



Market Reactions to Natural Disasters: An Event Study on the Impact of Hurricane Katrina on Insurance Stock Prices

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Abstract

This paper investigates the stock market response of insurance companies, during and after Hurricane Katrina landfall in Gulf Coast states of the U.S.

This research differentiates from previous studies by incorporating Allianz and Zurich due to their large presence and losses in the affected regions.

Using the Event Study Methodology, I examine two samples of Insurance Companies, separating those directly affected by the hurricane with those that had minimal exposure.

I firstly calculated the Average Abnormal Returns (AAR) in the days before and after the landfall and tested the significance of the results. Secondly, I cumulated the AARs obtaining the Cumulative Average Abnormal Returns across various time windows surrounding the hurricane's landfall, adjusting for currency fluctuations where necessary.

The findings reveal that Affected companies experienced negative and statistically significant CAARs. Conversely, the sample of Non Affected firms exhibited slightly negative but not significant CAARs. Thus, the comparison of CAARs between the Affected and Non Affected groups yielded a significant negative difference, supporting the hypothesis that Hurricane Katrina had a distinct and adverse financial impact on insurers with exposure to the disaster zones.

This thesis contributes to the literature by adding more evidence to the negative impact of Hurricane Katrina on Insurance companies, even when including non-U.S. companies in the sample.

Keywords: Event study, Hurricanes, Hurricane Katrina, Insurance companies, Market Reactions, Cumulative Average Abnormal Returns (CAAR).

Abstract

Este estudo investiga a resposta do mercado de ações das empresas de seguros durante e após o impacto do furacão Katrina nos estados da costa do Golfo dos EUA. Diferencia-se de estudos anteriores ao incluir a Allianz e a Zurich devido à sua grande presença e perdas nas regiões afetadas. Utilizando a Metodologia de Estudo de Eventos, examino duas amostras de empresas de seguros, separando aquelas diretamente afetadas pelo furacão das que tiveram exposição mínima. Calculei inicialmente os Retornos Anormais Médios (AAR) nos dias antes e depois do impacto e teste a significância dos resultados. Em segundo lugar, acumulei os AARs obtendo os Retornos Anormais Médios Cumulativos em várias janelas de tempo em torno do impacto do furacão, ajustando para flutuações cambiais quando necessário. Os resultados revelam que as empresas afetadas experimentaram CAARs negativos e estatisticamente significativos. Pelo contrário, as empresas não afetadas exibiram CAARs ligeiramente negativos, mas não significativos. Assim, a comparação dos CAARs entre os grupos afetados e não afetados resultou em uma diferença negativa significativa, apoiando a hipótese de que o furacão Katrina teve um impacto financeiro distinto e adverso nas seguradoras com exposição às zonas de desastre. Esta tese contribui para a literatura ao acrescentar mais evidências sobre o impacto negativo do furacão Katrina nas empresas de seguros, mesmo quando inclui empresas não americanas na amostra.

Keywords: Metodologia de Estudo de Eventos, Furacões, Furacão Katrina, Indústria de Seguros, Retornos Anormais Médios Acumulados, Reações do Mercado.

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1. Introduction

1.1 Background

Hurricane Katrina was the deadliest and the costliest natural disaster ever occurred in the history of the United States causing between 1,300 and 1,500 fatalities and over \$125 billion in total damages/costs (NOAA 2005).

The hurricane made his first landfall on August 25th in Florida as a Category 1 before moving to the Gulf of Mexico where the atmospheric and sea-surface conditions allowed the cyclone to rapidly fortify himself enough to be considered on August 26th as a “major hurricane”. On Sunday, August 28th, Hurricane Katrina reached Category 5 status with wind speeds of 160 mph and made its second U.S. landfall as a Category 3 storm on the morning of August 29th in southeast Louisiana (NOAA 2005). The hurricane moved north toward Mississippi and Tennessee where had weakened as a tropical storm on August 30th.

The Insurance Information Institute estimated losses of \$41.1 billion in insured damages (\$45.1 billion in 2009 dollars) and 1.7 million claims across six states. In addition, it is important to account \$16.1 billion in losses from flooding insured by the National Flood Insurance Program (NFIP), plus the \$2 billion to \$3 billion of insured damages to offshore energy facilities (Insurance Information Institute 2010). The total amount of Insured losses is around \$62 billion, according to Munich Re 2021 (Insurance Information Institute 2010).

Louisiana and Mississippi were the hardest-hit states, accounting for 63% and 34% respectively of the total losses. The rest was distributed between Alabama, Florida, and Tennessee (Insurance Information Institute 2010).

In 2021 the World Health Organization stated that the number of natural disasters, such as hurricanes is increasing due to climate change: “Climate change is a major driver of this increase, as it is leading to more extreme weather events, such as hurricanes, floods, and droughts” (Intergovernmental Panel on Climate Change 2023).

Generally, Insurers deal with a multitude of “independent” risks that follow a consistent trend over time, allowing firms to profit by investing the premiums and getting a return before paying out over claims. On the other hand, natural catastrophes’ losses lack consistent annual trends exposing insurance companies to the risk of incurring losses far higher than the cost of premiums or even declaring bankruptcy like Poe Financial.

After the 2004 and 2005 hurricane seasons, which included Hurricanes Katrina, Rita, and Wilma, Poe Financial Group, was declared insolvent in 2006 due to the overwhelming number of claims (Viscusi and Born 2006).

Damages from natural catastrophes are characterized by fat tails, meaning that the likelihood of a large loss is higher than a normal distribution (Kousky and Cooke 2010). This means that in the year of a natural disaster, insurance companies will likely pay out far more in claims than they earn in premiums. To stay profitable in the long run, the premiums need to be higher in years with no natural disasters to cover potential losses of future catastrophic events.

“Fat-tailed risks are expensive to insure” (Kousky and Cooke 2010), the increase in insurance premiums may make the low-class individuals or small businesses unable to afford insurance, exposing them to high risks in case of any damage to their properties.

At the end of 2005, the Insurance Services Office, Inc. (ISO) and the Property Casualty Insurers Association of America (PCI) released interesting results on the property/casualty industry, reporting rate of return on average surplus of 10.5% in 2005, which was above the 10.4% average return recorded during calendar year 2004. If compared with 14.9% Return of Equity of the Fortune 500 group of companies, the property/casualty insurance industry as a whole has underperformed the Fortune 500 (Insurance Information Institute 2005). This trend has been going on since 1987.

Although 2005 was a record season in terms of catastrophe losses, insurers managed to almost break even from an “underwriting prospective” and finished the year with a modest underwriting loss, exceeding the public expectations.

To conclude, the storms that hit U.S. coast in 2005 “were not solvency threatening to the industry as a whole”(Insurance Information Institute 2005).

1.2 Research Questions and Hypotheses

Numerous studies conducted in recent decades have examined the social and economic effects of various natural catastrophes on local communities, businesses, and economies. This study will center on Hurricane Katrina, one of the worst natural catastrophes to ever hit the United States, offering a case study to comprehend how the market reacted to this major calamity.

This research is important because it can help regulators, investors, and insurers understand how markets behave after large-scale natural shocks.

The research questions that drive this study are:

1. How did Hurricane Katrina affect the stock market performance of insurance companies with direct exposure to the affected regions compared to those without such exposure?

2. Is there a statistically significant difference in the Cumulative Average Abnormal Returns (CAAR) between affected and non-affected insurance firms during the event window surrounding Hurricane Katrina?

To find answers to the research questions the following hypotheses are formulated:

Hypothesis 1: Insurance companies with significant exposure in the regions heavily affected by Hurricane Katrina will experience negative CAAR, reflecting the market's reaction to the financial impact caused by potential losses.

Hypothesis 2: Insurance companies with minimal or zero exposure to hurricane-affected areas will not show a statistically significant change in their CAAR, suggesting that the market takes into account the available information regarding geographical exposure and first damages estimations.

Hypothesis 3: The difference in CAAR between the affected and non-affected groups will be significant and negative, indicating that the market differentiates between the type of exposure of insurance companies based on their geographical risk exposure to catastrophic events and available public information.

By investigating the previous hypotheses this study will help to expand the understanding of how the market integrates all available information when big natural calamities occur and provoke damages of important magnitude.

1.3 Paper structure

The study is organized as follows: Section 2 discusses the previous studies on stock reactions to natural disasters, focusing on Hurricanes in the U.S. This chapter offers an extensive review of existing literature, providing insights into the methodologies and findings of earlier studies. Next, Section 3 describes the Dataset, while Section 4 highlights the methodology chosen to study Abnormal Returns and the reasons behind specific methodological choices.

Section 5 shows the results and primary considerations.

Section 6 incorporates the Robustness tests to ensure the reliability and validity of the results across various model specifications and assumptions.

Section 7 discusses the empirical results and possible explanations.

Section 8 is the conclusion of the study.

2. Literature review

This literature examines the financial impacts of hurricanes on the insurance sector, primarily in the U.S.

The study of Lamb (1995) on Hurricane Andrew shows a significant negative property-liability stock reaction on insurers with direct premium volume in Florida or Louisiana. In particular, the market's reaction was focused on the initial Day 0 and Day +1 following the hurricane's landfall on Florida's coast. Lamb observed that companies operating in the hardest-hit states experienced substantial negative returns of -0.05%. Oppositely, firms with no exposure in the two states had no significant stock price returns: the market efficiently interpreted the information on the hurricane and P&L companies' exposure. Lamb (1998) compared the effect of Hurricane Hugo with Hurricane Andrew showing that they produced different market reactions depending on the intensity of the Hurricane: independently of the degree of exposure, firms were not affected by Hurricane Hugo.

Again, on Hurricane Andrew, (Angbazo and Narayanan 1996) found a significant and negative impact on the property-liability insurance stock, the negative influence was extended also to less exposed firms, even if weakly. The study also found that the negative impact was offset due to the market's expectations of future premium expenses.

Ewing et al. (2006) which studied how information about hurricane Floyd affected insurer stock, found cumulative negative returns on insurers stocks showing how significant was market reaction to the news path and strength of the storm.

Cagle (1996)'s results indicate that for Hurricane Hugo insurers with greater exposure to the storm experienced a negative stock price reaction, while the stock prices of less-exposed insurers were not significantly affected. Which is in contrast with Lamb (1998).

Viscusi and Born (2006) focused on the effects of natural disasters on insurance rates from the perspectives of insurers and homeowners. Their analysis utilizes an extensive dataset from 1984 to 2004, examining the 20 most devastating events, including 12 hurricanes. The evidence shows that insurers do not fully anticipate catastrophes, and the substantial negative impacts lead firms to set higher premium rates. Subsequently, insurers experience a reduction in earned premiums in the affected regions due to decreased insurance coverage purchased by consumers. Catastrophes result in a decline in the number of firms offering insurance in the affected states and increase the likelihood of firms exiting the market.

Hagendorff and Keasey (2015) examine the impact of mega-catastrophes between 1996 and 2010 on insurance firms in the U.S., the sample is composed of 57 publicly traded P&L insurers.

The results show significant negative cumulative average abnormal returns of -0.28% and -0.67% for the window [0; +1] and [0, +5], both 1% significance level. The results show that, on average, the magnitude of share price losses is moderate demonstrating the market's confidence in insurers to absorb the losses caused by mega-catastrophes. The results also suggest that insurer's stock returns suffer more with greater exposure to mega-catastrophe and in more competitive markets, where raising premiums to offset losses is challenging.

The study of Lanfear et al. (2017) studies how stock prices react following hurricanes across decile portfolios. Their research utilizes data from 34 hurricanes that hit the United States between 1990 and 2004, including companies listed on the NYSE and NASDAQ. These companies are sorted into decile portfolios based on market equity and book-to-market equity. The results (Panel A, Lanfear et al. 2017) show an inverse relationship between abnormal returns and company size following a hurricane. In particular, smaller firms tend to experience more significant negative abnormal returns than larger firms, with the negative impact progressively diminishing as one moves from smaller to larger stock-size portfolios. The study also reveals that low and high book-to-market equity ratio companies have larger negative abnormal returns in comparison with companies in the middle range of the portfolio.

Howerton and Bacon (2017) studied the impact of Hurricane Katrina on a sample of 10 P&C firms stock prices. The normal expected returns were computed following the Market Model approach. The results show that Hurricane Katrina had a significantly negative impact on the risk adjusted rate of return. The findings suggest that in the event window [-30, +30] a fluctuating trend up to Day 0 when there was a notable decline in cumulative average excess returns followed by a continued pattern of ups and downs until day 25. It's important to highlight that on September 18th Hurricane Rita hit the Gulf of Mexico area, becoming a Category 5 Hurricane on the 22nd and making its landfall in southwest Louisiana on September 24th. This information suggests the possibility that the proximity of the two hurricanes could have a confounding impact on stock prices. This hypothesis warrants further investigation.

Author et al. (2010) provide empirical evidence that supports the Efficient Market Hypothesis in regard to share prices response to hurricanes Katrina and Rita. They find that negative abnormal returns of Hurricane Katrina are concentrated on the timing of the related press releases.

The study also finds that both insurers exposed and non-exposed exhibited similar negative stock returns, suggesting contagion effects extended to unexposed firms. However, during the [0, +1] window insurers with direct exposure showed a greater negative abnormal return of -1.55%, compared to a -0.98% drop for unexposed insurers, with both being statistically

significant. The regression analyses conducted reveal that the market capitalization does not significantly affect cumulative abnormal returns within the $[-1; +1]$ window.

A more recent study, Feria-Domínguez, Paneque, and Gil-Hurtado (2017) investigates the financial impact of hurricanes from 2005 to 2012 on P&C firms listed on the NYSE. Out of the seven hurricanes analyzed, significant stock return impacts were found for Rita (2005), Felix (2007), Ike (2008), Igor (2010), and Ophelia (2012), indicating that the Efficient Market Theory (EMT) may not always hold in these scenarios. The results showed no significant cumulative average abnormal returns for hurricanes Katrina and Sandy.

Schuh and Jaeckle (2023) investigate how hurricanes impact the stock returns of U.S. insurance companies. Shares price reactions of 32 P&L insurers to the 13 most costly hurricanes since 2004 are examined using an event study methodology. The research aims to identify key factors driving abnormal returns such as hurricane category, the extent of damage, and inclusion in the S&P 500. The study's regression model only explains about 10% of the variance of CAR $[0; +5]$.

The results indicate that higher-category hurricanes lead to more significant negative abnormal returns that are mainly concentrated on Days 1 and 2 after hurricane landfall.

3. Data

3.1 Sample

The first step in conducting the study was the selection of two samples of companies: Affected and Non-Affected, depending on the exposure in the U.S. regions hit by the Hurricane: Louisiana, Mississippi, Alabama, Florida, and Tennessee.

The methodology for selecting the appropriate Affected companies was inspired by the paper of Grace, Klein, and Liu (2006), which provides tables detailing market shares per region in 2004.

Further validation of market shares for the year 2005 was sought through records from the archives of the Louisiana Department of Insurance and the Mississippi Insurance Department. Relying on this data, the identified Affected companies are: The Allstate Corporation (ALL), The Chubb Corporation (CB), Travellers (TRV), American International Group (AIG), Continental National American Group (CNA), Hartford Financial Services Group (HIG), Zurich Insurance Group (ZURN) and Allianz SE (ALV).

Despite Zurich being listed in Switzerland, its significant operations in the affected region in Louisiana and Mississippi justified his inclusion in the sample. Similarly, Allianz SE was included due to its important loss exposure as indicated by initial loss estimates post-Katrina¹. On the other side, the Non Affected sample incorporates companies from the paper published by Author et al. (2010): Berkshire Hathaway (BRK.A), Loews (L), Mercer Insurance Group (MERC), 21st Century In. Group (FOXA), Prudential Fnl (PRF), MetLife (MET), Affirmative In. Holding (AFFM), GAINSCO (GANS), NY Magic (NYM). These companies were selected based on their exposure, which is calculated as the “Direct Written Premiums in the State” on “Total Direct Written Premiums”, as mentioned in the paper (Author et al. 2010).

3.2 Stocks Data

The dataset consists of daily stock prices, and it was sourced from Refinitiv Eikon DataStream. The dataset includes the “Price Index” values, defined as “Price of an equity as a percentage of its value on the base date, adjusted for capital changes”².

The time frame for the data collection starts from 01-11-2004 and it finishes 31-10-2005

To adjust for currency fluctuations for Allianz and Zurich, daily exchange rate data were obtained from Refinitiv Eikon DataStream.

4. Methodology

4.1 Methodological Background

The objective of my research is to identify the effects of Hurricane Katrina on the stock prices of P&C companies with high and low exposure in the regions highly hit by the Hurricane in 2005. The most appropriate approach for this research is the Event Study Methodology.

This methodology allows the researcher to measure the effects of an economic event on a firm’s value (A. Mackinlay 1997). Through financial market data, an event study evaluates the influence of a specific event on a company’s valuation.

This approach is based on the assumptions of the Efficient Market hypothesis where the repercussions of any event are immediately reflected in the prices of securities. Therefore, by observing security prices over a relatively short period of time we can measure the economic impact of the event (A. Mackinlay 1997).

Event studies have wide-ranging applications across various fields. In the realms of accounting and finance, they are applied for various firm specific events such as company mergers and

¹ Hurricane Katrina: Analysis of the Impact on the Insurance Industry, Tower Watson October 2005

² Definition of Price Index by Refinitiv Eikon DataStream

acquisitions, earnings announcements, new debt or equity issues, and macroeconomic announcements. Beyond these, event studies find relevance in other disciplines too. For instance, according to Kothari and Warner (2007), in law and economics, they assess the effect of regulatory changes on a company's value.

Bowman (1983) outlines the main steps for conducting Event studies which can be synthesized into three key stages:

Defining the event of interest and identifying the period over which the share prices of the companies involved will be examined

Selecting a benchmark model to calculate the normal expected returns, i.e., the returns we would expect without the occurrence of the event

Calculate the abnormal returns around the event date

The definition of the event day, defined as Day 0 plays a crucial role, especially in the case of hurricanes, since investors may react as the day of landfall approaches. Usually, hurricanes are anticipated occurrences since the presence of the storm is recognized prior to its landfall as well as its intensity category (Cagle, 1996, p. 60). However, it is possible to assess the actual level of destruction caused by the hurricane only after the landfall. The market will supposedly react based on the first estimations and any news report.

In event study methodology, we can recognize three distinct phases: the estimation window, the event window, and the post-event window.

The estimation window is the period prior to the event day, and it generally comprises between 200-120 trading days ranging from T_0 to T_1 . The previous literature does not agree on the best approach in terms of number of days. However, a longer estimation window might provide a more accurate estimation but could also coincide with other events, that could potentially bias the results.

The event window period spans from T_1 to T_2 and it contains the Day 0. The literature distinguishes between short-horizon and long-horizon event windows (José Feria-Domínguez et al 2017). In my analysis, I will consider various short-horizon event windows as the impact is expected to be concentrated around the day of landfall (Author et al. 2010).

Finally, the post-event window, between T_2 and T_3 is used to verify whether the stock's daily return reverts to their pre-hurricane trends.

The assessment of the event's impact on the selected companies requires the calculation of abnormal returns.

Abnormal return (AR) is defined as the difference between the actual return of the stock and the normal or expected return. In this case, the expected return is equal to the Market returns,

following the Market Adjusted model. For the U.S. companies, the proxy for the market is the S&P500, while for Allianz and Zurich DAX30 and SMI respectively:

$$1) \quad AR_{it} = R_{it} - R_{Mt}$$

Where R_{it} is the daily Natural logarithmic Return of a company “i” at time “t” and R_{Mt} is the daily natural logarithmic Return of the Market.

Since Allianz and Zurich are listed on the Frankfurt Stock Exchange in Germany and the SIX Swiss Exchange in Switzerland respectively, it is necessary to adjust their stock prices for currency fluctuations to enable comparison with U.S. companies. After downloading their stock prices, which are already converted to U.S. Dollars from Refinitiv Eikon DataStream, we adjust for currency fluctuations by subtracting the daily rate of return of the Euro and the Swiss Franc against the U.S. Dollar:

$$2) \quad \text{Adjusted Ln Return} = \text{Ln Return}_{it} - \text{Ln Return}_{\text{currency},t}$$

The next step is the calculation of Abnormal returns using the formula (1).

Then, I used the unweight cross sectional average of abnormal returns (AAR), in period t, calculated as follows:

$$3) \quad AAR = \overline{AR}_{it} = \frac{1}{N} \sum_{i=1}^N AR_{it}$$

Moreover, is also interesting to aggregate AR_{it} into cumulative abnormal returns within the event window from T_1 to T_2 :

$$4) \quad CAR_i = \sum_{t=T_1}^{T_2} AR_{it}$$

Generally, in event studies CAR_i is also aggregated over the cross section to calculate Cumulative average abnormal return (CAAR):

$$5) \quad CAAR = \overline{CAR} = \frac{1}{N} \sum_{i=1}^N CAR_i$$

CAAR can also be calculated by aggregating AAR over time:

$$6) \quad \overline{CAR} = \sum_{t=T_1}^{T_2} \overline{AR}_t$$

The last phase in event study methodology involves statistically validating the significance of the findings to ensure that the observed changes in stock prices are not merely due to random

fluctuations. To determine the significance of the cumulative average abnormal returns, we initially conducted a parametric t-test. This conventional t-test is based on the premise that the abnormal returns follow a normal distribution:

$$7) \quad AR_t \sim N\left(0, \frac{\sigma^2}{N}\right)$$

The variance σ^2 is not known, the variance of the AR_{it} of the estimation window is used as an estimator. To conduct the t-test we first need to calculate the standard error as the standard deviation of the Average abnormal returns of the estimation window divided by the square root of the number of observations (for example $n=5$ if we are testing for 5 days of Average abnormal return):

$$8) \quad Stand.error = \frac{\sigma}{\sqrt{N}}$$

The parametric t-test of CAARs is conducted where t-stat is calculated as follows:

$$9) \quad T - stat = \frac{CAAR}{Stand.error_{CAAR}}$$

After calculating the t-stat the next crucial step is to compare the t-statistic against the critical value to establish the statistical significance of our results. This comparison allows us to determine whether the observed CAAR are significant enough to be attributed to the effect of the event and not to random fluctuations.

The critical value is derived from the t-distribution table, which is based on the degrees of freedom in our sample and the chosen level of confidence. Commonly, a 95% confidence level is selected, which corresponds to a 5% significance level. This means we are accepting a 5% probability of rejecting the null hypothesis when it is true (Type I error).

To confirm the robustness of my findings, P-value obtained from these tests will be compared with the predetermined significance level, set again at 5%. If the p-value is less than or equal to α , we reject the null hypothesis.

4.2 Research Design

Following this theoretical framework, the first step is to identify the day of the event, defined as Day 0. As suggested by Erving et al. (2006), the landfall of the hurricane is set as the event date which is August 29th, 2005. The Day 0 is equal for U.S. companies as Zurich and Allianz

since Hurricane Katrina was declared a Category 5 Hurricane on Sunday August 28th and made the landfall at 06:10 CDT³ (NOAA 2005), when in Europe the markets were already open.

To define the estimation window, this paper uses the framework from Lanfear et al. (2017) which is based on the Atlantic hurricanes season. This period extends from the 1st of June to the 30th of November (NHC & CPHC). Therefore, the timeframe that falls from December 1st to May 31st, is designated as the estimation window. During this period there were 4 non-trading days for U.S. stock exchanges that were trading days in Europe's stock exchange: 24th of December 2004, 17th January 2005, 21st February 2005 and 30th May 2005. To assess these differences, the estimation window for all companies is comprised by 125 trading days that corresponds to Days -187 to -63 prior to Day 0.

This approach is designed to prevent the potential confounding effects of other hurricanes.

In this study, various event windows are utilized to capture the diverse impacts of hurricanes on stock prices. The event windows range from shorter spans such as [-5, +5], [-3, +3], [-2, +2], [-1, +3] and [-1, +1] to longer durations including [0, +10], and [0, +15].

The shorter windows, such as [-1, +1] and [-2, +2], are selected to focus on the immediate market response to the hurricane event. The idea is to capture the initial shock and immediate reactions of investors reflecting the market's incorporations of news like Hurricane Category and initial damage assessment.

The extended windows, such as [0, +10] and [0, +15], are incorporated to observe any prolonged effects on the stock market. These windows also allow us to study the investors sentiment after the short-term developments and news since +10 and +15 days should be enough for the market to incorporate more detailed information about the hurricane's impact.

Due to the U.S. stock exchange being close on September 5th, Day +5 for Allianz and Zurich is September 5th, while for the other companies is September 6th.

The first step to study AR is to calculate the daily stock returns for both samples of affected and non-affected companies, S&p500, DAX30 and SMI. To do so, I applied the natural logarithmic formula to all sample from 01/12/2004 to the end.

Once that the returns are calculated, I proceeded to calculate the Abnormal returns for estimation windows and event windows, throughout all the samples. The formula applied is "equation 1)" and following the Market Adjusted Model, the returns of S&P500, DAX30 and SMI are the proxy for the normal returns, respectively to U.S. companies, Allianz and Zurich.

³ Corresponds to 12 AM London time

It is important to mention that before the calculation of AR for Allianz and Zurich, the daily natural logarithmic returns have been adjusted for currency fluctuations applying the equation 2). This is fundamental since stock returns of companies listed in different countries converted in a different currency are influenced by changes in exchange rates. For instance, if the value of the Euro increases relative to the U.S. Dollar, the U.S. Dollar-denominated returns of a Euro-based company like Allianz in our case, would also increase, independently from the real company's stock performance. This would create bias in our data that could have a huge impact on the findings.

The abnormal returns are now ready to be averaged to create the Average abnormal return for any trading days in the sample. the equation 3) is used for this calculation.

The Average Abnormal return will be cumulated following equation 6). The AAR will cumulate depending on the horizon of each event windows.

To test the significance of the CAAR, we do not know the variance of the AR in the event window and following the approach suggested from the literature the variance of the estimation window was used.

This is where the Hypothesis 1 is tested, which consist in testing whether the mean of CAAR (Affected sample) is equal or different from zero, which is defined as follow:

$$H_0 = E(CAAR_{it}) = 0$$

$$H_1 = E(CAAR_{it}) \neq 0$$

The parametric t-test is conducted using equation 9).

If the calculated t-statistic exceeds the critical value, assuming a specific confidence level (i.e. 95%) we reject the null hypothesis, meaning that there is a significant difference between the observed CAAR and zero. Conversely, if the t-statistic is less than the critical value, we cannot reject the null hypothesis, implying that the CAAR is not significantly different from zero.

The same test is conducted for the sample of Not-Affected companies, this time we want to Hypothesis 2.

The existing literature mentioned in Section 2 show that for the two hypotheses both types of stocks reactions are possible: in the study of José Feria-Domínguez et al (2017) the CAAR of Hurricane Katrina are negative and non-significant and in the study of A. Gangopadhy et al. (2010) the negative stock returns are also extended to the non-affected companies, suggesting a contagion effect.

To test Hypothesis 3, CAARs of Affected and Non-Affected firms are compared and the difference is taken. To test the significance of the Difference, the standard deviation of Affected

and Non-affected firms had to be taken in account, using the following formula to calculate the standard error for each event window:

$$10) \quad SE_n \equiv \sqrt{\frac{\sigma_{Aff}^2 + \sigma_{NAff}^2}{N}}$$

By incorporating the Standard error calculated above, T-test is conducted as for the previous hypotheses.

In the results showed in the tables, both T-statistic and P-values are included.

5. Empirical Results

5.1 Affected Companies' Sample

This first section examines the shares' prices reactions from the sample of 8 affected companies. In Figure 1 the resulting AARs are shown from day -5 to day +5, along with their t-stats.

From Day -3 we can observe a pattern of negative AARs, excluding Day -1, that continues till Day +3. By looking at the chronological news report from NOAA, we know that Hurricane Katrina was declared a major hurricane on Friday afternoon of August 26th and reached Category 5 during the weekend when the stock markets were already closed.

On August 29th, the day of landfall, and on August 31st the lowest AARs in all sample were registered, being -1.11% and -1.14% respectively, but all the returns were still not significant. When testing their significance trough t-test, no AARs were significant at a 5% significance level.

Figure 1 Average Abnormal Returns of Affected Companies

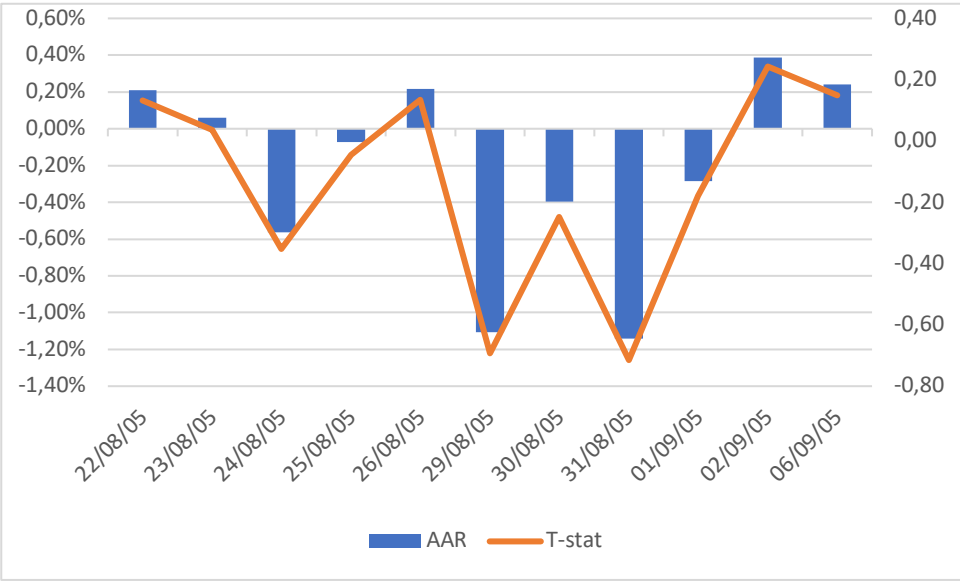


Table 1 shows the observed CAARs for different event windows with the respective significance t-tests and p-values. In all of the 8 event windows, the respective CAARs are negative but only in 4 windows are significant: [-3, +3], [-2, +2], [0, +5] and [-1, +3] corresponding respectively to CAARs of -3.35%, -2.5%, -2.3% and -2.7%, with all being significant at a 5% level. Negative CAARs of -2.7% are extended until the last window [0, +15] but they are not significant.

To summarize, when cumulating the Average abnormal returns, Hurricane Katrina created both significant and insignificant negative CAARs on companies affected by the hurricane. However, when examining the average abnormal returns on a day-to-day basis, the event did not significantly impact the stocks prices.

Table 1 Cumulative Average Abnormal Returns of Affected Companies

| Window | CAAR | T-stat | P-value |
|----------|--------|--------|---------|
| [-5, +5] | -2.45% | -1.31 | 0.10 |
| [-1, +1] | -1.29% | -1.32 | 0.09 |
| [-3, +3] | -3.35% | -2.24 | 0.01 |
| [-2, +2] | -2.50% | -1.98 | 0.02 |
| [-1, +3] | -2.72% | -2.15 | 0.02 |
| [0, +5] | -2.30% | -1.67 | 0.05 |
| [0, +10] | -2.34% | -1.25 | 0.11 |
| [0, +15] | -2.69% | -1.19 | 0.12 |

5.2 Non-Affected Companies' Sample

This section examines the results from the sample of the 9 Non affected companies.

In Figure 2 the resulting AARs are shown from day -5 to day +5, along with their t-stats.

From Day -2, we observe a pattern of of negative AARs that continues until Day +2. A notable observation from Figure 2 is that the AARs of non-affected companies are higher on average compared to affected companies, especially on Day 0 where the returns were -0.94% against -1.11% for affected companies. However, none of the AARs in this sample were significant at a 5% significance level.

Figure 2 Average Abnormal Returns of Non Affected Companies

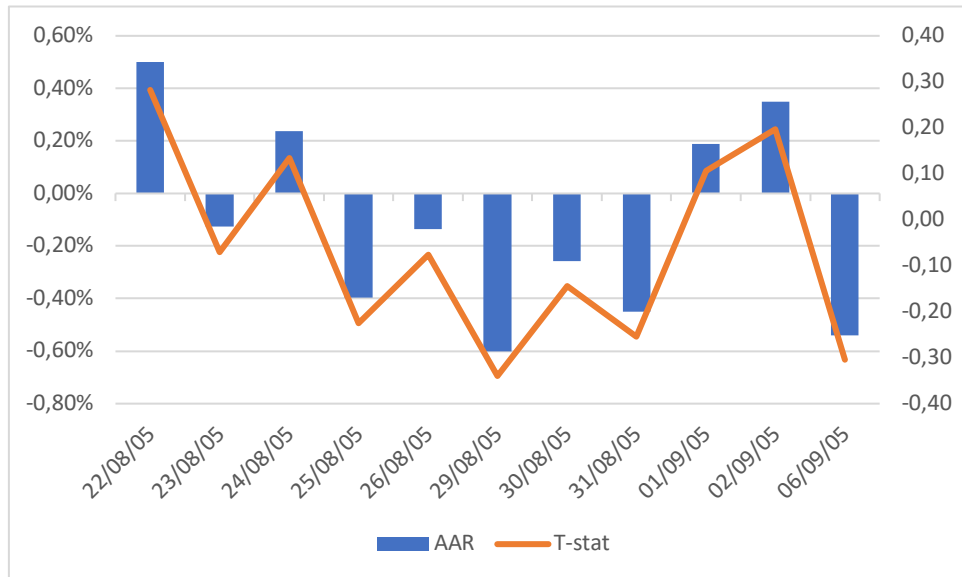


Table 2 presents the observed CAARs for different event windows along with their respective t-tests and p-values.

Out of the 8 event windows, the CAARs are always negative except for the window [0, +15], where a positive CAAR of +0.15% is observed. The lowest CAARs, observed in windows [-3, +3], [-2, +2] were -1.4% and -1.8%, respectively. Nonetheless, all results are non-significant at a 5% level, with the window [-2, +2] being the only one to achieve a t-stat of 1.4 making it significant at a 10% level.

In summary, the cumulated average abnormal returns for non-affected companies are negative and not significant.

Table 2 Cumulative Average Abnormal Returns of Non Affected Companies

| Window | CAAR | T-stat | P-value |
|----------|--------|--------|---------|
| [-5, +5] | -1.23% | -0.63 | 0.26 |
| [-1, +1] | -0.99% | -0.97 | 0.17 |
| [-3, +3] | -1.41% | -0.90 | 0.18 |
| [-2, +2] | -1.84% | -1.39 | 0.08 |
| [-1, +3] | -1.25% | -0.95 | 0.17 |
| [0, +5] | -1.31% | -0.91 | 0.18 |
| [0, +10] | -0.15% | -0.07 | 0.47 |
| [0, +15] | 0.15% | 0.06 | 0.53 |

5.3 Difference between Affected and Non-Affected Companies

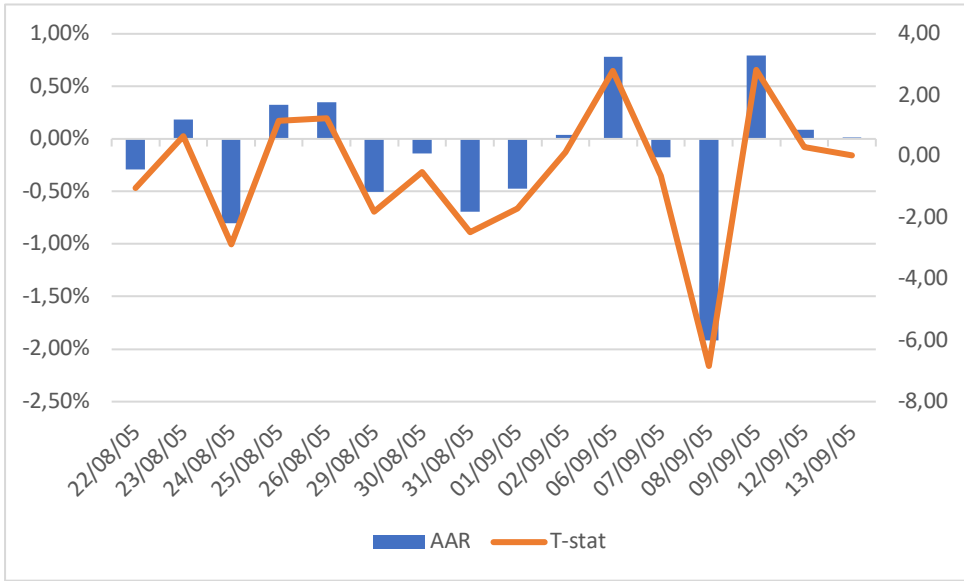
This section examines the results from the differences in CAARs of the two samples.

In Figure 3, the resulting difference in AARs is shown from Day -5 to Day +10, along with their t-stats.

From Day -5 to Day +5 we find significant t-stats in many days, specifically Day -3, Day 0, Day +2, Day +3 and Day +5, these results show that during those days the difference in returns were significant but moderate, as the difference oscillates between -0.80% and +0.78%.

As we proceed till Day +10, more significant AARs are observed, for example in Day +7 and Day +8 the respective t-stats were -6.84 and 2.82 with respective -1.92% and +0.79% difference in returns.

Figure 3 Differences in Average Abnormal Returns between Affected and Non Affected companies



In Table 3, the observed difference in CAARs for different windows is presented, along with the respective t-stats and p-values. This time the post event window [+6, +10] is included due to the interesting difference in AARs, CAARs confirmed the significance of those post event days.

All the windows show negative and significant CAARs, with t-stats and p-values showing high significance levels, especially in windows [-3, +3], [-5, +5], [0, +10] and [0, +15].

The difference in CAARs is always negative, with major differences in windows [-3, +3], [0, +10] and [0, +15] being respectively -1.94%, -2.20% and -2.84%.

Table 3 Differences in Cumulative Average Abnormal Returns between Affected and Non Affected Companies

| Window | CAAR | T-stat | P-value |
|-----------|--------|--------|---------|
| [-5, +5] | -1.23% | -4.98 | 0.00 |
| [-1, +1] | -0.30% | -0.63 | 0.26 |
| [-3, +3] | -1.94% | -6.28 | 0.00 |
| [-2, +2] | -0.66% | -1.82 | 0.03 |
| [-1, +3] | -1.46% | -4.01 | 0.00 |
| [0, +5] | -0.99% | -2.98 | 0.00 |
| [0, +10] | -2.20% | -8.93 | 0.00 |
| [0, +15] | -2.84% | -13.93 | 0.00 |
| [+6, +10] | -0.42% | -3.30 | 0.00 |

In Summary, by comparing the two samples, the difference in AARs is significant enough to be captured in the days following the landfall of Hurricane Katrina. Conversely, the difference in CAARs is significant and negative across all the event windows, window [-1, +1] excluded.

6. Robustness Tests

To verify the robustness of my study, I conducted two additional tests altering both the methodology for estimating CAARs and the sample composition. These tests affirm the reliability of the primary results. These findings are summarized as follows:

6.1 Market Model

Market Model approach to estimate abnormal returns is widely used in event studies and particularly used by all the researchers, as highlighted in the literature review. For this reason, I applied it to be sure that my results hold after the application of one of the most common approaches used in the field.

This Model differentiates from the Market Adjusted Model in how it computes normal returns, adjusting for the stock's systematic risks:

$$11) \quad R_{it} = a_i + \beta_i \times R_{Mt} + \varepsilon_{it}$$

Where α is the constant term, β_i is a measure of the sensitivity between R_{it} with respect to R_{Mt} and ε_{it} is the random disturbance term.

The parameters α and β are estimated by Ordinary Least Squares (OLS):

$$12) \quad NR_{it} = \hat{\alpha}_i + \hat{\beta}_i \times R_{Mt}$$

Where NR_{it} is the normal return of one of a stock “i” at time “t”. R_{Mt} is the daily market index (S&P500 for U.S. stocks, DAX30 and SMI for Allianz and Zurich). $\hat{\alpha}_i$ and $\hat{\beta}_i$ are OLS estimates of the regression coefficients.

Abnormal returns were then calculated as follows:

$$13) \quad AR_{it} = R_{it} - NR_{it}$$

These ARs are averaged and cumulated similarly to the Market Adjusted Model.

In Figure 4, the estimated AARs and their t-stats for the affected companies’ sample are presented. The AARs between Day -5 and Day +5 are not significant, consistent with Figure 1.

The lack of significance, including the AAR on Day 0, is similarly observed.

However, when examining cumulative average abnormal returns, we can observe some differences.

Abnormal returns are then averaged and cumulated the same way as Market Adjusted Model.

Figure 4 Average Abnormal Returns of Affected Companies

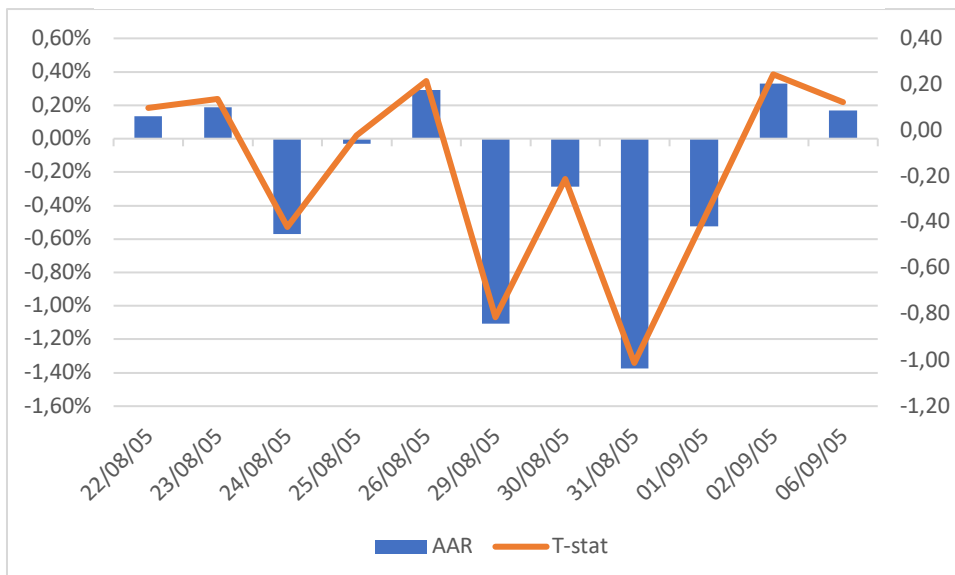


Table 4 displays the observed CAARs for the event windows, along with their respective significance t-tests and p-values. Once again, all CAARs in the windows are negative, showing slightly higher negative returns compared with Table 1. When looking at the significance of

CAARs, we notice that this time also window [-5, +5] and [0, +10] are significant at a 5% level, with t-stats of -1.85 and -1.82 respectively. Additionally, window [0, +15] is negative and significant at 10% level.

Table 4 Cumulative Average Abnormal Returns of Affected Companies

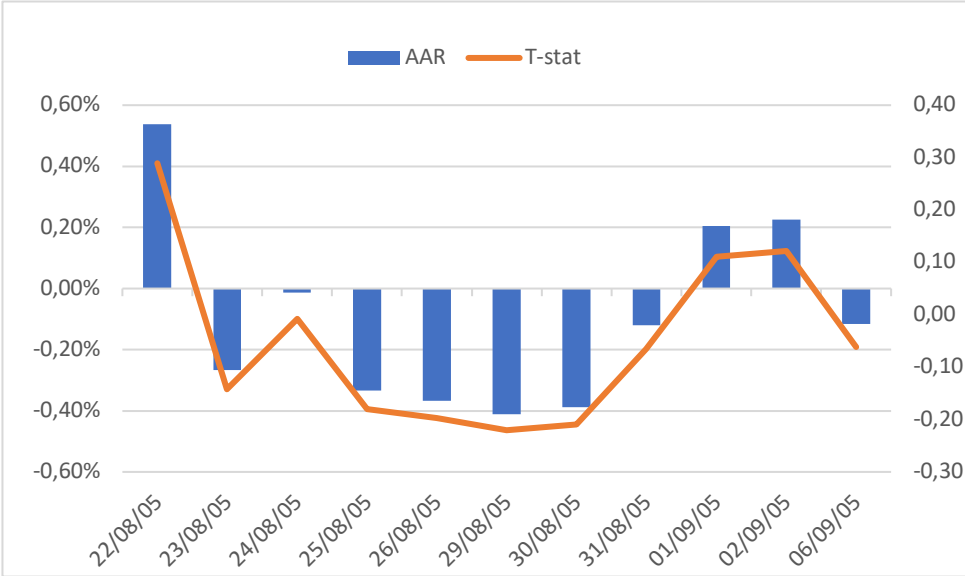
| Window | CAAR | T-stat | P-value |
|----------|--------|--------|---------|
| [-5, +5] | -2.95% | -1.85 | 0.03 |
| [-1, +1] | -1.10% | -1.33 | 0.09 |
| [-3, +3] | -3.60% | -2.83 | 0.00 |
| [-2, +2] | -2.51% | -2.33 | 0.01 |
| [-1, +3] | -3.00% | -2.79 | 0.00 |
| [0, +5] | -2.80% | -2.37 | 0.01 |
| [0, +10] | -2.90% | -1.82 | 0.03 |
| [0, +15] | -3.11% | -1.62 | 0.06 |

Looking at the sample of Non Affected companies, Figure 5 presents the results obtained for the AARs.

When comparing the results with those from Figure 2, we observe a similar pattern, with again all the AARs being non-significant. For instance, on Day -1 and Day -2 the AARs (Market Model) are more negative than those computed with the Market Adjusted Model.

On Day 0, Figure 3 showed negative AARs of -0.60%, which is in line with what we observe from Figure 5. The AARs of the following days also follow the same trend in sign and remain not significant.

Figure 5 Average Abnormal Returns of Non Affected Companies



Moving to Table 5, the CAARs observed are very close to the results from Table 4. For example, in window [-3, +3], we observed negative CAARs of -1.41% (Market Adjusted Model) in contrast to the negative CAARs of -1.43% under the Market Model, both being insignificant. Only in the window [0, +10] we notice a pronounced difference with CAARs (Market Model) being positive at 0.40% compared to -0.15% under the Market Adjusted Model.

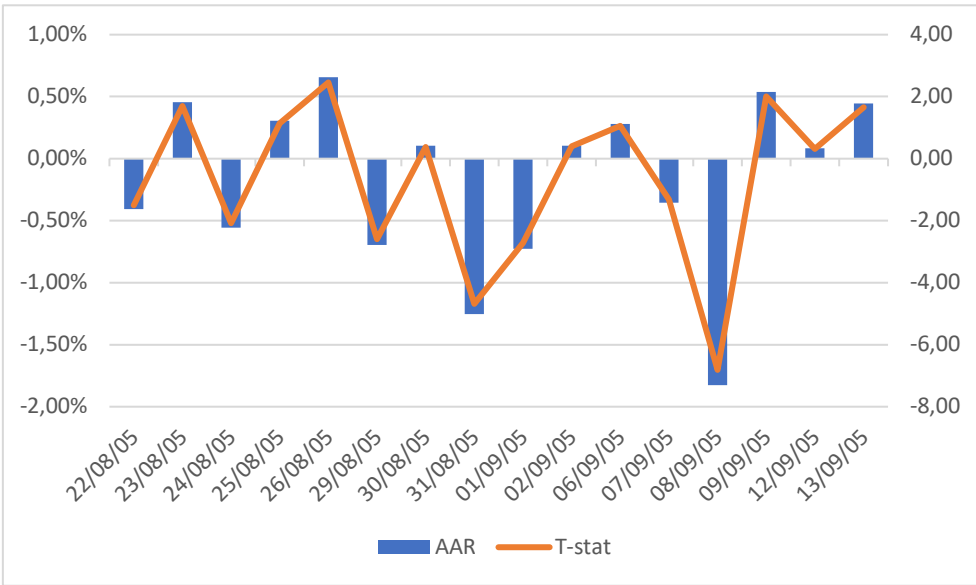
Table 5 Cumulative Average Abnormal Returns of Non Affected Companies

| Window | CAAR | T-stat | P-value |
|----------|--------|--------|---------|
| [-5, +5] | -0.93% | -0.45 | 0.33 |
| [-1, +1] | -1.17% | -1.09 | 0.14 |
| [-3, +3] | -1.43% | -0.87 | 0.19 |
| [-2, +2] | -1.62% | -1.17 | 0.12 |
| [-1, +3] | -1.08% | -0.78 | 0.22 |
| [0, +5] | -0.61% | -0.40 | 0.35 |
| [0, +10] | 0.40% | 0.19 | 0.58 |
| [0, +15] | 0.31% | 0.13 | 0.55 |

Figure 6 shows the results for the differences in AARs between the two samples. When compared with Table 6, we observe similar differences in AARs in the days before the landfall. On Day 0, the AARs register at -0.70%, which is in line compared with Figure 3, where the AARs are -0.51%, with both being significant at 5% level.

The pattern between the two models is similar in the days following the event, it is interesting to observe on Day +7 large and negative differences of -1.82% for the Market Model and -1.92% Market Adjusted Model.

Figure 6 Differences in Average Abnormal Returns between Affected and Non Affected companies



Finally, Table 6 shows the results for the differences in CAARs. Here, we observe a pattern similar to that in Table 3, but with the Market Model showing greater differences in CAARs. For example, in window [0, +5] table 6 shows CAARs of -2.19% which is much lower than Table 3, showing -0.99%. This is also observed for windows [0, +10] and [0, +15]. The T-stats in Table 6 are similar to Table 3 but are in general lower and consequently more significant.

Table 6 Differences in Cumulative Average Abnormal Returns between Affected and Non Affected Companies

| Window | CAAR | T-stat | P-value |
|-----------|--------|--------|---------|
| [-5, +5] | -1.74% | -7.33 | 0.00 |
| [-1, +1] | 0.06% | 0.14 | 0.56 |
| [-3, +3] | -2.17% | -5.47 | 0.00 |
| [-2, +2] | -0.89% | -2.52 | 0.01 |
| [-1, +3] | -1.92% | -5.47 | 0.00 |
| [0, +5] | -2.19% | -6.83 | 0.00 |
| [0, +10] | -3.30% | -13.95 | 0.00 |
| [0, +15] | -3.42% | -17.42 | 0.00 |
| [+6, +10] | -1.11% | -3.17 | 0.00 |

6.2 Extended sample for Affected Companies

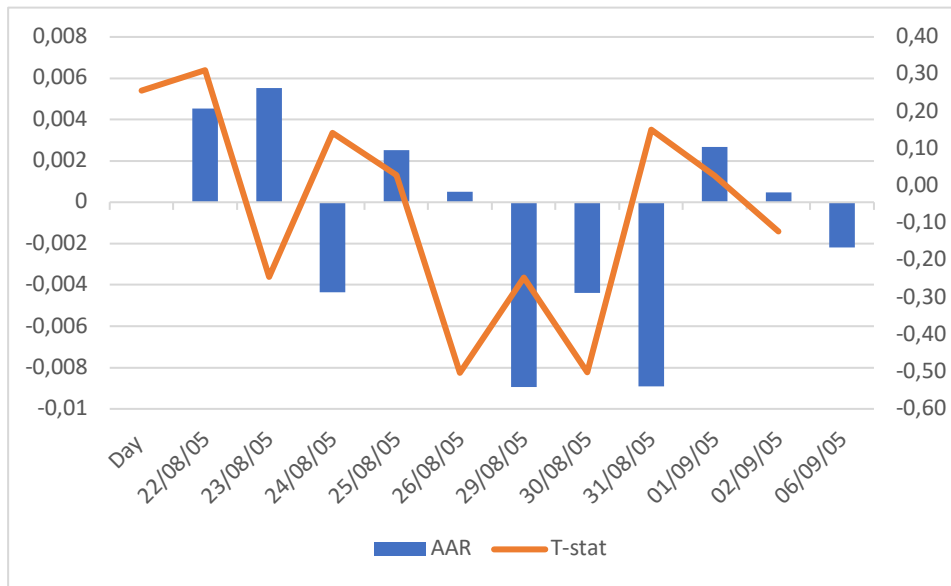
For this robustness test, I expanded the sample of affected companies by including five additional firms, as identified in the study of Author et al. (2010). These new companies are Hanover Insurance Group (THG), Arch Capital Group (ACGL), Infinity Property and Casualty Corporation (IPCC) and Zenith National Insurance (ZNAT).

This brings the total number of companies in the sample to 13.

The methodology applied for this test is consistent with the Market Adjusted Model, used in Section 4.

In Figure 7, which presents the AARs of the extended sample, we notice that the AARs prior to Day 0 follow a similar pattern to those in Table 1. An exception is on Day -2, where the extended sample registers a positive value of 0.25% against -0.07%, with both being insignificant. On Day 0, both the extended and original samples register negative returns. A similar trend is observed in the days after the event, with some differences in signs, such as on Day +3. Similar to Table 1, AARs are not significant across all the windows.

Figure 7 Average Abnormal Returns of Affected Companies



Moving to Figure 7, which shows the results for CAARs, we observe that the CAARs in the extended sample are generally lower than those in Table 1. For example, window [-5, +5] shows CAARs of -1.26% compared with -2.45% in the original sample. This trend is also evident in windows [-3, +3], [-2, +2]. Longer windows, such as [0, +15], exhibit even greater differences, with the extended showing CAARs of -1.05% against -2.69% in the original one.

We observe that the level significance shifts in Window [-3, +3], which loses its significance at 5% level, but remains significant at 10%. Other windows like [-2, +2], [-1, +3] and [0, +5] continue to show significant at a 5% level.

Table 7 Cumulative Average Abnormal Returns of Affected Companies

| Window | CAAR | T-stat | P-value |
|----------|--------|--------|---------|
| [-5, +5] | -1.26% | -0.77 | 0.22 |
| [-1, +1] | -1.28% | -1.50 | 0.07 |
| [-3, +3] | -2.09% | -1.60 | 0.1 |
| [-2, +2] | -1.92% | -1.74 | 0.04 |
| [-1, +3] | -1.91% | -1.73 | 0.04 |
| [0, +5] | -2.13% | -1.76 | 0.04 |
| [0, +10] | -1.57% | -0.96 | 0.17 |
| [0, +15] | -1.05% | -0.53 | 0.30 |

7. Discussion

This study examines how Hurricane Katrina impacted the stock prices of Insurance companies, offering key insights on investors' sentiment towards Insurance firms with different degrees of exposure to the most affected regions, namely Louisiana and Mississippi.

The literature background suggests that event study methodology is an effective method to analyze the market's reactions to a natural disaster. In this context, the Market Adjusted Model offers a straightforward approach that focuses directly on the abnormal returns attributed to the events. This should be particularly effective to capture the immediate stocks' reactions.

However, it is also important to recognize the possible limitations of this approach. In particular, the Market Adjusted Model does not take into account stock's systematic risks or broader market movements. To address this, I conducted the robustness test through the application of the Market Model, which makes our results even more comparable with prior studies.

My study not only differs from previous studies on Hurricane Katrina due to the use of both Models to calculate Abnormal returns but also because of the integration of two non-U.S. based companies, Allianz SE and Zurich Insurance Group. These firms were taken into account because of their huge exposure in Louisiana and Mississippi.

The archives from 2005 of the Louisiana Department of Insurance and the Mississippi Insurance Department show that the incurred losses were more than \$550 million for Allianz and more than \$850 million for Zurich. With this available information, including these two companies in my sample seemed reasonable.

I also conducted a second robustness test where I extended the sample of Affected companies by including five new firms. The original sample of eight firms may raise some concerns regarding the representativeness and generalizability of the results.

Limited sample size can sometimes lead to biased outcomes, particularly if the selected firms do not adequately capture the diversity of responses within the broader insurance industry.

Since events like Hurricane Katrina can cause different impact based on specific firm characteristics, this robustness test is also important to compare the initial results against a broader array of companies which may differ in financial health and operational strategies.

The original sample of affected companies shows a pattern of negative Average Abnormal Returns, starting from Day -3, which persisted until Day +3, with the exclusion of the day prior to the landfall. This trend aligns with the progression of Hurricane Katrina and the availability of news regarding the characteristics of the hurricane. However, these daily changes were not

statistically significant suggesting that the market reacted to the hurricane but not in a consistently significant manner, on a day-to-day basis.

When looking at the Cumulative Average Abnormal Returns, we observe a negative and statistically significant impact on the affected companies' shares, especially on the days around the landfall registering a -3.35% in window [-3, +3] and -2.30% in Window [0, +5], with both CAARs being statistically significant at 5 % level.

My results suggest the validity of Hypothesis 1: Hurricane Katrina caused statistically significant and negative CAARs on the sample of Affected companies, this reflects the ability of the market to incorporate all available information, demonstrating that the Efficient Market Theory (EMT) holds. My results align with Schuh and Jaeckle (2023) who found negative CAARs on P&L insurers samples following Hurricanes Katrina, Harvey, and Maria.

These results are opposite to those from Feria-Domínguez, Paneque, and Gil-Hurtado (2017) which did not find any significant and negative CAARs in the sample of seven P & C Insurance firms, suggesting that shares reaction was insensitive to Hurricane Katrina (Feria-Domínguez, Paneque, and Gil-Hurtado 2017).

When looking at the sample of Non Affected companies, we observed negative CAARs in most event windows, apart from window [0, +15] showing positive +0.15% CAARs. However, the lack of statistical significance suggests that the impact on this set of companies was not substantial enough to be distinguished from normal fluctuations, supporting Hypothesis 2.

This could indicate that the market did not perceive that these companies could face financial distress caused by Hurricane Katrina's consequences, possibly due to their lack of exposure in the affected regions. Author et al. (2010) also found that Hurricane Katrina and Rita caused negative abnormal returns on both samples, affected and non-affected companies, however on days -3, 0, +1, and +2 their results are significant even for the Non Affected sample, suggesting the possibility a contagion effect.

When taking the differences between the two samples, we observe significant and negative findings, even in the AARs difference, highlighting the different market reactions to affected and non-affected companies. In particular significant T-stats on Day -3, Day 0, Day +2, Day +3, Day +5, Day +7 and Day +8 suggest that the market perceived a distinct disparity in risk and impact between these two groups. However, these differences are generally moderate, oscillating between -0.80% and +0.78%. The observed negative and significant CAARs across every event window, excluding window [-1, +1], bring us to support Hypothesis 3: the market seems to differentiate between companies based on their geographical risk exposure and from the hurricane, as evidenced by the significant differences in both AARs and CAARs.

The application of the Market Model as the first robustness test helped me to reinforce the primary findings. In fact, even when accounting for the stock's systematic risks, the observed results show a very similar trend to the Market Adjusted Model.

In the affected sample, AARs show almost the same pattern in the days before and after the event. When looking at CAARs, two windows more are now significant at a 5% level, being [-5, +5] and [0, +10], with respective CAARs of -2.95% and -2.90%.

In the Non-affected and Differences samples, the results are in line with the Market Adjusted Model, with the market Model showing greater differences.

The second robustness test shows that even if we extended the sample of Affected companies Hurricane Katrina had a significant and negative impact on the shares' performance.

The consistency across different samples suggests the results obtained in this study are robust and reliable.

8. Conclusions

This thesis has focused on the market reactions to Hurricane Katrina of different samples of companies, distinguishing between affected and non-affected companies based on the degree of exposure in the regions that have been heavily impacted by the hurricane.

The event study methodology, using the Market Adjusted Model, captured the immediate stock's reactions to the hurricane. Through the robustness tests conducted, including the application of the Market Model, I addressed the limitations by accounting for systematic risks and offering an easier comparability con the previous literature.

What makes this study differ from similar studies is the inclusion of international companies like Allianz SE and Zurich Insurance Group.

The market reaction to the Hurricane was reflected in the significant and negative CAARs of affected companies, supporting the Efficient Market Theory (EMT). Conversely, non-affected companies showed negative and non-significant CAARs, suggesting the idea that the market can differentiate the geographical risk exposure of insurance firms.

The differences between the two samples highlighted these "discriminatory" reactions, with consistent and significant differences across all the samples, increasing the confidence in the reliability of these findings.

The results of this study add more evidence to the negative relationships between Hurricane Katrina and stock market reactions for Insurance companies, extending this impact on non-U.S. companies with a degree of exposure in the affected regions.

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