

## Impact of Natural Disasters on the Value of (Re)Insurance Companies

*Anita Maček, Snejana Gheceva and Michael Murg*

### Abstract

Natural catastrophes represent a significant financial burden for the (re)insurance industry, which can affect both the profitability and the financial stability of companies. This paper analyzes the impact of five significant natural events on the share prices of 36 (re)insurance companies listed in the MSCI World Index. The analysis is conducted using the event study methodology and examines the extent to which insured losses from natural catastrophes lead to abnormal returns on share prices. The results show a significant short-term impact of catastrophes on share prices and confirm the tendency for investors to overreact.

### Zusammenfassung

Naturkatastrophen stellen für die (Rück-)Versicherungsbranche eine erhebliche finanzielle Belastung dar, die sowohl die Rentabilität als auch die finanzielle Stabilität von Unternehmen beeinträchtigen kann. Der vorliegende Beitrag widmet sich der Analyse der Auswirkungen von fünf bedeutenden Naturereignissen auf die Aktienkurse von 36 im

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Dr. Anita Maček (corresponding author)

FH Joanneum, Institute of Banking and Insurance Industry

Senior Lecturer

Eggenberger Allee 11

8020 Graz

Email: [anita.macek@fh-joanneum.at](mailto:anita.macek@fh-joanneum.at)

Snejana Gheceva, MA (first author)

Fadata Group

Business Consultant

Erlaaer Straße 60

1230 Wien

Email: [ghecevas@gmail.com](mailto:ghecevas@gmail.com)

Dr. Michael Murg

FH Joanneum, Institute of Banking and Insurance Industry

Head of Institute

Eggenberger Allee 11

8020 Graz

Email: [michael.murg@fh-joanneum.at](mailto:michael.murg@fh-joanneum.at)

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MSCI World Index gelisteten (Rück-)Versicherungsunternehmen. Die Analyse erfolgt unter Anwendung der Event Study-Methodik und untersucht, inwiefern versicherte Schäden aus Naturkatastrophen zu abnormalen Renditen der Aktienkurse führen. Die Ergebnisse verdeutlichen einen signifikanten kurzfristigen Einfluss der Katastrophen auf die Aktienkurse und bestätigen die Tendenz zu Überreaktionen der Investor:innen.

## 1. Introduction

Due to the severe damages they cause all over the world, and especially because of the consequences, they have for the insurance and reinsurance industry natural disasters have become a global problem. Numerous studies were carried out on the prevention of natural catastrophe risk, risk management, and risk minimization (e.g. Benson and Twigg 2004; Benson et al. 2007; Blau et al. 2008; Cambridge Centre for Risk Studies, 2018; Von-Dahlen and Von-Peter 2012). Further, many studies were conducted to investigate the effect of natural catastrophes on the stock prices of insurance companies (e.g. Shelor et al. 1992; Takao et al. 2013, p. 449; Lamb 1995, p. 120; Born and Viscusi 2006; Chen et al. 2008).

Shelor, Anderson and Cross (1992) examined the Loma Prieta Earthquake on 17.10.1989 and found positive abnormal returns on stock performance of insurance companies during 10 days after the occurrence of the event its impact. Aiuppa and Krueger (1995) analyzed the 1994 Los Angeles Earthquake in terms of its effect on the stock prices of insurance companies. Contrary to the results in the Loma Prieta Earthquake on 17.10.1989, there were no positive stock prices reactions following the 1994 Los Angeles Earthquake (Aiuppa and Krueger 1995). The influence of the Great East Japan Earthquake on 11.03.2011 on stock prices of nonlife insurance companies was thoroughly analyzed by Takao, Yoshizawa, Hsu and Yamasaki. During the study, it was found, that the earthquake did have a negative impact on the stock prices of local non-life insurers. Additionally, it was found that the companies with a higher level of capitalization had higher stock prices (Takao et al. 2013, p. 449).

Lamb (1995) examined the Andrew Hurricane in August 1992 and its impact on the stock prices of property insurers, categorizing them into 'exposed' and 'not exposed' insurers. He found that the hurricane had a significantly negative effect on stock prices of the exposed insurers, whereas there was no significant influence on stocks performance of unexposed insurers (Lamb 1995, p. 120). The subsequent studies in respect of major hurricanes and their influence on the firm value of an insurance company also show a negative reaction of stocks to those natural catastrophes.

The problem of the phenomenon 'natural catastrophe' lies in the fact that it has a low frequency but causes such severe losses which might endanger the financial stability of insurers and reinsurers (Nguyen 2008, p. 189). So, it is in the

interests of a (re)insurance company to run a reliable and profitable business in order to attract and to increase the interest of investors, thereby increasing the equity of the company and its value.

The aim of this article is to investigate, whether three successive destructive hurricanes named Harvey, Irma and Maria (in the (re)insurance industry called HIM) have an impact on stock prices of the (re)insurance companies and if such events influence the investors' behavior. The selected events were chosen because they were the costliest natural catastrophes in terms of economic and insured losses in the past five years. After introduction the methodology section is presented, the third section brings results and the fourth conclusion.

## 2. Methodology

The analysis was conducted based on the event study methodology. The market model is a statistical one-factor model, it represents a regression of the individual company stock returns and the returns of the whole market (Event Study Tools 2018). Thus, it illustrates the dependence of an individual stock return on the market portfolio. In the course of the analysis of the stock prices the following steps have been performed:

1. The calculation of log returns based on historical prices
2. The calculation of the expected returns based on the market model formula
3. The calculation of the abnormal returns (AR), average abnormal returns (AAR), cumulative abnormal returns (CAR) and cumulative average abnormal returns (CAAR). The graphic illustration of AAR and CAAR results is provided for each event separately.
4. The definition of hypotheses and assumptions
  - a) H0: the natural catastrophe has no significant impact on the stock prices of the sample portfolio within the event window, meaning that the abnormal returns are equal to zero.
  - b) H1: the natural catastrophe has a significant impact on stock prices of the sample portfolio within the event window period the event window
5. To answer the second research question, if the investors anticipate the natural catastrophe and, therefore, overreact, the following assumption A1 was formulated:
 

A1: the investors anticipate the forthcoming natural disaster and thus overreact prior to the event and after the event within the defined period
6. Testing of the hypotheses by means of selected statistical significance tests
7. The interpretation of the results

To avoid the repetitive description of the calculations necessary for the analysis, the main formulas are given below and should be referred to in all the three events. In order to calculate the abnormal returns in the event window, the expected returns have to be calculated in the first step. The expected or normal returns show the behavior of stock prices on condition that the event has not taken place. For the expected return the daily returns in the defined estimation window are used. The expected returns shall be calculated as follows:

$$r_{it} = \alpha_i + \beta_i r_{Mt}$$

where  $r_{it}$  is the stock return on a given day,  $r_{Mt}$  is the market return on a given day, and  $\alpha_i$  and  $\beta_i$  are estimates from a regression of the stock return against the market index. The abnormal returns (AR) will then be defined as follows:

$$AR_{it} = R_{it} - (\alpha_i + \beta_i R_{mt})$$

The average abnormal returns (AAR) are denoted as follows:

$$AAR_t = \frac{1}{N} \sum_{i=1}^N AR_{i,t}$$

The following formula defines the cumulative average abnormal returns (CAAR):

$$CAAR = \sum_{i=1}^N AAR_t$$

The technical part of the analysis (the calculation of AR, AAR, CAR, AAR and statistical significance tests) is performed by using the research web-application of the website Event Study Tools (Event Study Tools 2018). The following statistical parametric and non-parametric tests were considered for testing the hypotheses for all five events:

- The parametric Patell Z-test
- The parametric Standardized Cross-Sectional Z-test
- The non-parametric Generalized Sign Z-Test
- The non-parametric Generalized Rank Z-Test

To examine the stock reactions of the (re)insurance companies to the events in question, the sample of 36 (re)insurance companies has been collected. The MSCI World Index has been chosen as a benchmark index, which represents large and mid-cap equity performance in 23 developed markets countries. The selected sample companies comprise mainly of global reinsurance companies, global insurance companies and also local insurance companies from the exposed areas, which run property and casualty business and are supposedly exposed to the events in question. 33 out of 36 companies are listed on the MSCI

World Index, the 3 companies which are not listed on this index were included in the sample due to their exposure to some of the events. The list of selected companies is provided in the Annex 1 to the article. One of the main criteria considered for the sample selection was the exposure of (re)insurance companies to the events in question. The information whether a company was affected by one of the selected natural catastrophes, as well as the amount of sustained losses, is to be found in the annual reports of the given (re)insurance companies for the respective year of the occurrence of the event. The financial dataset comprises of historical data of daily stock prices (adjusted close price) for the selected (re)insurance companies and the MSCI World Index, which were selected from the financial portals Yahoo Finance and Reuters.

### 3. Results

#### *Hurricane Katrina*

Hurricane Katrina belongs to the category of the costliest and most destructive hurricanes in the USA in terms of economic and insured losses. Hurricane Katrina was formed as tropical depression in the south-eastern Bahamas on 24.08.2005. The intensity of the hurricane rapidly grew from the Category 3 into Category 5 after it entered the Gulf of Mexico on 27.08.2005. The intensity of storm decreased to Category 3 before making the landfall in southeast Louisiana and then on the Gulf Coast on 29.08.2005. According to the National Weather Service of the USA, Hurricane Katrina was considered one of the five deadliest hurricanes in the history of the USA (National Weather Service 2005).

For the analysis of the reaction of the stock prices in the period around Hurricane Katrina, a sample of 32 of 36 selected (re)insurance companies has been analyzed. This sample does not include 4 companies, since the information on stock prices for the observed period is missing for these companies. For the data preparation for the analysis, according to the event study methodology, the following time periods have been defined:

- The estimation window of 120 trading days (01.03.2005–15.08.2005).
- The event day 29.08.2005 (day '0').
- The event window of 11 trading days [-5; 0; +5] for observing the abnormal returns is defined, which is extended to 30 days [-5; 0; +23] to observe the cumulated abnormal returns.

In the Figure 1 below the results of the average abnormal returns are presented.

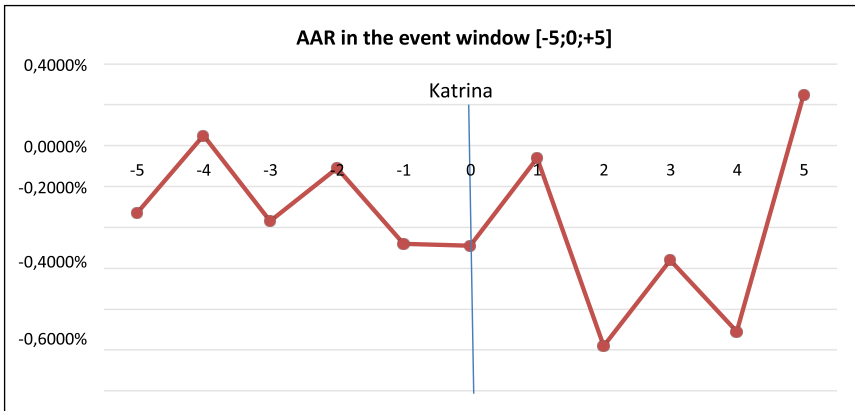


Fig. 1: Average abnormal returns generated by Katrina within the period [-5; 0; +5]

Source: own diagram

As it can be seen from Figure 1, the average abnormal returns were generated 5 days prior to the event, on the event day and 4 days after the event day. During the period [-3; 0; +4] (except days -2 and +1) the values for the average abnormal returns become statistically significant (see Table 1). Table 1 provides the p-values (the probability values) for the statistical tests at all the significance levels of 1%, 5% and 10%. On day -3, the average abnormal return dropped to -0.37% at the significance level of 1%. On day -2, the values slightly rebounded up to -0.11%, but none of the tests showed that it was significantly different from zero. On day -1 and 0, a negative response of stock prices of -0.48% and -0.49% respectively can be observed. According to Table 1, these values are statistically significant at the level 1%, which gives enough evidence to reject the  $H_0$  hypothesis and to support the  $H_1$ . It can be concluded, that the investors start reacting on the forthcoming natural catastrophe a few days prior to the event and on the event day.

On day +1 after the event, the average abnormal returns rebounded to -0.06%, which was quite close to zero. However, statistical testing does not show the statistical significance on that day.

Table 1  
Statistical testing of the impact of Katrina in the event window [-5; 0; +5]

Date	Day	AAR (%)	Standardized Cross-Sectional Test				Generalized Sign-Test				Generalized Rank-Test			
			z-value	p-value	z-value	p-value	z-value	p-value	z-value	p-value	z-value	p-value	z-value	p-value
8/22/2005	-5	-0.33	-1.1147	0.265	-1.0205	0.3075	-1.4402	0.1498	-1.326	0.1848				
8/23/2005	-4	0.05	0.2958	0.7674	0.3896	0.6968	1.0389	0.2989	0.0304	0.9757				
8/24/2005	-3	-0.37	-1.9405*	0.0524	-3.5557***	0.0004	-2.8569***	0.0043	-3.396***	0.0007				
8/25/2005	-2	-0.11	-0.6475	0.5173	-0.7523	0.4519	-0.0236	0.9812	-0.4707	0.6379				
8/26/2005	-1	-0.48	-1.9754**	0.0482	-1.9544*	0.0507	-2.1485**	0.0317	-2.5963***	0.0094				
<b>8/29/2005</b>	<b>0</b>	<b>-0.49</b>	<b>-2.4789**</b>	<b>0.0132</b>	<b>-3.6295***</b>	<b>0.0003</b>	<b>-1.7944*</b>	<b>0.0735</b>	<b>-3.0215***</b>	<b>0.0025</b>				
8/30/2005	1	-0.06	-0.37	0.7114	-0.4338	0.6644	-1.0861	0.2884	-0.9819	0.3261				
8/31/2005	2	-0.98	-5.1314***	0.0001	-4.8608***	0.0001	-3.211***	0.0013	-4.6663***	0.0001				
9/1/2005	3	-0.56	-3.0145***	0.0026	-2.4643**	0.0137	-2.8569***	0.0043	-3.315***	0.0009				
9/2/2005	4	-0.91	-3.9966***	0.0001	-4.923***	0.0001	-3.5652***	0.0004	-4.2766***	0.0001				
9/5/2005	5	0.25	0.7571	0.449	1.2722	0.2033	-1.0861	0.2774	0.3897	0.6969				

\* significant at p<0.1; \*\*significant at p<0.05; \*\*\* significant at p<0.01  
Source: own table based on z-values provided by the EventStudyTools

On day +2, a substantial decrease up to  $-0.98\%$  can be observed which is much lower than on day 0 (the event day). All statistical tests show that this value is statistically different from zero at 1% significance level, which gives the evidence to believe that the values were not randomly generated and the  $H_0$  can be rejected. On day +3, the average abnormal returns slightly rebounded to  $-0.56\%$ , but still remained negative, which is statistically significant at 1% level. On day +4, the average abnormal returns drop again up to  $-0.91\%$ , which is statistically significant at 1% level, which gives an evidence to reject the  $H_0$  and to support the  $H_1$ .

In order to test the assumption A1 whether the investors anticipate the forthcoming hurricane, it is useful to observe the development of CAAR. The cumulative abnormal returns show the cumulative effect of the impact of an event on the stock prices and demonstrate the behavior of investors within the time frame around the event.

Figure 2 shows the cumulative abnormal returns within the event window  $[-5; 0; +23]$ . It can be seen from the diagram starting from day  $-3$  and until day  $+4$  the cumulative average abnormal returns drop essentially reaching the level of  $-4.24\%$ . This is a sign of a negative overreaction of the investors, which is consistent with the assumption A1. The uncertainty regarding the exposure of (re)insurance companies to the hurricane and its extent can also be the reason of investors' overreaction.

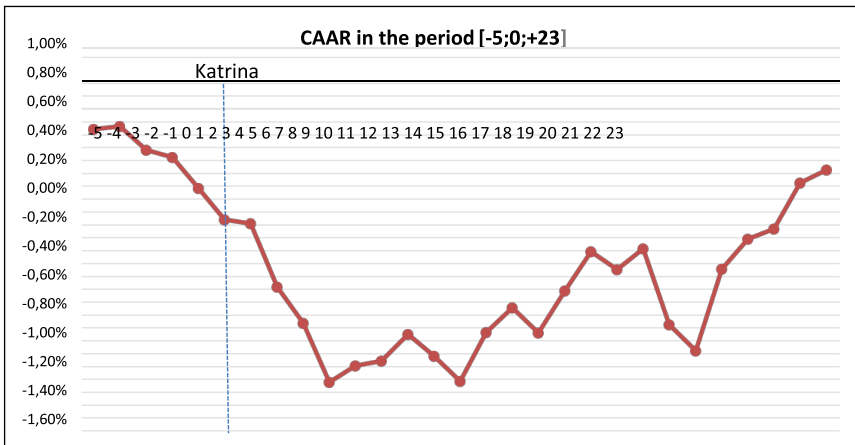


Fig. 2: The cumulative average abnormal returns generated by Katrina within the event window  $[-5; 0; +23]$

Source: own diagram



On day +10 CAAR start rebounding and reach  $-0.96\%$  on day +23, but still remain negative. The fact that the cumulative abnormal returns rebound can be a sign that investors realize, that the (re)insurance sector is has enough financial resources to cover the losses incurred as a result of Hurricane Katrina, thus bringing the feeling of certainty and trust in the invested companies.

To summarize the above described observations, it can be concluded that stock process start reacting already a few days prior to the hurricane, which resulted in the significant negative average abnormal returns in the period  $[-3; 0]$ , which gives the evidence to reject the  $H_0$  and to support the  $H_1$ . This can be also explained by the press releases regarding the forthcoming hurricane and the uncertainty of losses and consequences.

On the subsequent days after the hurricane, in the period  $[+2; +4]$  a stronger negative response of the abnormal returns can be observed. Statistical testing shows that the negative AAR during this period were significantly different from zero, which the sign that this negative effect was caused by Hurricane Katrina, thus the  $H_0$  can be rejected. The negative stocks reaction could be caused by the first estimations of losses and the extent of destructions, since investors are concerned, whether the (re)insurance companies are able to cover those losses and how this can affect their financial stability.

Despite a significantly negative reaction of the sample portfolio in the period  $[-3; +4]$ , certain sample companies showed positive abnormal returns This could be explained by the fact, that some of these companies could be less exposed to the damages.

The above described observations show that Hurricane Katrina had an impact on stock reaction of the sample portfolio and generated negative average abnormal returns within the period  $[-3; 0; +4]$ , which gives enough evidence to reject the  $H_0$  and to support the  $H_1$ .

### *The Great East Japan Earthquake (Geje), Tōhoku*

Two days before the main earthquake there was a 7.2 magnitude earthquake not far from the epicenter. The powerful 9.0 magnitude earthquake occurred on 11.03.2011 in the region of Tōhoku, on Honshu Island in Japan, triggering tsunami waves, which shortly reached the regions on the coastline. The waves in the affected areas (Iwate, Miyagi, and Fukushima) varied between 5 and 15 meters. This event is considered to be the largest humanitarian catastrophe, causing more than 13.390 killed people and 15.130 missing people went missing. The 2011 Tōhoku magnitude 9.0 Earthquake and Tsunami was named the third highest ever recorded in the world (RMS, 2011, p. 2) (Norio, Ye, Kajitani, Shi, and Tatano, 2011, p. 34).

The 2011 Tōhoku Earthquake and Tsunami caused a record economic loss in the amount of US\$210 billion, of which approximately US\$40 billion were covered by (re)insurance companies. This event is the largest catastrophe in the history in terms of insured losses and it caused an impact on financial results of the exposed (re)insurance companies, as well as affected the global and insurance equity indexes (Munich Re, 2012).

The selected sample comprises of 36 (re)insurance companies, including global (re)insurance companies, companies from the USA insurance markets and a few companies from Asian insurance market. The following time periods around the event were defined:

- The estimation window of 110 trading days (01.10.2010–03.03.2010)
- The event day 11.03.2011 (the day '0')
- The event window of 12 trading days for observing the abnormal returns (04.03.2011–21.03.2011), which is extended to 30 days to observe the cumulated effect of abnormal returns (04.03.2011–14.04.2011)

In order to investigate, whether the 2011 Tōhoku Earthquake generated an effect on stock returns, the average abnormal returns were calculated within the event window  $[-5; 0; +6]$ . The result of AAR is demonstrated in Figure 3. Table 2 provides statistical significance of AAR during the event window  $[-5; 0; +6]$ .

As it can be observed in Figure 3, two days prior to the main earthquake the stocks reacted positively resulting in AAR of +0.40%, which is statistically significant at 1% level. It should be mentioned that a few days before the main

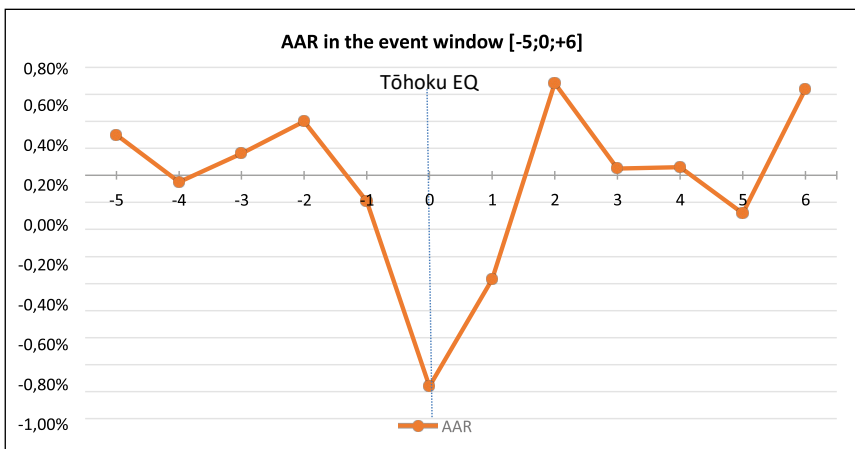


Fig. 3: The average abnormal returns generated by the Tōhoku earthquake within the event window  $[-5; 0; +6]$

Source: own diagram

Table 2  
Statistical testing of the impact of Tohoku earthquake in the period [-5; 0; +6]

Date	Day	AAR (%)	Patell Z		Standardized Cross-Sectional Test		Generalized Sign Z		Generalized Rank Z	
			z-score	p-value	z-score	p-value	z-score	p-value	z-score	p-value
2/7/2011	-5	0.30	0.9268	0.354	0.966	0.334	0.9587	0.3377	0.8843	0.3765
3/7/2011	-4	-0.05	-0.1368	0.8912	-0.247	0.8049	1.2924	0.1962	0.1196	0.9048
3/8/2011	-3	0.16	1.695	0.0901	1.5276	0.1266	0.9587	0.3377	1.4356	0.1511
3/9/2011	-2	0.40	1.9242*	0.0543	2.7248***	0.0064	1.6262	0.1039	2.6944***	0.0071
3/10/2011	-1	-0.19	-0.9139	0.3608	-1.3906	0.1643	-1.0437	0.2966	-1.5137	0.1301
<b>3/11/2011</b>	<b>0</b>	<b>-1.56</b>	<b>-7.4057***</b>	<b>0.0001</b>	<b>-3.033***</b>	<b>0.0005</b>	<b>-0.7099</b>	<b>0.4778</b>	<b>-2.8869***</b>	<b>0.0039</b>
3/14/2011	1	-0.77	-2.9704***	0.003	-1.7273	0.0841	-0.3762	0.7068	-1.3472	0.1779
3/15/2011	2	0.68	4.0905***	0.0001	3.1508***	0.0016	3.2948***	0.001	3.6359***	0.0003
3/16/2011	3	0.05	0.0896	0.9286	0.0682	0.9456	0.2913	0.7708	0.0676	0.9461
3/17/2011	4	0.06	0.3371	0.736	0.2662	0.7901	-1.0437	0.2966	0.0702	0.944
3/18/2011	5	-0.28	-1.36	0.1738	-1.3916	0.164	-0.3762	0.7068	-0.7698	0.4414
3/21/2011	6	0.64	3.3217***	0.0009	4.7302***	0.0001	3.6285***	0.0003	4.4994***	0.0001

\* significant at p<0.1; \*\*significant at p<0.05; \*\*\* significant at p<0.01  
Source: own table, z-scores based on the EventStudyTools

earthquake a magnitude 7.2 foreshock took place. It could be the case that it was expected that a subsequent earthquake might occur. On the day prior to the event a slightly negative average abnormal return of  $-0.19\%$ , but this result not significantly different from zero. On the day of the event, the day 0, a considerable negative average abnormal return of  $-1.56\%$  was generated and this reaction is statistically significant at 1% level. This means that the probability that this outcome could happen by chance is very low (less than 1%).

This observation gives a strong evidence to reject the  $H_0$  and to support the  $H_1$ , meaning that the earthquake did have a negative significant effect on stock prices of the sample portfolio on the event day. This outcome is also comparable with findings in the research from Takao&Yoshizawa&Hsu&Yamasaki (2013).

On 11.03.2011 it was clear that this disaster would cause enormous losses and consequences on the long term and there was high uncertainty in the estimation of losses, given the fact that the triggered tsunami has led to the nuclear crisis.

However, the losses caused by nuclear energy are as a rule excluded from the (re)insurance coverage. On 11.03.2011, the global leading reinsurance company Munich Re released a statement, according to which the damages caused by nuclear plants would not be a subject of private insurance. In that press release, it was also mentioned that, only a small portion of Japanese personal insurance risks was transferred abroad. Munich Re also stated that it would contribute to the settlement of losses being a reliably partner in the business relations with the Japanese insurance market (Munich Re, 2011).

On the event day there were more statements issued by other (re)insurance companies announcing their preliminary exposure to the damages caused by the earthquake. The largest insurance company in Australia, QBE Insurance Group, issued a statement with the preliminary estimation of their exposure in the payment of losses in the amount of US\$125.28 million, which was within their allowance of US\$1.65 billion net of reinsurance (QBE Insurance Group, 2011).

On the day after the event the average abnormal returns slightly rebounded, but still remained negative at the level of  $-0.77\%$ , which is not statistically significant. Day +2 exhibits an essential increase of the abnormal up to  $+0.68\%$  and it is statistically significant, which gives the evidence that this outcome could be caused by the event, which supports the  $H_1$  and rejects  $H_0$ . During the period [+3; +5] there was a decrease in AAR, but the values were not significantly different from zero. On day +6 the average abnormal returns were also positive at the level of  $+0.64\%$  and this result is significant at 1% level. This positive stock prices response can be associated with a reaction to the published in the media after the earthquake regarding the estimation of losses, as well as the more accurate assessment of the exposure of (re)insurance companies to this

event. This result is also consistent with findings in the study from Takao & Yoshizawa & Hsu & Yamasaki (2013).

An interesting observation can be made when considering the abnormal returns of individual companies. On day -2, where AAR of the sample portfolio were significantly positive, 14 companies out of 36 companies exhibited negative abnormal returns. On the event day 0, where the average abnormal returns for the whole sample were significantly negative, 15 companies out of 36 had a positive reaction to the event. Two days after the event, on day +2, where AAR of the sample portfolio were significantly positive, 9 companies out of 36 had a negative response to the event. This finding means, that not all the sample companies faced a similar response to the event due to different reasons; however, the average result for the whole sample is statistically significant.

Figure 4 provides the information on the cumulative effect of stocks' reactions within the event window [-5; 0; +24]. It can be observed that on day -2, there was a favorable reaction and the cumulative average abnormal return reached its positive level of 0.81%. This could be a sign of investors' awareness about the earthquake two days before it. However, as it was mentioned before, the earthquake is not easy to predict in advance, so there could be other also other reasons for this response. On the event day 0 the cumulative abnormal returns became negative and dropped down to -0.94% and on the day after the earthquake, day +1, it reached its peak negative level of -1.71%. On day +2 the cumulative abnormal returns have started rebounding and reached their positive level on day +15, and regained their value.

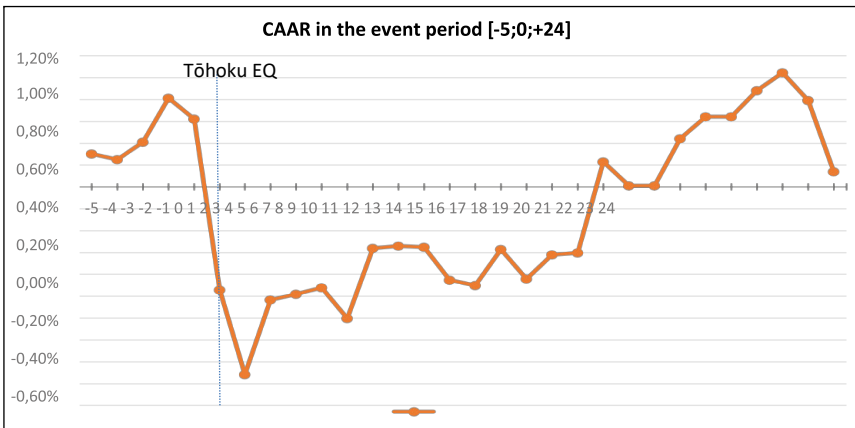


Fig. 4: The cumulative average abnormal returns generated by the Tōhoku earthquake within the event window [-5; 0; +24]

Source: own diagram

In summary, the acquired findings show both positive and negative response of the stock prices of the sample portfolio around the event and it is statistically significant at 1 % level. Therefore, there is a significant evidence to reject the H0 and to support the H1 assuming that the Tōhoku Earthquake had a significant impact of stock prices of the sample companies. The results on the cumulative average abnormal returns indicate a similar result, exhibiting positive cumulative abnormal returns a few days prior to the event and a strong negative reaction on the event day and after, regaining the value to the positive level on the day +15. These findings can support the assumption A1 that the investors anticipate the event and overreact.

It is essential to mention, that the Japanese government, the non-life insurance companies and Japan Earthquake Reinsurance were actively involved in recovering the insured losses after the earthquake in Tōhoku (Takao, Takuya, Shuofen, & Yamasaki, 2013, p. 450). Therefore, the extent of the exposure of foreign (re)insurance companies in this event was reduced by payments made by the Japanese government, the Japanese earthquake insurance and reinsurance scheme. It is assumed that a positive stock prices response a few days after the earthquake could be the result of investors' awareness of the probable exposure of the (re)insurance companies they invested in. It can be also the case that, after such an earthquake, it is expected that the (re)insurance companies might increase the premium rates for the earthquake risk and thus offset the losses sustained as a result of Tōhoku earthquake, which will also have a positive effect on the financial results of (re)insurance companies. It can be also expected, that the demand of earthquake coverage will increase due to the awareness of people of the necessity to have the insurance coverage in case of such devastating catastrophe (Takao, Takuya, Shuofen, & Yamasaki, 2013). This could also result in the increase of premium volumes of the (re)insurance companies, which is positively considered by their investors.

Harvey, Irma and Maria sizably affected the USA and Caribbean Islands in the Atlantic hurricane season during the period August-October 2017. This trio of hurricanes is considered to be the costliest hurricanes in terms of economic and insured losses, which amounted to US\$ 215 billion and US\$92 billion respectively. The (re)insurance industry has not experienced such extraordinary insured losses caused by a series of successive hurricanes before (MunichRe, 2018). However, the significant part of losses was not insured, resulting in the protection gap of US\$ 123 billion, meaning that more than a half of total losses will not affect the financial stability of the (re)insurance industry.

An essential part of losses was caused by flooding, which was triggered by hurricanes. In this context, it is to be noted that flood risk does not form part of a standard homeowners' insurance policy and is covered by the National Flood

Insurance Program, which will reduce the burden of covering the insured losses by local and global (re)insurance companies.

Hurricanes Harvey and Irma had an impact on financial markets in different fields, including (re)insurance industry. The stock prices of several domestic insurance companies like Progressive, Allstate, Berkshire Hathaway, AIG, Travelers and Chubb Limited dropped after the landfall of Hurricane Harvey (Low, 2017). According to Financial Times the stock price of the reinsurance company Everest also experienced an essential decline, but then rebounded on 08.09.2017.

The trio of hurricanes HIM is considered as a cluster event due to the fact that they occurred shortly one after another. In the following sections the impact of each of the three hurricanes Harvey, Irma and Maria on the stock prices of the sample portfolio will be analyzed separately.

### *Hurricane Harvey*

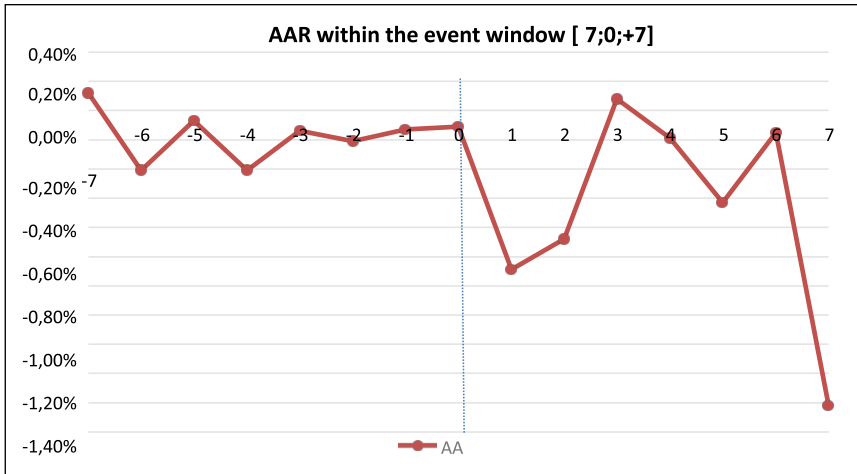
Harvey was formed as a tropical wave on the African coast on 13.08.2017 and on 17.08.2017 it grew into a tropical storm moving to the Caribbean Sea. On 23.08.2017 the storm grew into Tropical Depression Harvey with the Category 1 hurricane and then moved towards Texas with increasing intensity. On 24.08.2017 Harvey was assigned the Category 4 hurricane by The National Hurricane Center. Harvey made its landfall in southeast Texas on Friday 25.08.2017 late in the evening as a Category 4 hurricane. The hurricane resulted in heavy rains and enormous flooding, damaging two flood-control reservoirs and significantly raising the level of water in Houston area (National Weather Service, 2017). Hurricane Harvey caused US\$85 billion economic losses, among which US\$30 billion was insured (MunichRe, 2018).

For the analysis of the effect of Hurricane Harvey on stock prices of (re)insurance companies the sample portfolio compounded of 36 (re)insurance companies was used.

The time line was defined as follows:

- The estimation window of 135 trading days (08.02.2017–15.08.2017)
- The event day 25.08.2017 (the day ‘0’)
- The event window of 15 trading days for observing the abnormal returns (16.08.2017–05.09.2017), which is extended to 30 trading days to observe the cumulated effect of abnormal returns (16.08.2017–29.09.2017). It should be noted here, that this event window includes all the three hurricanes as they occurred very close to each.

In the Figure 5 behavior of AAR generated by Hurricane Harvey within the period  $[-7; 0; +7]$  is presented, while in the Table 3 statistical testing of the effects on stock prices caused by Harvey is presented.



*Fig. 5: Average abnormal returns generated by Harvey within the event window  $[-7; 0; +7]$*

Source: own diagram

Figure 5 shows the decline in the average abnormal returns on days  $-6$ ,  $-4$  and  $-2$  to  $-0.41\%$ ,  $-0.41\%$  and  $-0.21\%$  respectively and these results as is shown in the Table 3 are statically significant at 1% level.



Table 3  
Statistical testing of the impact of Harvey in the event window [-7; 0; +7]

Day	AAR (%)	Patell Z		Standardized Cross-Sectional Test		Generalized Sign Z		Generalized Rank Z	
		z-score	p-value	z-score	p-value	z-score	p-value	z-score	p-value
8/16/2017	0.12	0.7525	0.4518	0.8293	0.4069	-0.0148	0.9882	-0.034	0.9729
8/17/2017	-0.41	-2.3492**	0.0188	-2.2769**	0.0228	-1.0148	0.3102	-2.1779**	0.0294
8/18/2017	-0.07	-0.2964	0.7669	-0.3294	0.7419	-0.3481	0.7278	-0.2377	0.8121
8/21/2017	-0.41	-2.6222***	0.0087	-3.8671***	0.0001	-3.0148***	0.0026	-3.8081	0.0001
8/22/2017	-0.14	-0.7354	0.4621	-1.1644	0.2443	-1.0148	0.3102	-1.3967	0.1625
8/23/2017	-0.21	-1.5246	0.1274	-3.1246***	0.0018	-2.3482**	0.0189	-3.2222***	0.0013
8/24/2017	-0.13	-1.3478	0.1777	-0.9802	0.327	-1.0148	0.3102	-1.5028	0.1329
8/25/2017	<b>0</b>	<b>-0.4061</b>	<b>0.6847</b>	<b>-0.5232</b>	<b>0.6008</b>	<b>-0.6815</b>	<b>0.4956</b>	<b>-0.4245</b>	<b>0.6712</b>
8/28/2017	-1.09	-8.4272***	0.0001	-7.3883***	0.0001	-5.0148***	0.0001	-6.5293***	0.0001
8/29/2017	-0.88	-6.019***	0.0001	-5.5865***	0.0001	-3.6815***	0.0002	-5.192***	0.0001
8/30/2017	0.08	0.4746	0.6351	0.3918	0.6952	-0.0148	0.9882	0.5774	0.5637
8/31/2017	-0.19	-1.5819	0.1137	-2.2228**	0.0262	-1.6815*	0.0927	-2.1014**	0.0356
9/1/2017	-0.63	-4.5456***	0.0001	-4.239***	0.0001	-3.3482***	0.0008	-3.9439***	0.0001
9/4/2017	-0.15	-1.5452	0.1223	-1.7541*	0.0794	-0.0148	0.9882	-1.3521	0.1763
9/5/2017	-2.02	-15.5521***	0.0001	-6.5032***	0.0001	-5.3482***	0.0001	-6.1005***	0.0001

\* significant at p<0.1; \*\*significant at p<0.05; \*\*\* significant at p<0.01

Source: own table, z-values are based on the EventStudyTools

This outcome gives the evidence that those negative reactions could be caused by the hurricane, therefore the H0 can be rejected and the H1 can be supported. It should be also taken into consideration that during those days there were warnings about the forthcoming hurricane and its growing intensity. On day 0 the average abnormal returns were negative at the level  $-0.11\%$ , but this value is not statistically significant. On day +1 there was a substantial decrease of AAR to  $-1.09\%$  and this value is statistically significant at 1% level. The significant result on day +1 (and not on the day of the event 0) can be explained by the fact, that the landfall of the hurricane took place late in the evening on Friday 25.08.2017, when the stock exchange was closed. Day +1 (28.08.2017) was the first trading day after the landfall of Harvey. Since the negative effect on that day is statistically significant, it gives enough evidence to consider that it was caused by hurricane Harvey, therefore the H0 can be rejected and the H1 can be supported. On day +2 the abnormal returns slightly rebounded, but still stayed negative at  $-0.88\%$  and this value is statistically significant at 1% level. On these days the statements with the first estimations of large losses were announced, still there was a lot of uncertainty. This information could affect the decisions of investors. On day +3 positive AAR can be observed, but this result is not statistically significant. On the subsequent days +4 and +5, AAR dropped again to  $-0.19\%$  and  $-0.63\%$  respectively, which is statistically significant at 5% and at 1%. A strong negative average abnormal returns of  $-2.02\%$  at significance level 1% can be observed on day +7 (05.08.2017). However, this can be an effect of the following devastating Hurricane Irma, which made its landfall on 06.09.2017. This effect will be described in the section about Hurricane Irma. The length of the event window was restricted in order to avoid the overlapping of event days of the three hurricanes. In the Figure 2 the cumulative average abnormal returns within the period  $[-7; 0; +22]$  is illustrated. This information is helpful to see the cumulative impact of Hurricane Harvey on the stock prices of the sample portfolio. It can be observed that CAAR essentially declined and reached a negative value starting with day  $-4$  and it kept gradually dropping until the event day 0 reaching the level of  $-1.36\%$ . This can be a sign that investors anticipated the hurricane, which supports the assumption A1. Starting with the trading day after the event (28.08.2017), CAAR significantly dropped to  $-2.45\%$ . CAAR kept falling until day +6 and constituted  $-4.22\%$ , which indicates that the over-reaction of investors continued and this supports the assumption A1. On day +7, a strong negative reaction of  $-6.24\%$  can be observed and it kept essentially decreasing to  $-8.63\%$  on day +9. However, the observation during the days +7 till the day +9 can be associated more with the effect, caused by the next coming major Hurricane Irma, which occurred on day +8 (landfall on 06.09.2017).

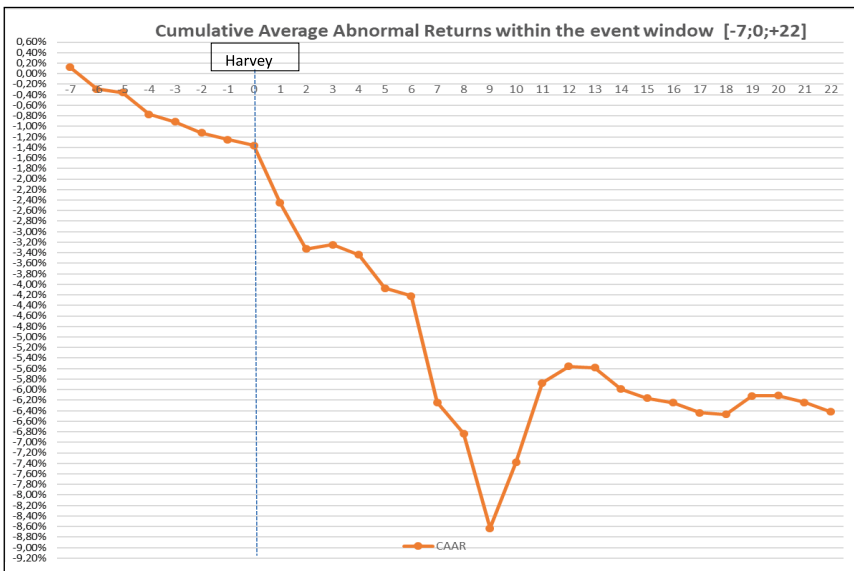


Fig. 6: Cumulative average abnormal returns generated by Harvey within the event window  $[-7; 0; +22]$

Source: own diagram

Figure 6 illustrates that the cumulative negative effect in stock prices lasted until the last day of the event window and still did not rebound to the positive level. However, it should be mentioned here, that the 22 days after the event include also the effects caused by the two subsequent major hurricanes occurred close to each other, namely hurricanes Irma and Maria. The impact of these two hurricanes will be analyzed in the following sections.

Summarizing the stocks effects generated around Hurricane Harvey during the event window  $[-7; 0; +7]$ , it can be concluded that the negative stocks prices response a few days prior to the hurricane (days  $-6$ ,  $-4$  and  $-2$ ) was not by chance due to the statistical significance at 1% level. This gives the evidence to reject the  $H_0$  and to support the  $H_1$ , assuming that this negative effect was caused by Hurricane Harvey. On the day of the event, the day 0, the average abnormal return stayed at the negative level of  $-0,11\%$ , which was not statistically significant. A possible reason for this result might be the uncertainty concerning where and when Hurricane Harvey was going to make its landfall, as well as which impact in terms of inflicted damages it could have. Therefore, a significant stocks reaction on the event day is not seen on Friday 25.08.2017.

The results in the after-event periods  $[+1; +2]$  and  $[+4; +5]$  show a negative stocks' reaction at the significance level 1% (except day +4 at significance level

5 %). These findings give enough evidence to believe that this negative response was not generated randomly, but caused by Hurricane Harvey, which rejects the H0 and supports the H1.

An interesting observation can be made on day +1. Only 3 sample companies from 36 still had positive abnormal returns on that day, which means that the stocks of 91,6 % of the whole sample companies reacted negatively. This information can be seen as a contribution to the H1, that Hurricane Harvey caused the negative stock prices response of (re)insurance companies on that day. These results are also consistent with the statements of financial and investments analysts made after the landfall of Hurricane Harvey. The investment bank Morgan Stanley issued a statement on 28.08.2017 published by a financial and business news website Business Insider, mentioning the impact of Hurricane Harvey on the stock prices of certain domestic insurance companies, which were exposed to the damages caused. According to Morgan Stanley, an essential share of losses will be borne by the ten largest domestic homeowner's companies. The company Allstate and Travellers experienced a negative stock prices reaction on 28.08.2017, dropping by 1.53 % and 2.63 % respectively. The stocks of Progressive and Berkshire Hathaway also declined by 2.1 % and 0.77 % respectively. Additionally, it was stated that the (re)insurance industry had sufficient capital to face the losses (Rapier, 2017).

On 28.08.2017, the first estimations of the insured losses were provided by Wall Street analysts and published by Reuters, according to which the property and casualty insurers will cover approximately US\$20 billion and named Hurricane Harvey the 'costliest storm in history for U.S. insurers' (Reuters, 2017). The announcement of such enormous losses could have influenced the reaction of investors, which resulted in negative effects.

Answering the question, if investors anticipated the hurricane and overreacted, it can be noted that 4 days prior to the event there was a negative reaction in the cumulative average abnormal returns and it remained negative till day 0 approximately at the same level. Considering the warnings and permanent updates on the news about the hurricane, it can be assumed that the investors were aware of the coming event. The negative response of the cumulative abnormal returns shows a slight overreaction. Starting from day +1 and lasting until day +6 after the event, an essential strengthening of the cumulative negative effect of -4.22 % can be observed.

These findings give reasons to believe that the investors overreacted prior to and a few days after the event and the stock prices did not regain their value, which gives reasons to support the assumption A1.

*Hurricane Irma*

Hurricane Irma was the next major hurricane following Hurricane Harvey. Irma was formed as a tropical wave off the African coast on 27.08.2017 and then grew into a hurricane with strength category 2 and 3 on 01.09.2017. The hurricane was assigned the highest category 5 in east-southeast of Barbuda Island on 05.09.2017 and later on 06.09.2017 made its first landfall on Barbuda as a category 5 hurricane at its highest intensity with a speed of 285km/h. On the same day, Irma made its next landfall in the British Virgin Islands. During three days, the hurricane maintained the highest intensity. On 09.09.2017, Irma made another landfall in Cuba and then moved to south-west coast of Florida, where it made its last landfall as a Category 3 hurricane on Sunday 10.09.2017 at 19:30UTC (NationalHurricaneCenter, 2018). As a result of the damages caused, one fourth of the population of Florida had to be evacuated.

Hurricane Irma caused US\$67 billion economic losses, including US\$32 billion insured losses. The protection gap constituted USD\$35 billion. According to Munich Re, Irma was the most expensive natural catastrophe in terms of insured losses in the year 2017 (MunichRe, 2018). The number and the components of the sample portfolio remained the same as for Hurricane Harvey.

The following observation periods were considered for the analysis:

- The estimation window of 140 trading days (09.02.2017–23.08.2017).
- The event day 06.09.2017 (the day ‘0’), the day of the first landfall. The last major landfall took place on 10.09.2017, which will be also taken into consideration in the analysis.
- The event window of 13 trading days for observing the abnormal returns (29.08.2017–14.09.2017), which is extended to 30 trading days to analyze the cumulated effect of abnormal returns during the period 29.08.2017–09.10.2017. The later period includes the third destructive hurricane Maria, which made its landfall on 19.09.2017.

The hypotheses were tested based on statistical testing. As in previous events the Generalized Rank Z-Test was used as a reference test.

The average abnormal returns generated by Hurricane Irma in the event window  $[-6; 0; +6]$  are presented in the Figure 7.

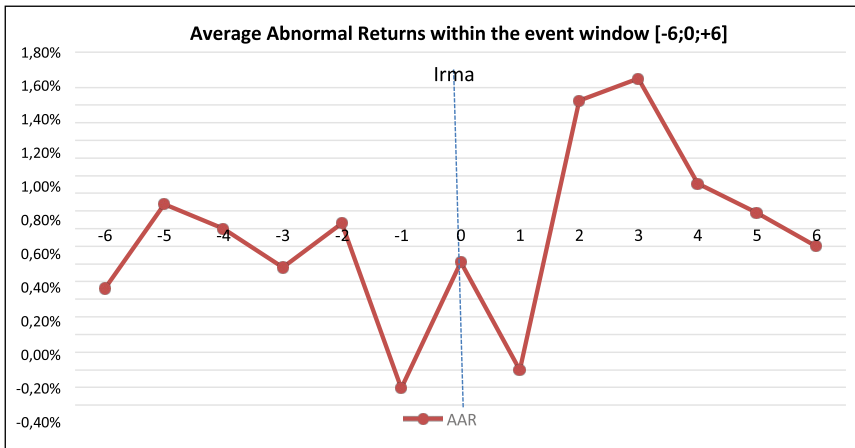


Fig. 7: Average abnormal returns generated by Irma within the event window  $[-6; 0; +6]$

Source: own diagram

Figure 7 shows significant negative AAR of  $-0.88\%$  on day  $-6$ , which is associated with the effect of previous Hurricane Harvey. On day  $-3$  before the event a significantly negative AAR of  $-0.64\%$  can be observed, which can be associated with Hurricane Irma. This result gives the evidence that this effect was not caused randomly, but was the result of the reaction caused by the forthcoming landfall of Hurricane Irma, due to the information published on the hurricane gaining the intensity and becoming a Category 3 hurricane. However, it is not excluded, that this stocks' decline could still be the result of the impact caused by Harvey due to more realistic estimation of the incurred damages and the exposure of the (re)insurance industry to those damages. In both cases, due to the statistical significance on such a high level, it can be assumed, that it was the effect caused either by Harvey or by Irma. One day before the first landfall of Irma a strong negative reaction down to  $-2.01\%$  can be observed and is statistically significant at 1% level. This evidence allows assuming that such a drop in stock prices could be caused by the coming Hurricane Irma and that it was anticipated, hence the  $H_0$  can be rejected and the  $H_1$  is supported. Such a decline could be a sign of investors' fears regarding the damages this Category 5 hurricane could lead to. It has to be stated that on that day only one sample company had a positive abnormal return and the rest 35 were negative, so this was a strong impact almost on all sample companies. Detailed results of statistical testing of the effects on stock prices caused by Irma are shown in Table 4.

Table 4  
 Statistical testing of the impact of Irma within the event window [-6; 0; +6]

Date	Day	AAR (%)	Patell Z		Standardized Cross-Sectional Test		Generalized Sign Z		Generalized Rank Z	
			z-score	p-value	z-score	p-value	z-score	p-value	z-score	p-value
8/29/2017	-6	-0.88	-6.0477***	0.0001	-5.5366***	0.0001	-4.0119***	0.0001	-5.1062***	0.0001
8/30/2017	-5	0.08	0.5127	0.6082	0.4229	0.6724	-0.0119	0.3116	0.606	0.5445
8/31/2017	-4	-0.20	-1.6704*	0.0948	-2.3017	0.0214	-1.6786*	0.0932	-2.1661	0.0303
9/1/2017	-3	-0.64	-4.5745***	0.0001	-4.2716***	0.0001	-3.3452***	0.0008	-3.9638***	0.0001
9/4/2017	-2	-0.14	-1.51	0.131	-1.6911	0.0908	0.6548	0.5126	-1.2858	0.1985
9/5/2017	-1	-2.01	-15.7206***	0.0001	-6.4979***	0.0001	-5.6786***	0.0001	-6.1176***	0.0001
9/6/2017	0	-0.58	-3.7039***	0.0002	-2.235**	0.0254	-3.0119	0.0026	-2.4036**	0.0162
9/7/2017	1	-1.80	-13.7122***	0.0001	-7.1163***	0.0001	-4.6786***	0.0001	-6.609***	0.0001
9/8/2017	2	1.25	10.6422***	0.0001	4.0583***	0.0001	2.3214**	0.0203	3.714***	0.0002
9/11/2017	3	1.50	11.7208***	0.0001	6.3307***	0.0001	4.3214***	0.0001	5.745***	0.0001
9/12/2017	4	0.31	1.8943*	0.0582	2.4063**	0.0161	1.9881**	0.0468	2.4814**	0.0131
9/13/2017	5	-0.02	-0.4342	0.6641	-0.3684	0.7126	-0.6786	0.4974	-0.7166	0.4736
9/14/2017	6	-0.40	-2.9599***	0.0031	-3.1989***	0.0014	-2.6786***	0.0074	-3.282***	0.001

\* significant at p<0.1; \*\*significant at p<0.05; \*\*\* significant at p<0.01  
 Source: own table, z-scores provided by the EventStudy/Tools

On day 0, the day of Irma's first landfall, AAR slightly rebounded to  $-0.58\%$ , but still remained negative at the significance level  $5\%$ . The day after the event (day +1), AAR fell again to  $-1.80\%$  and this change is statistically significant at  $1\%$  level. It can be assumed that this drop in stock prices could be caused by this event, which is the evidence to reject the  $H_0$  and to support the  $H_1$ . Such a negative response could be also caused by the expectations that a Category 5 hurricane could cause enormous destructions also in its further landfalls it was going to make. Looking at the reactions of the individual sample companies, it can be observed that 33 companies had negative abnormal returns and 3 companies had a positive reaction, so this event negatively affected almost all the sample companies.

A noteworthy stocks' reaction can be observed on day +2 (on 08.09.2017) after the event, the average abnormal returns have sharply increased and reached the level of  $+1.25\%$  in comparison with the day before with  $-1.80\%$ . This increase is statistically significant at  $1\%$  level and is the evidence, that this reaction was caused by Hurricane Irma and thereby the  $H_0$  can be rejected. On that day, 25 analyzed companies had a positive abnormal return and 11 companies had a decline in their stock prices.

On Sunday 10.09.2017, Irma made its last and the most destructive landfall in Florida. This day was a non-trading day therefore the eventual effects can be seen on 11.09.2017, which is day +3 in the analysis. According to the obtained results, AAR continued increasing and reached the level of  $+1.5\%$  on that day. This result is statistically significant at  $1\%$  level, meaning that this positive response was still the effect of Hurricane Irma. Such a positive stocks' reaction on days +2 and +3 could be associated with the reaction to statements made in press regarding the fact, that insurance industry was strong enough to cover the damages without having an impact on the capital, which means that (re)insurance companies are financially strong and have enough earnings (Financial Times, 2017). Examining the stock reaction of the sample companies, it can be observed that 31 companies had a positive abnormal return and 5 of them were negative. Overall, this event had a positive effect on the stocks of majority sample companies on trading days +2 and +3. In order to analyze, if the investors anticipated the hurricane, the cumulative average abnormal returns during the period  $[-6; 0; +23]$  were calculated and they are illustrated in the Figure 8.

Figure 8 shows that the average abnormal returns were already at the negative level of  $-2.20\%$  on day  $-6$ . As it was previously mentioned, this negative effect could be associated with the impact of previous Hurricane Harvey. Starting with day  $-3$ , the cumulative average abnormal return started falling essentially and reached the level of  $-5.11\%$  on day  $-1$ , when the average abnormal returns had the lowest level. This can be a sign that investors anticipated the forthcoming hurricane.



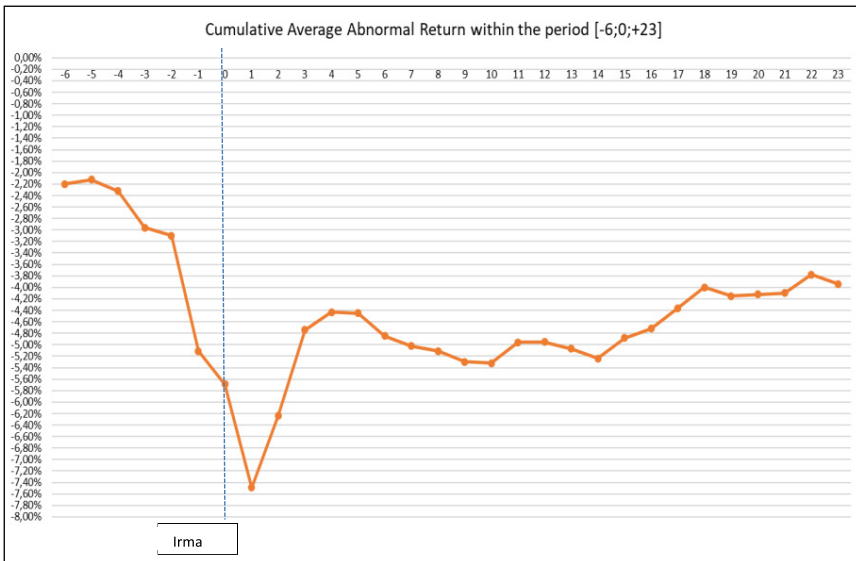


Fig. 8: Cumulative average abnormal returns generated by Irma within the event window [-6; 0; +23]

Source: own diagram

On the event day 0 and the day after the event, CAAR kept falling down to -5.69% and 7.49% respectively. This strongly negative cumulative effect indicates the overreaction of investors, which supports the assumption A1. During the period [+2; +4] CAAR rebounded from -6.24% to -4.43%, even considering the last most devastating landfall on 10.09.2017. However, it seems that the impact of Hurricane Irma was quite strong (also considering the effect of Hurricane Harvey) and the stock prices did not get back to a positive level within the observed event window.

Summarizing the behavior of AAR of the sample portfolio around Hurricane Irma, it can be concluded that this event had a significant effect on each day during the period [-1;+4], resulting in both negative and positive stocks' reactions. The significant negative reaction can be observed during the period [-1; 0;+1]. This result is also consistent with the statements made by the large American business and financial news Chanel CNBC on 05.09.2017, declaring that this day showed a very large decline in insurance stock prices (CNBC, 2017). During the period [+2; +4] there was a significantly positive effect of the stock prices, even prior and after the last the most destructive landfall of Irma in Florida on 10.09.2017. In that period, many statements were published in the media, which might have also influenced the behavior of investors. On 08.09.2017, CBS News stated that due to the fact, that flood coverage was not included in the

standard home-owners' insurance policy, insurance companies would not be exposed to these kind of damages. It was also stated that according to the estimations of the USB Group AG analysts, insurance companies were strong enough to cover the losses without the need to raise the capital (Mirhaydari, 2017).

On 11.09.2017 (day +3), the American business and finance magazine Fortune published a statement based on insurer's view of hurricanes Harvey and Irma, in which it was declared that the damages caused by Irma in Florida might affect the financial result of insurance companies, but would not affect their capital and their ratings (Fortune, 2017). This information could be seen as favorable by investors.

On 13.09.2017 Munich Re made a statement that the losses caused by Harvey and Irma threat profit guidance for the year 2017. However, even experiencing such record losses, Munich Re has enough capital and resources to continue providing the reinsurance protection to the clients (MunichRe, 2017).

Analyzing the cumulative effect of AAR it can be concluded that there were signs of investors anticipating the event and overreacting right prior to and a few days after the event. The cumulative average abnormal returns did not rebound to the positive level during the observed event window.

### *Hurricane Maria*

The next devastating subsequent hurricane was Maria, which was considered the third costliest hurricane in the history of the USA. Maria took its start as a tropical wave on the west coast of Africa on 12.09.2017 and then grew into a tropical storm on 16.09.2017. On 18.09.2017 Maria got a status of a Category 5 hurricane, as it approached Dominica, where it made its landfall on 19.09.2017. Maria moved then towards Puerto Rico and made its landfall on 20.09.2017 as a Category 4 hurricane (National Hurricane Center, 2019, pp. 1–3).

As a consequence, Maria caused enormous damages to the Caribbean Islands, resulting in the destruction of the infrastructure and production plants of Puerto Rico. Maria was a relatively small, but a very intensive hurricane. The economic damages constituted approximately US\$65 billion, including insured losses in the amount of US\$30 billion (MunichRe, 2018, p. 2). As in previous events, the same data sample consisting of 36 (re)insurance companies was used for the analysis.

The following observation periods have been defined:

- The estimation window length is 140 trading days (21.02.2017–04.09.2017)
- The event day is 19.09.2017 (the day '0')

- The event window of 12 trading days for observing the abnormal returns (12.09.2017–27.09.2017) and 30 trading days for watching the cumulative effect of abnormal returns during the period 12.09.2017–23.10.2017.

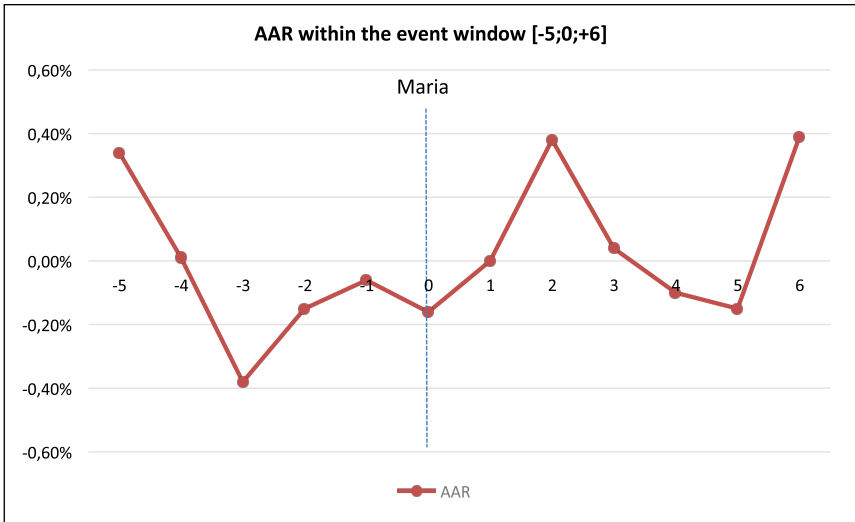


Fig. 9: Average abnormal returns generated by Maria within the event window [-5; 0; +6]

Source: own diagram

Figure 5 shows a positive result of 0.34% on day -5 and it is statistically significant at 1% level. However, it should be kept in mind that this positive effect could still be the result of the previous Hurricane Irma, which generated positive abnormal returns after the event day. Starting from day -4, the average abnormal returns fall and reach a negative result of -0.38% on day -3, which is statically significant at 1% level. This can be a sign that this outcome is associated with the coming Hurricane Maria and was not generated randomly. Therefore, the H0 can be rejected and the H1 supported, although this negative decline is not as strong as in case of hurricanes Harvey and Irma.

Further it can be observed that AAR rebound to -0.06% by day -1 and fall to -0,16% on the day 0, the day of Maria’s landfall. Detailed results of statistical testing of the average abnormal returns is given in Table 5.

Table 5  
 Statistical testing of the effect of Maria on stock prices within the period [-5; 0; +6]

Date	Days	AAR (%)	Patell Z		Standardized Cross-Sectional Test		Generalized Sign Z		Generalized Rank Z	
			z-score	p-value	z-score	p-value	z-score	p-value	z-score	p-value
9/12/2017	-5	0.34	2.1583**	0.0309	2.7666***	0.0057	2.3072**	0.021	2.7148***	0.0066
9/13/2017	-4	0.01	-0.3091	0.7572	-0.2825	0.7776	-0.3595	0.7192	-0.5241	0.6002
9/14/2017	-3	-0.38	-2.7538***	0.0059	-3.0728***	0.0021	-2.3595**	0.0183	-3.0834***	0.002
9/15/2017	-2	-0.15	-1.2459	0.2128	-0.9295	0.3526	-0.6929	0.4884	-0.7657	0.4439
9/18/2017	-1	-0.06	-0.3868	0.6989	-0.4454	0.656	-1.0262	0.3048	-0.3931	0.6942
9/19/2017	0	-0.16	-1.4024	0.1608	-1.2084	0.2269	-2.0262**	0.0427	-1.6625	0.0964
9/20/2017	1	0.0006	0.0361	0.9712	0.0433	0.9655	0.6405	0.5218	0.1024	0.9184
9/21/2017	2	0.38	3.1578***	0.0016	3.0719***	0.0021	2.6405***	0.0083	2.7722***	0.0056
9/22/2017	3	0.04	0.0931	0.9258	0.1311	0.8957	-0.3595	0.7192	-0.0123	0.9902
9/25/2017	4	-0.1	-0.1582	0.8743	-0.1618	0.8715	0.3071	0.7588	0.434	0.6643
9/26/2017	5	-0.15	-0.9496	0.3423	-1.2069	0.2275	-0.6929	0.4884	-0.9909	0.3217
9/27/2017	6	0.39	3.0047***	0.0027	2.5344***	0.0113	1.6405	0.1009	2.3258**	0.02

\* significant at p<0.1; \*\*significant at p<0.05; \*\*\* significant at p<0.01  
 Source: own diagram, z-scores provided by the EventStudyTools

According to the results presented in the Table 3 the values during the days [-1; 0;+1] do not represent a strong statistical significance, therefore the H0 cannot be rejected. It means that even if Maria caused AAR these days, the values are not convincing to conclude that it had a significant impact. When looking at the reactions of stock prices of the individual sample companies, it is useful to mention that 22 out of 36 companies had negative abnormal returns on the day of the event, but in average, the decline was not very strong. A few companies lost, however, 1.8% and this can be associated by the event. The media statements on the event day also provide the information about the fall in stock prices of several (re)insurance companies (a few of them are included in the sample) due to their exposure which was caused by Hurricane Maria. However, the average abnormal return for the whole sample portfolio does not seem to be significant. Few companies, whose stocks gained value on that day, can also influence this result.

Two days after the event day the average abnormal returns rebounded and reached a positive level of 0,38% and it is statistically significant at 1%. This provides an evidence to consider that this rebound in stock returns could be caused by Hurricane Maria.

During the days [+3; +5] AAR again fell and reached a negative level of -0.15%, but this is not statistically significant, therefore, the H0 cannot be rejected. On day +6 AAR re- bounded to 0,39% and it is statistically significant at

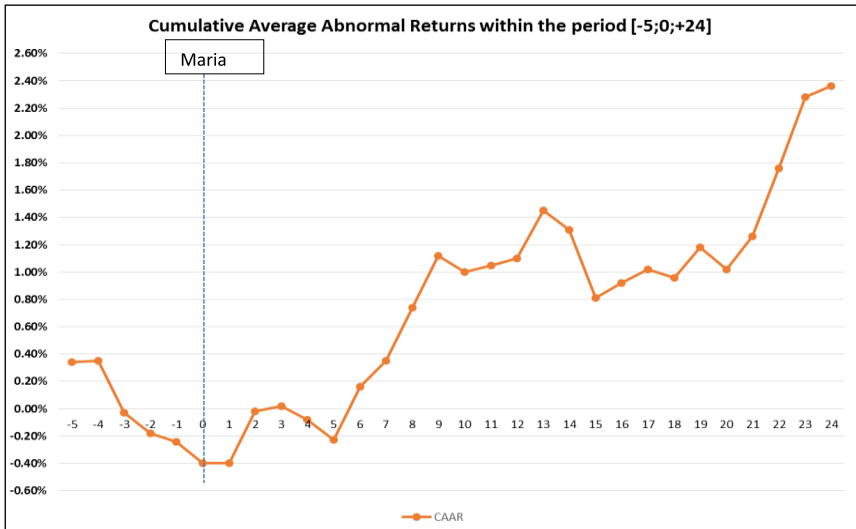


Fig. 10: Cumulative average abnormal returns generated by Maria within the period [-5; 0; +24]

Source: own diagram.

level 1%. Figure 10 illustrates the cumulative average abnormal returns within the event window  $[-5; 0; +24]$ .

As it can be seen from the Figure 6, Hurricane Maria did not have a strong cumulative effect on stock returns. On day  $-3$  CAAR fell down to  $-0.03\%$  and then kept falling reaching the level of  $-0.4\%$  on the event day. The day after the event, it remained on the same level and on day  $+3$  CAAR turned positive. On day  $+9$  CAAR essentially increased up to  $+1.12\%$  and on day  $+24$  it reached  $+2.36\%$ , so the stocks regained their value quite fast in comparison with the other two hurricanes. This result means that the investors did not demonstrate a significant overreaction around Hurricane Maria (although this hurricane caused enormous economic and insured losses), which does not provide enough information support the assumption A1. It is noteworthy to mention despite the fact that Hurricane Maria caused enormous economic and insured losses comparable with hurricanes Harvey and Irma, it had a different effect of stock prices.

To summarize the results on Hurricane Maria, it can be concluded that this natural catastrophe had a considerably less significant impact on the stock returns of the sample portfolio. Three days before the event, there was a statistically significant decline in AAR. This result can be associated with the fact that investors were anticipating of Hurricane Maria, which supports the assumption A1. During the period  $[-2; 0; +1]$  there was no evidence to consider that Maria had an impact on stock returns and hence did not generate significant excess returns, which supports the H0 and rejects the H1. A positive significant reaction is observed on day  $+2$ , where the average abnormal returns constituted  $0.38\%$  and this can be associated with the effect caused by Maria two days after its landfall, which supports the H1.

Such a considerably different effect of Maria on stock prices of the (re)insurance companies in comparison with Harvey and Irma, could be explained by the fact that investors have already seen the consequences of the two previous hurricanes, but despite this fact, the (re)insurance companies were able to face such devastating losses and to fulfill their obligations resulting from the natural disasters without affecting their capital. This means that investors believe that the companies they have invested in have enough earnings and they are financially strong, thus they build sufficient technical reserves to cover losses arising out of such major natural disasters.

The results of the quantitative analysis show clear evidence that there was a short-term significant effect of the analyzed natural disasters on the selected sample portfolio, resulting in abnormal returns and overreaction of investors within the period around the events. The findings indicate both negative and positive impacts of those natural disasters on stocks returns shortly prior to the event day, on the event day and several days after the event.

#### 4. Conclusion

Results of the analysis show that natural catastrophes have a short-term impact on stocks prices of (re)insurance companies. Further results show that the impact resulted in both negative and positive excess returns during the short-term event window around the event. Results also show that investors anticipated the natural disasters and overreacted. However, the strength of the reaction is not the same for all the analyzed events. The magnitude of the effect on stock prices is, however, different from one event to another.

It should be noted that the (re)insurance industry is strictly regulated and according to Solvency II or comparable regimes, the (re)insurance companies are required to build sufficient capital and technical reserves to be able to fulfill their contractual obligations. This implies also that the catastrophe risk and the related worst scenarios in case of a natural disaster should be included in the underwriting and pricing process using the NatCat modelling, as well as building the technical reserves.

Additionally, it should be mentioned the publicly traded (re)insurance companies issue quarterly and annually reports on their activity and financial situation, including the information on their exposure to insured losses caused by natural catastrophes and them on the financial stability of the company. These reports are used by the investors to assess the financial health of a company and are contributing to the decision-making process. This means that not only the announcement of a natural disaster and its severe consequences can influence the investors' behavior, especially in the long-term perspective.

For future work, it could be of interest to analyze and to compare the effect of natural disasters on stocks of reinsurance industry and insurance industry separately. Additionally, it would be interesting to investigate the effect on stocks of the individual companies, since the analysis in the present article showed the opposite reaction of stock prices of certain companies in comparison with the average values of the sample portfolio. This task might be more complex, since such analysis implies collecting and access more comprehensive information on each individual company, which is not always publicly available.

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