	-6.74	-8.38	9.30
A	12	-3.37	-7.05	-0.88
A-	3	-2.06	-5.51	-8.75
Not Rated	5	-3.97	-7.29	9.18

Table 5
Cross-Sectional Regression Results: Rating Impact on Insurer Returns
Standardized Cumulative Abnormal Returns (SCAR)

Panel A: SCAR in the week following September 11th (0-4 Event Window)

$$SCAR_{(0,4)} = -0.1116 + .03097\ LowRating + \varepsilon_t$$
$$(-4.21)\quad(0.72)$$

F-Test = 0.52 P-value = 0.4766 R^2 = 0.0142

Panel B: SCAR during weeks following the week of September 11th (5-30 Event Window):

$$SCAR_{(5,30)} = 0.12902 - 0.1406\ LowRating + \varepsilon_t$$
$$(4.12)\quad(-2.78)$$

F-Test = 7.70 P-value = 0.0087 R^2 = 0.1762

Note: t-statistics are in parentheses. LowRating takes the value of 0 for companies with an AmBest Rating of A+ or better, and 1 otherwise.

Appendix A

Table A1
Daily Average Abnormal Returns: Hurricane Andrew (8/24/1992)
Market Model, Equally-Weighted Index

Day	N	Mean Abnormal Return	Patell Z-Score	Variance-adjusted Z-Score	Estimated GLS Z-Score	General Sign Z-Score
-5	28	1.330	0.613	0.559	0.329	0.697
-4	28	0.370	0.049	0.055	0.041	0.318
-3	28	-0.390	-0.903	-1.298	-1.116	-0.818
-2	28	-0.660	-1.101	-1.779 *	-1.234	-1.954 *
-1	28	-0.840	-1.453	-1.796 *	-1.234	-1.197
0	28	0.410	-0.338	-0.308	-0.216	-1.197
1	28	-2.520	-3.992 ***	-1.667 *	-1.173	-0.439
2	28	-1.490	-3.027 **	-2.097 *	-1.650	-1.954 *
3	28	0.620	-0.029	-0.022	-0.019	0.697
4	28	-0.950	-1.520	-1.054	-1.000	-0.061
5	28	0.050	-0.537	-0.367	-0.280	-0.439
6	28	-0.270	-1.013	-0.487	-0.506	-1.197
7	28	0.700	-0.429	-0.285	-0.277	0.318
8	28	-0.890	-1.180	-0.717	-0.761	-1.575
9	28	-0.220	0.128	-0.216	0.184	0.318
10	28	-0.390	-1.734 *	-1.782 *	-1.562	-0.818

Note: The symbols *, **, and *** represent statistical significance at the 5%, 1% and 0.1% level.

Table A2
Daily Average Abnormal Returns: Northridge Earthquake (1/17/1994)
Market Model, Equally-Weighted Index

Day	N	Mean Abnormal Return	Patell Z-Score	Variance-adjusted Z-Score	Estimated GLS Z-Score	General Sign Z-Score
-5	55	1.140	3.243 ***	3.319 ***	3.029 **	2.577 **
-4	55	0.010	0.091	0.094	0.092	0.684
-3	55	-0.550	-0.428	-0.480	-0.448	-1.750
-2	55	-0.470	-1.100	-1.727 *	-1.442	-2.561 **
-1	55	0.510	0.759	0.912	0.800	0.143
0	55	-0.650	-3.026 **	-3.667 ***	-3.412 ***	-2.561 **
1	55	-0.510	-1.194	-0.970	-0.962	-1.209
2	55	-0.250	-0.484	-0.514	-0.433	0.684
3	55	0.290	2.068 *	2.039 *	1.648	0.954
4	55	0.190	0.527	0.471	0.400	-0.275
5	55	-0.570	-1.798 *	-2.093 *	-2.011 *	-0.275
6	55	-0.110	0.147	0.200	0.180	-0.275
7	55	0.140	-0.044	-0.033	-0.033	-0.275
8	55	0.180	0.373	0.277	0.271	1.089
9	55	0.060	1.066	0.889	0.817	-0.003
10	55	0.110	0.960	0.872	0.873	0.816

Note: The symbols *, **, and *** represent statistical significance at the 5%, 1% and 0.1% level.

Table A3
Companies in Final Sample for WTC Attack

21st Century Insurance Group
ACE Ltd
Allianz Aktiengesellschaft
Allmerica Financial Group
AMBAC Financial Group
American International Group
Arch Capital Group
Argonaut Group Inc.
Berkshire Hathaway Inc.
Chubb Corp.
Cincinnati Financial Corp.
CNA Financial Corp.
Commerce Group Inc
Erie Indemnity
Everest Re Group
Fidelity National Financial
Harleysville Group Inc.
Hartford Financial Services
Horace Mann Educators
Markel Corp.
Mercury General Corp.
Odyssey Re Holdings
Ohio Casualty
Old Republic International
Philadelphia Consolidated
PMA Capital Corp.
Proassurance Corp.
PXRE Group Ltd
Radian Group
Renaissance Re Holdings
RLI Corp.
Royal and Sun Alliance
Safeco Corp.
SCOR Re
Selective Insurance Group
The Allstate Corp.
The First American Corp.
The Progressive Corp.
The St. Paul Companies
Unitrin Inc
White Mountains Ins Group
Berkley W.R. Corp.
Zenith National Insurance Corp.