

CRANFIELD UNIVERSITY

PRISCILLA SCHELP

THE EFFECTS OF SUPPLY CHAIN DISRUPTIONS DUE TO
HURRICANES ON STOCK PRICE

CRANFIELD SCHOOL OF MANAGEMENT
PhD in Leadership and Management

Academic Year: 2015 - 2022

Supervisor: Dr. Heather Skipworth
Associate Supervisor: Prof. Emel Aktas
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ABSTRACT

Purpose and Rationale: It is known that supply chain disruptions have a negative stock price effect and that the effect is stronger if these are caused by catastrophes. However, these effects of hurricane-induced supply chain disruptions on stock price remain unexplored, even though the annual average hurricane damage in the US due to hurricanes is \$54bn, of which \$9bn is to commercial businesses. This thesis aims to: 1. Explore, classify and connect the three concepts of natural disasters, supply chain disruption (SCD) and firm financial performance in one framework. 2. Identify potentially influencing factors and test if, and in which way, these influence the effect of hurricanes on stock price. 3. Define a statistical model to evaluate the effect of hurricanes on stock price. The main focus is on manufacturing firms.

Design/Methodology/Approach: This research is quantitative. The daily closing value of 625 manufacturing companies that were listed on the NYSE between 2014 and 2018 was analysed. Autoregressive Integrated Moving Average (ARIMA) was applied in combination with intervention analysis to model the stock price time series. In total six deduced hypotheses were tested. The statistical interruptions in stock prices due to hurricane announcements and hurricane incident announcements were investigated. The method allowed estimation of the magnitude and temporal patterns of change by applying transfer functions. Multiple factors that potentially influence the magnitude or pattern of the stock price reaction were tested, including details of damage.

Findings: Both hurricane incident announcements and hurricane announcements negatively affect a firm's stock price, mostly in the form of a transitory change. Industry moderates the stock price reaction to hurricane announcements. Minor supply chain disruptions are the only impacts resulting in a positive reaction. Providing details on actual damage leads to less negative and mostly positive reactions. Companies providing information on preventive closures are unlikely to suffer a negative reaction.

Practical Implications: Hurricane risk needs to be actively managed by firms in all sectors; however, the preparation needs to be sector-specific. Firms should focus their efforts on managing supply chain disruptions. Additionally, firms need to communicate in a transparent way to reduce shareholders' uncertainty and increase trust, so that the stock prices reactions are less negative.

Originality: This thesis provides a single framework connecting disasters, supply chain disruptions and firm performance, thereby bridging supply chain management and financial economics literature. The thesis evaluates the effect of hurricane-induced supply chain disruptions for the first time. It does not analyse just the effect of hurricane incident announcements but also hurricane announcements and compares both. Autoregressive integrated moving average (ARIMA) in combination with an intervention model was applied as an alternative to the frequently used event study methodology. This approach is chosen to evaluate the effect of hurricane announcements and hurricane incident announcements on the daily stock price time series of the firms in scope. Longer term effects can be evaluated, and the best fitting transfer functions are assessed. The model accounts for autocorrelation, trend, seasonality, and drift patterns. Additionally, the effect of the following potentially influencing factors was tested as these have only been touched on in the existing literature so far: impact type, impact extent, detailed damage, and preventive closure.

Keywords:

Supply Chain Risk Management, Disaster, Catastrophe, Hurricane, Supply Chain Disruption, Share Price, Stock Price, Time Series Analysis, ARIMA-intervention model

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LIST OF ABBREVIATIONS

9/11	Terrorist attacks on the World Trade Center and the Pentagon on 9.11.2001
AIC	Akaike Information Criterion
API	Application Programming Interface
AR	Autoregressive
ARIMA	Autoregressive Integrated Moving Average
Bn	Billion
CARs	Cumulative Abnormal Returns
CSR	Corporate Social Responsibility
DEA	Data Envelopment Analysis
DJNS	Dow Jones News Service
EAT	Earnings After Tax
EBIT	Earnings Before Interest and Taxes
EDGAR	Electronic Data Gathering, Analysis, and Retrieval, Database by the US SEC
EU	European Union
FMCG	Fast Moving Consumer Goods
GARCH	Generalized AutoRegressive Conditional Heteroscedasticity
H	Hypothesis
IT	Information Technology
ITSA	Interrupted Time Series Analysis
KPI	Key Performance Indicator
KPSS	Kwiatkowski-Phillips-Schmidt-Shin
LBCP	Logistical Business Continuity Planning
LRT	Likelihood-Ratio-Test
MA	Moving-Average
MLE	Maximum Likelihood Estimation
MTO	Make-to-Order
MTS	Make-to-Stock
N/A	Not Applicable
NAT	Normal Accident Theory
NGO	Non-Governmental Organization

NHC	National Hurricane Center and the Central Pacific Hurricane Center
NHS	National Health Services
NY	New York
NYSE	New York Stock Exchange
OBE	Order of the British Empire
OEM	Original Equipment Manufacturer
PC	Personal Computer
PhD	Doctor of Philosophy
Q	Question
R	A programming language for statistical computing and graphics supported by the R Core Team and the R Foundation for Statistical Computing
RQ	Research Question
SARS	Severe Acute Respiratory Syndrome
SARIMA	Seasonal Autoregressive Integrated Moving Average
SCD	Supply Chain Disruption
SCM	Supply Chain Management
SCRM	Supply Chain Risk Management
SEC	US regulator US Securities and Exchange Commission
SLR	Systematic Literature Review
SRQ	Sub Research Question
TCE	Transaction Cost Economics
UK	United Kingdom
UN	United Nations
UNDRR	UN Office for Disaster Risk Reduction
US	United States
USD	US Dollar
WHO	World Health Organization
WSJ	Wall Street Journal

1 Introduction

1.1 Research Motivation

The researcher identified two areas in the supply chain risk management literature that seemed to be gaining importance: sustainability risks (Hoffmann et al., 2014) and supply chain disruption (SCD) due to disasters (Altay and Green, 2008; Wagner and Bode, 2008). The researcher decided to focus on the second topic because it is more measurable and because she had previously worked in the field, undertaken research and also had personal encounters with natural and man-made disasters. The researcher further decided to narrow the topic down to natural disasters, the reason being that terror attacks are rarer and more unique than natural disasters, which makes comparisons and generalizations of results more difficult.

Destruction and disruptions of supply chains by disasters, especially hurricanes, are prevalent in the US. One example is the recent devastation caused by Hurricane Ida to many cities in the US, including NY. The hurricane resulted in \$95bn estimated cost (CNBC, 2021). Natural disasters can cause serious financial damage to supply chain companies and also to their share price; however, natural disasters are hardly predictable. The destructive and unpredictable features of natural disasters motivated me to study their impacts on supply chain disruptions. The interest of academics in supply chain risks (Wieland and Wallenburg, 2012) and specifically in supply chain risk management (SCRM) is increasing (Babich et al., 2007; Blackhurst et al., 2005; Chopra and Sodhi, 2004; Hendricks and Singhal, 2003; Mizgier et al., 2015).

SCDs can have a severe impact on firm performance. An SCD is defined as a disruption to the flow of information, goods (materials and products) or finance (Akintoye and MacLeod, 1997; Juettner et al., 2003; Reason, 1990; Shrivastava et al., 1988; Swierczek, 2016). The interest in supply chain management research assessing the effect of SCDs on firm financial performance was sparked when in 2003 Hendricks and Singhal determined in an event study that a 10% decrease in stock price returns of listed companies occurred after the

announcement of an SCD, which was confirmed in subsequent studies (Hendricks and Singhal, 2005a; Zsidisin et al., 2016).

One cause of SCDs is a natural disaster, such as a hurricane. Just to provide an example, according to a study presented to the US congress, the annual economic losses in the US by hurricanes account for \$54 billion in total – \$9 billion to commercial businesses in the US (Congressional Budget Committee, 2019). It is anticipated that there will be an increase in SCDs in the coming years due to diseases, terrorist attacks and natural disasters. Therefore, this form of risk has become a major concern for many organisations' executives, especially for the boards of listed companies which have the responsibility and accountability/ownership for the financial performance of the company. A specific research need was identified in the context of globally operating organisations (Blackhurst et al., 2005; Juettner, 2005; Schoenherr et al., 2012). For the above-mentioned reasons, this thesis is focused on supply chain risks that can have significant impact on financial, and especially share price, performance. There are several papers available that evaluate the causes of SCDs, but only a few explore their impact. Most of the available research focuses on assessing either the stock price impact of disasters or SCDs without bringing both concepts together. Research indicates that disaster-induced SCDs tend to be severe in damage. This thesis focuses on SCDs that are caused by external factors such as natural uncertainties as these are unpredictable and tend to have a severe impact when they occur. Due to climate change, both the likelihood of occurrence and the impact of natural disasters are increasing, thereby presenting more than just irregular unpredictable events for firms but becoming a regular phenomenon.

1.2 Research Streams

In the following the main relevant concepts and literature bodies for this thesis are presented. There are two literature bodies (see Figure 1): Supply Chain Management (SCM) is represented by the yellow area on the left. Financial Economics literature is represented by the red area on the right. The circles represent the three key concepts: disasters, supply chain risks and firm

performance. The concepts overlap as represented by the overlaps of the circles. The research question is allocated in the overlap of the three key concepts.

SCM literature is focused on changes in firm performance related to SCDs. The effects of natural disasters are studied to identify and assess supply chain risks and develop supply chain risk management (SCRM) improvements to decrease the impact of these risks (Altay and Ramirez, 2010; Aula, 2010; Khan and Bumes, 2007). Risk management theory and financial performance form a large part of financial economics literature, where quantitative measurements and detailed modelling are of primary importance (Dryden, 1969) and applied in event studies (Flouris and Walker, 2007; Kannan et al., 2007). This thesis consolidates both literature bodies to define and connect the three concepts of disasters, SCDs and firm performance. Within the course of the research there was a zoom in into the concepts based on relevance, initial research results and data availability. From the two types of supply chain risks that are especially relevant to firm performance: corporate social responsibility (CSR) and supply chain disruption (SCD), I focused on the latter. I narrowed down “firm performance” to “share price”. Furthermore, I narrowed down the concept “disasters” to “hurricanes” as the descriptive analysis showed that 82% of all disasters/incidents at New York Stock Exchange (NYSE) firms are due to hurricanes.

1.3 Research Question, Aim and Objectives

The overall aim of this thesis is to evaluate the relationship between hurricanes, SCDs and stock price. So, how are these three concepts connected? Disasters are one cause of SCDs, but they can also have a direct effect on firm performance. SCD itself, regardless of its cause, can have direct effect on firm performance. In terms of disaster-induced supply chain disruptions, SCRM can lower the likelihood and severity, and thereby decrease the negative effect on firm performance (see Figure 1).

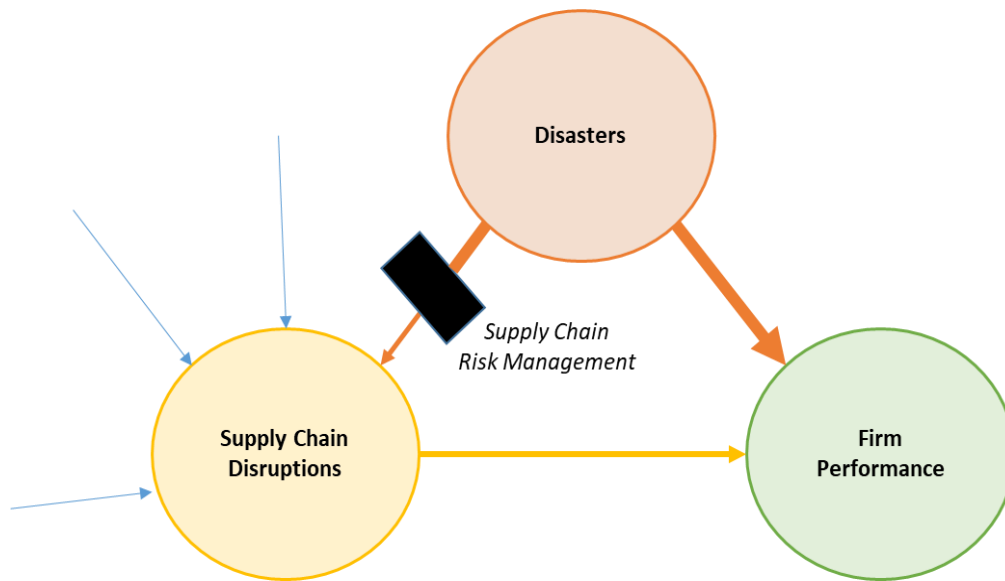


Figure 1. *The relationship between disasters, supply chain disruptions of different origins (blue arrows), firm performance and the role of supply chain risk management (black)* (Source: Author)

The unit of analysis for this thesis is “company”. The research assesses the magnitude and pattern of change in stock prices due to hurricane announcements and hurricane-related firm announcements, and how this depends on firm- and event-related factors. The following main research question is answered in detail by using different variables and models:

What are the effects of supply chain disruptions due to hurricanes on stock price?

The following research objectives address the research question:

1. Explore, classify and connect the three concepts of natural disasters, supply chain disruption (SCD) and firm financial performance in one framework (covered in the systematic literature review (SLR) in Chapter 2).
2. Identify potentially influencing factors and test if and in which way these influence the effect of hurricanes on stock price.
3. Define a statistical model to evaluate the effect of hurricanes on stock price.

This thesis is structured as follows: literature review (Chapter 2), thematic analysis (Chapter 3), methodology (Chapter 4), results (Chapter 5), discussion (Chapter 6), contribution (Chapter 7) and limitations and further research directions (Chapter 8).

To clarify the main differences between the results, discussions, and the contribution: the results section (Chapter 5) solely describes the analyses findings, the discussion section (Chapter 6) aims to explain the results and analyses how these fit with previous research findings. Resulting from these insights, in the conclusion section (Chapter 7) it is highlighted how the new insights gained in this thesis and especially in the discussion section add to the existing body of knowledge (contribution to the research field) and which managerial conclusions can be drawn (contribution to practice).

1.4 Summary of Contributions to Knowledge

The **contributions to theory** of this thesis are summarised as follows:

- Hurricane incident announcements and hurricane announcements tend to lead to a significant reaction that is mostly negative.
- Industry moderates the stock price reaction to hurricane announcements.
- Minor supply chain disruptions are the only impacts resulting in a positive reaction.
- Providing details on actual damage leads to less negative and mostly positive reactions.
- Companies providing information on preventive closures are unlikely to suffer a negative reaction.

The **contributions to practice** of this thesis are summarised as follows:

- Hurricane risk has to be actively managed by firms.
- Companies from all sectors need to manage hurricane risk; however the preparation needs to be sector-specific.
- Firms should focus their efforts on managing supply chain disruptions.
- Firms need to communicate in a transparent manner to reduce shareholders' uncertainty and build trust.

2 Literature Review

This chapter concludes with the key literature around disasters, SCDs and firm performance. The literature review was updated and extended due to changes in methodology and topic. This thesis challenges the existing literature on the effect of disaster-originated SCDs due to both the lack of a holistic conceptualisation and of a detailed evaluation of disaster-originated correlation effects on firm performance. The research reviewed is mainly rooted in the SCM and financial economics literature, which stresses the increasing recognition of firm performance impact of SCDs and disasters on the performance of firms. The effect of SCDs on firm performance is evaluated in the SCM literature (Altay and Ramirez, 2010; Aula, 2010; Khan and Bumes, 2007; Zsidisin and Wagner, 2010). The effect of disasters on firm performance is assessed in the financial economics literature in the form of event studies (Flouris and Walker, 2007; Kannan et al., 2007).

This thesis aims to bring both literature bodies together to define and connect the three concepts of: disasters, SCDs and firm performance. Furthermore, it aims to investigate, in order to connect, the concepts, assess the correlation of disasters/disaster-induced SCDs on firm performance, identify potentially influencing factors, and identify suitable theoretic underpinnings for explaining the model and model results. The literature review chapter is structured as follows: in Chapter 2.1 the SLR methodology and structure are explained. In Chapter 2.2 the descriptive analysis results are presented.

2.1 SLR Methodology and Structure

This section describes the detailed steps taken to collect, select and analyse the identified literature. Prior to the SLR, one or more review questions are defined. These questions will be answered by the SLR, after evaluating the existing literature. One result from the SLR is the generation of the final research question. To ensure a certain quality standard, only peer reviewed academic literature is considered. To conduct the SLR, the established SLR structure below was

adapted from Tranfield et al. (2003) and is in line with the Cranfield School of Management guidelines (Figure 2).



Figure 2. *Systematic Literature Review Framework (Source: Tranfield et al., 2003)*

2.1.1 Systematic Literature Review Protocol

The SLR has the purpose of enabling me to identify, assess and interpret all available research that provides information on the impact of disasters on supply chains from a firm performance point of view. From the key papers, data are extracted and analysed (Centre for Reviews and Dissemination, University of York (2001). The main reasons for undertaking the SLR in the context of this thesis are (Hart, 1998):

1. To summarise existing evidence on the effect of disaster-originated SCDs on the firm performance of manufacturing firms.
 - a. As this thesis aims to provide insight into the effect of disasters and disaster-induced SCDs on firm performance, I hope to identify potentially relevant variables and mechanisms (Hart, 1998).

- b. Furthermore, I aim to obtain an impression of to what extent and in which way these have been studied so far (Hart, 1998).
2. To evaluate the importance of the suggested research for the improvement of the operational and strategic practices of practitioners.
3. To develop a background and framework of the existing knowledge to position the proposed research.

An SLR was chosen over a traditional narrative review as it increases the research quality for the following reasons (Centre for Reviews and Dissemination, University of York, 2001; Tranfield et al., 2003):

- Documentation of my assumptions, procedures and decisions of the review provide an audit trail (Easterby-Smith et al., 2012; Centre for Reviews and Dissemination, University of York, 2001; Tranfield et al., 2003).
- Application of systematic and explicit methods reduce my bias (NHS Centre for Reviews and Dissemination, 2001; Tranfield et al., 2003).

Therefore, the overall objective of the systematic review is to map and assess the existing knowledge that is relevant to answer the review questions in a scientific, transparent and replicable way (Tranfield et al., 2003). The methodology of the SLR protocol will enable a third person to repeat the review and come to the same conclusion. The review protocol provides a roadmap covering the selection process and inclusion and exclusion decisions made by me (Tranfield et al., 2003).

2.1.2 Review Questions

As previously mentioned, the review questions are those that will be answered by the SLR; for that purpose, they were defined as precisely as possible to ensure my reviews of all the literature are relevant to this study. This has enabled me to make the decision to include or exclude a potentially relevant publication (Greenhalgh, 2006). To ensure the unambiguous definition of the review questions, the related key concepts in relation to the literature are defined in this

section. SCDs, disasters and firm performance were identified as the three key concepts related to the main review question (See Figure 3).

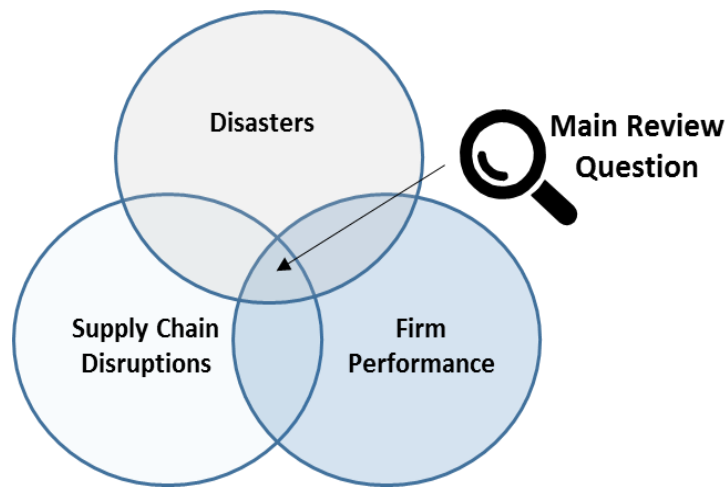


Figure 3. Key Concepts and Positioning of Main Review Question (Source: Author)

To evaluate the current state of research relevant to the main review question below, two sub review questions were developed as a result of a positioning study:

Review Question (RQ): *“What does the literature tell us about the effect of disaster-originated supply chain disruptions on the performance of firms with a physical supply chain?”*

Originally, I just generated this one review question. However, based on the preliminary literature review I decided that the question is too narrow. I expected to find too little relevant literature and furthermore believed publications containing relevant information would be excluded. This is not uncommon and can be seen as positive, as it is an indicator of a research gap. To include more relevant literature, the below sub review questions were developed. The overlap of both review questions is equal to the main review question.

Sub review question 1 investigates the relationship between disasters and firm performance, and was regarded as necessary to include relevant financial economics research that evaluates the effect of disasters on firm performance, especially on share price, without mentioning SCDs, e.g. Hill and Schneeweis (1983):

Sub Review Question 1 (SRQ1): “What does the literature tell us about the effect of disasters on the performance of firms with a physical supply chain?”

Sub review question 2 evaluates the relationship between SCDs and firm performance. This sub review question includes particularly relevant supply chain literature such as Hendricks and Singhal (2005a, b, 2003) that evaluates the firm performance effect of SCDs irrespective of the cause of disruption. To focus on the most relevant SCD literature, the sub review question was limited to SCDs that are caused externally or through accidents.

Sub Review Question 2 (SRQ2): “What does the literature tell us about the effect of external and accident-caused supply chain disruptions on the performance of firms with a physical supply chain?”

The sub review questions are within the overlaps of the domains as I am interested in evaluating the relationships in causality and causal mechanisms (Figure 4).

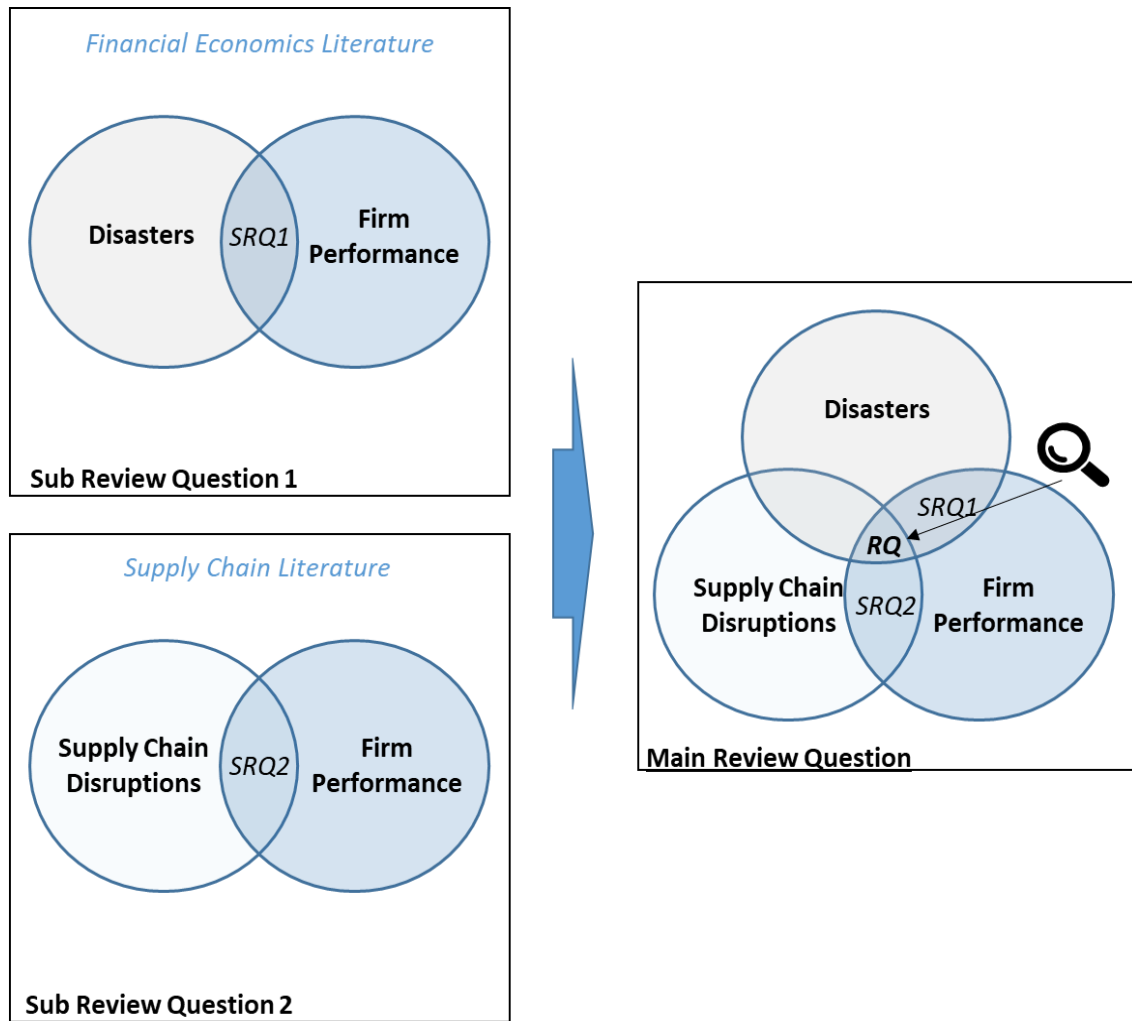


Figure 4. Analysis of review questions (Source: Author)

2.1.3 Search Strategy

I aim to identify only the relevant literature. Therefore, to all literature a predefined set of selection and quality criteria is applied. SCDs can be seen through different lenses, e.g., according to the source, their cause, the actual event or their impact. Different types of SCDs have different effects on the performance of an organisation (Altay and Ramirez, 2010; Aula, 2010; Khan and Bumes, 2007; Petersen and Lemke, 2015; Zsidisin and Wagner, 2010). Furthermore, the relevance and impact of SCDs may differ between industrial sectors (Worthington and Valadkhani, 2005).

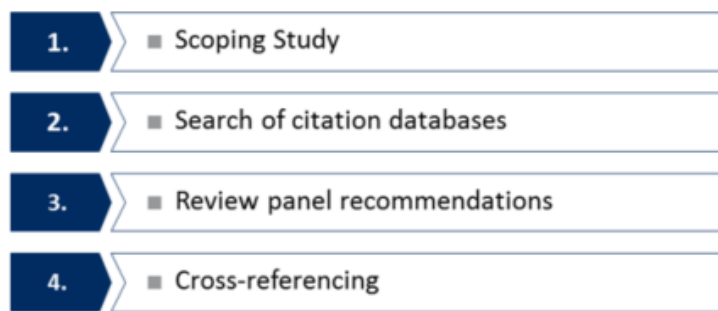


Figure 5. *Identification of Literature* (Source: Tranfield et al., 2003)

2.1.4 Keyword Identification

To build the search strings for the review questions, keywords were identified (**Table 1**). The components of the search strings are the three key concepts that feature in the two review questions: disasters, supply chain disruptions and firm performance. The search strings have the purpose to focus and guide the literature search. The different keywords were identified from the literature reviewed until that point. In the papers the terms used, and the papers' keywords were reviewed.

Even though I aimed to create the research strings in a way that not an immense number of publications needed to be reviewed, the main priority when creating the search strings was to ensure that no relevant publications were missed. The keywords were extracted from the review questions, definitions of the key questions and the relevant identified publications. The body of literature for the first sub review question will discuss the effect of disasters on firm performance. The second body of literature will cover the effect of external and accident-caused SCDs on firm performance. The main review question will be answered by synthesising the results from both literature bodies – which is the actual area of the research question.

Table 1. Keywords for Search Strings (Source: Author)

<p>Sub Review Question 1: <i>"SLR Q1: What does the literature tell us about the effect of disasters on the performance of firms with a physical supply chain?"</i></p>			
<p>Sub Review Question 2: <i>"SLR Q2: What does the literature tell us about the effect of external and accident-caused supply chain disruptions on the performance of firms with a physical supply chain?"</i></p>			
Keywords			
Supply Chain Disruption	Disaster	Firm Performance	Search Area
(Supply n/8 (Glitch* OR disrupt* OR vulnerab* OR risk* OR resilien*))	(Disaster*OR Catastroph* OR Calamit* OR Unanticipated Event* OR Accident OR Fire OR Terror*)	((Firm OR organi?ation* OR financial* OR operation* OR stock OR share OR "Supply Chain") n/8 performance) OR (Sales OR Revenue* OR Turnover OR profit* OR Cash flow OR Working Capital OR Inventory Turnover* OR ROI OR Return on Capital OR Gross Profit OR Delivery OR Responsiv* OR Speed OR Flexibility OR Quality OR Efficiency)	Title, Abstract, Keywords

* keywords that were added in the extended search

2.1.5 Creation of Search Strings

To create the search strings, the selected keywords are connected by applying Boolean Logic (i.e. OR, AND, NOT). **Table 1** comprises the search strings that were used to run the initial search. In the panel review in January 2017, it was decided to include a further breakdown of some aspects of financial and operational firm performance and to use some of these terms as additional

keywords. One reason for that was the initial search resulted in fewer than 50 key papers. Therefore, the search was extended, and new keywords were added around firm performance. While the original search words were performance types, the added search words included specific performance metrics. These keywords were inserted in the original search strings and were run additionally in 2017 (see Table 1). The same selection and quality assurance project as for the initial search was applied and documented.

2.1.6 Identification of Information Sources

After identifying how to search, it was determined where to do so. The test for academic databases with the biggest coverage showed that I can focus the search and just search in ABI Inform Complete (ProQuest) and Business Source Complete (EBSCO). The primary sources of information for this SLR are scholarly, peer-reviewed academic journals which are searchable in academic databases. The academic databases available at Cranfield University were evaluated and the database analysis indicated that ABI Inform Complete (ProQuest), Business Source Complete (EBSCO), Emerald Insight and Science Direct (Elsevier Science Journals) combined provide the most apposite coverage. These four databases were tested for their coverage firstly by using the keywords and later by testing the initial search strings. It is clear that ABI Inform Complete (ProQuest) and Business Source Complete (EBSCO) are the most comprehensive and largest databases of the four; further I acknowledge that Emerald is a publisher database and therefore included those two databases. For the initial keywords and search strings below, a pilot test showed that ABI Inform Complete (ProQuest) and Business Source Complete (EBSCO) comprise the highest numbers of search results (**Table 2**). Therefore, it was decided to focus solely on searching in ProQuest and EBSCO. I am aware that there will be overlaps between the two databases and that duplicates will have to be identified and eliminated during the systematic review process.

Table 2. Identification of Database Resources (Source: Author)

Name of Database	Coverage (extracted from website)	(Supply n/8 (Glitch* OR disrupt* OR vulnerab* OR risk* OR resilien*))	(Disaster*OR Catastroph* OR Calamit* OR Unanticipated Event* OR Accident OR Fire OR Terror*)	((Firm OR organi?ation* OR financial* OR operation* OR stock OR share OR "Supply Chain") n/8 performance) OR (Sales OR Revenue* OR Turnover OR profit* OR Cash flow OR Working Capital OR Inventory Turnover* OR ROI OR Return on Capital OR Gross Profit OR Delivery OR Responsiv* OR Speed OR Flexibility OR Quality OR Efficiency)
ABI Inform Complete (ProQuest)	Full-text access to around 2400 scholarly international business journals. Coverage: Since 1971	9988	18267	51240
Business Source Complete (EBSCO)	Full-text access to around 2000 peer-reviewed journals. Coverage: Since 1886.	23186	43045	133046
Emerald Insight	Full-text access to nearly 300 journals. Coverage (Full-text): Since 1994	1275	758	26015
Science Direct (Elsevier Science Journals)	Access to articles from more than 3800 journals. Focus on scientific, technical, and medical research.	7603	4762	25826
* Results for peer reviewed/scholarly articles for ABI and EBSCO. Emerald, chapters and books, solely accepted articles. Science Direct, Review Articles. Search anywhere except full text. DATE OF SEARCH: 30.01.2017				

Even though there is a clear focus on peer-reviewed journals, secondary sources were also considered. Secondary sources of non-academic applied literature such as practitioner journals, publications of well-regarded consulting and accounting firms, and companies' annual reports contributed to the research motivation; however, only articles from peer-reviewed, scholarly journals are included in the SLR in order to apply scrutiny and ensure a minimum level of academic quality. Papers, identified additionally to the results of the SLR searches, were also considered if they fulfilled the predefined selection and quality criteria. To test the coverage of the preliminary initial search strings, the above keywords were combined and tested for the two largest databases ABI Inform Complete and EBSCO Business Source Complete (Table 3). The only database settings applied were the filter "peer reviewed" to ensure minimum quality. The search using the search strings was conducted anywhere apart from in the full text. The number of search results of the preliminary search strings shown in Table 3 are higher than the results from the finalised initial search strings because for these proximity operators were used.

Table 3. *Testing the Coverage of Preliminary Initial Search Strings*

Name of Database	Sub Review Question 1: Disasters & Firm Performance (Initial Search String)	Sub Review Question 2: External/Accident-caused Supply Chain Disruptions & Firm Performance (Initial Search String)
ABI Inform Complete	633	1499
EBSCO Business Source Complete	1894	3362
Date of Initial Search: 09.05.2016	*Results: ABI and EBSCO: Peer reviewed/scholarly articles; Emerald: chapters & books, solely accepted articles; Science Direct: Review Articles. Search: Anywhere apart full text.	

To identify the most relevant literature and to scope the existing literature efficiently, a set of filters was developed to identify and select studies. In the filtering methodology the following selection criteria were applied (see Table 4).

Filter 1: Isolates articles that are detected in the selected databases that fulfil at least one of the two search strings. An article will show up as a search result if at least one root search word per literature domain is mentioned in the title, abstract or keywords.

Filter 2: Review against the predefined selection criteria on basis of the title, abstract and keywords.

Filter 3: Elimination of duplicates.

Filter 4: Full text review of remaining articles to ensure theoretical, conceptual, substantive and academic quality is defined by assessing the overall quality score per article.

Filter 5: Full text review to ensure the article meets the selection criteria. Review regarding theoretical, conceptual, substantive and academic quality as defined in the Data Extraction Form.

Table 4. Selection Criteria (Source: Author)

Area	Inclusion Criteria	Exclusion Criteria	Justification
Language	English or German	Any other language not formally translated	Limited resources for translation.
Peer Review	Peer reviewed journals (all years) Conference papers (from 2013 onwards)	Other non-peer reviewed documents	It is assumed that peer reviewed journals provide a minimum quality regarding data and methodology. Recent conference papers are included to ensure that the research considers the newest academic outlook on the topic.
Industry	Manufacturing, Retail, Natural Resource Exploration Companies, Construction, Logistics Companies	Financial Sector (Banks and Insurances), NGO'S; Service Sector	The research focuses on organisations that have a significant supply chain in terms of physical goods that is relevant for firm performance.
First Review Question	Disasters & Firm Performance	Others	Aligned with the research focus, for the first review question articles are excluded that cover some type of disaster(s) and at least aspects of firm performance.
Second Review Question	Supply Chain Disruption & Firm Performance	Others	Aligned with the research focus, for the first review question articles are excluded that cover a and at least aspects of firm performance.
Sources	Published journals listed in identified bibliographic databases, including conference proceedings	Non-academic sources	Due to the practical notion of the topic, valuable information is expected from applied sources such as in practitioner literature; however, for the review of academic knowledge these sources are excluded from the SLR.
Research Methods	All included	Have to meet minimum quality criteria	

Table 5. SLR Filters (Source: Author, based on: Tranfield et al., 2003)

No.	Filter Type	Filter	Inclusion Criteria	Exclusion Criteria	Focus
1	Substantive	Search String	Articles that do include the search string	Articles that do not include the search words in title, abstract or keywords.	Title, Abstract & Keywords
2.1	Substantive	Second Review Question	External/Disaster-induced Supply Chain Disruptions & Firm Performance	Aligned with the research focus, for the second review question articles are excluded that do not cover the effect of external/disaster-induced supply chain disruptions on at least one aspect of firm performance.	Title, Abstract & Keywords
2.2	Substantive	First Review Question	Disasters & Firm Performance	Aligned with the research focus, for the first review question articles are excluded that do not cover the effect of disasters on at least one aspect of firm performance.	Title, Abstract & Keywords
2.3	Substantive	Industry	Manufacturing, Retail, Natural Resource Exploration Companies, Construction, Logistics Companies, Airlines, Pharma & Healthcare	Financial Sector (Banks and Insurances), Non Profit Organisations (NGOs), Government Institutions, Service Sector, Tourism (hotels and cruise ships), Education sector, Hospitals, Public-private Partnership initiatives.	Title, Abstract & Keywords
2.4	Substantive	Company Size	Listed and medium-sized companies	Small businesses and and business people.	Title, Abstract & Keywords
2.5	Methodological	Method	Empirical and Conceptual Articles	Others.	Title, Abstract & Keywords
3	Duplicates	Duplicates	Deletion of Duplicates	Duplicates.	Full Text
4	Substantive	Quality	Articles that meet the quality requirements in the checklist	Articles that do not meet the quality requirements.	Full Text
5	Substantive	Review of full article	Articles that meet the selection criteria	Articles that do not meet the selection criteria.	Full Text

An overview over the entire SLR filter process is provided in the form of a flowchart in Figure 6. There are five filter steps: Search string, selection criteria, duplicate removal, quality score and full text review.

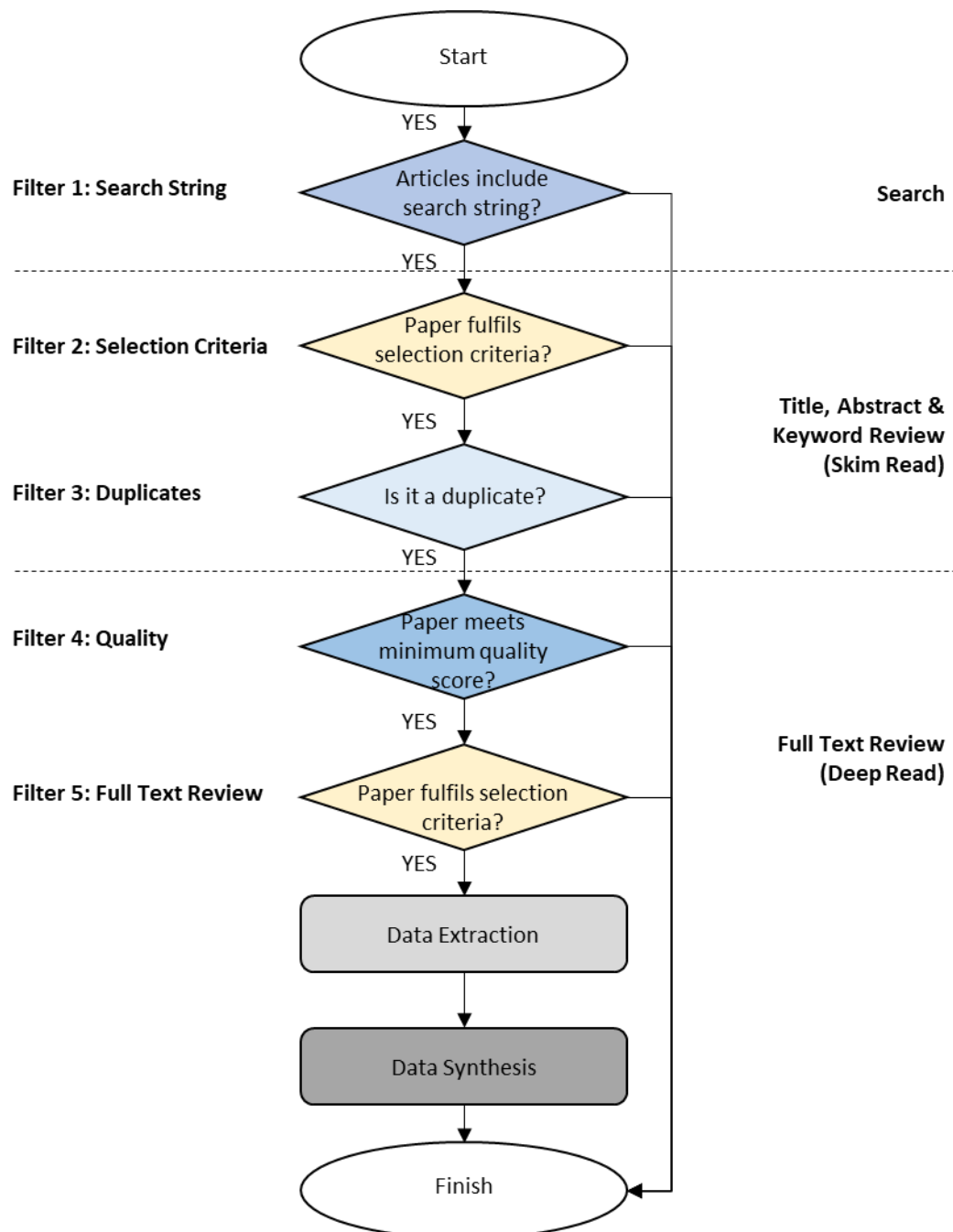


Figure 6. Flowchart Filter Process (Source: Author)

2.1.7 Quality Criteria

For the papers that got through the filtering process by applying the selection criteria, quality criteria were applied. Quality criteria were applied for filter 4 and followed the grading system in Table 6. These quality criteria were developed on the basis of papers conducting SLRs (Denyer et al., 2008; Denyer and Tranfield, 2009; Tranfield et al., 2003). It was decided that for an article to be included, the total quality score must be at least 6 (out of 15).

Table 6. *Quality Assessment Criteria (Source: Denyer et al., 2008; Denyer and Tranfield, 2009; Tranfield et al., 2003)*

Elements to consider	Level				
	3-High	2-Medium	1-Low	0-Absence	Not Applicable
1. Literature Review	Excellent review of existing literature.	General understanding of the problems around the research topic.	Inadequate literature review.	The publication does not provide sufficient information to assess this element.	This element is not applicable to this publication.
2. Contribution	Significant contribution to academic knowledge. Fills an important gap in theory.	The contribution to knowledge is of moderate importance.	The publication contributes in a limited way to the academic knowledge in the field.	The publication does not provide sufficient information to assess this element.	This element is not applicable to this publication.
3. Theory	Strongly based on underlying theory.	Underlying theory is not well communicated.	Underlying theory is missing.	The publication does not provide sufficient information to assess this element.	This element is not applicable to this publication.
4. Methodology	Excellent research design and strong execution of methodology.	Robust research design but weak methodology execution.	Low quality of methodology design and execution.	The publication does not provide sufficient information to assess this element.	This element is not applicable to this publication.
5. Data Analysis	Adequate sample size and quality. Results are well explained. Linkage of results to theory. Limitations and bias are well explained.	Limited data sample. Analysis results are linked to theory.	Insufficient data sample. Findings are not conclusive. Limited link to theory.	The publication does not provide sufficient information to assess this element.	This element is not applicable to this publication.

2.1.8 Identification and Selection of Studies

Table 7 provides an overview of the key articles in each filter stage based on the selection that is based on the predefined process and criteria. The filtering process was applied for the initial search and the extension; thereby all included papers fulfil the selection and quality criteria. For each excluded paper the exclusion criteria and a justification were documented.

Table 7. Flow of Selection

Settings	Filter Type	Description	Total Reduction	Total in Scope	Added
Initial Search Strings					
0	Substantive	Search String(s)	-	1240	-
1	Substantive	Screening of Title, Abstract and Key Words	965	274	-
2	Duplicates	Remove Duplicates	97	177	-
3	Substantive	Selection Criteria	77	49	-
-	Inclusion of relevant references articles		-	54	5
4	Substantive	Quality Evaluation	5	49	-
5	Substantive	Review of full article	-	49	-
Extended Search					
0	Substantive	Search String(s)	-	28145	-
1	Substantive	Screening of Title, Abstract and Key Words	28,091	54	-
2	Duplicates	Remove Duplicates (overall)	30	24	-
3	Substantive	Selection Criteria			
4	Substantive	Quality Evaluation	0	24	-
5	Substantive	Review of full article	-	24	-
Consolidated Pool of papers in scope					
5	Substantive	Review of full article	-	73	-

2.1.9 Data Extraction Procedure

Based on the inclusion and quality criteria, a list of key papers was selected for in-depth review and analysis. This pool of papers represents the relevant basis of academic literature used for this thesis. The journals were rated according to the Cranfield University Rating (2015). Based on the selection and quality criteria in the initial searches, 49 relevant articles were identified. In the search extension another 24 relevant articles were detected. The total pool of articles therefore

comprises 73 relevant papers. The characteristics of these in-scope papers are presented in the following chapter.

2.2 Descriptive Analysis of an SLR

2.2.1 Topics Covered

Table 8 provides an overview over the topic focus of the papers included. A total number of 73 relevant papers are included in the analysis. I decided to unambiguously classify the relevant papers according to the main topic focus, i.e. into the two categories of disaster or external/disaster-originated supply chain disruption. However, a few papers also cover aspects of both concepts. The categorisation was performed without overlaps to make the descriptive analysis clearer. No information will be lost, as both literature bodies are combined and synthesised in the end. The distribution of papers is nearly even: 52% have a focus on the impact of disasters and 48% on the impact of external/accident-caused SCDs on firm performance.

Table 8. *Topic Coverage (Source: Author)*

Topic covered	Distribution of articles
Disaster	38 (52%)
Supply Chain Disruption	35 (48%)
Total	73

Figure 7 indicates the number of published articles for both topic areas over time; it demonstrates that the literature on disasters had already evolved in 1989, while literature on SCDs evolved later. Early contributions on SCDs were done in 2001 and 2003; the SCD literature body then developed continuously from 2005 onwards. Interesting to notice is that the years that are strong in publications in one topic are usually also strong in the other, which could be seen an indication for the correlation of both topics. Both topics' publications peaked from 2011 to 2013; however, since then the number of publications in the disaster and supply chain disaster literature has decreased. However, in contrast to the disaster literature the supply chain literature started picking up again in 2016.

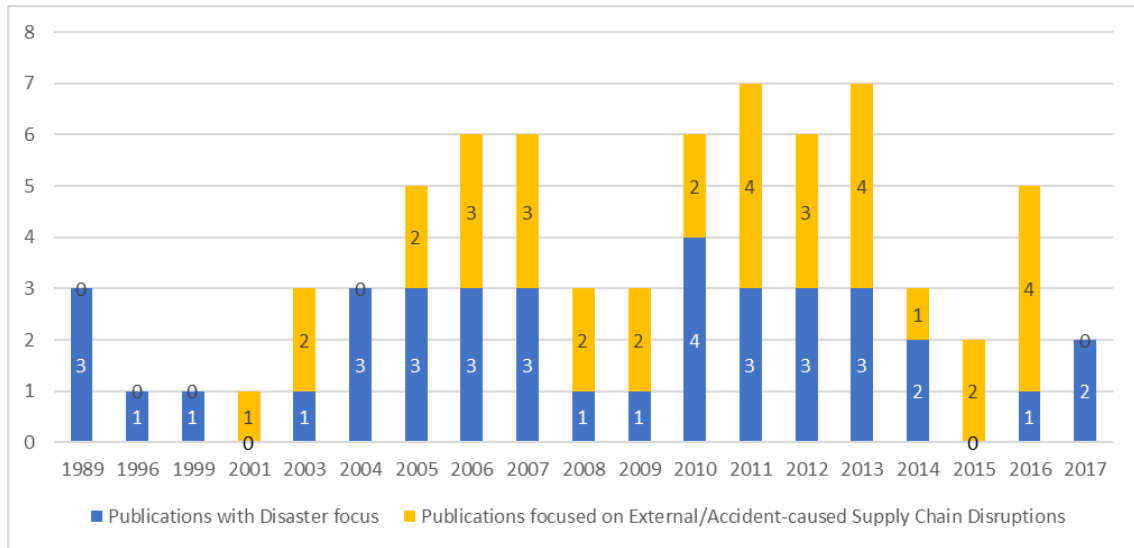


Figure 7. Publication of academic papers for both topic areas over time (Source: Author)

2.2.2 Methodologies Covered

Figure 8 indicates that the most common research method used is some form of regression analysis. Around 50% of the papers use such methodology; around 10% use case study methodology, 10% are literature reviews and 10% are based on surveys; data envelopment analysis (DEA), GARCH model or system dynamics simulation are each used for 3% of the papers (i.e. two papers); for the remaining 12%, other methodologies were used.

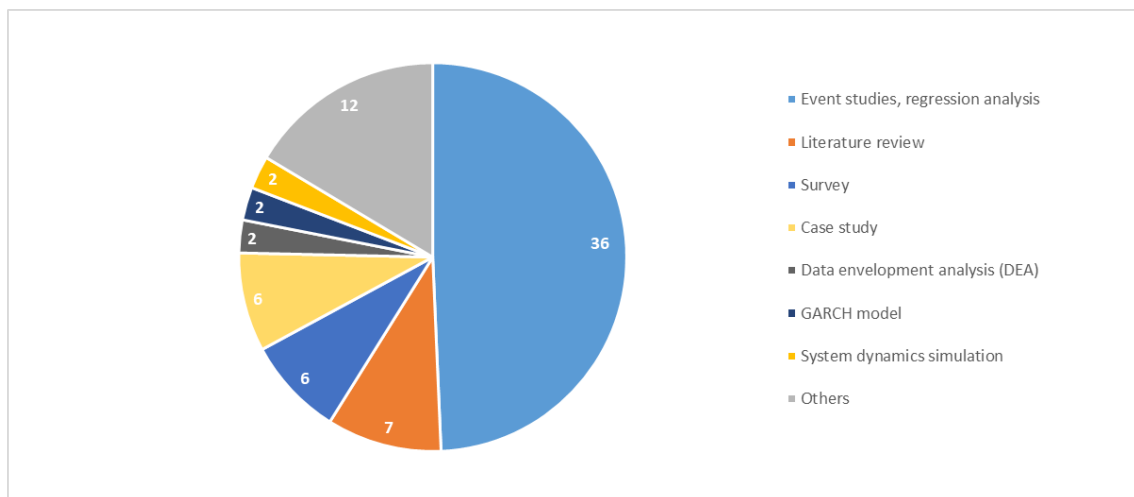


Figure 8. Academic papers per methodology (Source: Author)

Figure 9 shows the use of the most frequently used methodologies over time. Regression analysis seems to be the first way of measuring the effect of disasters or external/accident-caused SCDs on firm performance and is regularly and still often used. Case studies and literature reviews have been used since 1991/2001 occasionally. Other methodologies evolved in 2005 and since then are frequently used with lows in 2010 and 2015. The use of methodology with regard to the topic area and the theoretical underpinning applied will be considered in the later analysis.

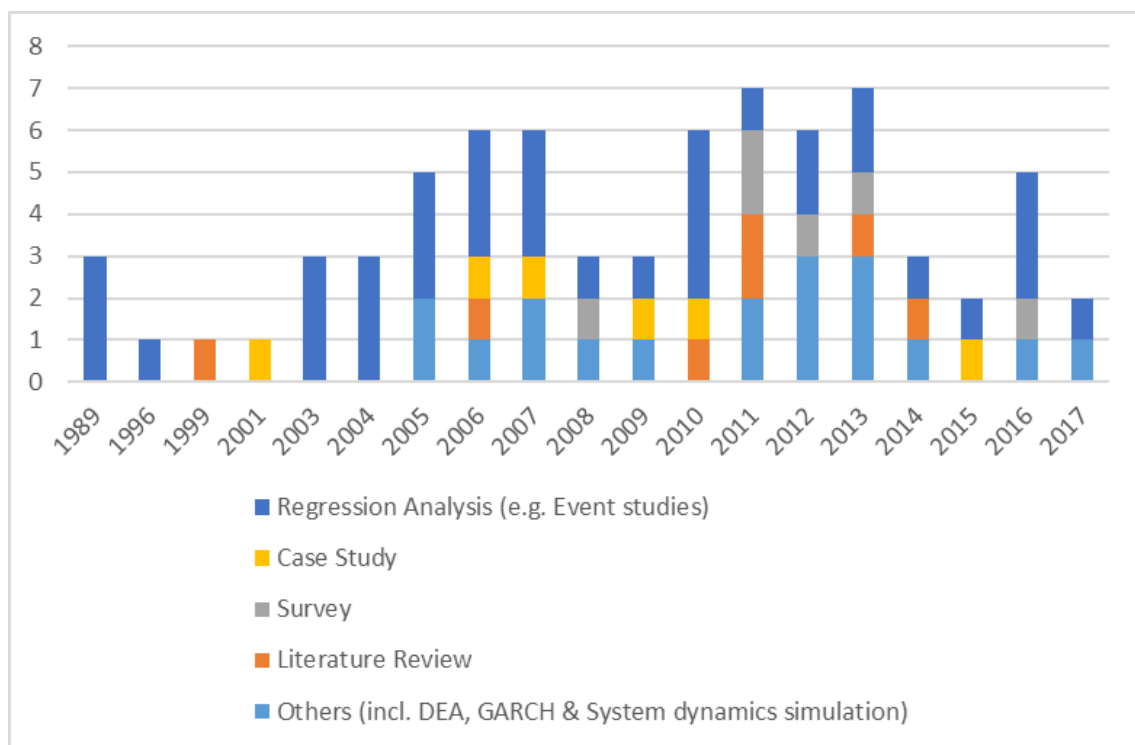


Figure 9. *Applied methodologies over time (Source: Author)*

2.2.3 Industry Focus

Figure 10 indicates that for both topic areas around 40% of the papers do not focus on one or two but cover a range of industries. It is interesting that around one third (35%) of the publications on disasters focuses on airlines and airline manufacturers. This can be explained by the fact that many of these papers analyse the impact of 9/11. 10% of the papers in the disaster area cover the energy industry. The remaining disaster-focused papers evaluate the impact of single incidents in different industries. Interestingly, there are just two disaster

papers that have no industry focus, which may be explained by the fact that there seem to be very few conceptual papers but more that analyse actual events. Around one third of publications on SCDs have their focus on one specific industry: on the PC/cell phone industry (14%), manufacturing (11%) or the automotive sector (8%). 17% of the SCD papers have no industrial focus, which indicates that these tend to be conceptual papers.

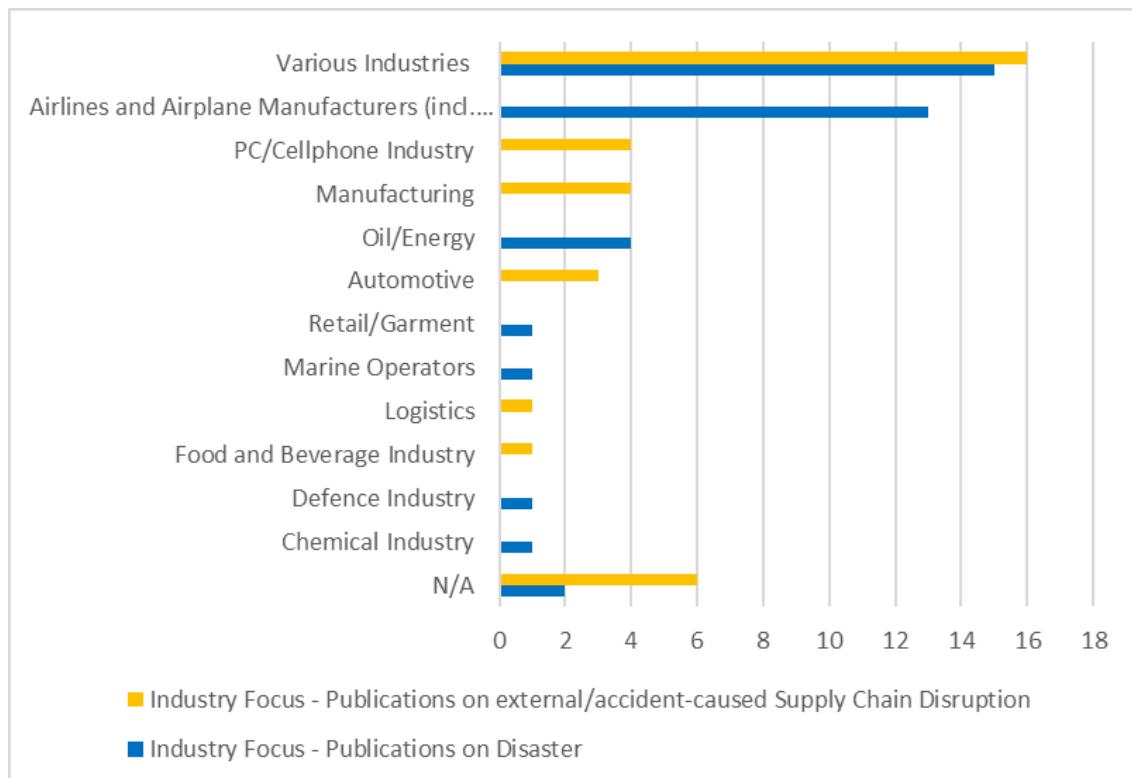


Figure 10. Industrial focus of papers per topic area (Source: Author)

2.2.4 Geographies Covered

Figure 11 indicates the geographic focus of publications. Interestingly, around half of all papers (48%) focus on North America; 16% of the papers do not clearly indicate any geographic focus and another 16% cover/compare various countries. The strong focus on North America especially applies to the publications on disasters as more than 60% of these focus on North America. This is also because many of these papers analyse the 9/11 terrorist attack that occurred in the US. However, even in the external/accident-caused SCD literature, the US has the most predominant geographic focus (40% of papers).

23% of the disaster publications compare or cover various countries. In the supply chain literature covering or comparing different geographic areas seems to be less common as there are just three such papers available (around 8%). There is no disaster paper particularly focusing on Europe. One reason for that might be that Europe does not tend to be prone to natural disasters due to its geographical characteristics; it has also tended to be fairly stable politically in recent years. Furthermore, in Europe high regulatory standards by the countries themselves and by the European Union (EU) (for member countries) are applied. Therefore, fewer industrial accidents may occur than in less regulated markets. However recently, Europe has been the victim of different terrorist attacks, e.g., recently in Paris (2015 and 2017) and in London (2016 and 2017). Therefore, it is expected that the number of disaster publications, especially terrorism publications on Europe, might increase. In contrast there seems to be an interest in SCD research, as around seven papers (around 20%) are focusing on Europe (especially Germany). Generally, there are not many papers on Asia (8% in total); there are four disaster papers and just two SCD publications available for this region. However, even less interest seems to be in Australia as just one paper focuses on this continent. Interestingly just one disaster paper does not have a geographic focus, which might be because the research tends to focus on the analysis of actual events. In contrast, 30% of the SCD research does not focus on a particular geographic region, which might be because some of the research is more conceptual.

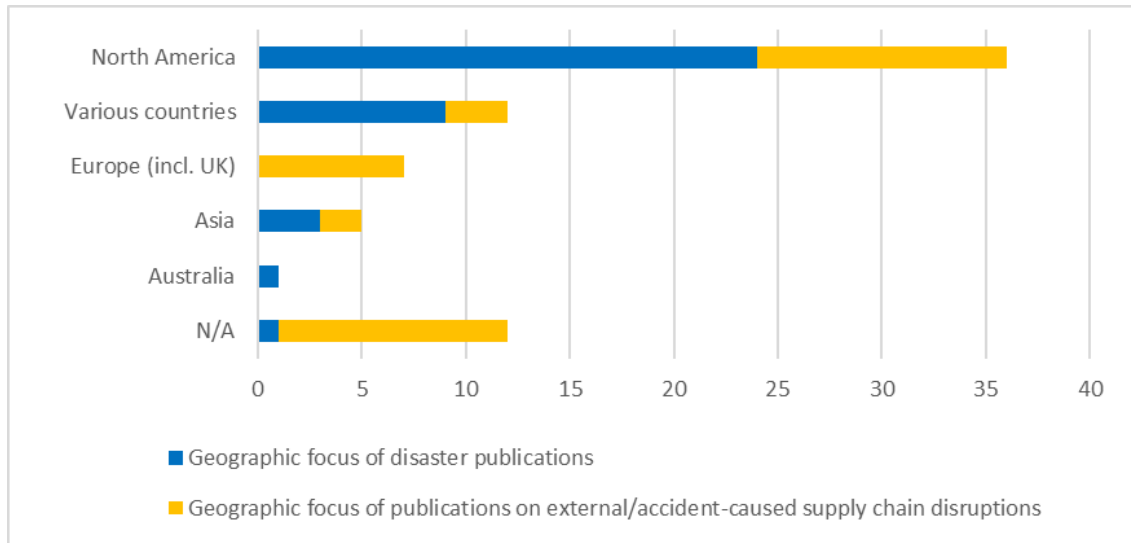


Figure 11. *Geography focus of papers per topic area (Source: Author)*

2.2.5 Journals Published

Table 9 indicates which journals published the articles that are included in this analysis. The journals mentioned below seem to have a particular interest in the subject. Generally, most of these journals are Supply Chain/Logistics Journals, the area the research from this thesis is intended to be published in. The 3-star journal “International Journal of Physical Distribution & Logistics Management” seems to have the most interest in the subject area, as it published the largest number of relevant articles (four papers). Other good supply chain journals (3-star) seem to be interested in the subject too: Transportation Research: Part E, International Journal of Logistics Management, International Journal of Production Economics and Journal of Business Logistics published three relevant papers each. The only 4-star journal that seems to have an interest in the subject is the Supply Chain Management journal “Journal of Operations Management”, therefore my aim is to publish in that journal.

Table 9. Journal Ratings (Source: Author, based on the Cranfield Journal Rating)

Journal	Rating	Papers on Disasters	Papers on external/ accident-caused Supply Chain Disruptions	Total
International Journal of Physical Distribution & Logistics Management	3		4	4
Transportation Research: Part E	3		3	3
Journal of Operations Management	4	1	2	3
International Journal of Logistics Management	3		3	3
International Journal of Production Economics	3	1	2	3
Journal of Business Logistics	3		3	3
Canadian Journal of Administrative Sciences	N/A	2		2
Transportation Journal	N/A		2	2
International Journal of Production Research	3		2	2
Journal of Air Transportation	N/A	2		2
Journal of Manufacturing Technology Management	2		2	2
Logistics and Transportation Review	N/A	1	1	2
Others		31	12	42

2.2.6 Theoretical Underpinnings

In this section the theoretical underpinnings of the papers in scope are analysed. In Table 10 these are ranked according to the number of papers they apply to overall; the table indicates a large amount of the papers (38%) does not have a defined theoretical perspective for their research. Missing theoretical underpinning can be seen as a qualitative issue of academic research as it fails to explain why relationships exist or should be existing (Colbert, 2004). Overall, the most frequently used theory is the efficient market hypothesis (20%), other

theories occasionally used were contingency/strategic choice theory, contagion theory, systems theory and game theory (each applied in three papers). Papers that apply two theories are counted twice. Papers introducing more than two theories are covered in the category “Various Theories”.

Table 10. *Rating of Theoretical Underpinnings per Topic Area (Source: Author)*

Papers by theory used	Number of papers		
	External/accident-originated Supply chain disruptions & firm performance impact	Disasters & firm performance impact	Total
No theory	13	15	31
Efficient Market Theory	3	12	15
Contingency Theory/Strategic Choice Theory	3		3
Contagion Effect	2	1	3
Systems Theory	3		3
Game theory	2	1	3
Supply Chain Theory	2		2
High Reliability Theory	2		2
Various Theories	2		2
Normal Accident Theory	1		1
Entropy/Information Theory	1		1
Financial Portfolio Theory	1		1
Overreaction Hypothesis	1		1
Multivariate Dependence Theory	1		1
Rational Choice Theory		1	1
Rational Pricing Theory		1	1
Disruptive Change Theory		1	1
Signalling Theory		1	1
Theory on the Economics of Natural Disasters	1		1
Transaction Cost Economics	1		1
Resource Based View	1		1
Capital Structure Theory		1	1
Network Theory	1		1
Wurgler's Theory: Investor Sentiment		1	1

The theoretical focus of the disaster research lies on several theories. Table 10 indicates that the disaster research is strongly driven by the view of the efficient market hypothesis as around one third of the disaster papers apply this theory. The remaining theories were all just applied in one paper each, which indicates that in disaster-focused articles, no more than one paper applies the theory, which indicates that the use of other theories has not been widely accepted in the research community. 40% of the articles on disaster impact have no sound theoretical underpinning.

In the research on external/accident-caused supply chain disruptions, various theories are applied. This indicates that there is no single, commonly accepted

theoretical underpinning established to explain the effect of SCDs on firm performance. Efficient market hypothesis, contingency/strategic choice theory and systems theory are the most frequently applied theories with just three papers each (in total nearly half of external/accident-caused SCD research). There are also other theories that are used occasionally (two papers each): contagion theory, game theory, supply chain theory and high reliability theory. There are also two papers that introduce various theories, this is because they are SLRs; 37% of these are supply chain disruption papers.

2.2.7 Firm Performance Focus

Table 11 provides an overview of the firm performance aspects overall and in both literature bodies. 70% of all papers focus on financial performance, 20% focus on operational/supply chain performance and just 3% cover both aspects. 92% of all disaster publications focus on the effects of disasters on financial performance, just 5% focus on the effect on operational/supply chain performance and only one paper combines both aspects. This is not surprising as most of the papers on disasters are from Financial Economics. Even in the literature on external/accident-caused SCDs nearly half of the papers (46%) evaluate the impact on financial performance. As these papers are predominantly supply chain research, it is not surprising that most of the papers (51%) focus on the operational/supply chain performance aspect. The same applies to the disaster literature; just 3% of the papers (two papers) cover both operational/supply chain performance and financial performance.

Table 11. *Firm Performance Focus: Operational/Supply Chain vs. Financial Performance (Source: Author)*

Firm Performance	No. of Publications on Disasters	No. of Publications on External/Accident-caused Supply Chain Disruptions	Total No. of Publications
Financial Performance	35 (92%)	16 (46%)	51 (70%)
Operational/Supply Chain Performance	2 (5%)	18 (51%)	20 (27%)
Combination	1(3%)	1 (3%)	2 (3%)
Total	38	35	73

In Figure 12 financial performance was analysed using the performance focus in a more granular way by also considering the two main ways to measure financial performance: market-based measures and accounting-based measures. Most of

the papers (55%) cover the measurement of impact with market-based measures. The next most common way to measure the firm performance aspect is with operational/supply chain performance measures (30%). Finally, 25% of all papers cover the measurement of financial performance using accounting-based measures.

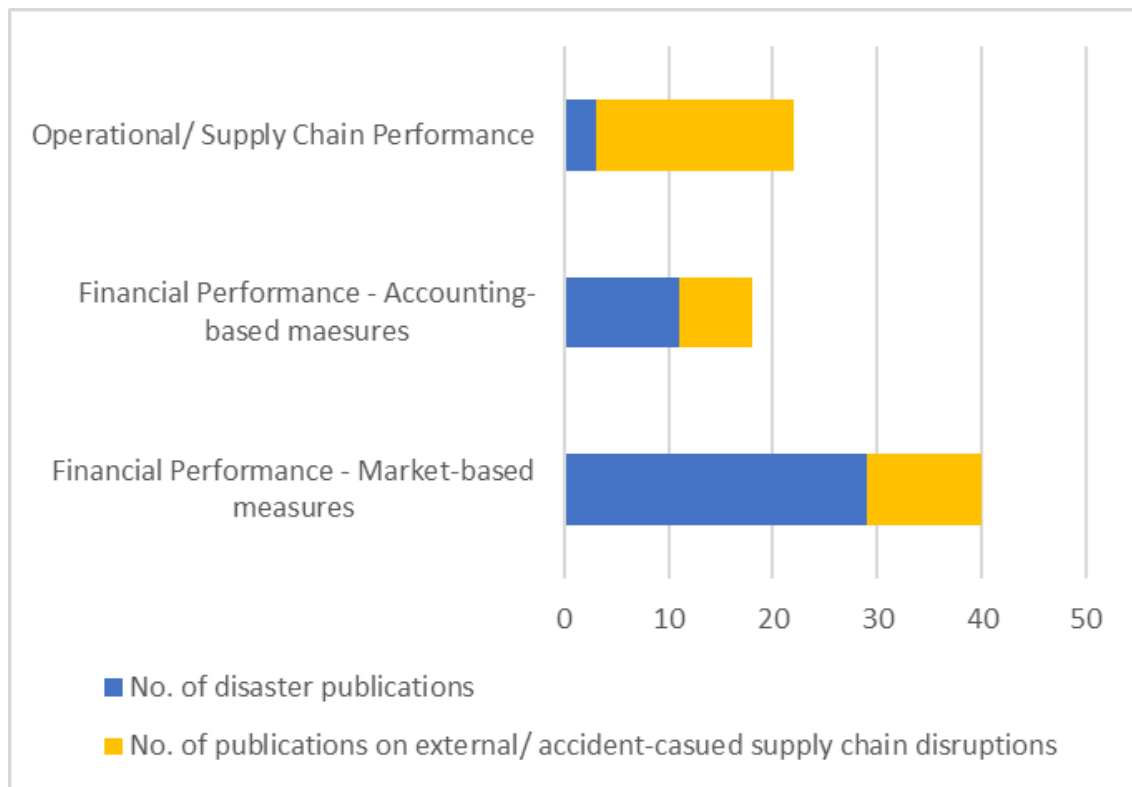


Figure 12. Firm Performance Aspect that were Measured in Previous Research (Source: Author)

As Table 12 indicates, within both literature bodies, papers tend to focus on one performance aspect and one main way of measuring it. Within the disaster literature there are four papers that evaluate the impact on financial performance in two main ways: with market- and accounting-based measures. Furthermore, there are two papers available that evaluate financial performance with accounting-based measures plus operational/supply chain performance. Within the literature on external/accident-caused SCDs all papers apart from one just focus on either market-based financial performance, accounting-based financial performance or operational/supply chain performance. One paper covers all the mentioned performance aspects; the reason for this is that it is a literature review.

Table 12. *Firm Performance Aspects evaluated in Detail (Source: Author)*

Firm Performance Aspects evaluated	No. of Publications on Disasters	No. of Publications on External/Accident-caused Supply Chain Disruptions
Financial Performance - Market-based measures	25	10
Financial Performance - Accounting based measures	6	6
Operational/Supply Chain Performance	2	18
Combination		
Financial Performance - Market & Accounting based measures	4	0
Operational/Supply Chain Performance & Financial Performance - Accounting-based measures	2	0
Operational/Supply Chain Performance & Financial Performance - Market-based measures	0	0
All Performance Aspects	0	1

In summary, papers tend to focus and measure one firm performance aspect. The most common way to measure the impact of disasters and external/accident-caused supply chain disruptions seem to be the evaluation of market-based measures.

The rest of this chapter is structured the following way: for each literature body definitions and classifications are provided. On the basis of these the firm performance links are evaluated for disasters and for external/accident-caused SCDs. Both results are synthesised at the end and are aggregated to a conceptual model in Chapter 6.

2.2.8 Summary of Descriptive Analysis

The relevant literature consists of 73 peer-reviewed papers published until 2020, half of which focus on the impact of disasters and the other half on the impact of external/accident-caused SCDs on firm performance. This proportion reflects the allocation of the papers to either financial economics or supply chain literature, respectively. The literature review indicates that the most common research method used is some form of regression analysis (51%). The disaster-focused papers evaluate the impact of single incidents in different industries with just two papers having no industry focus, indicating there are few conceptual papers as

opposed to analyses of specific events. SCM literature on the other hand seems to be more conceptual in nature with just one third focusing on a specific industry. It is striking that there are studies that either consider SCDs in SCM on stock price or disasters on stock price in financial economics. This is a disconnect, as I found when developing the concepts, that disasters are one source of SCD. Two thirds of publications on disasters and half of all supply chain papers focus on North America with a large proportion of the remaining papers covering several countries or lacking geographic focus. The lack of geographic focus again reflects more conceptual papers in SCM literature. In both the US and Europe legal requirements are strictest regarding the reporting of listed firms, which ensures data availability and quality. As not many natural disasters occur in Europe, this thesis follows the trend to focus on the US. Another reason for selecting the US was that the first papers in the early 2000s were focusing on the US whilst recent studies transported the approach to countries such as Ukraine. Therefore, an update of studies for the US is appropriate.

3 Thematic Analysis

In this chapter the relevant concepts are explained – it is basically a thematic analysis. In Chapter 3.1 relevant concepts and theories are explored and in Chapter 3.2 limitations and a critique of existing research are presented. Finally, in Chapter 3.3 the hypotheses are deduced from theory

3.1 Themes and Theories

In this chapter all relevant themes and theories are described. An overview of the logic of this chapter is visualised in Figure 13.

Disasters and SCDs can be seen as risks that companies want to avoid. As supply chain risk management was developed later than the general risk management literature, I started out with the relevant aspects and concepts of risk, and the risk management literature was reviewed (Chapter 3.1.1). The risk definitions were reviewed, and I decided on the risk definition for this thesis.

Subsequently, I placed this thesis within the SCM and SCRM literature (Chapter 3.1.2); this is the literature body I aim to mainly contribute to.

I then explored and defined the three concepts: disasters (3.1.3), SCDs, specifically supply chain disruptions (3.1.4) and firm performance (3.1.5). I explained the parts of the concepts further that are particularly relevant for this research: external SCDs, natural disasters – specifically hurricanes, and financial performance – stock price.

Afterwards, I brought these concepts together by connecting them in Chapter 3.1.6. To do that I summarised the existing literature connecting these concepts.

In Chapter 3.1.7 I explain the factors that were found to have an influence on stock price – called potentially influencing factors – and define which factors are tested.

Finally, in Chapter 1.3.8 I introduced underlying theories, and explain the way in which these are relevant by explaining the effects of hurricane-induced supply chain disruptions on stock price.

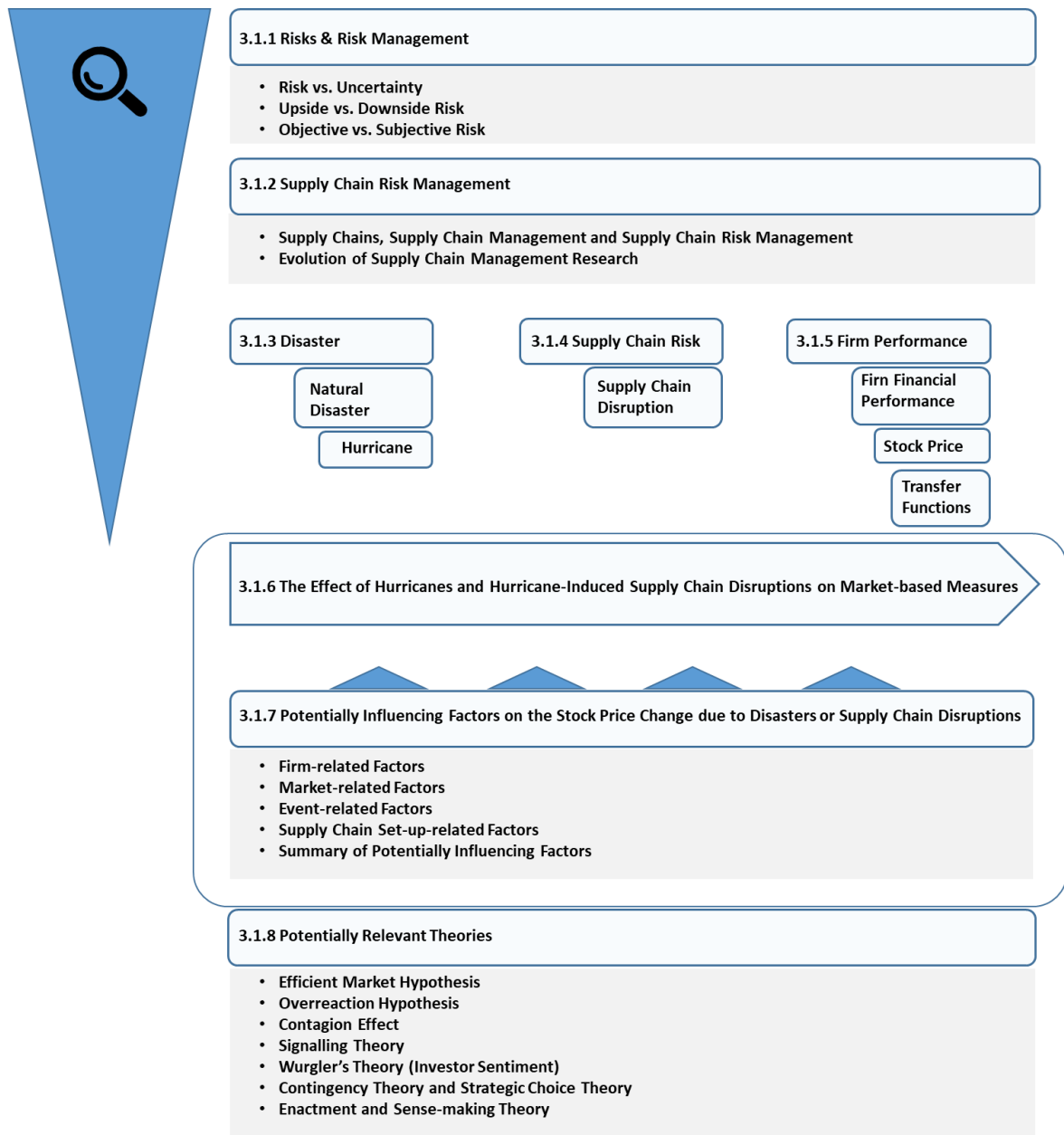


Figure 13 Schematic of the Chapter 3.1 Themes and Theories

3.1.1 Risks and Risk Management

To address the critique of the lack of connection with SCRM, different risk management literature was reviewed, and key definitions and concepts found are presented below. There is extensive literature on risk management available in different fields, such as in decision theory (Arrow, 1965), finance (Altman, 1968), marketing (Cox, 1967), management (March and Shapira, 1987), and psychology (Kahneman and Tversky, 1979; Wagner and Bode, 2008). The construct “risk”

has a variety of different meanings, measurements and interpretations, depending on the research area (Jemison, 1987). Even within the disciplines, there is much discussion, therefore only a few clear and concise risk definitions exist (Chiles and McMackin, 1996; Holton, 2004; Khan and Burnes, 2007; Rao and Goldsby, 2009).

3.1.1.1 Risk vs. Uncertainty

Risk can be defined as the likelihood of variance in an expected outcome, implying risk is a quantifiable outcome (Khan and Burnes, 2007; Lockamy, 2014; Spekman and Davis, 2004). Consequently, risk can be measured by probability of occurrence and impact (variance from the expected outcome) (Khan and Burnes, 2007; Lockamy, 2014). In contrast, uncertainty cannot be quantified and measured, as the possible outcomes are unknown (Knight, 1921). Risk may be viewed as an uncertainty associated with a known outcome, implying there is no unknown risk (Yates and Stone, 1992). This way uncertainty can be seen as a key determinant of risk. Uncertainties caused by natural and man-made disasters are sources for supply chain risks (Lockamy, 2014; Tang, 2006). A risk may be defined by these two dimensions' exposure and uncertainty (Holton, 2004) or in the supply chain context as "exposure to a premise, the outcome of which is uncertain" (Rao and Goldsby, 2009, p. 100).

3.1.1.2 Upside vs. Downside Risk

Some research in decision theory and finance argues that risk is not just the downside, but also the upside possibility, such as a higher performance than expected (Arrow, 1970; Kahneman and Tversky, 1979; Rao and Goldsby, 2009; Wagner and Bode, 2008). For example, after a natural disaster, some industrial sectors or firms might benefit from the crisis and experience higher demands. Thus, risk is not limited to the downside possibility and includes the deviation/fluctuation of the expected outcome and thereby the lack of controllability (Arrow, 1970; Kahneman and Tversky, 1979; Rao and Goldsby, 2009; Wagner and Bode, 2008). However, most business researchers define risk as a negative change in performance, with downside risk being more threatening for organisations than upside risk (Chiles and McMackin, 1996; Khan and Burnes,

2007; March and Shapira, 1987). This discussion is also reflected in the supply chain risk research, which considers upside and downside risk and defines supply chain risk as a “variation in the distribution of possible supply chain outcomes, their likelihood, and their subjective value” (Juettner et al., 2003, p. 200). In contrast, others postulated that managers tend to exaggerate downside risk (March and Shapira, 1987). Most supply chain researchers agree with the downside view on risk as well (Harland et al., 2003; Wagner and Bode, 2008). This research will assess downside and upside risk. The research also assesses the effect of hurricanes/hurricane incidents on stock price. Previous research has shown that there are not just losers but also winners after a crisis, e.g., after a natural disaster. For example, after a hurricane many companies will have a negative stock price reaction as investors expect damage. But if companies are not damaged and produce for example goods that are specifically needed after the event, such as generators, investors anticipate that, thus these firms will have a positive stock price movement. Because both positive and negative reactions are possible, no direction of change is provided in the hypotheses.

3.1.1.3 Objective vs. Subjective Risk

There is an ongoing discussion between researchers in the risk and risk management theory on whether a risk is subjective or objective (Khan and Burnes, 2007). Some supply chain researchers (Cousins et al., 2004; Kraljic, 1983; Williamson, 1979; Zsidisin and Wagner, 2010) use terms such as “perception” or “perceived”, indicating a more subjective perspective (Khan and Burnes, 2007). Another theory underlying the subjectivity is the utility theory which states that customers make buying decisions based on the degree of utility or satisfaction they gain (Witt, 2016). This theory could probably also be transferred to the buying and selling decisions of investors; however, it will not be evaluated further in this thesis. Other researchers use terms such as “probability” (Harland et al., 2003) indicating a more objective view on supply chain risks (Khan and Burnes, 2007).

The discussion of risk as either objective or subjective does not seem to be broadly reflected in the academic supply chain risk literature (Khan and Burnes,

2007). In practice, business executives tend to prefer approaches to risk management which combine subjective and objective measures for two reasons (Hendricks and Singhal, 2005b; Hood and Rothstein, 2000): Firstly, it allows for a certain degree of freedom of manoeuvring instead of being pushed into taking decisions based just on quantitative analysis (Hood and Rothstein, 2000). Secondly, top executives acknowledge that risks can affect different stakeholders in the business in different ways (Hendricks and Singhal, 2005b). Even though the discussion might not be resolvable, the debate should be at least reflected in the supply chain risk literature as it has implications for how risks are viewed (Khan and Burnes, 2007). A more recent supply chain paper takes a different approach and aims to ground the subjective view on SCD risk on enactment and sense-making theory (Ellis et al., 2011). Enactment theory provides a framework, which describes the process of sense making of individuals of equivocal environments and is further explained in the theory chapter (Ellis et al., 2011). Based on the previously evaluated supply chain risk definitions, I see supply chain risk as the likelihood of a quantifiable variance in an expected outcome (Harland et al., 2003; Khan and Burnes, 2007; Lockamy, 2014; Spekman and Davis, 2004). In this thesis both upside and downside risk will be evaluated. In the ongoing discussion regarding if supply chain risk should be seen from an objective and subjective perspective, I have the view that both sides are valid and should be considered. I agree with most supply chain researchers on a contingency view on the management of supply chain risks (Chang et al., 2015; Groetsch et al., 2013; Juettnner et al., 2003; Wagner and Bode, 2008).

3.1.2 Positioning in the Supply Chain Management Research

This research contributes to the SCM, specifically to the SCRM literature. Supply chain risks are no longer just the domain of practitioners, with academics showing an increased interest in the last few years (Wieland and Wallenburg, 2012). There is extensive SCM literature available on supply chain risks in general. The literature most relevant to this research will be presented in the following.

3.1.2.1 Supply Chains, Supply Chain Management and Supply Chain Risk Management

Supply chains consist of trading partners interconnected by flows of material, information and finances (Fugate et al., 2006; Spekman and Davis, 2004). Effective supply chains maximize the value for all trading partners and customers (Lockamy, 2014). SCM applies a holistic view to address business problems to globally match supply and demand to enhance the overall supply chain effectiveness while considering complexity and uncertainty (Lockamy, 2014). An increasing number of organisations are adopting SCM principles (Kopczak and Johnson, 2003) as supply chains are becoming increasingly global, complex and dynamic, and thus more exposed to external risks (Harland et al., 2003; Juettner, 2005; Khan and Burnes, 2007; The Boston Consulting Group, Inc., 2013; Wagner and Bode, 2008). Due to the increase in supply chain risk literature, there are some slightly varying definitions of SCRM available (Rao and Goldsby, 2009).

Most SCRM definitions state that “SCRM is an extension of the within-firm risk management ideology” (Rao and Goldsby, 2009, p. 101). According to one definition SCRM is the coordinated approach of managing external risks involving all supply chain members to reduce the vulnerability of the overall supply chain (Christopher, 2002). Another view is to ensure profitability and continuity as the purpose of SCRM (Tang, 2006). While the definitions are slightly different, supply chain researchers agree that the overall purpose of SCRM is to reduce vulnerability at the holistic and global supply chain level instead of just at the firm level (Rao and Goldsby, 2009). This in line with my view.

3.1.2.2 Evolution of Supply Chain Management Research

Apart from some work on risk with regard to procurement back in the 1960s, the academic interest in risk management in the supply chain context has only significantly developed in the last 15 years when researchers shifted from managing risks using an institutional focus to a more holistic supply chain view (Cousins et al., 2004; Harland et al., 2003; Khan and Burnes, 2007; Lewis, 2003; Peck, 2006; Wieland and Wallenburg, 2012). One reason might be that as supply chains are becoming increasingly global, complex and dynamic, they are more

exposed to external risks such as political, economic events and natural catastrophes (Harland et al., 2003; Juettner, 2005; Khan and Burnes, 2007; The Boston Consulting Group, Inc., 2013; Wagner and Bode, 2008). Many supply chain researchers built on the earlier studies on risks in procurement back in the 1960s and continued investigating the relationship between risk and SCM (Eisenhardt, 1989; Hallikas et al., 2004; Harland et al., 2003; Karjalainen et al., 2003; Kraljic, 1983; Zsidisin et al., 2000).

This research assesses the effect of hurricanes on the stock price of firms as the descriptive analysis showed that 82% of all disasters/incidents of NYSE firms are due to hurricanes. SCM literature is focused on changes in firm performance related to SCDs. Effects of natural disasters are studied to identify and assess supply chain risks and develop SCRM improvements to decrease the impact of these risks (Altay and Ramirez, 2010; Aula, 2010; Khan and Burnes, 2007). Risk management theory and financial performance form a large part of financial economics literature where quantitative measurements and detailed modelling is of primary importance (Dryden, 1969) and applied in event studies (Flouris and Walker, 2007; Kannan et al., 2007). This research consolidates both literature bodies to define and connect the three concepts of disasters, SCDs and firm performance (Figure 14). Management is represented by the yellow area on the left; Financial Economics literature is represented by the red area on the right. The circles represent the three key concepts: Disasters, Supply Chain Disruptions and Firm Performance (Source: Author). The concepts overlap as represented by the overlaps of the circles. The research question is allocated in the overlap of the three key concepts (Figure 14).

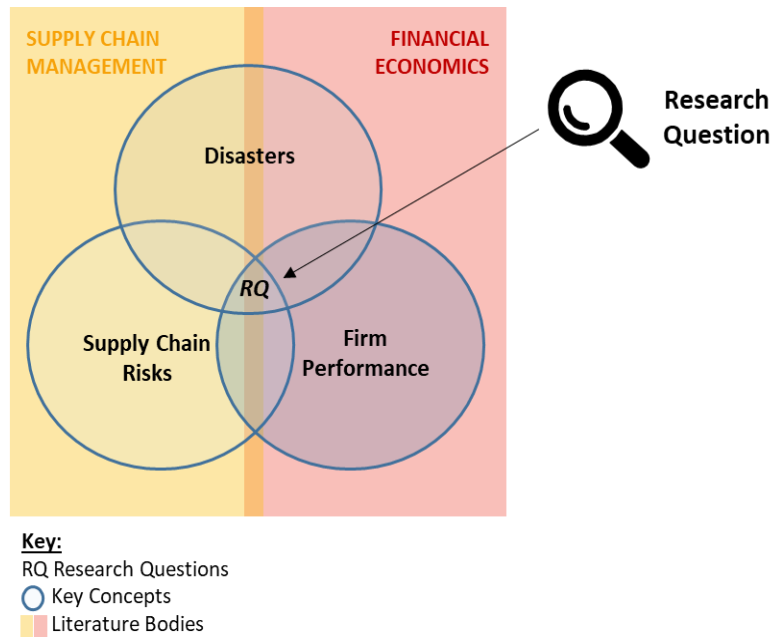


Figure 14. *Key Concepts and Literature Bodies (Source: Author)*

3.1.3 Disaster

Disasters or catastrophes are unanticipated events which may have a significant impact on organisations (Stecke and Kumar, 2009). This disaster classification of Stecke and Kumar (2009) was chosen, as it is precisely defined, and various potential threats can be unambiguously mapped to one disaster category. Disasters are classified according to their source into natural or man-made disasters (Lockamy, 2014; Stecke and Kumar, 2009; Tang, 2006) (Figure 15). Examples of natural disasters are earthquakes, hurricanes, and epidemics (Stecke and Kumar, 2009). Man-made disasters can be further broken down into intentional and non-intentional disasters (Stecke and Kumar, 2009; Worthington and Valadkhani, 2005). Intentional man-made disasters can be further broken down into terrorist and non-terrorist events (Stecke and Kumar, 2009). Examples of terrorist events are bombings and plane hijackings (Stecke and Kumar, 2009). However, a plane crash might also have been an accident if caused by weather conditions, technical problems, or human error. Non-terrorist disaster events include all types of intentional man-made events without terrorist intention, but with political or criminal intention and therefore are a collection of very different disasters such as IT security incidents, strikes, military events and changes in

events, hydrological events, meteorological events and geophysical events (Dada and Jagboro, 2007,

Figure 16). Diseases and epidemics were added from other categorisations to ensure completeness of the natural disaster category, even though they are special cases. Diseases can be viruses such as SARS and Coronavirus (Flouris and Walker, 2007; Vasigh and Fleming, 2005; Wei-Jiat and Enderwick, 2006). However, they may be seen as man-made events if applied as bioweapons. Climatological events are typically heatwaves, freezes, wildfires, and droughts (Dada and Jagboro, 2007). Flash floods, river floods, storm surges and mass movements (landslides) are grouped into the hydrological events class (Dada and Jagboro, 2007). Meteorological events have the most diversity: tropical storms, winter storms, severe weather, hails, tornados, local storms, hurricanes, and blizzards (Dada and Jagboro, 2007). Finally, there are geophysical events such as earthquakes and volcanic eruptions that are caused by tectonic movements (Dada and Jagboro, 2007). This thesis is focused on hurricanes, which belong to the group of meteorological disasters, the reason being that the descriptive analysis showed that 82% of the disaster-incidents at NYSE listed firms are due to hurricanes.

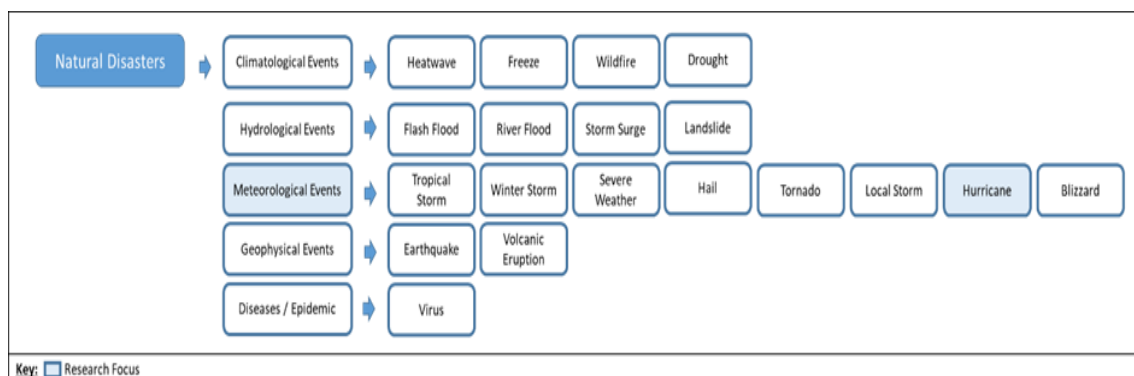


Figure 16. *Classification of Natural Disasters (Source: Author, based on Dada and Jagboro, 2007). The figure provides a breakdown structure of the natural disaster concept for the different disaster types.*

3.1.4 Supply Chain Risk

There are several supply chain papers identifying and defining supply chain risks.

These typologies allocate uncertainties or “supply chain risk sources” to a “risk event” (Christopher and Peck, 2004; Hallikas et al. 2004; Juettner, 2005; Lockamy, 2014; Spekman and Davis, 2004; Zsidisin and Wagner, 2010). This terminology of risk source and event seems to be aligned with general academic risk management literature (Ritchie and Marshall, 1993). There does not exist one commonly accepted categorisation/classification for supply chain risks and the following observations can therefore be made: Firstly, the way of classification depends on the view taken, i.e., if risks are classified by their source or by the event itself (Christopher and Peck, 2004; Hallikas et al., 2004; Juettner, 2005; Spekman and Davis, 2004; Zsidisin and Wagner, 2010). Many supply chain researchers classify supply chain risk events by their sources, few researchers classify by risk event and no typology classified by risk impact was found (Spekman and Davis, 2004) (see Table 13). Secondly, many supply chain researchers seem to focus solely on the risk event SCD while others focus on supply chain risks in general (see Table 13). Thirdly, the terminology used, and the way researchers group risk sources vary (see Table 13). There is no universal academic agreement on a certain classification (Blackhurst et al., 2005; Chopra and Sodhi, 2004; Craighead et al., 2007; Juettner et al., 2003; Rao and Goldsby, 2009; Wieland and Wallenburg, 2012). Many supply chain researchers seem to focus on risks that result in SCDs, which emphasises the relevance of SCDs in the supply chain risk literature (Craighead et al., 2007; Juettner et al., 2003; Wieland and Wallenburg, 2012). These typologies can be seen as SCD typologies but not as complete supply chain risk typologies as risks such as CSR risks do not seem to be considered. Supply chain risks in this context appear to be risks that affect the supply chain rather than risks emerging from the supply chain. A three-category typology is applied to group SCD sources, i.e. Operational (inside the firm), Network (outside the firm but within the supply chain) and External/Environmental Risks (outside the supply chain) (see Table 13, first row). However, I decided to adopt the typology chosen by Rao and Goldsby (2009) as it is aligned with the general risk management literature (Ritchie and Marshall, 1993). Rao and Goldsby (2009) grouped the risk sources into five categories: environmental factors, industry factors, organisational

factors, problem-specific factors and decision-maker-related factors, whereby environmental factors, industry factors, organisational factors are seen as framework factors that represent the circumstances/environment the organisation is operating in.

Table 13. *Literature Review on Supply Chain Risk Typologies (Source: Author)*

Author (Year)	Risk Source	Risk Event
Lockamy (2014), Handfield and McCormack (2007), Christopher and Peck (2004), Juettner et al. (2003)	Operational risks/internal to the firm Network risks/external to the firm but internal to the network External/environmental risks/external to the network	Supply chain risk (SCD)
Zsidisin and Wagner (2010), Juettner (2005)	Supplier/supply risk (internal) Supply market/demand risk (internal) Extended supply chain environment (external)	Supply chain risk (SCD)
Rao and Goldsby (2009)	Environmental risk Industry factors Organisational risk Problem-specific risk Decision-maker risk	Supply chain risk
Stecke and Kumar (2009)	Catastrophes: Terrorist Natural Accidents Non-terrorist	Supply chain risk (SCD)

Wagner and Bode (2008)	Demand side risk Supply side risk Regulatory, legal and bureaucratic risk Infrastructure risk Catastrophe risk	Supply chain risk (supply chain disruption)
Chopra and Sodhi (2004)	Disruptions or delays that cause supply chain risk: Systems Forecast Intellectual Property Procurement Receivables Inventory Capacity	Supply chain risk
Hallikas et al. (2004)	Too low or inappropriate demand Problems in fulfilling customer deliveries Cost management and pricing Weaknesses in resources, development and flexibility	Supply chain risk
Spekman and Davis (2004)	Various	Supplier capacity Quality Changes in product design and production processes An inability to reduce costs

		Unanticipated delays and supply disruptions
Norrman and Lindroth (2004)	Strategic risk Financial risk Operational risk Commercial risk Technical risk	Supply chain risk
Cousins et al. (2004)	Technological risk Strategic risk	Supply chain risk (SCD)
Zsidisin (2003)	Supplier Market Item characteristics	Supply side risk
Svensson (2000)	Quantitative Qualitative	Disturbance of the inbound logistics flow of manufacturers
Zsidisin et al. (2000)	Business risk Supplier capacity constraints Quality Production technological changes Product design changes Disasters	Supply risks

Supply chain risks can have significant impact on firm performance. Supply Chain and Financial Economics research links two type of supply chain risk events to a significant effect on firm performance: CSR risks (Arx and Ziegler, 2014; Blacconiere and Patten, 1994; Foerstl et al., 2010; Giannakis and Papadopoulos,

2016; Hill and Schneeweis, 1983; Humphrey et al., 2016; Nuryaman, 2013; Wang and Berens, 2015) and supply chain disruption risks (Altay and Ramirez, 2010; Babich et al., 2007; Blackhurst et al., 2005; Chopra and Sodhi, 2004; Hendricks and Singhal, 2005 a, b, 2003; Lockamy, 2014). The research proposed in this document aims to focus on SCDs for the following reasons: firstly, externally caused SCDs are a major concern for organisations as they are unpredictable and uncontrollable (Barnett and Hoffman, 2008; Fauchart and Cowan, 2014; Juettner, 2005; Petersen and Lemke, 2015). Secondly, SCDs are increasing due to diseases, terrorist attacks and natural disasters (Juettner, 2005; Khan and Burnes, 2007; The Boston Consulting Group, Inc., 2013). Thirdly, data on external SCD causes are available on the internet and in the media, such as warnings, and present and past information on natural catastrophes, such as tsunamis. Finally, there is little research available that focuses on the impact of SCDs. A basic typology for supply chain risks is illustrated in Figure 17.

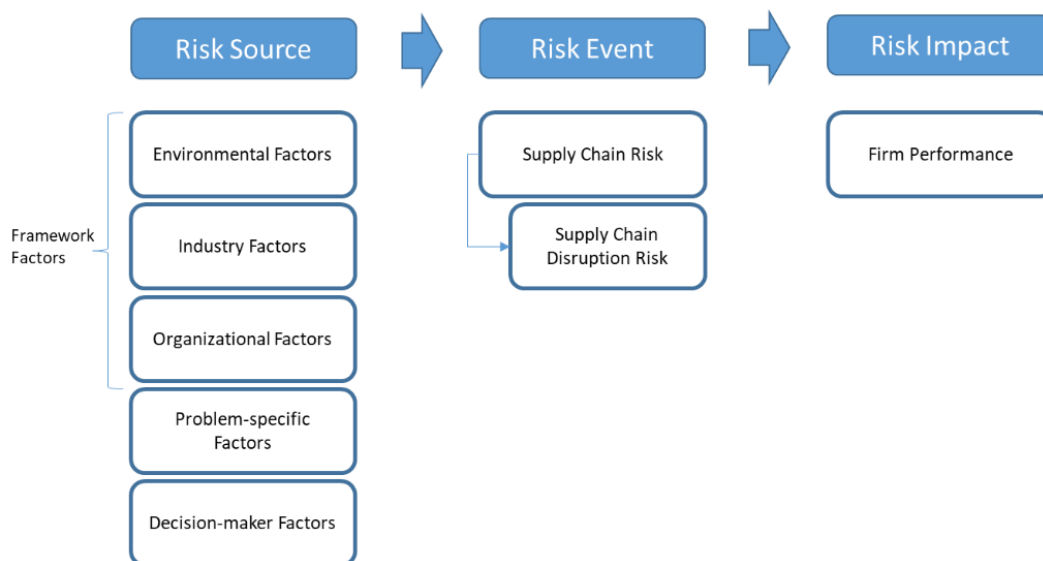


Figure 17. *Supply Chain Risk Typology (Source: Rao and Goldsby, 2009)*

3.1.4.1 Supply Chain Disruption

SCDs are one type of supply chain risk and these risks are classified in the literature in various ways (Table 13): e.g. by source, cause, primary location, disrupted flow or duration; the most common classifications for SCDs are by source and cause of disruption (Filbeck et al., 2016; Hendricks et al., 2009, 2005a,b, 2003; Wagner and Neshat, 2012). Some researchers apply several

classifications or a combination thereof, e.g., source and cause, allowing for different perspectives on SCDs (Hendricks and Singhal, 2005a and b). Some researchers seem to use the terms “cause” and “source” synonymously (Filbeck et al., 2016; Hendricks and Singhal, 2008; Wagner and Neshat, 2012). With regard to SCDs, the “risk cause” seems to be frequently used, therefore the supply chain risk typology from Figure 17 is extended by this dimension (see Figure 18). In this thesis, SCDs are evaluated by the risk source, cause, event and impact (Stecke and Kumar, 2009) (Figure 18). In this work the four dimensions of SCDs, i.e. risk source, risk cause, risk event and risk impact are considered. These dimensions can be identified and assessed by asking dedicated questions.

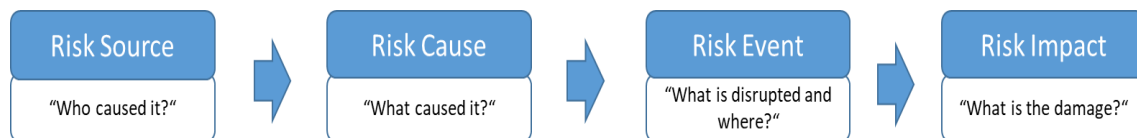


Figure 18. *Characteristics of a Supply Chain Disruption (Source: Author).*

Risk Source: The term “source” is understood as a classification of the responsibility for the SCD (Hendricks and Singhal, 2003; Hendricks et al., 2009; Macdonald and Corsi, 2013) (Figure 18). Risk source is also called responsibility, primary source and location (Filbeck et al., 2016; Hendricks and Singhal, 2008, 2005a, b; Hendricks et al., 2009; Kumar et al., 2015; Macdonald and Corsi, 2013; Thun and Hoenig, 2011; Wagner and Neshat, 2012). The risk source can be classified into internal and external to the supply chain and environmental (Christopher and Peck, 2004; Kumar et al., 2015; Thun and Hoenig, 2011). Internal may be defined as within the company (Hendricks and Singhal, 2008), or as within the supply chain that is evaluated (Thun and Hoenig, 2011) or both (Kumar et al. 2015). Within the supply chain also discusses supply chain structure (Wagner and Neshat, 2012). Here, internal is defined as within the supply chain including all supply chain members, such as suppliers, the focal company itself, retailers, and customers (Kumar et al., 2015; Wagner and Neshat, 2012). The term company-internal is used for risks which have their source within the focal company (Hendricks and Singhal, 2003; Hendricks et al., 2009; Thun

and Hoenig, 2011). External SCDs may be caused by a source outside of the supply chain (Christopher and Peck, 2004) and “deal with environmental causes that can barely be influenced” (Kumar et al., 2015; Thun and Hoenig, 2011, p. 244). This category can be further broken down into e.g., government, regulatory, and nature as sources of responsibility (Hendricks and Singhal, 2008, 2005 a, b.). SCD might not always be allocated to a single source (Hendricks and Singhal, 2005 a, b; Kumar et al., 2015). Hurricanes, like most other disasters, are classified as external (Kleindorfer and Saad, 2005).

Risk Cause: The risk cause or “risk reason” defines “what” caused the SCD (Figure 18). SCDs emerge from various risk causes within or from outside the supply chain (Zsidisin and Wagner, 2010). There are several classifications available (Filbeck et al., 2016; Hendricks and Singhal, 2008, 2005 a, b, 2003; Hendricks et al., 2009). Supply chain risks are grouped by cause (Rao and Goldsby, 2009), coherent with general risk management literature (Ritchie and Marshall, 1993). Supply chain risks are classified into the following five main categories: environmental, industrial, organisational, problem-specific, and decision-making factors. Environmental causes such as natural uncertainties are causes for major SCDs (Stecke and Kumar, 2009). Hurricanes fall into the category of natural uncertainty.

Risk Event: The risk event “supply chain disruption” is defined as a supply-demand mismatch (Hendricks and Singhal, 2005b) either by a disruption of the flow of goods, the information flow or financial flow (Akintoye and MacLeod, 1997; Juettner et al., 2003; Reason, 1990; Shrivastava et al., 1988; Swierczek, 2016). Disruptions may occur at different locations in the supply chain: upstream the supply chain at a supplier, at the focal company itself or downstream the supply chain at a customer (Kumar et al., 2015). This thesis focuses on SCDs at the upstream of the supply chain or at the focal company itself as these are the most threatening (Altay and Ramirez, 2010; Giunipero and Eltantawy, 2004).

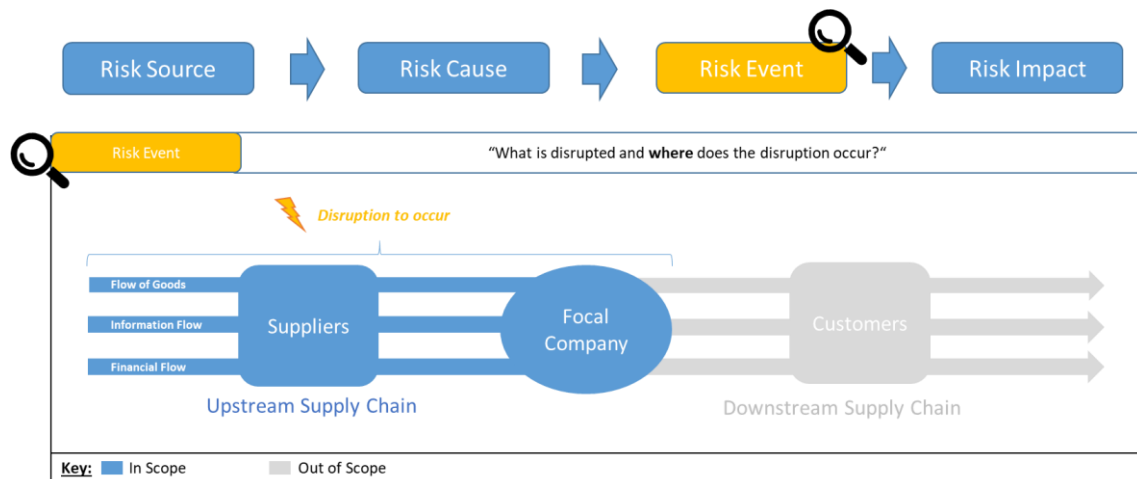


Figure 19. Schematic of a Supply Chain Disruption Event (Source: Author)

Risk Impact: SCDs have had a significant direct and indirect negative impact on corporate reputation, operational, operating and stock price performance (Altay and Ramirez, 2010; Aula, 2010; Khan and Bumes, 2007; Zsidisin and Wagner, 2010) (Figure 20). Though negative financial consequences of supply chain disruptions are found, the severity of impact varies (Hendricks and Singhal, 2005b; Zsidisin, 2016). A link between SCM and firm financial performance has been established to prove the relevance of proper SCM and thereby increasing the importance of the topic (Ellinger et al., 2011; Johnson and Templar, 2011; Shi and Yu, 2013).

Figure 20 summarises the four different supply chain dimensions, i.e. risk source, cause, event and impact. Scoping is indicated by shading.

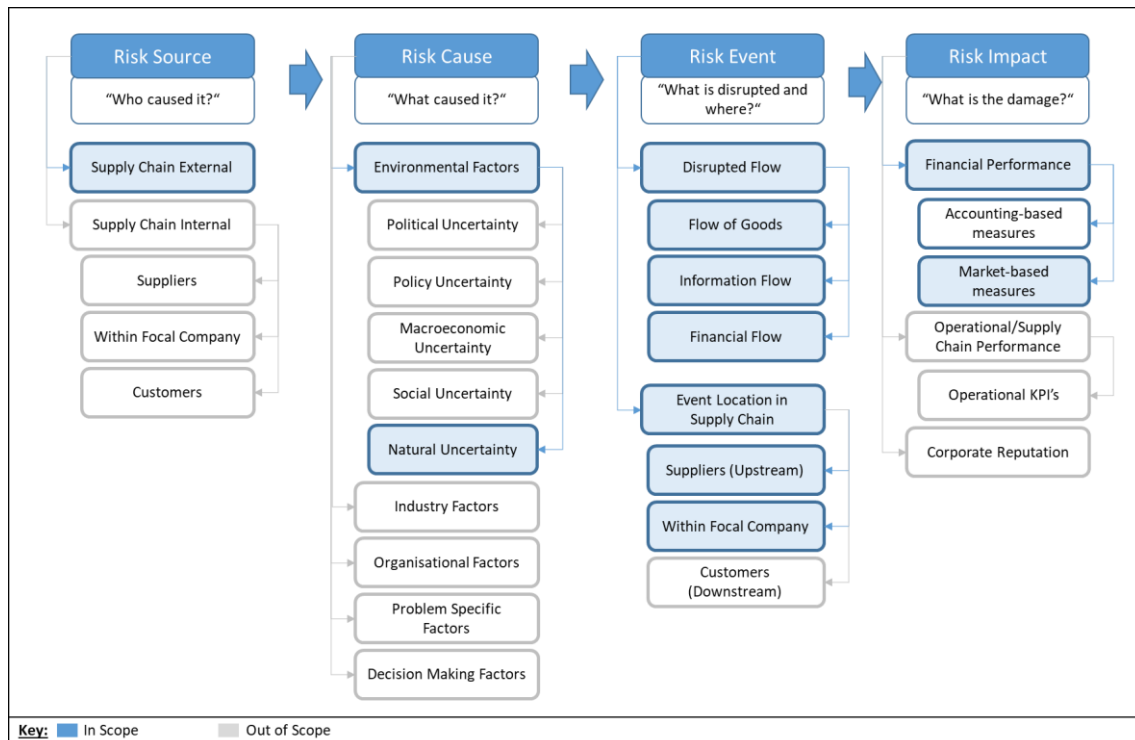


Figure 20. Supply Chain Disruption: Overview of Definition and Scoping as indicated by shading (Source: Author)

3.1.5 Firm Performance

Several terms are used for "firm performance" such as "business performance" (Neely, 1998) or "organisational performance". Only measured parameters can be managed, highlighting the importance of measuring organisational performance (Neely, 1998). Simultaneously that view is challenged by the notion that even though the performance measurement system may be impeccable, the actions taken afterwards may still be ineffective. Thus, the main value of performance measurement is not the knowledge about the current performance itself but the selection and execution of effective actions, implying that means of controlling firm performance are key. However, this may trigger gaming behaviour, as manipulating performance measures may have the same or a better effect on thus measured firm performance than managing the actual performance itself. For that reason, alternative performance measurement frameworks and tools for product costing and business valuation were developed, such as the balanced scorecard, activity-based costing, shareholder value analysis, market value analysis and throughput accounting (Neely, 1998).

Firm financial performance can be represented by accounting ratios to determine the book value, or by market-based measures that determine the market/shareholder value (Filbeck et al., 2016; Shi and Yu, 2013). The book value is the shareholder's equity which is calculated by subtracting the liabilities from the organisation's assets in the balance sheet (Penman, 2004). Examples of the difference between book value and market value are some of the world's biggest companies, such as Coca Cola (Neely, 1998). Companies' investors do not just evaluate the tangible and possibly intangible assets (such as patents) that are included in the balance sheet, but also have expectations and react to new information so that book value and market/shareholder value are often different (Filbeck et al., 2016; Marcus and Goodman, 1989; Neely, 1998). An equity market's reaction is determined by prices, volume, trading location, spreads, and volatility (Brooks et al., 2003; Chen et al., 2015). Derived from these market-based financial measures are Tobin's q, the Sharpe ratio and abnormal stock returns (Shi and Yu, 2013).

Supply chain or operational performance is usually measured by operational key performance indicators (KPIs) such as "Orders Delivered in Full" and "Order Fill Rate" (Ainapur et al., 2012). Corporate reputation influences customer and stakeholder perception but is difficult to measure (Humphrey et al., 2016; Khan and Burnes, 2007; Suh et al., 2007), but some frameworks exist in the strategic management and marketing literature (Alsop, 2004; Dowling, 2001; Fombrun, 1996; Jackson, 2004; Marquina Feldman et al., 2014; Suh et al., 2007; Vidaver-Cohen and Brønn, 2015).

A firm's performance can be measured by different parameters and in different ways such as firm financial performance, operational/supply chain performance or even corporate reputation (Figure 21). Papers tend to focus on one measure of firm performance. The most common way to measure the impact of disasters and external/accident-caused SCDs seems to be the evaluation of market-based measures. Data availability is very important for research and stock price data are publicly available and provide very frequent data points (every trading day). Compared to that many other firm performance data, such as operational KPIs,

are not publicly available or financial records are, for example, quarterly and therefore it is more difficult to evaluate the effect of an event such as a disaster.

In contrast to previous research that applied event study methodology in combination with stock price returns, this thesis analyses stock price,. The reason being that the model applied in this thesis already accounts for autocorrelation, non-stationarity, trends, seasonal and cyclic changes, as well as drifts. Thereby the applied model creates more accurate results. Previous research papers on financial economics applied the model used in this thesis, e.g. for modelling with intervention analysis to forecast and analyse Chinese stock prices (Jarrett and Kyper, 2011).

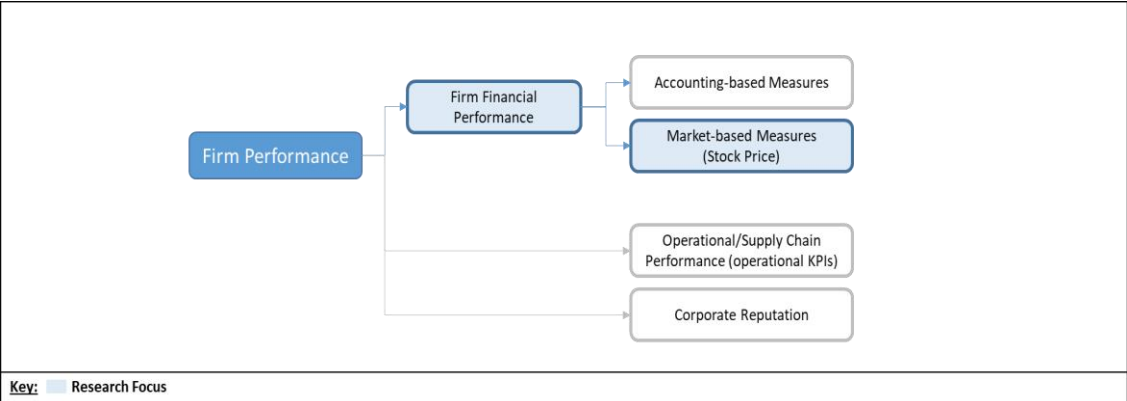


Figure 21. *Classification of Firm Performance (Source: Author)*

3.1.5.1 Transfer Functions Describing Stock Price Patterns

Stock price data are time series data which can therefore be very well analysed by an autoregressive integrated moving average (ARIMA) model (explained later in detail in the methodology section). In combination with ARIMA, interventions such as a hurricane announcement/hurricane incident announcement can be defined as transfer functions where the focus will be on pulse, step and transitory changes of the time series data (Box and Tiao, 1975).

3.1.6 The Effect of Hurricanes and Hurricane-Induced Supply Chain Disruptions on Market-based Measures

The probability of a disaster-originated SCD is low; however, if it occurs it may be very costly (Horwich, 2000). Researchers agree on the statistically significant

negative effect of disasters, SCDs and disaster-induced SCDs on stock price (Brooks et al., 2003; Donadelli and Lucchetta, 2013; Hendricks and Singhal, 2003; Worthington and Valadkhani, 2005; Zsidisin et al., 2016). Regression studies such as event studies are applied to estimate the impact of SCD announcements on stock price returns based on the efficient market hypothesis (Hendricks and Singhal, 2003). These stock price analyses tend to be quantitative in nature and focus on the correlation between SCDs and stock price returns (Hendricks and Singhal, 2005a, 2003; Papadakis, 2006; Zsidisin et al., 2016). Supply chain studies also assess the impact on short- and long-term stock price returns (Caporale and Makarenko, 2019; Hendricks and Singhal, 2005a). A 10% decrease in the stock price of listed companies was identified after the announcement of an SCD (Hendricks and Singhal, 2003). More recent studies confirm a significant drop in stock price returns, but with smaller effect sizes (Zsidisin et al., 2016). Even though a significant negative relationship between SCD announcements and stock price returns has already been established, the duration and extent of the average effect differ (Hendricks and Singhal, 2003; Zsidisin et al., 2016). A significant decrease in stock price returns is found in the year after a disruption (Hendricks and Singhal, 2005a). The general effect of disaster-induced SCDs may be longer-term (Hendricks and Singhal, 2005b).

Catastrophes such as natural disasters like hurricanes can directly affect a firm's stock price returns (Brooks et al., 2003; Donadelli and Lucchetta, 2013; Worthington and Valadkhani, 2005). Financial economics literature focuses on reviewing significant changes caused by natural disasters over a shorter duration of a single or a few trading days (Caporale and Makarenko, 2019; Hendricks and Singhal, 2005a). The impact on firms by force majeure events and specifically natural disasters, leads to an immediate significant negative effect on stock price returns for the first trading day (Caporale and Makarenko, 2019). However, different types of disasters are usually examined, with natural disasters representing just one type that is covered (Brooks et al., 2003; Donadelli and Lucchetta, 2013; Worthington and Valadkhani, 2005). The economic effect (stock returns, banking returns and insurance claims) of earthquakes and floods is only assessed for the stock price returns of bank and insurance company's value

(Najam and Mehmood, 2019). Other outcomes of natural disasters such as victim numbers, the number of people affected, and economic damages, are analysed without grouping hurricanes into a separate category (Coronese et al., 2018). Natural disasters and specifically hurricanes are linked to significant negative impacts on several aspects of financial economics, as in whole economies, industrial sectors, properties and human losses.

Effects of hurricanes are analysed with regard to state government finances including expenditures, tax revenues, intergovernmental transfers, and issuance of debt over four decades (Miao et al., 2018). The features of typhoon damages have been studied to develop a metric for estimating financial loss due to property damage (Ji-Myong et al., 2018). The indirect effects of hurricanes are evaluated in an event study of hurricanes Katrina and Rita in 2005 by analysing the stock price of insurance companies (Gangopadhyay et al., 2010). However, insurances are just indirectly affected by hurricanes.

SCDs caused by natural uncertainty/disasters such as an earthquake are linked to significant cumulative abnormal returns (CARs). Computer producers suffered from component price increases due to SCDs after the Taiwan earthquake resulting in a negative stock price effect (Papadakis, 2006, 2003). Few papers assess the type of different natural disasters causing SCDs across companies of different industries for market-based measures; therefore, papers assessing accounting-based performance are evaluated. Various natural disasters affect the financial accounting-based performance of downstream supply chain members across all industrial sectors (Altay and Ramirez, 2010). The damage varies depending on the type of natural disaster. Independently of the type of disaster, firms across different industrial sectors are affected (Altay and Ramirez, 2010; Corey and Deitch, 2011; Wei-Jiat and Enderwick, 2006; Worthington and Valadkhani, 2005). Firms do not necessarily have to experience a disruption in their company or supply chain in order to have a negative effect on their stock price returns (Corey and Deitch, 2011; Kannan et al., 2007; Kaplanski and Levy, 2010; Karolyi and Martell, 2010; Sabet et al., 2012; Wei-Jiat and Enderwick, 2006).

The geographic proximity to a disaster and the risk or mere suspicion that the firm might be affected (e.g., same industry or competitor) can lead to a contagion effect sufficient to negatively influence the stock price (Corey and Deitch, 2011; Filbeck et al., 2016; Kaplanski and Levy, 2010; Karolyi and Martell, 2010; Wei-Jiat and Enderwick, 2006). Similarly to the effects of some SCD studies, disasters can affect firms' stock price returns from the mere suspicion of investors that a company is affected by simply being in the same industry as an affected firm (Hobbs et al., 2016) or in the geographic proximity of a disaster (Kaplanski and Levy, 2010) to an affected firm (Brooks et al., 2003; Corey and Deitch, 2011; Donadelli and Lucchetta, 2013; Wei-Jiat and Enderwick, 2006; Worthington and Valadkhani, 2005). Not all shareholder reactions are justifiable regarding a disaster's extreme extent and thus there might have been an overreaction which could explain a strong and immediate change in share price (Filbeck et al., 2016). Some disasters such as wars or 9/11 may affect stock price performance even beyond the geographic regions affected and across various industries, indicating an overreaction (Brooks et al., 2003; Donadelli and Lucchetta, 2013; Worthington and Valadkhani, 2005). The existing literature indicates that SCDs, disasters and disaster-induced SCDs have a significant negative effect on stock price returns with varying size and duration of the effect. In this section, an overview of the key literature is given as that could help to link hurricane-induced SCDs to financial performance, specifically stock price. An overview of the key papers linking disasters and SCDs to firm financial performance – specifically market-based measures – is provided in Table 14.

Table 14. *Key Academic Papers (Source: Author)*

Reference	Metho- dology	Unit of Analysis	Disaster/ Disruption	Impact	Underlying Theory	Study weaknesses/ Limitations	Findings
Latour, 2001	Case Study	Single event, 2 companies	Accident/ Fire	Operational and financial performance	N/A	Limited sample, data quality uncertain, not focused on hurricanes but on another disaster type	Describes the impact of a fire at a Phillips plant in 2000 on Nokia and Ericsson. Tries to explain why Nokia had lower impact than Ericsson through its supply chain strategy.
Hendricks and Singhal, 2003	Event study	Multiple events, Multiple companies	Supply Chain Disruption	Stock price performance	Efficient market hypothesis	Does not specifically test disruption causes, and thereby does not analyse natural disasters/ hurricanes, limited variables, quite old data	Supply chain glitches negatively impact stock price performance. Smaller firms are more affected than larger ones.

Hendricks and Singhal, 2005a	Event study	Multiple events, Multiple companies	Supply Chain Disruption	Stock price performance	N/A	SCD causes not further evaluated, does not specifically cover natural disasters/hurricanes, limited variables, quite old data	Organisations do not recover quickly from negative stock price effect of SCDs.
Hendricks and Singhal, 2005b	Event study	Multiple events, Multiple companies	Supply Chain Disruption	Operating performance	N/A	Does not focus on stock price effect, supply chain causes not further evaluated, does not specifically cover natural disasters/hurricanes, limited variables, quite old data	SCDs significantly affect operational and financial performance of organisations.

Papadakis, 2006	Event study and case study	One event, 5 companies, one specifically evaluated	Taiwan Earthquake (1999)	Stock price performance	Supply chain theory	Just one event and few firms studied, does not specifically cover hurricanes, limited variables, quite old data	The stock price performance of PC producers with pull-supply chains shows stronger decrease following the component price decrease after the Taiwan earthquake in 1999 than companies with push-supply chains.
Altay and Ramirez, 2010	Fixed effect regression analysis	Multiple events, Multiple companies	Natural Disasters	Firm Profitability	Theory on the economics of natural disasters	Does not analyse the stock price effect, does not specifically cover hurricanes, limited variables, quite old data	Disaster impacts the business performance of companies from all sectors downstream of the natural disaster.

Zsidisin et al., 2016	Event study	Multiple events, Multiple companies	Supply Chain Disruption: i.e. Catastrophic Risks	Stock price performance	N/A	Does not specifically cover natural disasters/ hurricanes, limited variables, quite old data	The average impact of supply chain glitches is lower than evaluated in previous studies by Hendricks and Singhal. Supply chain glitches caused through regulatory, catastrophic and infrastructural reasons seem to trigger a more significant negative reaction in financial markets compared to glitches caused by the supply side.
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Filbeck et al., 2016	Event study	Multiple events, Multiple companies	Supply Chain Disruptions	Stock price performance	Overreaction hypothesis, contagion theory	SCD causes not evaluated further	<p>SCD s have consequences for affected companies as well as competitors. The stock market impact from disruptions to automobile companies is affected by the market cycle as well as the brand domicile. The authors observe that the negative stock effect of disruptions occurs in bear but not bull markets.</p> <p>American.brand automakers experience a larger stock price decline in bear markets compared to Japanese.brands. The</p>
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							<p>results support a contagion effect as American-brand automakers experience negative stock reactions when a competitor announces disruptions.</p>
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Liu et al., 2018	Event study	Multiple events, Multiple companies	Supply Chain Disruption	Stock price performance	Efficient market hypothesis	SCD causes not further evaluated, does not specifically cover natural disasters/hurricanes, limited variables, quite old data	The study finds that the Japanese companies, in an 11-day window around the disruption announcement witness an average abnormal return of -0.61 percent, which is statistically significant. In comparison to the US, this stock decline is qualitatively smaller, yet statistically indifferent.
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Caporale and Makarenko , 2019	Event study	Multiple events, Multiple companies	Force Majeure Events: Economic, Social, Terrorist, Natural and Technological	Stock price performance	Efficient market hypothesis	Force majeure is a preselection of events as it might not include SCD and hurricane damage that is less severe, does not specifically cover hurricanes, limited variables	The result suggests that the Ukrainian stock market absorbs new information rather fast. Negative returns in most cases are observed only on the day of the event. The only exception is technological disasters, with the market needing up to ten days to react fully in this case.
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3.1.7 Potentially Influencing Factors on the Stock Price Change due to Disasters or Supply Chain Disruptions

Researchers evaluated several factors potentially influencing the effect on stock price returns caused by a disaster and/or SCD. This section provides an overview of all potentially influencing factors found in the relevant literature and summarises which ones were tested for relevance (and which not), and which ones are suggested for testing. I grouped these potentially influencing factors into factors related to the characteristics of the firm, market, the event itself or to the SCM set-up and these are displayed in Table 15. Note: Factors influencing the effect of SCDs/disasters on firm financial performance, specifically market-based measures, were identified from the literature. The factors are grouped into four categories: firm, market, event and supply chain set-up. The table provides an overview on the potentially influencing factors, the tested influence, description of research results and references.

Table 15. *Potentially Influencing Factors generated from the Literature (Source: Author)*

Potentially Influencing factors	Influence	Description	Reference
Firm			
Firm-size	SOMETIMES	Larger firms have less negative effect than smaller firms, not relevant for Indian firms	Hendricks and Singhal (2003); Kumar et al. (2015); Zsidisin et al. (2016)
Industry	SOMETIMES	No significant effect. The effect varies between industries	No effect: Hendricks and Singhal (2003); Liu et al. (2018) Effect: Dietch and Corey (2011); Donadelli and Lucchetta, 2013; Worthington and Valadkhani (2005); Zhang et al. (2009)
Industry Competitiveness	NO	No effect	Hendricks and Singhal (2003)
Firm Growth Perspective	YES	Firms with a good growth perspective had a less negative stock price effect	Hendricks and Singhal (2003); Zsidisin et al. (2016)

Market Capitalization	NO	No effect	Liu et al. (2018)
Capital Structure (Equity Debt Ratio)	SOMETIMES	No big effect on US firms (Hendricks and Singhal, 2003). Significant effect on US firms (Kumar et al., 2015). No effect on Indian firms.	Hendricks and Singhal (2003) Hendricks et al. (2009); Zsidsin et al. (2016)
Capital Intensity	NO	No effect	Hendricks and Singhal (2003)
Diverse Accounting Measures	NO	No effect	Liu et al. (2018); Hendricks et al. (2009); Kumar et al. (2015); Zsidsin et al. (2016)
Research and Development Intensity	NO	No effect	Hendricks and Singhal (2003)
Geographical Diversification	YES	Firms that are more geographically diversified had a more negative stock market reaction	Hendricks et al. (2009)
Business Diversification	NO	No effect	Hendricks et al. (2009)
Organisational Structures	YES	Negative stock effects of disruptions occur in bear markets but not in bull markets	Sarathy (2006)
Market			
Brand Domicile (Company's Trading Location)	YES	Reaction of Japanese and Indian firms stronger than that of US firms	Filbeck et al. (2016); Kumar et al. (2015); Liu et al. (2018)
Market Cycle (Bull vs. Bear Market)	YES	Negative stock effects of disruptions occur in bear markets but not in bull markets	Filbeck et al. (2016)
Event			
Time of Event (Year)	NO	No effect	Hendricks and Singhal (2003); Zsidsin et al. (2016)
Source of Responsibility in Supply Chain	YES	There are differences in the effect dependent on the source of responsibility	Hendricks and Singhal (2005a, 2003)

Reason for Supply Chain Disruption (e.g. part shortage)	YES	There are differences in the effect dependent on the reason for the SCD	Hendricks and Singhal (2005a, 2003)
Cause for Supply Chain Disruption (e.g. Catastrophic, Supply Side)	YES	Has an effect. Catastrophic causes trigger more significant reaction.	Zsidisin et al. (2016)
Location of Supply Chain Disruption	YES	Transportation disruptions at tier 1 supplier and the warehouse tend to have biggest effect	Wilson (2007)
Supply Chain Set-up			
Supply Chain Type (Pull vs. Push)	YES	Pull supply chains have stronger reactions than push supply chains	Papadakis (2006)
Slack in Supply Chain	YES	Firms with more slack have a less negative reaction	Hendricks et al. (2009)
Degree of Vertical Relatedness	YES	Firms with a high degree of vertical relatedness experience a less negative reaction	Hendricks et al. (2009)
Robustness	YES	Firms with increased robustness have a less negative effect	Wieland and Wallenburg (2012)
Agility	NO	No effect	Wieland and Wallenburg (2012)
Readiness	YES	Firms with increased readiness have a less negative effect	Sarathy (2006)
Managerial Focus (Logistics Importance, Supply Chain Risk Management)	YES	Firms with stronger focus have less negative effect	Thun and Hoenig (2011); Wagner and Neshat (2012)

3.1.7.1 Firm-related Factors

Existing research evaluates several firm characteristics for their potential influence on the stock price after disasters and supply chain disruptions: firm size, industry, industry competitiveness, firm growth perspective, market capitalization,

capital structure, capital intensity, geographical diversification, business diversification, research and development intensity, organisational structure and several accounting-based measures such as book-to-market-ratio. Of these firm-related factors, firm size, industry, firm growth perspective, geographical diversification and capital structure are quantitatively tested for any impact. Larger firms incur less negative impact on stock price by SCD announcements (Hendricks and Singhal, 2003; Zsidisin et al., 2016). The effect on market sector returns after disasters differ, depending on the industry (Worthington and Valadkhani, 2005). Firms with a good growth perspective have a less negative effect on stock price after SCDs (Hendricks and Singhal, 2003; Zsidisin et al., 2016). Firms with large geographical diversification experienced a more negative stock market reaction (Hendricks et al., 2009). Firms with a good growth perspective have a less negative effect on stock price after SCDs (Hendricks and Singhal, 2003; Zsidisin et al., 2016). Larger firms incur less negative impact on stock price by SCD announcements (Hendricks and Singhal, 2003; Zsidisin et al., 2016). Capital structure can have a significant negative effect on the stock price after disruptions; however, this depends on the listed stock exchange (Zsidisin et al., 2016). Organisational structures help to reduce the likelihood and impact of SCDs; however, this must be assessed quantitatively (Sarathy, 2006). As in previous research, the industrial sector is tested for any effect. SCDs have an effect on firms of all sectors (Hendricks and Singhal, 2003; Liu et al., 2018). The effect of disasters on firms varies between industries sectors (Worthington and Valadkhani, 2005). Most sensitive to disasters of any type are the consumer discretionary, financial services and materials sectors. From the firm-related factors just the industrial factors were tested; the reason for that is that previous test results for other firms were quite clear, while there were controversial results for the “industrial sector”.

3.1.7.2 Market-related Factors

In previous research two market-related factors are evaluated as positive regarding their influence on the stock price effect after disruptions: brand domicile (trading location) and market cycle. The performance impact on firms may vary depending on where they are listed (Filbeck et al., 2016; Kumar et al., 2015; Liu

et al., 2018). Studies on different stock exchanges, for example in Japan, Ukraine, South Korea and Pakistan indicate the relevance of where the company is listed (Caporale and Makarenko, 2019; Filbeck et al., 2016; Liu et al., 2018; Najam and Mehmood, 2019). The effect on Japanese and Indian firms is stronger than on US firms (Filbeck et al., 2016; Kumar et al., 2015; Liu et al., 2018). The effect on stock price of SCDs on companies listed in India is significantly higher than for US-listed firms (Kumar et al., 2015). For Indian-listed firms however, company size, book-to-market ratio and debt-to-equity ratio are not significant factors for the stock market reaction (Kumar et al., 2015). For firm-related factors to be significant, the trading location is a key factor. Larger US firms suffer a less negative impact than small ones, however, no such effect is detected for Indian firms, and the same applies to capital structure (Kumar et al., 2015).

These findings indicate relationships between the influencing factors and stock price returns. The stock price effect is influenced by the economic market cycle. Markets can be classified as a bull or a bear market (Filbeck et al., 2016). Bull markets are periods of rising prices and while bear markets are periods of declining prices. Negative stock price effects of disruptions occur in bear markets but not in bull markets (Filbeck et al., 2016). However, brand domicile remains relevant since US automakers experience a larger stock price decline in bear markets compared to Japanese automakers (Filbeck et al., 2016). Additionally, a contagion effect occurs as US carmakers experience negative stock price reactions when a competitor announces disruptions (Filbeck et al., 2016). No market-related factors are tested as this thesis focuses on one brand domicile: firms listed on the US stock exchange NYSE. Market cycle is not tested because the timeframe of five years is too short and only one stock exchange is analysed.

3.1.7.3 Event-related Factors

The time of the event (year), source, reason, cause and location of disruption in the supply chain were evaluated for their potential influence on the stock price effect (Hendricks and Singhal, 2003; Zsidisin et al., 2016). Of these, source, cause and location of SCDs are found to have a significant influence on the stock price effect (Hendricks and Singhal, 2003; Zsidisin et al., 2016). The point of time

of an SCD has no influence, indicating that SCDs are always seen negatively by shareholders (Hendricks and Singhal, 2003; Zsidisin et al., 2016). As several event-related factors tested positive for their influence on stock price returns, in this thesis some event-related factors are tested as well, namely impact, damage and preventive closures. A literature review is performed to identify other event-related factors in the academic literature that might affect stock price. On this basis, hypotheses H3 to H6 are deduced. Table 16 provides an overview of potentially influencing factors that were derived and will be tested. In the left column the influencing factor category and subcategory are shown. In the right column an explanation and examples of the potentially influencing factors are provided.

Table 16. *Overview of Potentially Influencing Factors Derived that will be tested (Source: Author)*

Main Category	Sub Category	Explanation
Impact	Major Supply Chain Disruption	Severe supply chain disruption if indicated in quarterly, annual reports and newspapers and if longer term or permanent closure of production facilities (just focus on upstream the supply chain)
Impact	Major Other Damage	Severe other damage if indicated in quarterly, annual reports and newspapers (includes e.g. decline in sales, property damage, downstream disruptions)
Impact	Minor Supply Chain Disruption	If indicated in quarterly, annual reports and newspapers and if just preventive closure for a short time period (just focus on upstream supply chain)
Impact	Minor Other Damage	If indicated in quarterly, annual reports and newspapers or if damage was mentioned in hurricane warnings, updates of firms, in newspapers but no damage was mentioned in financial reports (includes e.g. decline in sales, property damage, downstream disruptions)
Impact	Positive Effect on Demand	If indicated in quarterly, annual reports and newspapers. Not included when estimated rise in sales was mentioned by investors etc for reason of increasing share price as this is what we measure
Actual Damage	Own Facilities	Actual damage of own facilities e.g. production facilities, warehouses
Actual Damage	Infrastructure	Actual damage of e.g. road/ rail, airports and ports
Actual Damage	External Supply Chain Disruption	Indirectly affected through a supply chain disruption of a supplier
Actual Damage	Agriculture	Reduction of quality or quantity of harvest
Preventive Closure	Own Facilities	Mandatory or voluntary closure of e.g. production facilities
Preventive Closure	Infrastructure	Closure of infrastructure e.g. road/ rail, airports, ports

Impact

Impact is defined according to the research field, therefore SCM literature is focused on SCDs and financial economics literature focuses on other damages (Brooks et al., 2003; Donadelli and Lucchetta, 2013; Hendricks and Singhal, 2003; Worthington and Valadkhani, 2005; Zsidisin et al., 2016). Financial economics researchers tend to look at non-supply chain-related damage, such as decrease in demand, property damage and increase in insurance premiums. Supply chain research excludes announcements declaring other impacts or where SCD was not the only impact damage. But companies often declare both SCD and non-SCD-related impact e.g., Sherwin-Williams after the 2017 hurricane season (Yahoo Finance, 2017). The federal securities laws require regular mandatory reporting of publicly traded companies to the US regulator, i.e., US Securities and Exchange Commission (SEC). Additionally, in the case of certain events/incidents, such as force majeure events, a mandatory irregular reporting is required. Details on the regular and irregular reporting requirements are provided in Appendix B of this thesis. If firms have a major impact from a hurricane, there are several reasons and requirements regarding what, when and to whom it needs to be disclosed. Major is defined as the impact being so strong that companies have to report by law to the regulator, contractors and/or their shareholders that they will not be able to fulfil their predicted objectives set in their financial planning, pay their dividends or are not able to fulfil third party contracts. Impacts are classified as minor if, in the announcements, the impact is classified as minor or the impact is not tied to any significant negative financial consequences or abilities to fulfil contractual, regulatory or shareholder duties.

Most research is based on major impacts that are reported by major news or stock exchange news services (e.g. Wall Street Journal (WSJ) and the Dow Jones News Service (DJNS)) or news announcements from a database such as Factiva (Filbeck et al., 2016; Zsidisin, 2016); other sources or a combination of sources has not been evaluated so far. These news services tend to only cover major damage. The preselection of major events in the academic literature implies that the effects of minor hurricane damage or SCD have no relevant effect

on stock price by neglecting these. To include events and firms independently of impact, and whether an effect of the hurricane was experienced, other data sources are covered, such as media announcements and annual reports. The impact of SCD and other damage by hurricanes is assessed in the academic research on a more granular level. Academic research in business and economics, official government reports (e.g., for Hurricane Harvey: National Hurricane Center, 2017) and scientific reports on specific issues (e.g. for Hurricane Harvey: Sebastian et al., 2017) provide insights into the damage. However, the effect on stock price of these damage types has not been tested yet.

Actual Damage

Information on actual damage cannot be investigated solely based on regulatory announcements. The details on damage to facilities, equipment, infrastructure, and/or t agriculture are at best mentioned in the quarterly or annual reports but may have to be gathered from other sources such as scientific reports or public media (Sebastian et al., 2017). Further details on actual damage can be found in Appendix B of this thesis. Thus far the data collection in previous research usually only allows for a binary analysis, i.e., impact or no impact, omitting gradation of influential factors, which is an essential part of reliable data modelling. Additionally, a difference in the reaction to a hurricane incident announcement compared to the reaction to an actual hurricane announcement occurring has never been performed as non-announcing firms have not been investigated so far.

Preventive Closures

For major disasters like hurricanes, the government as well as companies take preventive measures such as preventive closures. Whereas this may be limited to adding shutters to your private home (DisasterSafety.org), the protection of entire communities requires flood prevention and closing of infrastructure. Individual companies must close their own facilities either as part of a government issued preventive measure or because these structures are more vulnerable during normal operation, or damage to the facilities if kept in operation would

endanger the environment, workforce or other surrounding facilities. Examples of avoidable damages due to operations can be found in the scientific reports of hurricanes (e.g. Sebastian et al., 2017). Further details on actual damage can also be found in Appendix B. During hurricanes critical infrastructure is closed to limit damage, including communications, roads, shipping terminals and airports (Sebastian et al., 2017). The decision regarding which infrastructure is to be closed is out of the control of companies, forcing them to adjust their supply chain accordingly if the firm is still operating.

3.1.7.4 Supply Chain Set-up-related Factors

Several supply chain management-related factors are identified, such as supply chain type (pull vs. push), slack in the supply chain, degree of vertical relatedness, robustness, agility, readiness and managerial focus in terms of logistics importance, supply chain risk planning, and SCRM. Certain supply chain set-ups may reduce the impact of SCDs (Birkie, 2016; Sarathy, 2006; Wieland and Wallenburg, 2012). Investors distinguish between firms in the personal computer (PC) industry with pull and push supply chains in the wake of the Taiwan earthquake (Papadakis, 2006, 2003). The supply chain type has a significant impact on stock price: pull supply chains, which are produced on actual orders (make-to-order (MTO)), have a stronger negative reaction as these are associated with lower profitability than companies with push supply chains that produce based on forecasts (make-to-stock (MTS)) (Papadakis, 2006). Investors seem to associate push supply chains with higher profitability (Papadakis, 2006, 2003). Slack and degree of vertical relatedness have a significant impact. Firms with more slack do not operate at the maximum of their capacity and experience a less negative impact on stock price (Hendricks et al., 2009). Vertical relatedness means that the company produces more of its inputs for its outputs, therefore it is less dependent on inputs of suppliers for its production; thus firms with a high degree of vertical relatedness experience a less negative stock price reaction (Hendricks et al., 2009). Other factors evaluated as possibly relevant in the case or conceptual studies are robustness, agility, readiness and managerial focus. Robustness decreases the firm performance impact while agility has no direct impact (Wieland and Wallenburg, 2012). Readiness reduces the impact of

SCDs (Sarathy, 2006). The managerial focus, in terms of logistics importance, supply chain risk planning, and SCRM, influences the firm performance impact (Thun and Hoenig, 2011; Wagner and Neshat, 2012). Specifically, for disruptions caused by disasters it is important to have a solid logistical business continuity planning (LBCP) as it improves operational capabilities (Ojha et al., 2013). The recovery strategy mediates the impact on firm performance after a disruption caused by a disaster, with a radical/most rapid strategy showing the best effect on firm recovery (Chen et al., 2015).

3.1.7.5 Summary of Potentially Influencing Factors

Potentially influencing factors are identified in the literature and grouped into the four categories: firm-related, market-related, event-related and supply chain set-up-related factors. The decision regarding which factors to test is mainly driven by the availability of data and an indication of an effect on stock price in the literature. As a result, just factors from two of these categories are tested: of the firm-related factors, the industrial sector is tested. Previous research suggests that some industries suffer a stronger stock price effect. Additionally, the descriptive analysis of this thesis suggests that certain industries have a higher proportion of hurricane incident announcements. The industrial sector information is readily available with the firm name, ticker and daily stock price from the stock exchange. Of the event-related factors impact, damage and preventive closures are tested. This information is obtained from the hurricane-induced impact announcements of firms. The literature suggests that these event-related factors have an influence; however, they are not statistically evaluated to the same extent as in this thesis.

3.1.8 Potentially Relevant Theories

Potentially relevant theories were identified during the systematic literature review and sorted according to the frequency of use (Table 10). This list of theories was worked through to identify potentially suitable theories that might be used to deduce the hypotheses or results of this study and is documented in Table 17. One theory, the enactment theory, was not identified in the literature review but highlighted by the supervisor. In this table both the inclusion and

exclusion of all theories was conducted based on if they are able to explain the effect of hurricane-induced supply chain disruptions on stock price or the effect on it by the potentially influencing factors. Three theories were identified to have key relevance. Ten other theories were identified to be partially applicable.

Firstly, the included main theories and then the partially relevant theories are briefly mentioned. The exact use of the included theories is explained in the subsections of this chapter. Finally, the excluded theories and the reasons for exclusions are stated.

The theories considered as **mainly relevant** are efficient market hypothesis, contagion effect and overreaction hypothesis. Efficient market hypothesis explains the effect of new information on stock price (e.g., Hendricks and Singhal, 2003) and would explain stock price reactions after hurricane or hurricane incident announcements. The contagion effect explains stock price reactions of firms that did not suffer direct damage but suffer from spill-over effects. This means the effect could be contagious from affected companies to other companies that are not directly affected (Bloise and Bornkamp, 1996). The overreaction hypothesis explains a stock price reaction that is not justified by the given information (Filbeck et al., 2016) and would be an explanation for an investor's reaction to a pulse pattern.

The theories considered **partially relevant** are contingency theory/strategic choice theory, high reliability theory, normal accident theory, rational pricing theory, disruptive change theory, transaction cost economics (TCE) and the resource-based view. Contingency theory highlights the importance of the business context, while strategic choice theory highlights the importance of managerial actions (Wagner and Bode, 2008). This might also apply to the shareholders who might consider a company's context and managerial actions. High reliability theory assumes that firms can contribute significantly to the prevention of disasters (Wagner and Neshat, 2012). In alignment with this theory shareholders might react better if companies apply preventive measures. In contrast, according to normal accident theory, accidents are inevitable (Wagner and Neshat, 2012). If the theory were to apply, shareholders would not

differentiate between companies applying preventive measures and those that do not. According to rational pricing theory, investors are quite rational with regard to pricing and can assess fairly well whether a company is affected and to what extent (Guzhva, 2008). Disruptive change theory indicates that dramatic changes can affect the whole business environment (Li and Tallmann, 2011); the theory could apply if the whole NYSE would be affected. TCE states that firm performance can be maximized by minimizing transaction costs. Therefore, investors might react better to lower costs for a firm resulting from a hurricane-induced supply chain disruption (Shi and Yu, 2013). The resource-based view sees a firm as a collection of resources that provides the basis for its strategic competition (Shi and Yu, 2013). Disaster damage can be seen as something that reduces the resources of a company and decreases its competitiveness, and explains a negative reaction by shareholders.

Theories that were **not** considered **relevant** are systems theory, game theory, supply chain theory, entropy/information theory, financial portfolio theory, multivariate dependence theory, rational choice theory, theory on the economics of natural disasters, capital structure theory and network theory. The main reasons for the exclusion of these theories were because they have a different unit of analysis or measure different performance aspects. Systems theory does not apply, as in this thesis no system analysis is performed. Game theory can be used to predict how market participants react, as their actions are interdependent (Czinkota et al., 2010); however, in this thesis, that cannot be measured. Supply chain theory attempts to clarify the interconnections between actors in a supply chain (Papadakis, 2006). In this thesis, that is not possible, as we just know that the unit of analysis, the company, is a manufacturer but not where the company is within the supply chain. Also, this model only explains correlation and no causal relationships between the supply chain parties. Entropy/information theory assesses the impact of the threats in Information systems (Olatunde et al., 2012). In this thesis, it was not analysed as it is not the focus of this thesis. Financial portfolio theory allows investors to assemble a portfolio (Ritchie and Brindley, 2007). Again, analysing financial portfolios is not the remit of this thesis. Multivariate dependence theory is used in the area of system performance and

optimization (Masih-Tehrani et al., 2011). As this thesis is not a system analysis, the theory is not applicable. Rational choice theory assumes rationality (broken down into a concept with different components) to be the main rationale behind behaviour (Czinkota et al., 2010). This thesis does not provide the necessary information to evaluate this theory. The theory on the economics of natural disasters is focused on the GDP effect of natural disasters (Altay and Ramirez, 2010). This thesis evaluates the business but not the economic effects of disasters. Capital structure theory indicates certain factors influence the choice of capital structure (Pires and Fernandes, 2012). In this thesis no information on capital structure was collected. Network theory is used to explain network effects (Swierczek, 2016). As this thesis does not analyse a network, the theory is not applicable.

Application in previous research	Relevant yes/no/partially	Explanation for in-or exclusion
New information (such as breaking news) quickly influences share and security prices (Fama et al., 1969). Explains effect of new information on stock price (e.g. Hendricks and Singhal, 2003).	y	Most frequently applied theory in key papers. May be used to explain correlation between disaster-induced SCDs and stock price.
Contingency theory implies that organisations have high efficiency and performance when they consider the context and environment in which their strategy is designed and implemented (Chang et al., 2015). Strategic choice theory is an extension that also gives importance to the manoeuvres of the management of a firm (Wagner and Bode, 2008).	p	Might be used to explain that shareholders react differently dependent on context or managerial actions.
The contagion effect describes the spreading of market reaction to companies in the same industry or at the same location as reflected in their share price value, even though they are not affected by the event themselves (Filbeck et al., 2016; Helwege and Zhang, 2015).	y	Stock price reactions could be contagious from affected companies to other companies that are not directly affected.
Systems theory was used to view supply chains as open systems that are influenced by, and interact with, their environment (Pettit, 2013).	n	In this research it is not a system analysis is analysed.
In one paper game theory was used to analyze strategic differences among proposed policies by comparing the costs and benefits likely to arise from efforts to prevent terrorism (Czinkota, et al., 2010). Game theory can be applied as market participants actions are interdependent.	n	Event though game theory theoretically applies to the stock price, in this study it cannot be evaluated.
Supply chain theory attempts to clarify the complex interconnections among many actors in supply networks (Papadakis, 2006).	n	This thesis cannot clarify causality just correlation.
High Reliability Theory assumes that organizations can contribute significantly to the prevention of accidents (Wagner and Neshat, 2012).	p	Better reactions of shareholders regarding preventative measures would be an indication that they believe in the prevention of accidents.
Normal Accident Theory states that accidents are inevitable (Wagner and Neshat, 2012).	p	This theory would be supported if investors do not make a difference between companies implementing preventive measures or not.
This theory is used to assess the impact of the threats in Information systems (Olatunde et al., 2012).	n	This research is not assessing impact on information systems.
This investment theory allows investors to assemble an asset portfolio that maximizes expected return for a predefined level of risk (Ritchie and Brindley, 2007).	n	This theory cannot be used to explain the stock price effects.
Markets overreact to good and bad news, resulting in an unjustifiable share price reaction (De Bondt, 1993; De Bondt and Thaler, 1990; Filbeck et al., 2016).	y	Explains if shareholders overreact to new information.
This theory is used to develop strong analytical properties for system performance and optimization (Masih-Tehrani, et al., 2011).	n	Not applicable as I do not optimize systems in this thesis.
Economic analysis within rational-choice theory was used to make predictions about the future behaviour of terrorists (Czinkota, et al., 2010). The theory assumes rationality as an assumption for the behaviour of individuals.	n	The theory does not directly contributes to link disaster-induced supply chain disruptions to performance.
There is an indication for rational pricing when investors react quite accurately e.g. if not all companies are equally hit by a disaster (Guzhva, 2008).	p	There is an indication for rational pricing when investors react quite accurately according to how affected companies are.
Dramatic changes such as the effect of 9/11 can have an effect on the global business environment (Li and Tallmann, 2011).	p	If the whole NYSE would be affected it would indicate the relevance of this theory.
Signalling Theory is focused on the perception of the investors to the managerial responses e.g., in the form of companies' statements/press releases (Marcus and Goodman, 1989).	p	The theory can be used to explain the implications of the perception of a firm's investors on managerial responses to explain the share price reactions.
The theory suggests that the Gross Domestic Product (GDP) is generally found to increase in the periods immediately following a natural disaster (Altay and Ramirez, 2010).	n	This thesis does not look at the economic but the business impact.
The theory states that firm performance can be maximized by minimizing transaction costs within and across the boundaries of organizations (Shi and Yu, 2013).	p	The theory might be relevant in the way that the investors are focused on minimizing cost and thereby reacting better to minor supply chain disruptions than to major.
The resource based view sees a firm as a collection of unique and inimitable resources that provides the basis for its strategic competition (Shi and Yu, 2013).	p	Disaster damage can be seen as something reduces the resources of a company and decreases its competitiveness and explains a negative reaction by shareholders.
This theory believes that certain factors influences the choice of capital structure (Pires and Fernandes, 2012).	n	This thesis does not analyse capital structure.
The network theory is used to explain the "snowball effect" in the transmission of disruptions (Swierczek, 2016).	n	In this research no network analysis is performed.
"Investor sentiment" is a "misperception that can cause mispricing. The theory explains if investors' belief about future cash flows and risk not justified by the facts at hand (Kaplanski and Levy, 2010).	p	The theory might explain unjustified reaction of investors.
Enactment theory provides a framework, which describes the process of sense making of individuals of equivocal environments (Ellis et al., 2011).	p	The theory could be used to explain how investors react after a catastrophe happens, in the way that investors make sense of the event.

Table 17 In- and exclusion of potentially relevant theories

The fully or partially relevant theories shown in Table 17 are further explained below:

An overview over the use of theories for the deduction of hypotheses is provided in Chapter 3.3.7. An overview of how the theories helped to explain the results, can be found in Chapter 6.1.7.

In the subsequent subsections, each theory that is mainly or partially relevant is explained in more detail: For each theory information is provided on the theory, its relevance for this thesis, the main content, and the rationale for potential relevance.

It starts with the three mainly relevant theories: Efficient market hypothesis, contagion effect and overreaction hypothesis.

3.1.8.1 Efficient Market Hypothesis

The efficient market hypothesis has evolved in financial economics and assumes that in an efficient market new information (such as news) will be immediately reflected in asset prices such as stock and security prices (Fama et al., 1969; Hendricks and Singhal, 2003; Najam and Mehmood, 2019). Therefore, the stock price is an appropriate indicator of a company's profitability (Fama et al., 1969). This concept is widely used in financial economics and probably the most popular theory used to explain the effect of one or multiple events on a defined response variable (Chen and Siems, 2004; Abadie and Gardeazabal, 2003). In papers evaluating the impact of disasters, the theory is used to explain the effect of unanticipated and catastrophic events on the stock price performance of firms (Brooks et al., 2003; Bruning and Kuzma, 1989; Carter and Simkins, 2004; Ferstl et al., 2012; Fletcher and Paleologos, 1999; Flouris and Walker, 2007; Haripriya et al., 2006; Homan, 2006; Kannan et al., 2007). In finance, the response variables' stock price and the changes in stock price (e.g., CARs) are evaluated for the study sample period for specific triggers (Najam and Mehmood, 2019). Assuming stock prices reflect all available information, insider trading may be identified by assessing whether there is a statistically significant stock price reaction before an event, even though it was not officially disclosed at that time

(Liu et al., 2018). In some of the key papers for this thesis, in SCM the effect of the announcements of SCDs on firm financial performance is evaluated (Caporale and Makarenko, 2019; Hendricks and Singhal, 2008, 2003; Liu et al., 2018). Here, the efficient market hypothesis might explain the correlation between hurricane-induced incidents and stock price. If stock prices show a statistically significant reaction after a hurricane announcement occurs or a company announces a hurricane incident, the market reacted to the newly available information.

3.1.8.2 Contagion Effect

The contagion effect describes the spreading of market reaction to companies of the same industry or at the same location as reflected in their stock price value, even though they are not affected by the event themselves (Filbeck et al., 2016). Extensive public interest after an unexpected catastrophic event due to, for example, intensive and stirring news coverage, can lead to an irrational market response such as a panic, sell-off or contagion effect (Bloise and Bornkamp, 1996). A contagion effect usually occurs due to investors being misled by, for example, news items that may be inaccurate, exaggerated, incomplete, or biased, paired with a pervasive and strong perception of uncertainty regarding the affected securities. The explosion of the space shuttle Challenger led to significantly negative average abnormal returns on the contractor's shares on the day of the event. SCDs affect companies, supply chain partners (suppliers and customers) as well as competitors or companies in the same industrial sector and the effect is influenced by market-cycle and brand domicile (Filbeck et al., 2016; Swierczek, 2016). The contagion effect theory might provide an explanation if companies' stock prices react in hurricane seasons without having an announcement. It might be explained by the perception/lack of information of investors leading to selling stocks of companies not affected but in the same industrial sector, supply chain or geographic region.

3.1.8.3 Overreaction Hypothesis

The overreaction hypothesis is promoted as a psychological alternative theory to the efficient market hypothesis (De Bondt and Thaler, 1990; Filbeck et al., 2016).

It suggests that investors and security analysts tend to overreact to good and bad news, mirrored by the estimation of earnings, resulting in an unjustifiable stock price reaction (De Bondt, 1993; De Bondt and Thaler, 1990; Filbeck et al., 2016). The terrorist attacks on the World Trade Center and the Pentagon on 9.11.2001 created a strong stock price reaction across the market – even in Austria (Worthington and Valadkhani, 2005). News on SCDs might be perceived differently with negative stock reactions to disruptions occurring in bear markets but not in bull markets (Filbeck et al., 2016). Generally viewed as insufficient to link disaster-induced SCD to stock price, the overreaction hypothesis can be used to explain the strong stock price reaction after a hurricane incident announcement as the theory explains the behavioural aspects of strong reactions of investors and analysts to events.

In the subsequent sections the theories considered that are **partially relevant** are contingency theory/strategic choice theory, high reliability theory, normal accident theory, rational pricing theory, disruptive change theory, TCE and the resource-based view.

3.1.8.4 Contingency Theory and Strategic Choice Theory

The theory is derived from organisational theory (Donaldson, 2001; Hofer, 1975). The central assumption is that organisations have high efficiency and performance when they consider the context and environment in which their strategy is designed and implemented (Chang et al., 2015). The context includes internal factors and external forces that are outside the firm's control (Chang et al., 2015; Wagner and Bode, 2008). In the contingency theory, researchers empirically test the direct relationships between contextual variables and, for example, organisational performance (Lawrence and Lorsch, 1967). Researchers such as Child (1972) additionally suggest the application of strategic choice theory as an extension to contingency theory, which suggests not just a response to the circumstances but strategic decision making considering the environment and the factors. Contingency theory is applied within the supply chain context for the mitigation of supply chain risks (Chang et al., 2015; Groetsch et al., 2013; Juettner et al., 2003; Wagner and Bode, 2008). It suggests that the

situation/circumstances and nature of a supply chain risk influence the impact on operational and financial performance of a firm (Chang et al., 2015; Donaldson, 2001; Hofer, 1975). This contingency view on the management of supply chain risks has been agreed upon in SCRM in general (Chang et al., 2015; Groetsch et al., 2013; Juettner et al., 2003). The impact of SCDs on firm performance might be different, depending on factors such as risk type (Zsidisin et al., 2016), firm size (Hendricks and Singhal, 2003) or supply chain strategy (Papadakis, 2006).

3.1.8.5 High Reliability Theory

The high reliability theory assumes that organizations can contribute significantly to the prevention of accidents (Wagner and Neshat, 2012); it was applied in their paper as the foundation for the comparison of supply chain vulnerability indices for different categories of firms. This theory could potentially be used to explain the results of this thesis. In the case of shareholders reacting less negative to firms that are putting effort into the prevention of hurricane damage, this would be an indication that they believe in the prevention of accidents.

3.1.8.6 Normal Accident Theory

Normal accident theory states that accidents are inevitable (Wagner and Neshat, 2012). The theory was also used for the development of the propositions and comparison of different supply chain vulnerability indices of firms (Wagner and Neshat, 2012). This theory could be used to explain the results if a difference cannot be found between firms that put effort into SCRM and preventive measures, and those that do not.

3.1.8.7 Rational Pricing Theory

Rational pricing theory assumes that investors price a company's stocks rationally. A study found that after 9/11 not all of the airlines were equally affected by the terrorist act (Guzhva, 2008). Instead, investors were fairly rational pricing major airline stocks, but were less accurate with the stocks of smaller regional carriers (Guzhva, 2008). This theory could be used to explain this thesis' results, if investors react quite accurately according to which companies are hit and the impact extent.

3.1.8.8 Disruptive Change Theory

The disruptive change theory states that dramatic changes can have an effect on the global business environment (Li and Tallmann, 2011). These effects were found to be a result of 9/11 (Li and Tallmann, 2011). In this thesis, global effects cannot be determined as only the NYSE is analysed. However, effects on the whole index could be identified in the case that hurricane incident announcements or hurricane announcements create a significant interruption to the index, or for a very high proportion of companies.

3.1.8.9 Signalling Theory

This communication theory is used to classify managerial responses after the catastrophic chemicals accident in India, also known as the “Bhopal incident” (Marcus and Goodman, 1989). Signalling theory makes a distinction between facts and their interpretation, in this case, the perception of investors of the managerial responses, e.g., in the form of companies’ statements/press releases; this investor perception is just one influencing factor explaining differences in stock price reaction between companies, e.g., based on press releases.

3.1.8.10 Transaction Cost Economics

TCE states that firm performance can be maximized by minimizing transaction costs within and across the boundaries of an organization (Shi and Yu, 2013). This theory might be relevant for deducing hypotheses and explaining the results. It would explain if shareholders would react less negatively to minor supply chain disruptions or other damages, than to major ones, as the latter result in higher cost.

3.1.8.11 Resource-Based View

The resource-based view sees a firm as a collection of specific resources that form the basis for its strategic competition (Shi and Yu, 2013). Disaster damage can be seen as something that reduces the resources of a company and decreases its competitiveness. This theory could explain a more negative reaction by shareholders on major vs. minor supply chain disruptions or other

damage. This theory could be the same as the TCE used for hypothesis deduction and explanation of results.

3.1.8.12 Wurgler's Theory (Investor Sentiment)

Defined as a misperception causing mispricing as the investors' belief about future cash flows and risk is not justified by the facts at hand (Baker and Wurgler, 2007), Wurgler's theory is used to evaluate the effect of aviation disasters on stock prices (Kaplanski and Levy, 2010). With increased anxiety following aviation disasters, there is a short-term reduction in the demand for risky assets, which in turn affects stock prices (Baker and Wurgler, 2006, 2007). When anxiety subsides, or when sophisticated investors exploit the effect, a reversal in the stock market takes place (Kaplanski and Levy, 2010). Wurgler's theory can explain strong stock price reactions and reversal reactions to catastrophes. However, this theory would just explain one (subjective) factor/phenomenon influencing the investor's decision making.

3.1.8.13 Enactment and Sense-making Theory

Enactment theory provides a framework, which describes the process of sense making of individuals of equivocal environments (Ellis et al., 2011). The theory describes the process, in which a certain reality is socially constructed. For example, if a catastrophe happens, investors make sense of it and, for example, sell their stocks to avoid losses and create the reality of stock price drops after disasters.

3.2 Limitations and Critique

3.2.1 Conceptual Gaps

There is research available that assesses the effect of disasters and SCDs on firm performance, as discussed in Section 2.4. However, SCDs can have sources other than disasters and disasters can affect firm performance without causing an SCD. Most of the available research focuses on assessing either the stock price impact of disasters or SCDs without bringing both concepts together. Research indicates that disaster-induced supply chain disruptions tend to be severe in their damage (Wagner and Bode, 2008) and the descriptive analysis

showed that 82% of NYSE listed companies reported hurricane impact. There is a lack of research and no conceptual framework considering all three components: disasters, SCDs and firm performance, and their interrelationships, to show when and how there is a performance impact of disaster-originated SCDs on firm performance. The effect of the announcement of SCDs on firm performance is not evaluated regarding the type of disruption cause or catastrophe – e.g., the evaluation of various hurricane-induced SCDs (Hendricks and Singhal, 2003). Studies often just assess SCDs from a single event on various firms or just on a particular industrial sector (Papadakis, 2006). SCDs impacting firm performance for different types of natural disasters are just investigated in one paper (Altay and Ramirez, 2010). It seems more common to measure the stock price effect of disasters in disaster research, than to measure the stock price effect of SCDs in the SCM research. Of the 21% of supply chain papers doing so, the majority are from two researches only (i.e. Hendricks and Singhal, 2008, 2005a,b, 2003; Hendricks et al., 2009; Papadakis, 2006). The reaction of stock price is only assessed for those firms reporting being affected by an SCD or a disaster and not specifically by an SCD caused by a disaster (e.g., Caporale and Makarenko, 2019; Hendricks and Singhal, 2003; Zsidisin, 2016).

In financial economics, there are some papers available that analyse the effect of natural disasters and even single hurricanes on firm financial performance (Gangopadhyay et al., 2010). Even though the event studies in financial economics are more sophisticated regarding statistical processing, the research does not specifically highlight SCDs as a disaster impact. Further, they usually do not evaluate the level of an individual firm but use a different unit of analysis, i.e., whole economies or industrial sectors, or different outcomes such as human losses and property damage. For directly affected companies, no studies evaluate whether investors react to the SCD or to other damage, e.g., to office facilities or decrease in demand, or maybe just to any information regarding a hurricane incident, even if it is just a preventive closure of production sites. Firms not reporting an incident might also be impacted in the case of a market overreaction, where the index or entire industrial sectors might shift (Corey and

Deitch, 2011; Filbeck et al., 2016; Kaplanski and Levy, 2010; Karolyi and Martell, 2010; Wei-Jiat and Enderwick, 2006) or, due to a contagion effect if they are competitor firms or a supply chain member of an affected firm, they might have a stock price reaction as well (Filbeck et al., 2016).

Existing research rarely connects the concepts of disasters and SCDs but assesses the effect of either one of them on stock price. Additionally, it has not yet been evaluated how investors react to SCDs compared to other damages, or if they are generally sensitive to the impact type or extent. Many studies just consider downside risk as disruptions often (but not always) having a negative impact on a firm, even though companies can actually experience a positive stock price effect after a disaster/SCD (Wagner and Bode, 2008).

3.2.2 Data-related Gaps

Apart from one study, most studies evaluating the stock price effect of disasters or SCDs measure just one or a few days after the event but not longer-term effects and thereby not longer-term patterns (Hendricks and Singhal, 2005). Thus far the data collection in previous research usually only allowed for a binary analysis, i.e., impact or no impact, omitting gradation of influential factors, an essential part of reliable data modelling. Additionally, an evaluation of the reaction to an incident announcement compared to the reaction to a hurricane announcement occurring has never been performed as non-announcing firms (i.e. firms that are not announcing any hurricane impact) have not been investigated so far. The data used to establish the model by Hendricks and Singhal in 2003 and used for all subsequent research, include only companies which specifically mention supply change disruptions in their announcements to comply with stock exchange regulations regarding adjusted expected earnings. This implies that a preselection is performed by including only samples of companies that issued disruption announcements. The studies available do not compare the stock price effect of companies exposed to a disaster but not suffering an SCD or other damage, companies that had an SCD and subsequent damage, and companies that had damage but this was unrelated to an SCD. This is an essential flaw in the experimental research design since the exclusion of

true negatives (i.e., negative controls) is needed to evaluate the impact of disasters on supply chains and determine the statistical significance of evaluated effects. In addition, these studies cannot investigate possible contagion effects since the observations necessary for the evaluation are left out by design (Filbeck et al., 2016).

Information on impact, actual damage and preventive closures cannot be investigated based solely on regulatory announcements. The details on damage to own facilities, infrastructure, by external SCD and/or to agriculture are, if at all, mentioned in the quarterly or annual reports but may have to be gathered from other sources such as scientific reports or public media. Thus far the data collection in previous research usually only allowed for a binary analysis, i.e., impact or no impact, omitting gradation of influential factors, which is an essential part of reliable data modelling. Additionally, current research does not evaluate which hurricane information is relevant for investors. Several reliable information sources are not included in previous research such as industry associations. Additionally, company reports that included SCDs and other impacts were excluded, introducing bias. Some information is not yet sufficiently statistically tested: announcing firms vs. non-announcing firms, potentially influencing factors such as impact, damage (e.g., high vs. low impact and SCD vs. other damage) and preventive closures of production facilities.

3.2.3 Methodologies

Recently the amount of research on SCDs due to disasters has increased. The event study methodology is most frequently applied to assess the effect on CARs. However, this method has the disadvantage that it cannot correct for trend, seasonality, cycles and drifts which are typical characteristics of stock price time series (Sengupta and Chaudhury, 2018). Residuals in event studies might not adhere to the assumption of normality and homoscedasticity (Corrado, 2011), leading to biased intervals of coefficient estimates. Independence of stock exchange values is assumed for a given time period, even though the measurements can be autocorrelated (Binder, 1998). In addition, the underlying slope coefficients will result in biased estimates of CARs when these change in

anticipation, or as a result, of the event (Larcker et al., 1980). This does not need to be an issue, but most research papers do not test the model assumptions. Another main critique is that the methodology of statistical analysis applied in supply chain research is not yet sufficiently developed as several studies break down the analysis to multiple pairwise comparisons using t-Tests. This can lead to an increase in the false positive rate since no correction for multiple testing is applied, e.g., the Bonferroni method. The event studies assessing the effect on cumulative returns so far have the disadvantage of not being able to correct for trend, seasonality, cycles and drifts, which are typical characteristics of stock price time series. Furthermore, the testing of model assumptions was prone to error.

3.3 Deduction of Hypothesis

The following six hypotheses are developed based on the literature review. One key factor for the selection of potentially influencing factors and establishing the hypotheses is data availability. Contingency theory assumes that organisations have high efficiency and performance when they consider the context and environment in which their strategy is designed and implemented (Donaldson, 2001; Hofer, 1975). Therefore, the contextual and environmental hypotheses H2 – H6 are tested. Key statements from existing papers are provided per hypotheses. For a detailed discussion, the reader is referred to Sections 1.4.4 and 1.4.5.

It was decided not to provide directionality in the hypotheses as it is not clear for all hypotheses if the expected effect will be positive or negative, for example for the preventive closures. The statistical approach used to test for effect and pattern in the stock price reaction and allows the direction to be observed.

3.3.1 Hypothesis 1

The probability of a disaster-originated SCD is low; however, if it occurs it may be very costly (Horwich, 2000). The efficient market hypothesis assumes that in an efficient market new information such as the announcement of an SCD will be immediately reflected in the share price (Fama et al., 1969; Hendricks and

Singhal, 2003; Najam and Mehmood, 2019). Past study results confirm the theory: a 10% decrease in stock price of listed companies was identified after the announcement of an SCD (Hendricks and Singhal, 2008, 2003). More recent studies confirmed a significant drop in stock price returns, but with smaller impacts (Zsdisin et al., 2016). SCDs caused by natural uncertainty/disasters such as an earthquake were linked to significant CARs (Papadakis, 2006).

The impact on firms by force majeure events, specifically natural disasters, was found to be mirrored by an immediate, significant negative effect on stock price returns for the first trading day (Caporale and Makarenko, 2019). On this basis hypothesis H1 is deduced.

Not just firm announcements but also general hurricane announcement information is tested to be able to compare investors' reactions to risk (a hurricane incident announcement) with the reaction to an uncertainty (e.g. hurricane landfall). This is supported by the contagion theory, which describes the spreading of market reaction to companies of the same industry or at the same location as reflected by their stock price value, even though they are not affected by the event themselves (Filbeck et al., 2016). As risk researchers in decision theory and finance argue that risk is not just the downside, but also the upside possibility (Arrow, 1970; Kahneman and Tversky, 1979; Rao and Goldsby, 2009; Wagner and Bode, 2008) and in past studies some firms had positive effects, e.g., due to increased demand, in the hypothesis the word "effect" is used, which includes upside and downside risk.

H1: A hurricane incident announcement/hurricane announcement has an effect on stock price.

Stock price allows measurement of the subjective risk perceived by the shareholders and thereby allows measurement of the risk, and translates it into an objective risk view (Khan and Burnes, 2007, Zsdisin and Wagner, 2010). The perception of investors, which is subjective, is reflected by the objective measurement of stock price and reflected in a specific pattern. Thereby the identification of different patterns is important to reverse engineer the perceived subjective risk origin. One study found, for example, that investors react

differently to disasters depending on if they were anticipated or unanticipated (Brooks, 2003). Apparently, investors react more slowly to unanticipated events than to scheduled events – probably because they need time to form an opinion on the subjective risks. Hurricanes can be seen as somewhat scheduled; however, they can change their path and their impact can be difficult to determine. It would be interesting to see how quickly investors react to different hurricane information or impact statements. Reactions of stock prices after an interruption such as a hurricane can be measured by transfer functions in the form of a pulse, step and a transitory change function of the time series (Box and Tiao, 1975). Certain stock price patterns can also be an indicator of psychological phenomena: a pulse pattern supports the overreaction hypothesis which suggests that investors and security analysts tend to overreact to good and bad news mirrored by the estimation of earnings, resulting in an unjustifiable stock price reaction (De Bondt, 1993; De Bondt and Thaler, 1990; Filbeck et al., 2016). Study results support overreactions: a significant negative reaction occurs on the day of and the day after an announcement of an SCD (Filbeck et al., 2016, Hendricks and Singhal, 2003). Similarly, negative returns after force majeure events are in most cases observed on the day of the event (Caporale and Makarenko, 2019). A 10% decrease in the stock price of listed companies is found after the announcement of an SCD (Hendricks and Singhal, 2008, 2003); however, more recent studies show smaller impacts such as 1.94% (Zsidisin et al., 2016). A significant long-term reaction was found: a decrease in stock price returns is found in the year after an SCD (Hendricks and Singhal, 2005a). Although a significant negative relationship between SCDs/disasters and stock price returns has been established, the magnitude and duration of the observed effects differ (Hendricks and Singhal, 2003; Zsidisin et al., 2016), therefore hypothesis 1 is split into three sub-hypotheses to test the nature of the stock price reaction. Figure 22 shows the null hypothesis and the main hypothesis and its sub-hypotheses together with the transfer functions representing these. Pulse function (A) lasts one day; step function (B) and transitory change function (C) last longer than one trading day.

H1a: A hurricane incident announcement/hurricane announcement has a short-term effect on stock price defined as a pulse function.

H1b: A hurricane incident announcement/hurricane announcement has a persisting effect on stock price defined as a step function.

H1c: A hurricane incident announcement/hurricane announcement has a transient effect on stock price defined as a transitory change function.

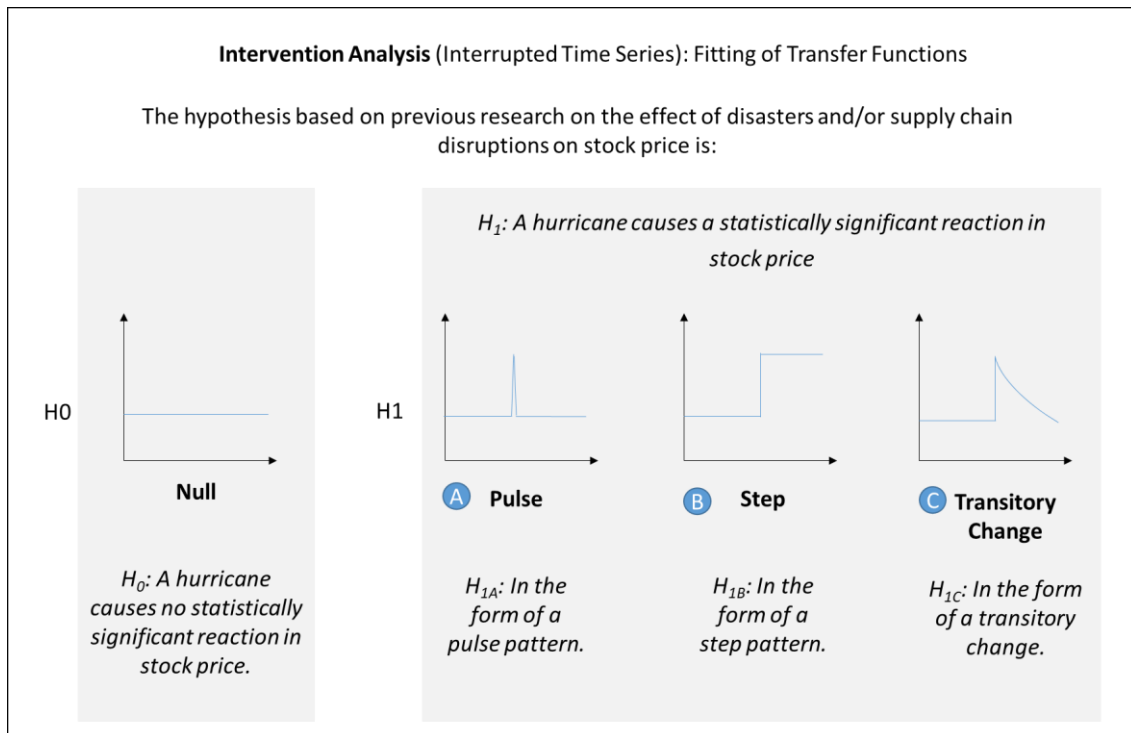


Figure 22. Fitting of transfer functions (Source: Author)

3.3.2 Hypothesis 2: Industrial Sector

According to contingency theory the situation/circumstances of the supply chain risk have an influence on the impact on the operational and financial performance of a firm (Chang et al., 2015). The industrial sector of a firm could be seen as such a contextual factor. The effect of disasters on market sector returns differs in financial economics literature (Worthington and Valadkhani, 2005). In SCM research, the industrial sector did not have an influence on the effect of SCDs on stock price returns; firms of all industrial sectors showed a reaction (Hendricks and Singhal, 2003; Liu et al., 2018). However, in several studies statistically significant differences were detected. According to one study, sensitive to any

type of disaster are consumer services, financial services and materials sectors (Worthington and Valadkhani, 2005). Another study finds it is not clear whether the service industry is doing better or worse, but it might just hold its ground (Webb et al., 2000). Studies also found that some industries are more resistant to disasters, and some even profit from it (Dietch and Corey, 2011). The sectors identified to receive a positive effect were construction and manufacturing businesses as they are required for rebuilding efforts (Zhang et al., 2009). Another study showed that after a disaster the healthcare and utilities sectors showed higher stock excess returns (Donadelli and Lucchetta, 2013). As in some previous research, the industrial sector has been shown to have an effect; this thesis tests the likelihood of damage and the pattern of damage per industrial sector. The following hypothesis is therefore formulated:

H2: The industrial sector influences the stock price reaction due to a hurricane incident announcement.

3.3.3 Hypothesis 3: Impact Type

The impact of hurricanes or hurricane-induced supply disruptions is defined according to the research field. SCM literature is focused on SCD impacts and economics literature focuses on other damages (Brooks et al., 2003; Donadelli and Lucchetta, 2013; Hendricks and Singhal, 2003; Worthington and Valadkhani, 2005; Zsidisin et al., 2016).

Financial economics researchers tend to look at non-supply chain-related damages, such as decrease in demand, property damage and increase in insurance premiums. Or they assess the overall impact of the disaster, including all kind of damages including the one from SCDs (Donadelli and Lucchetta, 2013). Overall, disasters such as hurricanes are found to have an overly negative effect (Donadelli and Lucchetta, 2013). SCDs are also found to lead to a statistically significant negative reaction on stock price. Supply chain research excludes announcements on firm performance declaring other impacts than SCDs, or where SCD is not the only impact damage. However, companies often declare both, i.e., SCD and non-SCD-related impact, e.g., Sherwin-Williams after the 2017 hurricane season (Yahoo Finance, 2017). As there is currently no direct

comparison in one paper, this thesis tests if there is a difference in stock price reaction, depending on if the impact is an SCD or other damage. Therefore, this thesis tests the following hypothesis:

H3: The impact type (supply chain disruption or other damage) influences the stock price reaction due to a hurricane incident announcement.

3.3.4 Hypothesis 4: Impact Effect Size

SCRM serves the purpose of reducing risks, such as SCDs (Wieland and Wallenburg, 2012). Researchers found that firms with a stronger focus on SCRM are less vulnerable and show a better supply chain performance (Thun and Hoenig, 2011; Wagner and Neshat, 2012). SCM and supply chain performance in turn have an impact on financial performance (Wahdan and Eman, 2017). Therefore, it can be argued that the smaller the impact of the SCD the lower the effect on financial performance in the form of stock price changes. This is consistent with efficient market hypothesis which assumes that new information, such as news reports on the impact of SCD, will immediately have an effect on stock price (Fama et al., 1969; Hendricks and Singhal, 2003; Najam and Mehmood, 2019); thereby the stock price is assumed to reflect the current state of the information available to investors (Fama et al., 1969). Based on that news on smaller SCDs, investors might react less negatively – seeing it as result of better SCRM (Ellis et al. 2011; Wagner and Neshat, 2012). This would be in line with high reliability theory and would suggest more positive reactions of shareholders regarding preventive measures as they believe in the prevention of accidents (Wagner and Neshat. 2012). Signalling Theory also suggests better reactions of shareholders as they react upon their perception of the managerial responses, e.g., in the form of good SCRM (Marcus and Goodman, 1989).

Most supply chain risk and disruption research is based on force majeure events and major impacts that are reported by news outlets, as these must be reported by law. The preselection of major events in the academic literature implies that the effects of minor hurricane damages or SCDs have been neglected.

Also other different theories indicate that impact extent might influence the stock price effect. According to rational pricing theory investors might react differently based on impact extent because they price rationally. Also, according to TCE, investors should be focused on minimizing cost and thereby would react better to minor supply chain disruptions than to major ones (Shi and Yu, 2013). Similarly, according to the resource-based view, disaster damage can be seen as something that reduces the resources of a company and decreases its competitiveness, which explains a negative reaction by shareholders (Shi and Yu, 2013).

This thesis fills the gap by including events and firms independent of impact effect size and whether an effect of the hurricane is experienced. These arguments thus lead to the following hypothesis:

H4: The extent of impact (minor or major) influences the stock price reaction due to a hurricane incident announcement.

3.3.5 Hypothesis 5: Damage

Disasters differ in terms of type and wide spread of damage (Dietch and Corey, 2011). The impact of SCDs and other damages by hurricanes are assessed on a more granular level in the academic research and reports of events, and can be tested for effect. SCDs can for example be in the operations of the focal company itself but also might result from a failure of their suppliers or difficulties in transporting supplies (Dietch and Corey, 2011). Many businesses experience major critical infrastructure breakdown of catastrophic proportions and due to a lack of gas and electricity availability (Boin and McConnell, 2007). Hurricanes can also result in several damages that do not result in an SCD. These can be physical damage to non-production buildings and loss of staff or customer base (Dietch and Corey, 2011). Academic research in business and economics, official government reports (e.g., for Hurricane Harvey: National Hurricane Center, 2017) and scientific reports on specific issues (e.g. for Hurricane Harvey: Sebastian et al., 2017) provide detailed insights into these damages. As the signalling theory indicates that shareholders might react upon their perception of the managerial

responses such as the transparency in their communication (Marcus and Goodman, 1989).

Therefore, the effect on stock price of these types of actual damage should be tested. Thus far the data collection in previous research usually only allows for a binary analysis, i.e. damage or no damage, omitting gradation by damage categories. The following hypothesis is therefore generated:

H5: Actual damage influences the stock price reaction due to a hurricane incident announcement.

3.3.6 Hypothesis 6: Preventive Closure

In alignment with the high reliability theory on major disasters, governments as well as companies take preventive measures against hurricane impact as they believe that preventive measures lower the disaster impact (Wagner and Neshat, 2012). Individual companies must close their own facilities either as part of a government issued preventive measure or voluntarily as part of their supply chain strategy to avoid more severe disruptions, or because these structures are more vulnerable during normal operation or damage to operating facilities would endanger the environment, workforce or other surrounding facilities (Corey and Deitch, 2011). Examples of avoidable damages due to operations can be found in the scientific reports of hurricanes (Sebastian et al., 2017). According to strategic choice theory, managerial actions such as preventive closures could lead to less negative reactions (Child, 1972). Similarly, according to signalling theory, shareholders make sense of the managerial responses and therefore might react better toward companies that conduct preventive closures. That means that preventive closure can be seen as a form of active supply chain strategy or SCRM, and even though it causes temporary disruption of operations, shareholders might appreciate it as it reduces or prevents long-term damage to operations. This leads to the deduction of the following hypothesis:

H6: Preventive closure influences the stock price reaction due to a hurricane incident announcement.

3.3.7 Hypotheses Deduction Overview

An overview of all six main hypotheses and their sub-hypotheses tested in this thesis is provided in Table 18. The hypothesis and its description are displayed.

Table 18. Overview of Tested Hypotheses (Source: Author)

Hypothesis	Description
<i>H0: A hurricane incident announcement/hurricane announcement has no effect on stock price.</i>	<i>0 Hypothesis</i>
<i>H1: A hurricane incident announcement/hurricane announcement has an effect on stock price.</i>	<i>Main Hypothesis</i>
<i>H1a: A hurricane incident announcement/hurricane announcement has a short-term effect on stock price defined as a pulse function.</i>	<i>Reaction Pattern</i>
<i>H1b: A hurricane incident announcement/hurricane announcement has a persisting effect on stock price defined as a step function.</i>	<i>Reaction Pattern</i>
<i>H1c: A hurricane incident announcement/hurricane announcement has a transient effect on stock price defined as a transitory change function.</i>	<i>Reaction Pattern</i>
<i>H2: The industrial sector influences the stock price reaction due to a hurricane incident announcement.</i>	<i>Firm-related Factor</i>
<i>H3: The impact type (supply chain disruption or other damage) influences the stock price reaction due to a hurricane incident announcement.</i>	<i>Event-related Factor</i>
<i>H4: The extent of impact (minor or major) influences the stock price reaction due to a hurricane incident announcement.</i>	<i>Event-related Factor</i>
<i>H5: Actual damage influences the stock price reaction due to a hurricane incident announcement.</i>	<i>Event-related Factor</i>
<i>H6: Preventive closure influences the stock price reaction due to a hurricane incident announcement.</i>	<i>Event-related Factor</i>

In the following an overview is provided on the theories used for the deduction of the hypotheses (Table 19).

There are three main theories: efficient market hypothesis, contagion effect and overreaction hypothesis (marked in light blue shading). These are key as they were used to deduce the main hypothesis H1 and its sub hypotheses H1a,b,c. The efficient market hypothesis is most frequently used for linking disaster-induced SCDs to stock price development. Therefore, this theory was used to deduce the main hypothesis. Overreaction hypothesis was used to deduce the sub-hypothesis of the main hypothesis to explain a pulse pattern of reaction. Contagion theory was used to deduce the main hypothesis for hurricane announcements. Overall, for each hypothesis at least one theoretic underpinning was used for deduction. A detailed deduction is provided for each respective hypothesis.

Table 19 Theories used to Deduce Hypotheses (Source: Author)

#	Hypothesis	Theory	Comment
H1	Stock Price Effect	Efficient Market Hypothesis	Shareholders react to new information in the form of hurricane announcements and hurricane incident announcements
H1	Stock Price Effect	Contagion Effect	Stock price reactions could be contagious due to uncertainty. Even non-announcing companies might have a stock price effect.
H1 a,b,c	Transfer Functions	Overreaction Hypothesis	Markets overreact to good and bad news. A pulse function can be seen as an overreaction - an unjustifiable share price reaction.
H2	Industrial Sector	Contingency Theory/ Strategic Choice Theory	Industrial sector is the context of the company or the incident and thereby might make a difference.
H3 & 4	Impact Type / Extent	Rational Pricing Theory	Investors might react differently based on impact extent because they price rationally.
H3 & 4	Impact Type / Extent	High Reliability Theory	Better reactions of shareholders regarding preventive measures would be an indication that they believe in the prevention of accidents.

H3 & 4	Impact Type / Extent	Signalling Theory	Better reactions of shareholders regarding the perception of investors regarding the managerial responses, e.g., in the form of good SCRM.
H3 & 4	Impact Type / Extent	Transaction Cost Economics	The theory might be relevant in the way that the investors are focused on minimizing cost and thereby reacting better to minor supply chain disruptions than to major ones.
H3 & 4	Impact Type / Extent	Resource-based View	Disaster damage can be seen as something that reduces the resources of a company and decreases its competitiveness, and explains a negative reaction by shareholders.
H5	Actual Damage	Signalling Theory	Better reactions of shareholders regarding the perception of investors regarding the managerial responses, e.g., in form of transparent communication.
H6	Preventive Closure	Contingency Theory/ Strategic Choice Theory	Managerial actions such as preventive closures could lead to less negative reactions.
H6	Preventive Closure	High Reliability Theory	Better reactions of shareholders regarding preventive closures would

			be an indication that they believe in the prevention of accidents.
H6	Preventive Closure	Signalling Theory	Better reactions of shareholders regarding preventive closures would be an indication that they believe in the prevention of accidents.

4 Methodology

4.1 Research Approach

This section will outline the implications of the chosen research approach presented in Figure 23. A top-down logic or deductive strategy narrows from generalisation to specific cases, whereas a bottom-up logic or inductive reasoning extrapolates generalisations from specific cases (Blaikie, 2007).

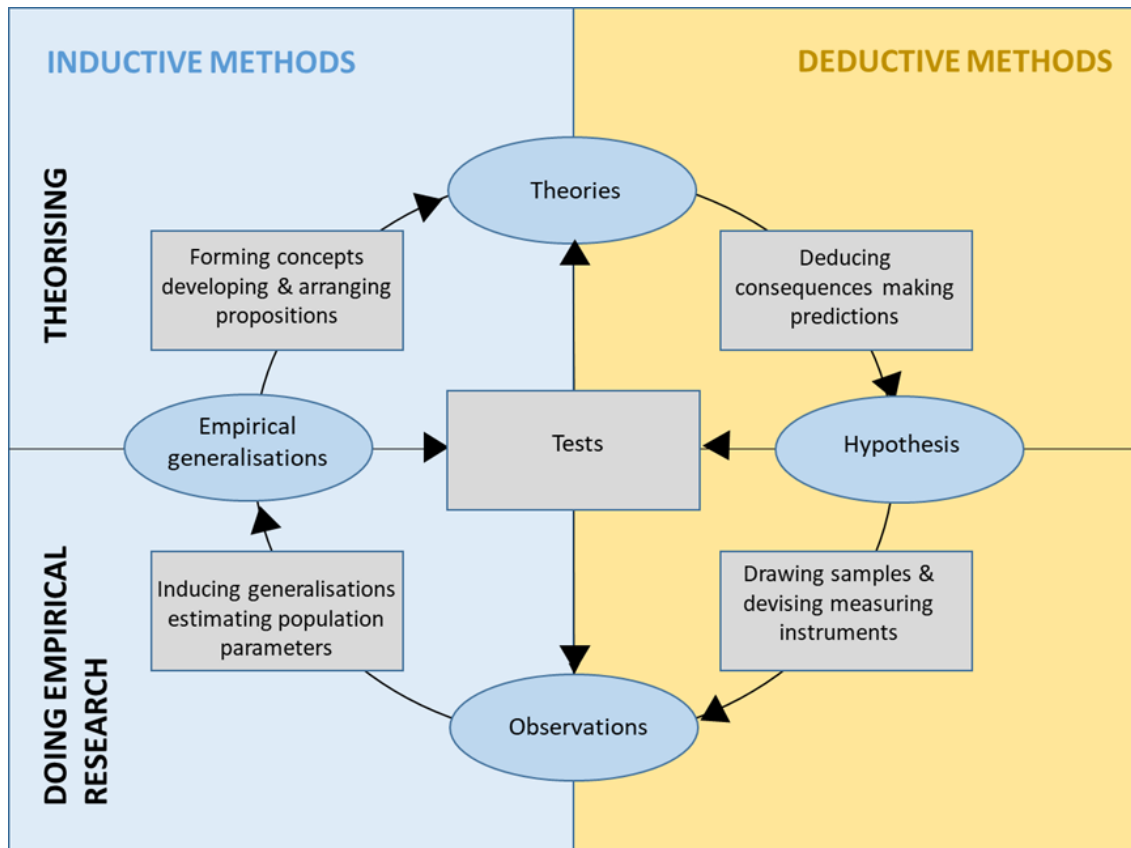


Figure 23. *Research cycle: Inductive vs. Deductive Methods (produced by author based on Wallace, 1971 in Blaikie, 2007)*

This thesis is based on a deductive research strategy where a series of hypotheses addressing the research question are deduced from the literature, as described in the Introduction (Section 1). The hypotheses are tested using sample population data gathered from publicly available sources including an official database (EDGAR by the US SEC), the information provided by companies, news and news agencies, industry associations and finance companies (such as Bloomberg) (see detailed overview in Appendix F). Stock price data are drawn from the application programming interface (API) of Yahoo Finance. Information on hurricane announcements was collected from the databases of the National Hurricane Center and the Central Pacific Hurricane Center (NHC).

4.2 Research Phases

The research is divided in two phases (Figure 24). A brief introduction to both research phases is provided here.

Research Phase 1 – Descriptive Analysis of Population: This section introduces the population and unit of analysis. It provides an overview of the secondary data collected from the NYSE on firms and their industrial sector, the hurricane data and on the novel factors from the announcements. The descriptive analysis is shown for comparison with existing literature. It additionally serves the purpose of selecting additional parameters for the modelling in research phase 2.

Research Phase 2 – Model: This section introduces the framework to model and analyse the time series with interruptions using ARIMA models with intervention analysis (Box and Jenkins, 1970; Lagarde, 2012). This approach is chosen to evaluate the effect of hurricane announcements and hurricane incident announcements on the daily stock price time series of firms in scope. The magnitude and patterns of these effects can be estimated by transfer functions in the ARIMA-intervention model per firm. Potentially influencing factors (Section 2.4.5) are deduced from previous studies (Table 15). Additionally, other factors are derived from the literature, which have not been tested previously. The importance of influencing factors is evaluated using statistical testing of coefficient estimates (Section 3.3.3).

Research Phase 2 is divided into two sub-phases a) ARIMA and b) Interrupted Time Series Analysis (ITSA).

Research Phase		Method	Research Purpose
Research Phase 1	Analysis of Population	Descriptive Analysis	Selection of the most relevant natural disaster type to be analysed in Research Phase 2
Research Phase 2 a)	ARIMA	Regression Analysis	Modelling of daily stock price time series per firm
Research Phase 2 b)	ITSA	Regression Analysis	Estimating the magnitude and pattern of possible change in daily stock price due to the hurricane or firm announcement

Figure 24. Connection of Research Phases and Research Questions (Source: Author). There are two research phases, while research phase 2 is split into sub-phases a) and b). The schematic displays the research phases and per research phase information on the research phase, the method applied and the research purpose.

4.3 Methodology Descriptive Analysis

First, scoping of the available companies according to the inclusion and exclusion criteria is defined; second, the data collection process for the companies in scope is laid out; and third, the descriptive analysis thereof is presented.

4.3.1 Scoping of Population

Here, the scoping criteria are provided, an overview of these can also be found in Figure 25.

1. Country: This thesis focuses on the **US**, a country with a high prevalence of industrial production and abundance of applicable companies and high financial regulatory reporting requirements of the US SEC that result in a sufficient amount of publicly available data.
2. Company's legal form: **Listed companies** are chosen, because most data are publicly available due to the highest regulatory requirements. For listed firms' stock price, regular financial quarterly and annual reports are publicly available. Press releases are also available as listed firms are obliged to inform about major changes (force majeure events amongst others) or indications that their planned strategic goals cannot be met, usually providing a cause/reason.
3. Manufacturing companies: Supply chain disruptions are particularly harmful at a focal company or in the upstream supply chain (Altay and Ramirez, 2010; Giunipero and Eltantawy, 2004). With regard to supply chain disruptions due to natural disasters, production facilities and transportation ways are particularly vulnerable (Wagner and Bode, 2008); the supply chain members that are most threatened are the focal company and its suppliers that typically are also manufacturers, and also the transportation companies in between. As in this thesis the stock price per firm as a measure of firm performance, is used to measure the effect of disaster-induced supply chain disruptions, this thesis just focuses on the manufacturing companies. The reason for that is that logistics and transportation companies transport for various client companies. Measuring their stock price does not allow for the allocation to the

respective supply chains or companies; it just measures the collective damage for the transportation company. As we are trying to obtain insights into the respective supply chains, analysing the stock price of transportation companies does not help the research question.

4. Timeframe: To ensure timely relevance and have sufficient data, information on **companies listed between 2014 and 2018** is collected.

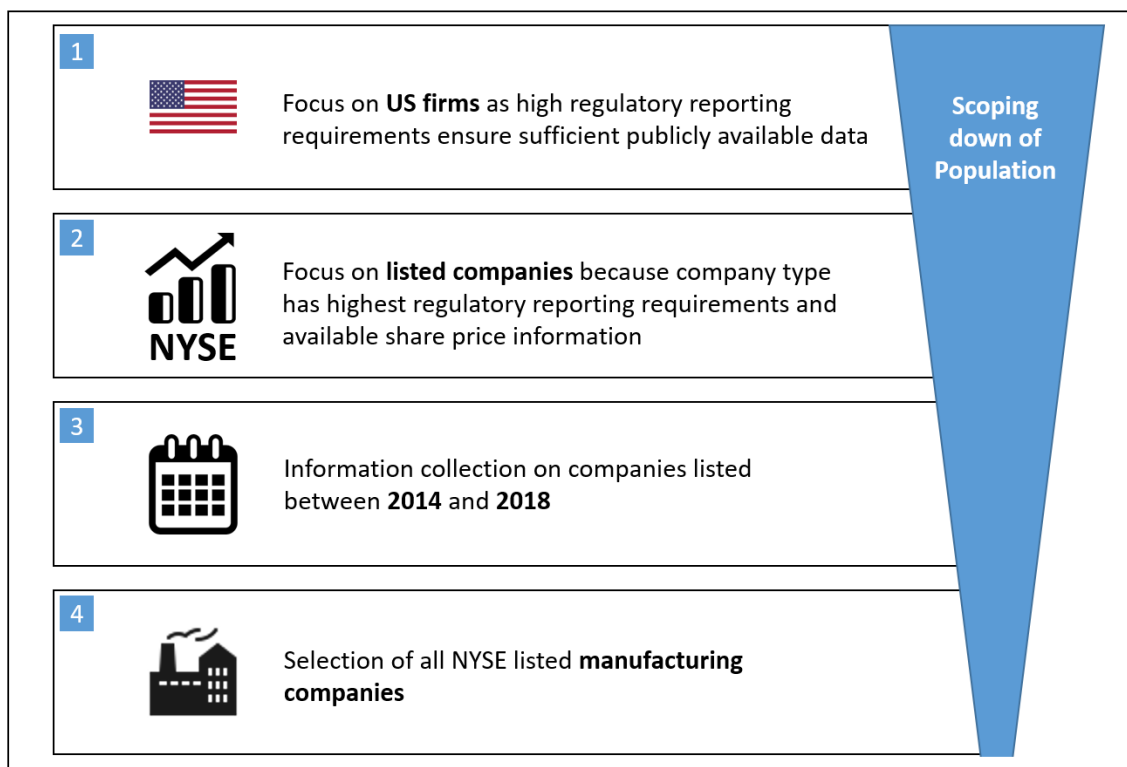


Figure 25. *Scoping of Population (Source: Author). The scoping of population was conducted in four subordinate steps.*

4.3.2 Supply Chain Criteria

As this thesis falls within the supply chain research domain, it is focused on manufacturing firms that are listed on the NYSE. For example, if the business is a bank and just procures some basic office supplies it would be excluded, or if the company is an energy provider that just distributes energy; another exclusion example is an airline that is not mainly doing logistics but just has a small part of a supply chain in order to serve its customers food. Additionally, some very specific industrial sectors were excluded to ensure that the results are more

comparable. For that purpose, both inclusion and exclusion criteria were defined: each company`s business is reviewed according to these criteria and the result was documented. For the evaluation of each firm the stock exchange name, ticker and industrial sector was collected.

Table 20. Filter criteria: Manufacturing Company Criteria

In Scope	Out of Scope
General condition: Companies that manufacture physical products as their main business purpose	General condition: Companies that do not have manufacturing as their main business purpose
Industrial sectors that are in scope	Industrial sectors that are out of scope
Chemical	Financial Services e.g., banks, insurances services, funds, trusts, asset management
Materials/Metal	Service Providers: e.g., transportation, logistics, education, consulting
Food & Beverage	Retail & Wholesale: e.g., fashion, consumer electronics & furniture
Manufacturer	Airlines
Technology (Hardware)	Hospitals
Paper producer	Media/Advertising
Automotive/Supplier	Energy/Utilities/Electricity
Pharma	Tourism/Hotels/Restaurants
Packaging manufacturer (plastic)	Real Estate
FMCG	Software
Apparel	Telecommunications
	Mining
	NGOs
	Governmental institutions
	Operators: e.g., satellite/network operators
	Recycling
	Construction

4.3.3 Description of Population Data Collection

The extent of a hurricane-induced SCD on the response defined by the stock price of the firm is evaluated (i.e., magnitude and direction of model coefficient estimates).

4.3.3.1 Included Companies

The list of NYSE-listed firms was generated on 19.11.2017. At that time 2687 companies were listed in the NYSE index. Each firm is individually reviewed. Companies not meeting scoping criterion 4 are excluded. If the information provided by the NYSE is insufficient (for example: very diversified companies with several business areas), the company website was reviewed. For each company, a rationale is provided. 625 companies met supply chain scoping criterion 4. Firms having left before or entering the index after 19.11.2017 are not included as the database could not be probed to provide the necessary data.

4.3.3.2 Identification of Information Sources

To identify the firms that had incidents, an initial analysis is performed on the publicly available information sources. The companies themselves are legally obliged to provide quarterly reports, annual reports and revenue warnings rendering them a reliable primary source (for details see Appendix F). The legally mandatory documents can be found in the SEC database EDGAR. Firms usually provide information to investors, employees and suppliers, and the public (media) as well. Information from reports of NYSE firms is collected from news agencies, industry associations, the stock exchanges, and investment and insurance firms. The information can be readily obtained from the internet.

4.3.3.3 Search Words/Strings and Source/Information Quality Assurance

All natural disaster types are included. For all articles, a manual review and data extraction are conducted to ensure diligence in terms of reliability of the source, relevance and correctness of the information. All incident reports, damages and announcements concerning hurricanes, independently of their effect on supply chains of the included firms, are collected and reviewed.

1. EDGAR: Search to cover mandatory reporting: 1. Gathering all documents submitted regarding the respective company. 2. Checking all documents gathered for all disaster types. This analysis leads to the inclusion of other mandatory information such as revenue warnings and force majeure reporting. Annual reports are audited and therefore have a higher quality than quarterly reports.
2. Company Website: The websites provide information in addition to quarterly and annual reports and voluntarily provided information for employees, suppliers and investors (e.g., information on evacuations, updates on hurricane preparation or hurricane damage) and earnings call or investor conference transcripts.
3. Internet: In order to include information not directly communicated by the companies themselves online resources are considered. Hurricane damage is usually only reported by the companies to the extent legally required by law or statute since the impact is negative in most cases. Therefore, internet search engines (Google, DuckDuckGo, Yahoo, Bing) are used to investigate the search strings “[company name] AND [disaster type] [name]”. For each search, the first two pages of results are reviewed. The articles are scanned for relevance, reliability/quality of source and information. Reliable sources are defined as the following:
 - a. Well-recognized financial and business news, general news services on the county/state, country or international level. News articles are included if the article is based on companies’ information in the form of press information by the company or interview with a company’s executives or public relations department.
 - b. Announcements of investment firms, stock exchanges and industry associations are considered if based on research reports.

4.3.3.4 Data Extraction

A data extraction matrix is generated. For each firm, the following information is listed:

1. General Information: Ticker Symbol (was checked if that changed over time); Firm name; Industrial sector description generated from industrial sector analysis; Industrial sector code according to the stock exchange. The firm-related information on the industrial sector provided by the NYSE is mirrored by the API of Yahoo Finance.
2. Event: Affected by disaster – YES/NO; If YES – per disaster:
 GENERAL: Disaster Name; Disaster Type; Year of Disaster incident (e.g., for drought, might be more than one year); Country where the incident happened; Detailed location of incident (optional)
 IMPACT: Affected by disaster-induced SCD resulting in damage; Damage just by disaster without SCD; Small SCD no relevant damage; Minor damage without SCD; Positive effect on demand
 ACTUAL DAMAGE: Own facilities/production site; Infrastructure – roads and rail; Infrastructure – ports; Infrastructure – airports; Infrastructure – electricity; External Supply Disruption; Agriculture – qualitative or quantitative; Details of Damage – Description (optional)
 PREVENTIVE CLOSURE: Closure or Evacuation of own facilities' production; Closure of infrastructure e.g. roads; Closure or Evacuation of ports; Closure or Evacuation of airports; Details of measures – Description (optional)
3. Natural Disaster Incidents: These data are only fully collected for hurricane incidents. An extensive review of all sources per hurricane incident is performed per company and the earliest announcement mentioning the hurricane is analysed in depth. Released announcements are often reposted by several channels (e.g., news) and have to be traced back to the earliest release. The data extracted include: Type of announcement; Date information released; The perspective of hurricane incident-related information (retrospective, forward looking, both); Format of information (e.g. annual report, press release); Source of original information; Comment (e.g. contains the title of article or document and the source).
4. Links to all sources the information is gathered from.

This extensive data collection is performed to evaluate whether the SCD or unrelated damages influence the stock price. The earliest announcement is recorded to detect a shareholder reaction in accordance with the efficient market hypothesis. The majority of first announcements are released by companies in the form of reports, press releases or meeting transcripts, most of which are from the SEC database EDGAR. Based on the results of the descriptive analysis, hurricanes are the most prominent natural disaster type and make up more than 336 (82%) of all natural disaster incidents affecting in-scope NYSE companies from 2014-2018. Additionally, the likelihood and impact of hurricanes is increasing due to climate change (El Niño vs. La Niña); therefore, the detailed analysis in research phase 2b focuses solely on hurricanes.

4.3.4 Description and Collection of Hurricane Announcement Data

The data on the hurricane announcements are collected from the NHC. In the archive a yearly overview is provided for all tropical cyclones, namely hurricanes, storms and tropical depressions. The annual Tropical Cyclone Advisory Archive is divided into Atlantic, East Pacific and Central Pacific regions. An “Advisory Archive” for each hurricane is sorted into different columns according to the advisory type. As this thesis aims to evaluate the reaction on publicly available data, the column “public advisories” is selected. The public advisories are sorted by date and time, and provide a link to a hurricane report. Tropical cyclone is the term used independently of the wind speed; they do not tend to be classified as hurricanes right from the beginning but build up over time until they reach hurricane strength with wind speeds above 74 miles per hour. Updates on tropical cyclone with wind speeds up to 74 miles per hour are provided every 5 to 6 hours. Once 74 miles per hour are exceeded immediate reports are published in between the regular reports. All reports per hurricane are reviewed. Data are extracted from each report and collected in a database; data related to all hurricanes in the predefined timeframe of five years from 2014-2018 are collected. However due to data processing restrictions just the eight hurricanes mentioned in incident announcements by firms are selected for modelling.

From the detailed information in the individual reports on the eight hurricanes, the parameters are selected that are most likely to have an impact on stock price, namely the following four specific points in time and two timeframes:

1. **Begin of Hurricane (Point in Time):** The first time a tropical cyclone is called a hurricane. In this case the heading of the report changes to e.g., “Hurricane Florence Intermediate Advisory Number 51A”. There is not necessarily information about if and when the hurricane will hit land, it is solely information on the strength of the tropical cyclone.
2. **Hurricane Warning (Point in Time):** A hurricane warning is always launched in connection with a geographical link. It means that a particular area is threatened by a hurricane.

The definition of a hurricane warning in a report may look like this: “A Hurricane Warning means that hurricane conditions are expected somewhere within the warning area. A warning is typically issued 36 hours before the anticipated first occurrence of tropical-storm-force winds, conditions that make outside preparations difficult or dangerous. Preparations to protect life and property should be rushed to completion.” This definition of a hurricane warning is an example from hurricane Florence in 2018. The timeframe given in the reports varies slightly. The example of the warning itself is: “A Hurricane Warning is in effect for...* South Santee River South Carolina to Duck North Carolina * Albemarle and Pamlico Sounds”. This information was also selected as an example from the report “Hurricane Florence Intermediate Advisory Number 51A”

3. **Hurricane Landfall (Point in Time):** If a hurricane hits land, there will be a report just after or at the time the hurricane hits land. The report will comprise the time and location of landfall and the possible path.
4. **End of Hurricane (Point in Time):** The end of the hurricane is marked by the first report that does not classify the tropical cyclone as a hurricane anymore, but as a tropical storm or depression.
5. **Hurricane Duration (Timeframe):** The hurricane duration is the time between the above defined points of time the hurricane begins and the end of the hurricane.

6. **After Hurricane (Timeframe):** The three months after the above-defined end of the hurricane.

4.4 Prediction Model

The stock prices over the sampling period comprise a time series of measurements exposed to interruptions due to hurricane announcements (interrupted time series analysis (ITSA)). The analysis is based on the following two-step approach (illustrated in Figure 26): Research Phase 2a) Estimation of Autoregressive integrated moving average (ARIMA) model parameters and Research Phase 2b) ITSA where the anchor points define the timing of the interruption, also called intervention. The justification for this approach is twofold: firstly, the outcome variable stock price is modelled appropriately by ARIMA (Appendix D and supplementary Figure 49). The estimation of ARIMA model parameters is created on the basis of the 12 months' stock price data before the anchor.

Secondly, the considered events of hurricane announcements and linked firm announcements represent both a well-defined time point of expected change, possibly interrupting the stock price pattern. The intervention analysis is run for three time horizons: 3, 6 and 12 months. For statistical analysis, the open-source statistical language 'R' (version 3.6) is used and particularly the packages forecast (version 8.12), tseries (version 0.10-47), and tsoutliers (version 0.6-8) for time series modelling are applied (R-Project). Data wrangling and visualisation are done in R as well, using particularly the packages of tidyverse (version 1.3.0).

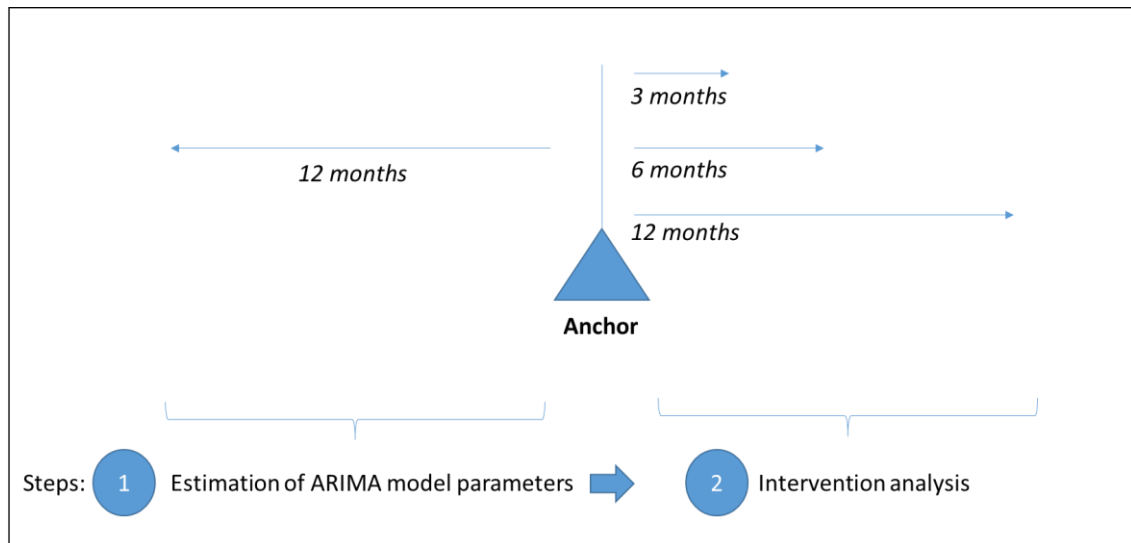


Figure 26. *Time Series Analysis: Steps of Model Creation and Fitting (Source: Author)*

4.4.1 Research Phase 2a) ARIMA Model

The stock price exhibits temporal patterns (Goetzmann, 1993). There are several possibilities to account for temporal patterns in regression models; of note are linear mixed effect models. These can handle repeated measurements well (Zuur et al., 2009). However, the stock prices can have more complex temporal patterns beyond simple autocorrelation. These patterns are, for example, due to seasonal and cyclical fluctuations (for an example reference for fluctuations in stock price see Appendix E). Thus, accounting for these temporal patterns is of utmost importance to ensure that the statistical modelling error is well controlled. Here the ARIMA model is chosen (Box and Tiao, 1975). The term autoregression indicates that it is a regression of the variable against itself, where the present value of the variable is based on a linear combination of past values of the variable. These past values can furthermore be averaged so that the regression is then based on moving averaged past values of the variable. Stationarity of the time series is achieved by replacing, also called integrating, values with the differences between consecutive observations. The applications of the ARIMA model with and without intervention analysis have been widely used in different aspects, such as flexible manufacturing system scheduling and simulation (Ip, 1997; Ip et al., 1999), tourism forecasting (Cho, 2001; DuPreez and Witt, 2003), investigation and forecast of economic factors (Chung, Ip and Chan, 2009), the

financial crisis in China's Manufacturing after 2008 (Chung, Ip and Chan, 2009) and impact analysis on air travel demand (Lai and Lu, 2005).

A process with non-seasonal and seasonal ARIMA is given by

Equation 1. Autoregressive Integrated Moving Average (ARIMA)

$$\Phi(B^s)\phi(B)(1 - B^s)^D(1 - B)^d \frac{y}{t} = c + \Theta(B^s)\theta(B) \frac{e}{t}$$

where ϵ_t is a white noise process; B is the backshift operator with 1-B containing the differenced data of order D and d with seasonal order s; $\Phi(z), \phi(z), \Theta(z), \theta(z)$ are polynomials of order P, p, Q and q respectively.

ARIMA models are often denoted as ARIMA(q,d,p), where q is the number of autoregressive (AR) terms, d is the level of differencing (I) and p is the number of moving-average (MA) terms (Hyndman and Athanasopoulos, 2018). If a seasonal model is to be specified, known as a seasonal ARIMA or SARIMA, then this is often denoted as ARIMA(q,d,p)(Q,D,P)s, where s reflects the seasonal order (e.g. 12 if monthly or 4 if quarterly or 7 if weekly), Q is the seasonal AR terms, D seasonal differencing and P seasonal MA terms (Hyndman and Athanasopoulos, 2018). The selection of the best fitting ARIMA model has been established by Box and Jenkins (1970), with further improvements in recent years (e.g., in forecasting by Hyndman and Khandakar, 2008). This process combines unit root tests, minimisation of the Akaike Information Criterion (AIC) and Maximum Likelihood Estimation (MLE). The number of differences needed is determined using repeated Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. By applying a stepwise search to traverse the model space to reduce computational load, the optimal orders of q AR and p MA terms are chosen by minimising the AICs. Thus, the ARIMA model accommodates the characteristics of time series such as autocorrelation, non-stationarity, trends, seasonal and cyclic changes as well as drifts (Hyndman and Athanasopoulos, 2018).

4.4.2 Research Phase 2b) Interrupted Time Series Analysis

After modelling the outcome variable stock price, the remaining question is how to define the interruptions due to hurricane announcements and hurricane incident announcements. A simple solution would be to fit two independent ARIMA models – once before and once after the event – and compare their estimated parameters. However, this would limit the detection to major shifts in the trendline. The detection of subtle and short-lived changes in the stock price spanning a couple of days would be hard to detect and might depend on the time window. On the other hand, ITSA, also known as intervention analysis in environmental and health policy research (Lagarde, 2012), is a valid alternative. An intervention model as discussed by Box and Jenkins (1970) is of the general form:

Equation 2. Intervention Model

$$Y_t = V(B)I_t + N_t$$

where I_t is a dummy variable (0 and 1) encoding the intervention, enabling the detection of different patterns of changes in stock price; $V(B)$ encompasses the ARIMA process as described in the previous section; N_t is an error or noise process which describes the unexplained part of Y_t (Helfenstein, 1991). For example, the interruption could only be present for one day or spanning multiple days. In combination with ARIMA, these interventions can be defined as transfer functions where the focus will be on pulse, step and transitory changes of the time series (Box and Tiao, 1975) (Figure 22). The statistical significance of each possible transfer function is evaluated by a likelihood ratio test per firm and event model. A likelihood ratio test is of the general form:

Equation 3. Likelihood Ration Test

$$LR = 2\ln \left(\frac{Lm_1}{Lm_2} \right)$$

where $\loglik(m^*)$ denotes the natural log of the model's likelihood for the null model (m_0), i.e., no intervention, and the model including an intervention (m_1). Assuming H_0 is true, i.e., no intervention effect, then the test statistic can be approximated by a Chi-squared distribution with degrees of freedom equal to the difference in dimensionality of m_0 and m_1 following Wilks' theorem (Kutner et al., 2005). The test statistic is then compared to the Chi-squared value corresponding to the desired statistical significance with nominal level 0.05. If multiple transfer functions give significant test results, the one which minimises the AIC the most is selected (Hyndman and Khandakar, 2008). The estimated coefficients of the transfer functions are the basis for calculating relative effect changes represented as percentage mean changes after the intervention, making the comparison across firms with diverging stock price ranges possible (Beard et al., 2019). Furthermore, the joint estimation of ARIMA model parameters and outlier effects in time series has also been established (Chen and Liu, 1993). Using this framework, one can determine whether the announcement days coincide with outlying temporal patterns, thereby extending the framework to the evaluation of unknown interventions (López-de-Lacalle, 2016).

4.4.3 Justification of the ARIMA-Intervention Model

The approach outlined above is driven by scientific rigour to model the data correctly. The selected modelling approaches have already been shown to be valid in other fields. For example, ARIMA in combination with interruption modelling has been shown to be more precise in explaining and analysing the marked decrease in gross industrial output, following the financial crisis of 2008, in China's manufacturing industry (Chung, Ip and Chan, 2009). ARIMA models are widely used in the field of financial forecasting because they have high predictive power and accuracy, also for short-term forecasts (Ariyo et al., 2014). ITSA with ARIMA processes is more flexible than general additive mixed models because one can not only determine whether the effects of the interruption were transient or permanent but also whether the changes in the outcome pre-empted the interruption (Beard et al., 2019). ITSA has been particularly applied in epidemiological research to model for example the effect of the financial crisis

2008 on suicides in Spain (Lopez Bernal, 2013) or to model the effects of pollutants released into the environment (Yamamuro et al., 2019). Nevertheless, the combination of the ARIMA model of stock price with intervention analysis specifically to investigate the effects of SCDs due to natural disasters on stock price is a novel utilization.

4.4.4 Anchors

The anchor represents the interruption, also called intervention in ITSA. In this thesis two anchors are tested (see Figure 27 and Figure 28).

4.4.4.1 Anchor A: Hurricane Incident Announcement

Figure 27 shows that anchor A is the interruption of the time series set on the date of the first public announcement that provides information on the hurricane incident at the respective firm. One can test whether the anchor time given by the announcement day can be identified as a significant outlier in the time series. The anchor is defined by the announcement date; however, if the announcement date is not a trading day, the next trading day is selected.



Figure 27. Definition of Anchors (Source: Author)

4.4.4.2 Anchor B: Hurricane Announcement

Anchor B includes announcements that are related to a certain hurricane but that are not linked to a firm.

1. **Begin of Hurricane (Point in Time):** The begin of the hurricane was selected as the first anchor point. Even though this information just states the strength of the tropical cyclone and does not link it to a threat to land yet, people might react to the information that a new hurricane has formed.

As the hurricane might be a potential threat, a negative stock price reaction might occur.

2. **Hurricane Warning (Point in Time):** Hurricane warning was selected as the second anchor as it ties the hurricane to a specific landfall. Before a hurricane warning there are often announced hurricane watches (there might be a hurricane), however hurricane warnings have a stronger meaning (warning, prepare for a hurricane). As this information indicates a specific threat to a specific geographic area, the hurricane threat is tangible, and people might react to it negatively which is expected to be reflected in stock price.
3. **Hurricane Landfall (Point in Time):** The information that a hurricane hits land is the first announcement that provides 100% likelihood of impact. It is expected that people react negatively to a materialising disaster.
4. **End of Hurricane (Point in Time):** People might react in different ways to the information. Some might react positively as they are relieved that the hurricane has slowed down. There might also be negative reactions to the hurricane damage.
5. **Hurricane Duration (Timeframe):** To analyse the effects for the timeframe, hurricane duration was selected as it is predicted that people will react negatively while the hurricane is happening.
6. **After Hurricane (Timeframe):** Initially 3, 6 and 9 months were tested. As the results were very similar the 3 months' timeframe was applied.

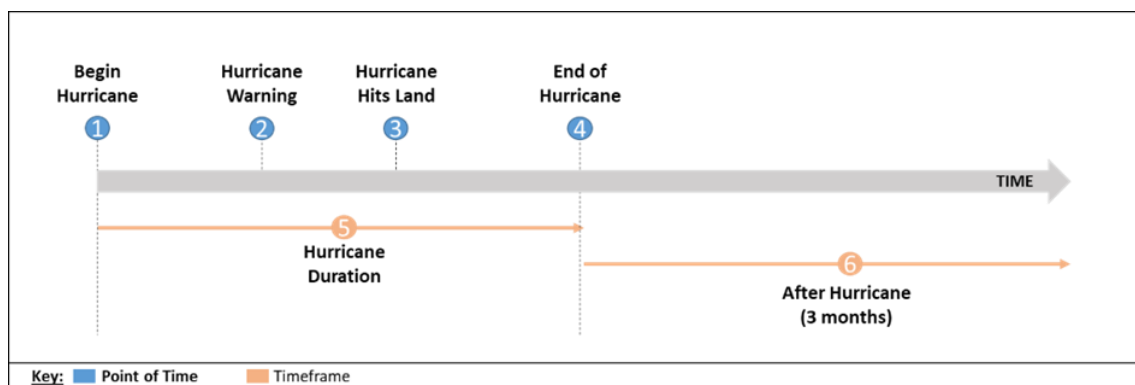


Figure 28. Type B Hurricane Announcement Anchors. 1. Begin hurricane, hurricane warning, hurricane hits land and end of hurricane being points in time. (Source: Author)

4.4.5 Variables

4.4.5.1 Outcome Variable

The outcome variable Y_{it} measures the stock price for each firm i of the ~625 companies over time t . To gather stock exchange data, the NYSE stock price information is collected via an API from Yahoo Finance and imported into “R”. The focus will be on the time of stock exchange closing per trading day, selecting the closing value per trading day. The timeframe for the regression analysis is tied (anchored) to the event date determined by the first hurricane incident announcement for a firm or the hurricane duration. The timeframe is one year prior to and one year after the anchor. Information may not be available for the entire chosen timeframe because the company just joined the NYSE, left the index or went through a merger or acquisition in that period. If the company data are available for less than 10% of the timeframe they are excluded. The hypotheses regarding the outcome variable are presented in Table 18.

4.4.5.2 Potentially Influencing Factors and Resulting Hypothesis

Previous research confirmed certain factors to modulate the effect of SCDs/disasters on the stock price change (Table 12). All hypotheses are rooted in the literature following a deductive approach (Figure 23). These were explained in the literature review (Table 13).

4.4.5.3 Variables from Hypotheses

The variables mentioned in the above hypotheses are explained further in this section and in

Table 21.

There are two main anchors: Hurricane incident announcements (1) and hurricane announcements (2). Hurricane incident announcements (1) are tested

for all hypotheses. The date of the earliest announcement is selected. Hurricane announcements (2) are just tested for H1, H1a, H1b and H1c; the reason for that is that announcements such as a hurricane warning are not for specific companies, therefore the other hypotheses are not applicable. The date of the earliest announcement is selected.

For all hypotheses the impact on stock price as an output variable is measured (3). For all hypotheses the three transfer functions are tested. For points in time all three functions are measured: pulse, transitory change and step function. For time durations just the step function applies (4).

In hypothesis 2 the potential influence of the industrial sector is tested (5). For all in-scope companies these seven industrial sector categories from NYSE are applied: Technology, Health Care, Consumer Services, Consumer Non-Durables, Consumer Durables, Capital Goods and Basic Industries.

In hypothesis 3 the impact type is tested: Supply Chain Disruption vs. Other Damage (6). At least one category needs to apply. There are three potential options, either SCDs, other damage or both.

In hypothesis 4 the impact extent is tested: Major vs. Minor (7). These two categories are tested per impact type (SCD vs. other damage). There are five possible options: Minor Supply Chain Disruption, Major Supply Chain Disruptions, Minor Other Damage, Major Other Damage and Positive Effect on Demand.

In hypothesis 5 the impact of information on actual damage is tested. Actual damage means that detailed information on the damage is provided. While Impact just states that it is, for example, an SCD/other damage but without providing further details; in the category “actual damages” details on the impact are provided. Information on impact has to be provided, therefore two options are available: Impact and Impact + Actual Damage.

In hypothesis 6 Preventive Closure includes closure of production sites due to regulatory requirements and closures based on the company's decision. Here

four different options were tested: Impact, Preventive Closure + Impact, Actual Damage + Impact and Preventive Closure + Actual Damage + Impact.

Table 21. *Variables from Hypotheses (Source: Author)*

#	Variables tested in the Hypotheses	Hypotheses	Type	Description
1	Hurricane Incident Announcement	All Hypotheses	Date	Earliest possible date of an announcement from a reliable source that confirms a hurricane incident at a respective firm.
2	Hurricane Announcement	H1, H1a, H1b & H1c	Date	Date of the earliest announcement about the hurricane status from the National Hurricane Center.
3	Stock Price	All Hypotheses	USD	Measured using the closing value of each trading day.
4	Transfer Functions	All Hypotheses	For Points in Time 3 Options: Pulse Transitory Step For Time Durations 1 Option: Step	For a point in time: All three transfer functions are tested and the best fitting one is selected. For time durations just the step function is applicable.
5	Industrial Sector	H2	7 Options: Technology Health Care Consumer Services Consumer Non-Durables Consumer Durables Capital Goods Basic Industries	The industrial sector categories from the NYSE are applied to the in-scope firms.

6	Impact Type (Supply Chain Disruption & Other Damage)	H3	3 Options: Supply Chain Disruption Other Damage Both	Information from hurricane incident announcements. There are two main categories of impact type: Supply Chain Disruption and Other Damage. At least one category needs to apply. Other Damage can be for example demand decrease and damage to administrative buildings
7	Extent of Impact (Minor & Major)	H4	5 Options: Minor Supply Chain Disruption Major Supply Chain Disruptions Minor Other Damage Major Other Damage Positive Effect on Demand	Information from hurricane incident announcements. There are two options Minor or Major. These are tested per Impact Type.
8	Actual Damages	H5	2 Options: Impact Impact + Actual Damage	Actual damage means detailed information on the damage is provided. While Impact just states that it is e.g. a supply chain disruption/other damage but without providing further details, in the category “actual damages” details on the impact are provided.
9	Preventive Closure	H6	4 Options: Impact Preventive Closure + Impact Actual Damage + Impact Preventive Closure + Actual Damage + Impact	Preventive Closure includes closure of production sites due to regulatory requirements and closures based on the company's decision.

4.4.6 The Two Test Cases: Hurricane Incident Announcement and Hurricane Announcements

The diagrams in Figure 29 outline the methodology of the two test cases. For the first test case, the time of the hurricane incident announcement is the anchor for the model. This test is just possible for firms announcing hurricane incidents from 2014-2018 (announcing firms). The NYSE stock price data per firm to test H1 and H1a, H1b and H1c are obtained via API from Yahoo Finance. The same applies to the information on the industrial sectors to test H2. Information on the event-

related factors tested by the H3 – H6 hypotheses is generated from the company announcements. In the second test case, the six Anchor Bs are applied as test cases. These anchors enable analysis of all firms, not just of the ones with announcements, allowing for a comparison between those two groups. In contrast to the Anchor A which is a specific time point like the stock data, i.e. a trading day, Anchor B may also be a timeframe. The same as for the first test case, NYSE stock price information on the listed firms is available and enables the testing of H1 and H1a, H1b, and H1c for announcing firms and non-announcing firms. The NYSE stock price data per firm enabling testing of H1 and H1a, H1b and H1c are obtained via API from Yahoo Finance. H2 could not be tested as the information would have been too granular, leading to excessive computational demand. The H3 hypothesis cannot be tested as the information from the announcements is not included. To compare the test case results, only hurricane incident announcements after the begin of the hurricane were considered. The upper section of Figure 29 shows the schematic for testing hurricane incident announcements (Anchor 1), the lower section for testing hurricane announcements (Anchor 2). For each schematic there are displayed: data sources, information flows, variables, hypotheses and outcomes.

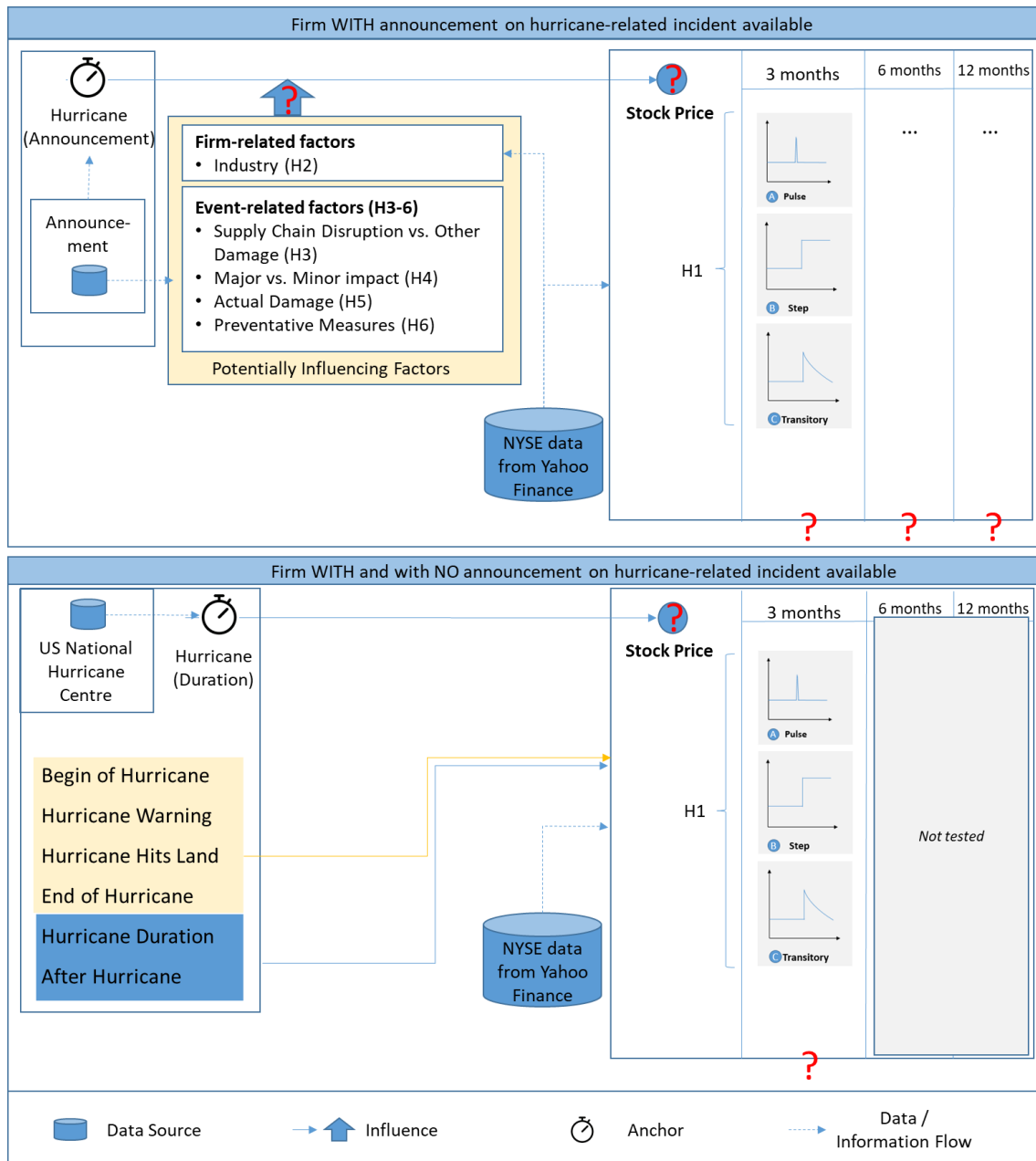


Figure 29. Schematic of the Testing for the Two Anchors (Source: Author).

5 Results

5.1 Descriptive Analysis of Population Data

In this chapter the test results will be presented. Of all 2,687 NYSE listed companies, 625 (23%) meet the scoping criteria displayed in Figure 25. In the following, the results of the descriptive analysis of all natural disasters and specifically hurricanes that affected in-scope firms in 2014-2018 are shown. The figures were produced in R. Out of these 625 firms, 235 were affected by in total

409 natural disaster incidents between 2014 and 2018. More than one third of the firms (38%) were affected by at least one natural disaster incident, half of these companies by even more than one disaster (Appendix C). In total more than one million observations were collected.

5.1.1 Hurricanes are the Most Prevalent Natural Disaster

Figure 30 shows the number of announced natural disaster incidents per disaster type in 2014-2018. The type of natural disaster sorted alphabetically is shown on the y-axis. Per disaster type, a bar shows the absolute number of incidents and as a percentage next to the bar representing the proportion of that type with respect to all disasters. When discriminating between types of natural disasters, hurricanes are the most prominent natural disaster type, causing 336 incidents at the companies in scope accounting for 82% of all natural disaster incidents. The other most frequent disasters were 7% earthquakes (27 incidents) and 4% droughts (17 incidents) (Figure 30).

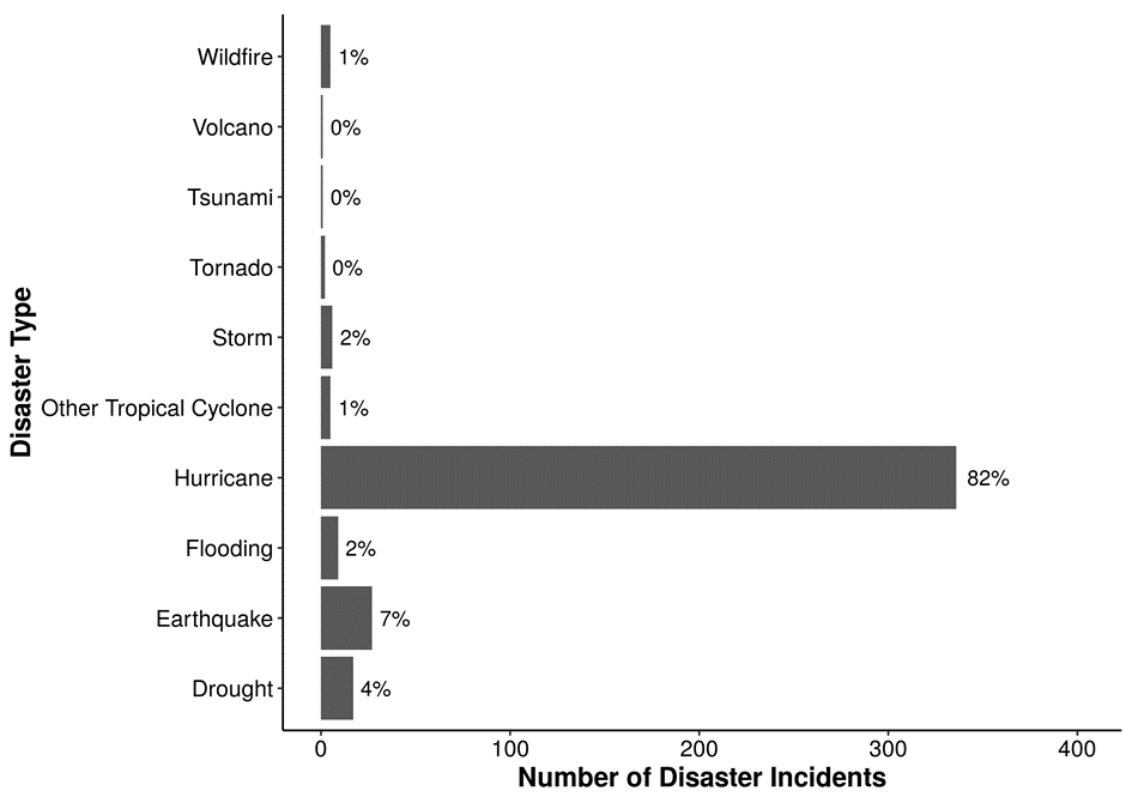


Figure 30. *Number of Announced Natural Disaster Incidents per Disaster Type in 2014-2018 (Source: Author)*

5.1.2 One Third of Companies reported at Least one Hurricane Incident

Figure 31 shows the number of announced hurricane incidents per company. The number of announced hurricane incidents per firm are shown on the y-axis. Per numerical category of reported hurricane incidents, a bar shows the number of companies and as a percentage next to the bar representing the proportion of all of the companies. Around 30% of all companies in scope were affected by hurricane incidents; half of the firms were affected by one hurricane and the other half suffered from a second, third or even fourth hurricane (Figure 31).

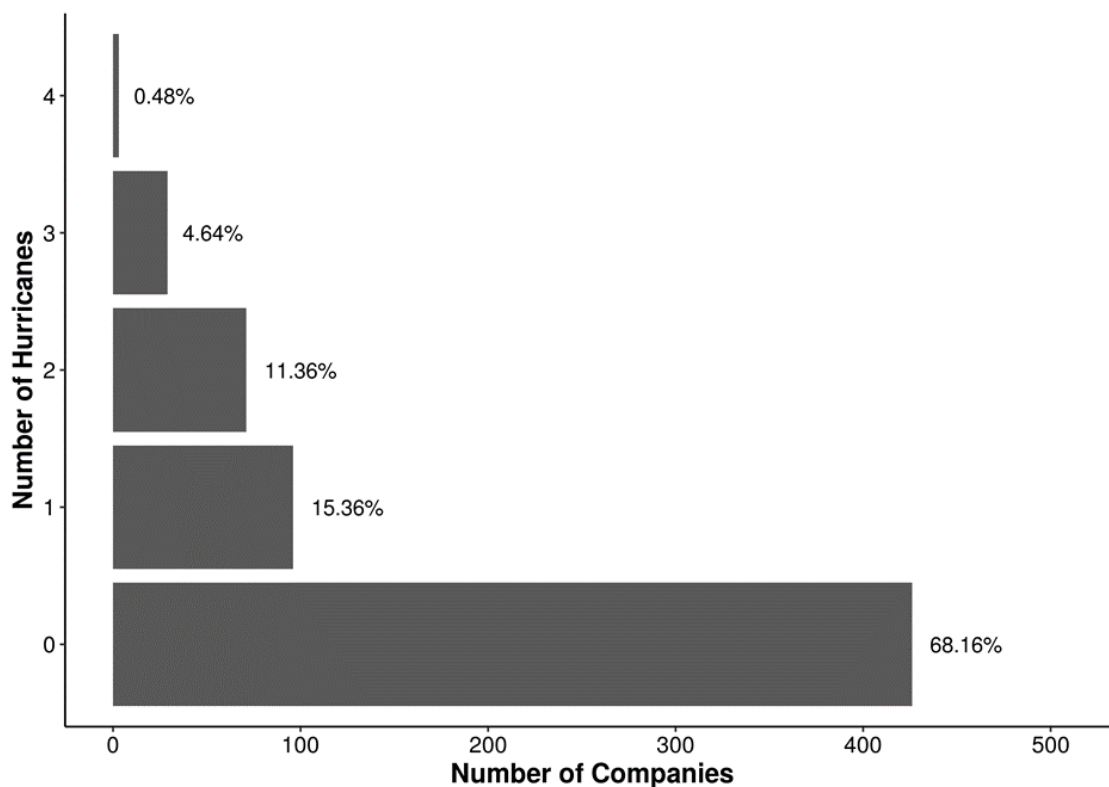


Figure 31. *Number of Announced Hurricane Incidents per Company (Source: Author)*

5.1.3 2017 was the Year that affected Firms most by Hurricanes

Figure 32 shows the number of announced natural disaster/hurricane incidents per year in 2014-2018. The calendar year of incident sorted chronologically is shown on the y-axis. There are spans of calendar years, when required, to cover incidents reported over timespans for more than one calendar year, i.e., droughts.

Per year or years' time span, two bar graphs show the number of hurricane incidents in yellow and other natural disaster incidents in grey both as a percentage next to the bars representing the proportion of natural disaster incidents and as an absolute, as shown on the x-axis. 2017 was the worst year in terms of natural disaster damage for companies with around 300 disaster incidents occurring. 2018 was the second-worst year with around 70 incidents (Figure 32). The events spanning several years are droughts as these last for a longer duration.

2017 (271 hurricane incidents) and 2018 (55 hurricane incidents) were years with massive hurricane damage. This means that 80% of all hurricane incident announcements occurred in 2017.

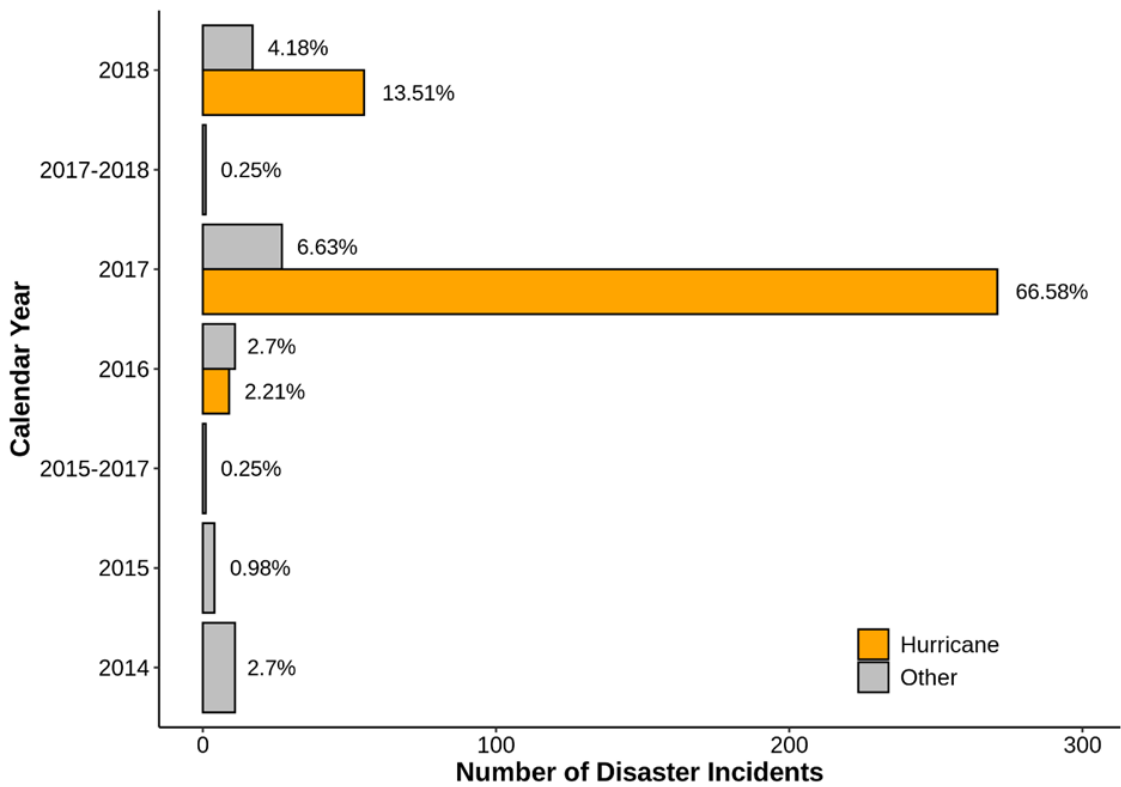


Figure 32. Number of Announced Natural Disaster/Hurricane Incidents per year in 2014-2018 (Source: Author)

5.1.4 North America is most Affected by Hurricanes

Figure 33 shows the number of announced natural disaster/hurricane incidents per geographic region in 2014-2018. The continent where the hurricane/other natural disaster incidents occurred is shown on the y-axis. Per continent bar graphs show the number of hurricane incidents in yellow and other natural disaster incidents in grey, both as a percentage next to the bar representing the proportion of natural disaster incidents and as an absolute as shown on the x-axis. Most companies were affected by natural disasters that occurred in North America. In total, more than 350 incidents of natural disaster exposure were recorded for North America which is nearly 90% of all incidents (Figure 33).

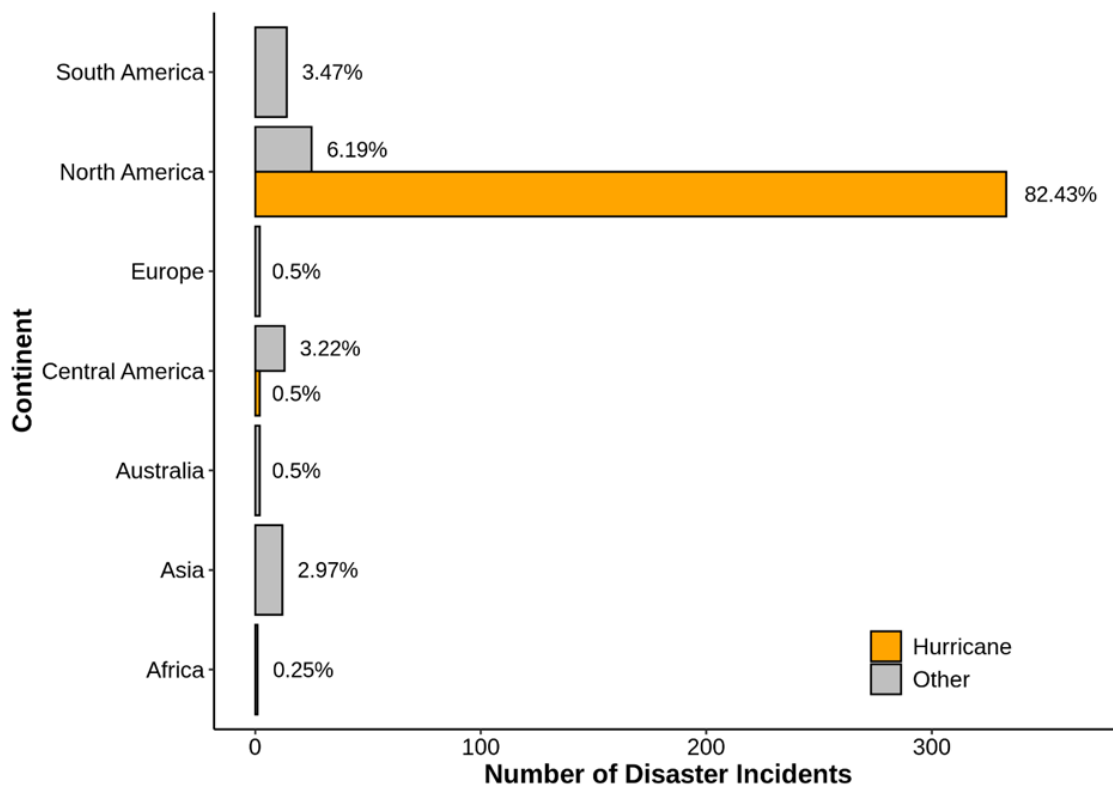


Figure 33. Number of Announced Natural Disaster/Hurricane incidents per Geographic Region in 2014-2018 (Source: Author)

5.1.5 Hurricane Incident Announcements are Reported across All Industrial Sectors

Figure 34 shows which industrial sectors were affected by how many hurricanes or other natural disaster incidents. The different industrial sectors are shown on the y-axis. Per industrial sector coloured bar charts report the number of reported incidents per firm. The number of firms as an absolute number is shown on the x-axis. The preliminary descriptive analysis of the population indicates that certain industrial sectors are more adversely affected by hurricane incidents. Firms of all industrial sectors were reporting up to three or four natural disasters. Companies in basic industries (31%), capital goods (17%), consumer non-durables (14%), health care (12%), consumer durables (12%) and consumer services (8%), account for 94% of all natural disaster incidents. Looking specifically at hurricane incidents, firms of all industrial sectors reported these. Across all sectors, there were companies reporting up to three hurricane incidents within the observed five years. Firms of the consumer durables sector and the basic industry sector reported even up to four hurricane incidents.

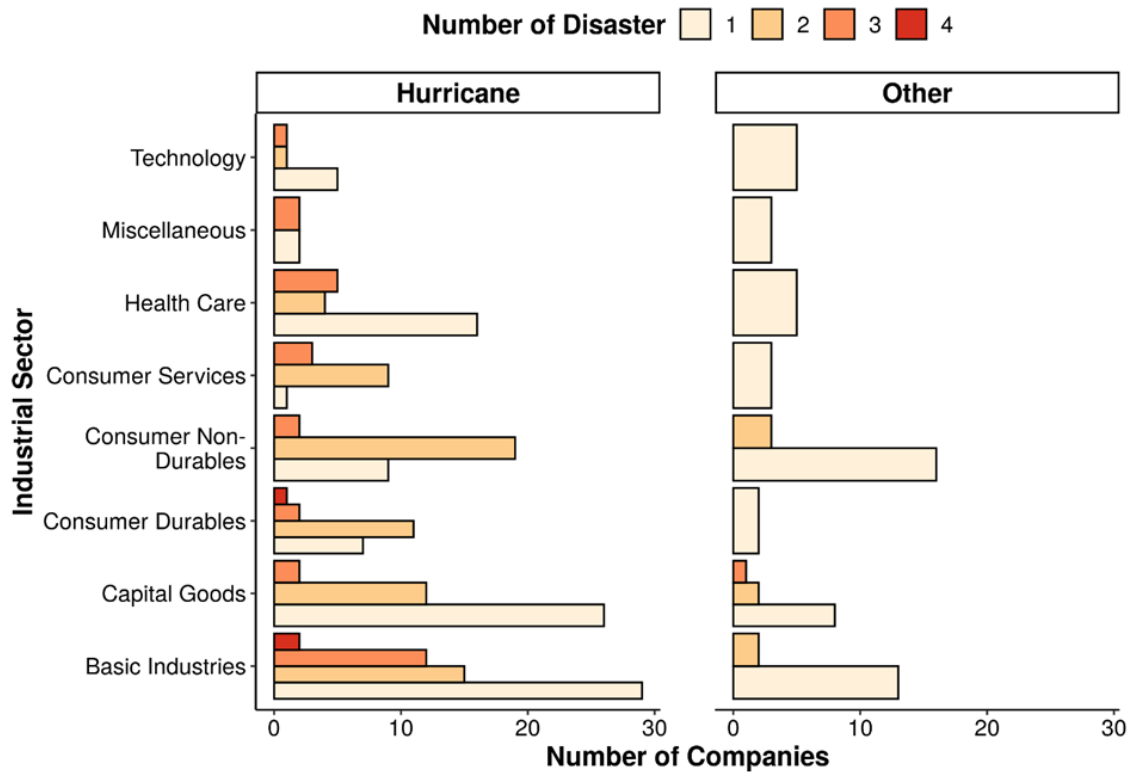


Figure 34. Number of companies per sector announcing the number of their hurricanes and other natural disaster incidents (Source: Author)

5.1.6 Influencing Factors: The Influence of Impact, Actual Damage and Preventive Closures

New event-related influencing factors based on the companies in the scope proposed from the data are reflected in the hypotheses. These can be grouped into preventive closures, actual damage and impact. Information on the event and supply chain set-up are secondary data gathered from announcements.

Impact: Finally, the population data suggests that the impact of SCDs upstream of the focal company can be categorised. Disruption to the physical flow of goods is seen as mandatory for an SCD. “Other damages” includes all damages not related to the SCD, e.g. damage to tangible assets such as properties, loss of sales (demand-side damage), store closure and damage to distribution to end customer (all downstream damage). Both SCD and other damages are split up into moderate and major categories. Moderate impacts of hurricanes are reported but not reflected in financial statements, whereas major impacts are mentioned in quarterly or annual reports. Positive impact might be observed for construction

firms, generator firms – again indicating that the explanatory variables on impact are related to the industrial sector. Positive effects might be preceded by a negative effect.

Hurricanes cause storm and flood damage. Damages relevant for SCDs were identified from the companies in scope. The data indicate that hurricanes can damage the supply chain-relevant facilities of companies' infrastructure and that companies may be affected indirectly by an upstream SCD. This can lead to a reduction of production volume or a temporary or even final closure of one or several production facilities. Infrastructure-related damages seem to lead to shorter-term SCDs. External SCDs can cause short- and long-term SCDs at a focal company, even though the company might not have suffered any damage itself (e.g. resin shortage for the healthcare sector). Agricultural damages were selected as a factor as they might lead to SCDs for food companies, for example.

The data indicated that preventive closures of supply chain-relevant facilities (production and storage facilities) or infrastructure can result in SCDs. Preventive closures of facilities and the timing of these closures may be regulated by guidelines or even be mandatory by law. However, several companies react earlier than legally required in order to prevent damage and protect their employees. As indicated above, the two factors of industry and preventive closure of own facilities might be interrelated. Preventive closures include infrastructure outside the control of the company, such as airports, ports and railways. The effect of preventive closures leading to SCDs on stock price will be evaluated.

The influencing factors can be aggregated in the following three categories:

Impact: Positive effect on demand, minor and major SCD, minor and major other damage.

Actual damage: External SCDs (disruptions at suppliers), actual damage to own facilities/production sites, actual damage to infrastructure, agricultural damage.

Preventive measures: Information on preventive closures of own facilities and preventive closures of infrastructure.

Figure 35-Figure 37 describe some factors that might influence the stock price reaction and that will be included in the model in Phase 2. In the figures “yes” means an interruption was detected, “no” means no interruption was detected.

5.1.7 Preventive Closures are Rarely Reported

Figure 35 shows the descriptive analysis of announced, potentially influencing factor, preventive closure. In Figure 35 the left of the diagram is covering the announced hurricane incidents and the right panel covers the other announced natural disaster incidents. The influencing factor category is on the y-axis. Per factor bar charts show the number of incidents where the factor was announced in yellow (caveat: one firm can announce more than once) and the number of announcing firms not mentioning the factor in grey. The percentage next to the bar represents the proportion of incidents of firms reporting the factor and with absolute values indicated by the x-axis. All percentages per panel add up to 100%. Preventive Closures: The data indicate that the announcement of preventive closures is very rare overall. Closure of production facilities occurs in only 3.8% of all natural disaster events, most of which for hurricanes (3.4%). Closure of production facilities can be government ordered. Many times, companies already even close their facilities earlier voluntarily to protect their assets. Preventive closures of infrastructure were reported for hurricanes for just 0.1% of hurricane incidents (Figure 35). Infrastructure closures are always ordered by the government. As for disasters, including hurricanes, the government at some point announces evacuation. It seems that because it is government ordered and applicable to everyone in the region, and it is publicly available information, companies do not disclose these closures specifically.

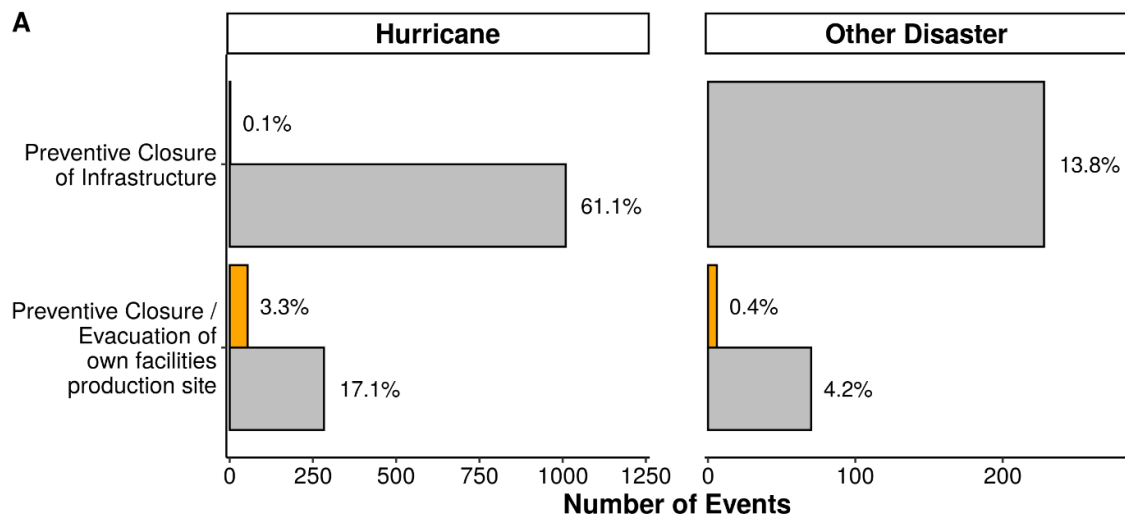


Figure 35. Descriptive Analysis of Announced Potentially Influencing Factor Preventive Closure (Source: Author)

5.1.8 Few Companies Report on their Hurricane Damage in Detail

Actual Damage: Figure 36 shows the descriptive analysis of announced, potentially influencing factor, actual damage. The left diagram covers the announced hurricane incidents, and the right panel covers the other announced natural disaster incidents. The influencing factor category is on the y-axis. Per factor bar charts show the number of incidents where the factor was announced in yellow (caveat: one firm can announce more than once) and the number of announcing firms not mentioning the factor in grey. The percentage next to the bar represents the proportion of incidents of firms reporting the factor and with absolute values indicated by the x-axis. All percentages per panel add up to 100%. Most frequently reported damages due to hurricanes are damage of own production facilities (applicable to 4.2% of all natural disaster incidents), actual damage of infrastructure (more than 1.6% of all natural disasters) and 1.1% are due to external SCDs at upstream suppliers (Figure 36). Few companies report on their damage in detail.

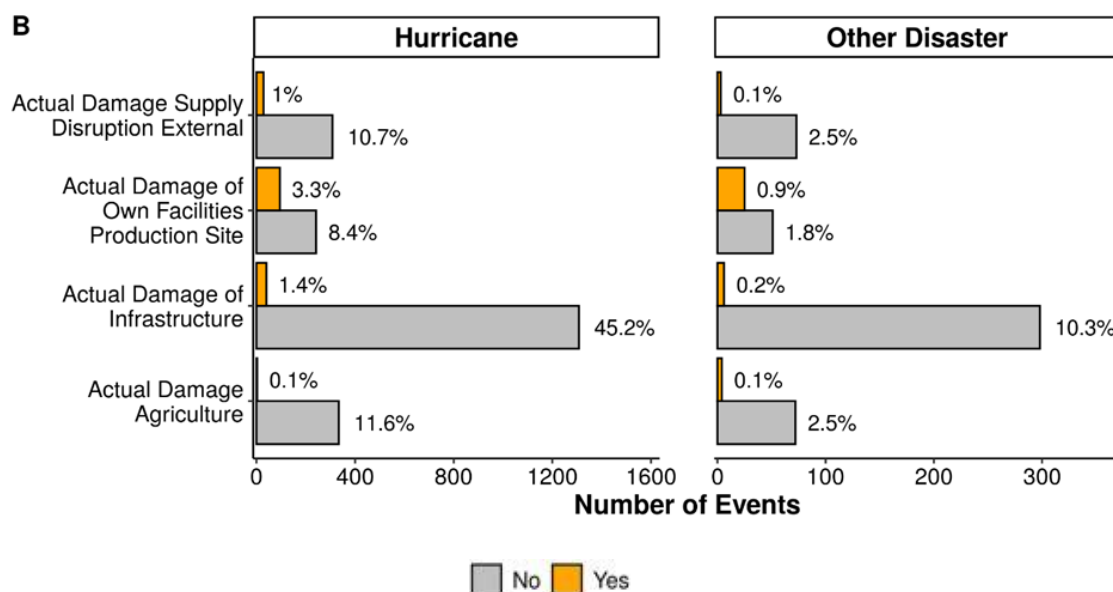


Figure 36. *Descriptive Analysis of Announced Potentially Influencing Factor Actual damage (Source: Author)*

5.1.9 The Most Reported Impact Type is Other Damages

Impact: Figure 37 shows the descriptive analysis of announced potentially influencing factor impact. The left diagram covers the announced hurricane incidents and the right panel covers the other announced natural disaster incidents. The influencing factor category is on the y-axis. Per factor bar charts show the number of incidents where the factor was announced in yellow (caveat: one firm can announce more than once) and the number of announcing firms not mentioning the factor in grey. The percentage next to the bar represents the proportion of incidents of firms reporting the factor and with absolute values indicated by the x-axis. All percentages per panel add up to 100%. 11.1% of incidents resulting in damage unrelated to SCDs are due to hurricanes, 77% of these damage incidents being major. 8.4% of all events are caused by hurricanes and disrupt the supply chain. 57% of these are severe SCDs (Figure 37). The overlaps within the categories are as represented in Figure 38-Figure 40.

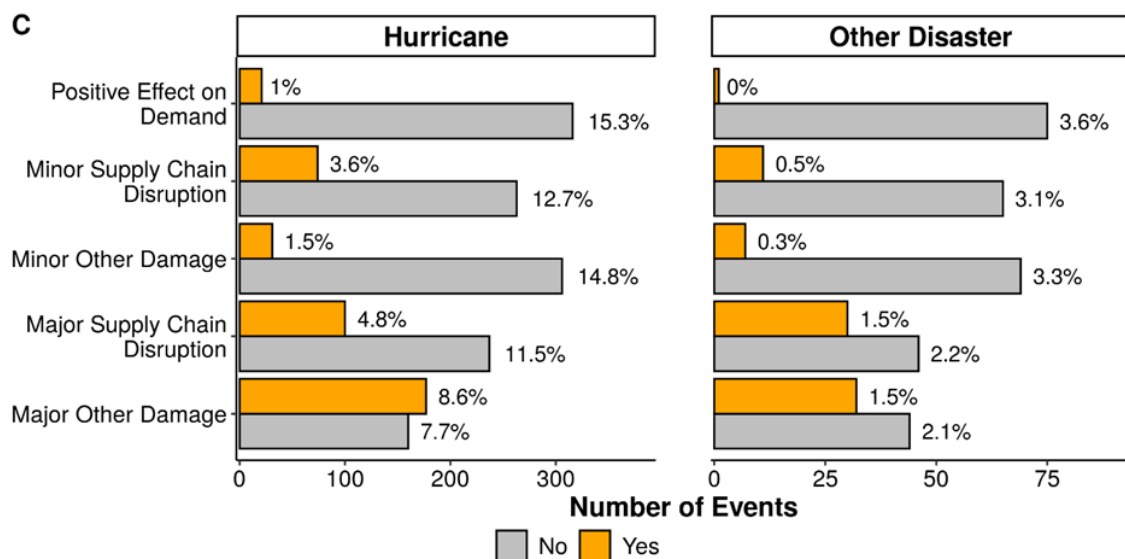


Figure 37. *Descriptive Analysis of Announced Potentially Influencing Factor Impact*
(Source: Author)

5.1.10 Companies Just Report Impact but do Not Necessarily Provide Details

During data collection, it was apparent that reported influencing factors did not occur in isolation, e.g., major and minor damages were often observed together. Figure 38-Figure 41 provide an overview of these co-occurrences within the potentially influencing factor categories for hurricane incidents. Figure 38 displays the three main categories of influencing factors preventive closure (both of own facilities and infrastructure), actual damage and impact, and their occurrence. Most incident (85) reports are on impact without providing details on preventive closures or actual damage related to their supply chain. 86 incidents are reporting impact and provide details on the supply chain-related damage. 20 incidents report impact but do not provide information on actual supply chain-related damage but information on preventive closures. 25 firms provide information that they are impacted and report preventive closures and actual supply chain-related damage. In Figure 38 each panel is split into two components. On the left, the horizontal bar tallies the total number of reports containing the influencing factor

subcategories. On the right, the number of unique subcategory reports as well as the co-occurring reports are tabulated.

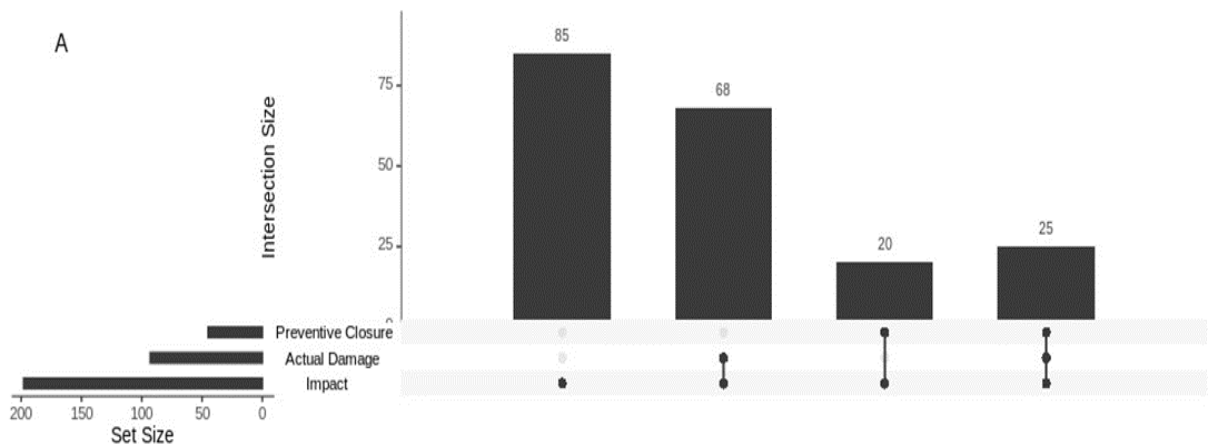


Figure 38. Descriptive Analysis Overlaps of main groups of Potentially Influencing Factors (Source: Author)

5.1.11 The Vast Majority of Preventive Closures is of the Production Facilities

Figure 39 indicates that all preventive closures include preventive closure of own facilities. Just one incident reported on preventive closure of own facilities and preventive closure of infrastructure. This was due to higher shipping costs and lower shipping rate. In Figure 39 each panel is split into two components. On the left, the horizontal bar tallies the total number of reports containing the influencing factor subcategories. On the right, number of unique subcategory reports as well as the co-occurring reports are tabulated.

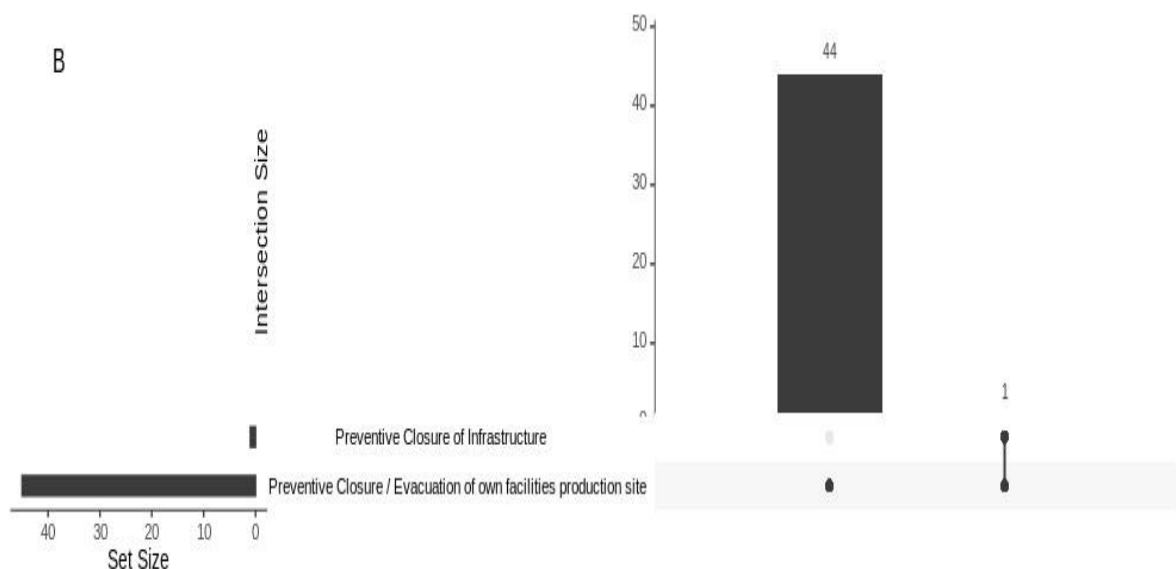


Figure 39. *Descriptive Analysis Overlaps of Potentially Influencing Factors within “preventive closures” (Source: Author)*

5.1.12 The Most Frequently Reported Damage is on The Production Facility

Figure 40: Incidents reports on solely damage to own production facilities are the most prevalent (53 incidents). The most frequent combination of damage type are incidents with both damages of own facilities and infrastructure. Nine Incident reports on external SCDs do not report any direct damage and eight incident

reports mention solely infrastructure damage (e.g., ports, airports, ports and electricity) and no direct damage to their own assets. In Figure 40 each panel is split into two components. On the left, the horizontal bar tallies the total number of reports containing the influencing factor subcategories. On the right, number of unique subcategory reports as well as the co-occurring reports are tabulated.

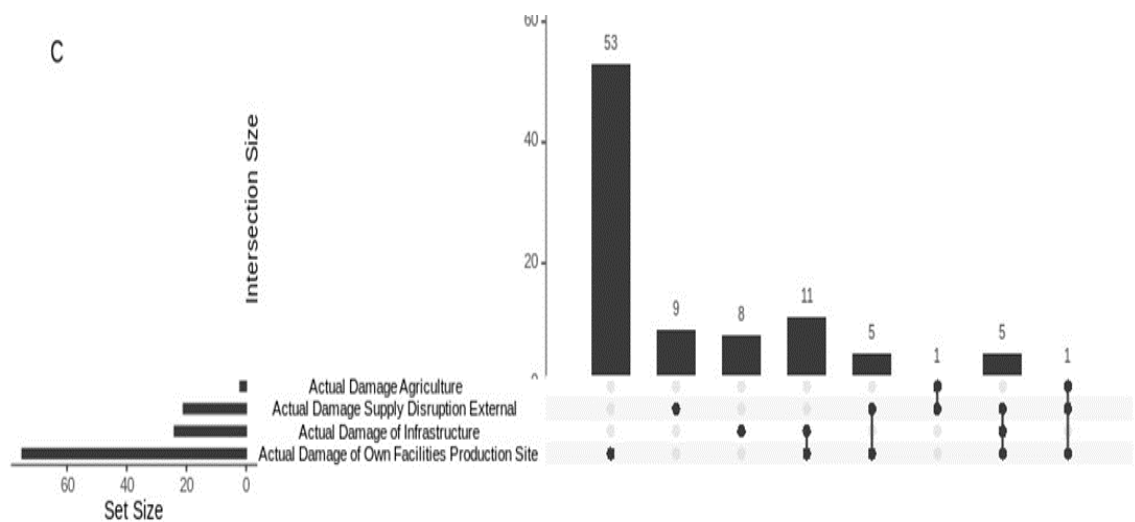


Figure 40. Descriptive Analysis Overlaps of Potentially Influencing Factors within “actual damage” (Source: Author)

5.1.13 Various Combinations of Potentially Influencing Factors Show

Figure 41 provides a detailed overview of the different combinations of impact. The most frequently reported, without any other damage, is major other damage (51%) which was e.g., damage to buildings or decrease in demand. The next biggest group is major SCDs (38 incident reports). To have a disruption of the supply chain, and as indicated previously in Figure 40, in the cases with more details known, is mostly damage to own production facilities. The third biggest category (28) is minor SCDs and the fourth biggest (26) includes those companies that report major SCDs and major other damage. In Figure 41 each panel is split into two components. On the left, the horizontal bar tallies the total number of reports containing the influencing factor subcategories. On the right, number of unique subcategories reports as well as the co-occurring reports are tabulated.

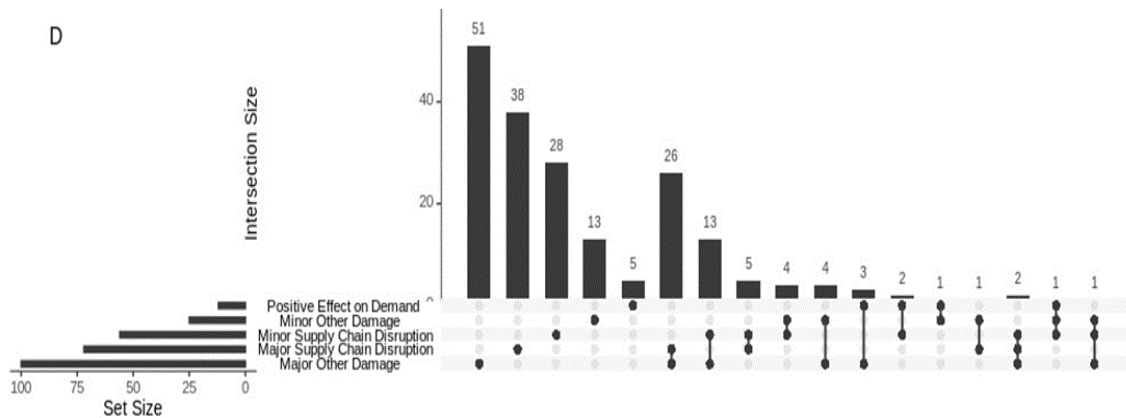


Figure 41. *Descriptive Analysis Overlaps of Potentially Influencing Factors within “impact” (Source: Author)*

The descriptive analysis of the companies in scope revealed that hurricanes are the most predominant natural disaster over the last five years (Figure 30). Therefore, the main analysis in Phase 2 is focused on the assessment of hurricane impact.

5.2 Model Results

5.2.1 Sampling of Outcome Variable Stock Price

An initial analysis was performed on the availability of NYSE index and the respective stock price information (Figure 42 and Figure 43). The NYSE information for 2014-2018 and one year before and after is covered (Figure 42). The timeframes of hurricanes are marked to demonstrate the necessity of a deeper analysis due to seasonality for example. A causal relationship between each hurricane and Index performance cannot be established based on this data. Hurricanes often (especially in 2017) occur in close timely proximity and therefore the stock price impact might not be completely separable. In Figure 42 Panel A shows the time (dates) on the x-axis and the closing prices per day for the NYSE index. The timeframe 2016 to 2019 was chosen for better illustration. The rose-coloured bars represent the hurricane with duration.

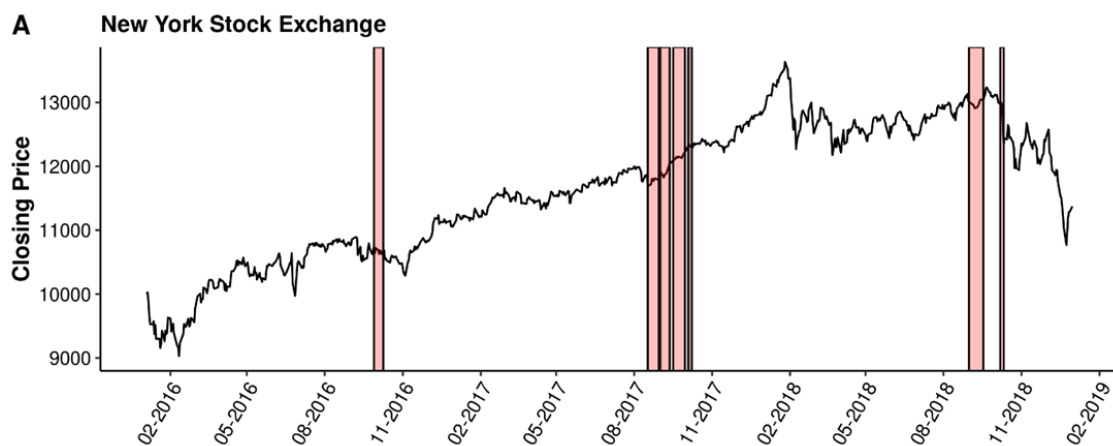


Figure 42. NYSE index (Source: Author).

An overview of the sampling of firms based on the available stock price information is provided. Firms that did not provide enough stock price information are excluded: in the diagrams 95% of announcing firms and 92% of the non-announcing firms provide sufficient information and are therefore included in the subsequent analyses (Figure 43). In Figure 43 the diagrams show the percentage of sampling periods covered for firms announcing hurricane incidents on the left and for non-announcing firms on the right.

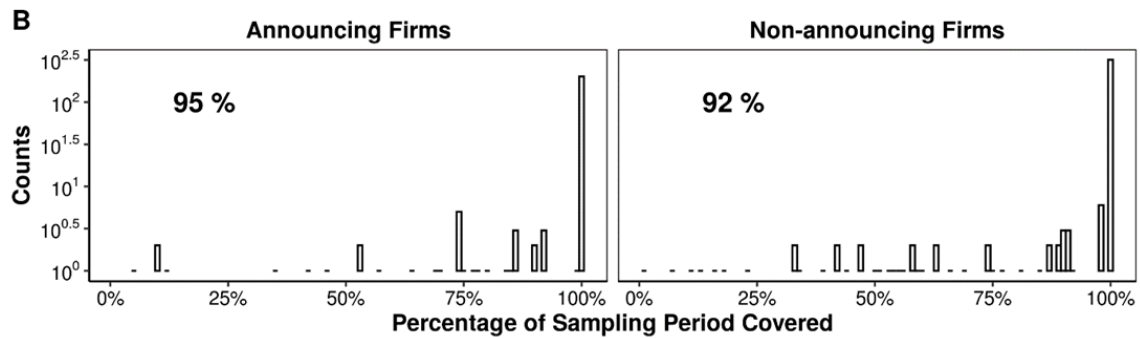


Figure 43. Sampling of Firms on the Basis of Available Stock Price Information (Source: Author).

For the later model, some firms were not listed over the whole timeframe but are included if the provided data does not negatively impact the estimation of the model, corresponding to a minimum of 90% recorded data over the timeframe.

It can be summarised that no causal relationship between each hurricane and Index performance can be established based on these data. Also, as hurricanes occur in seasons, due to their close timely proximity to each other stock price impact might not be completely separable. The sampling of firms revealed that for most companies sufficient data are available to include them within the main model.

5.2.2 ARIMA Model Results – Estimated ARIMA Model Parameters

The parameter definitions of all estimated ARIMA models, defined as $ARIMA(p, d, q)(P, D, Q)[\text{Drift}]$ for companies with an announcement are summarised in Figure 44. There is a considerable number of models needing auto-regressive (p, P) as well as moving average (q, Q) parameters to approximate the observed time series adequately. Furthermore, more than 75% require differencing (d, D) to ensure stationarity in the non-seasonal component. Interestingly, 40% of the time series exhibit drift, which is a marker for trends. Therefore, the stock price time series show seasonality and non-stationary, auto correlated patterns that need to be accounted for during modelling. Seasonality is a chosen cycle. For this thesis the seasonality over the five-day trading week is chosen, therefore the analysed timeframe is sufficient. Nevertheless, there are a number of fits where

the simplest, i.e., simple linear regression model, is a good fit, namely when all the components of the ARIMA are equal to zero.

In summary, the model accounts well for the typical characteristics of stock price time series.

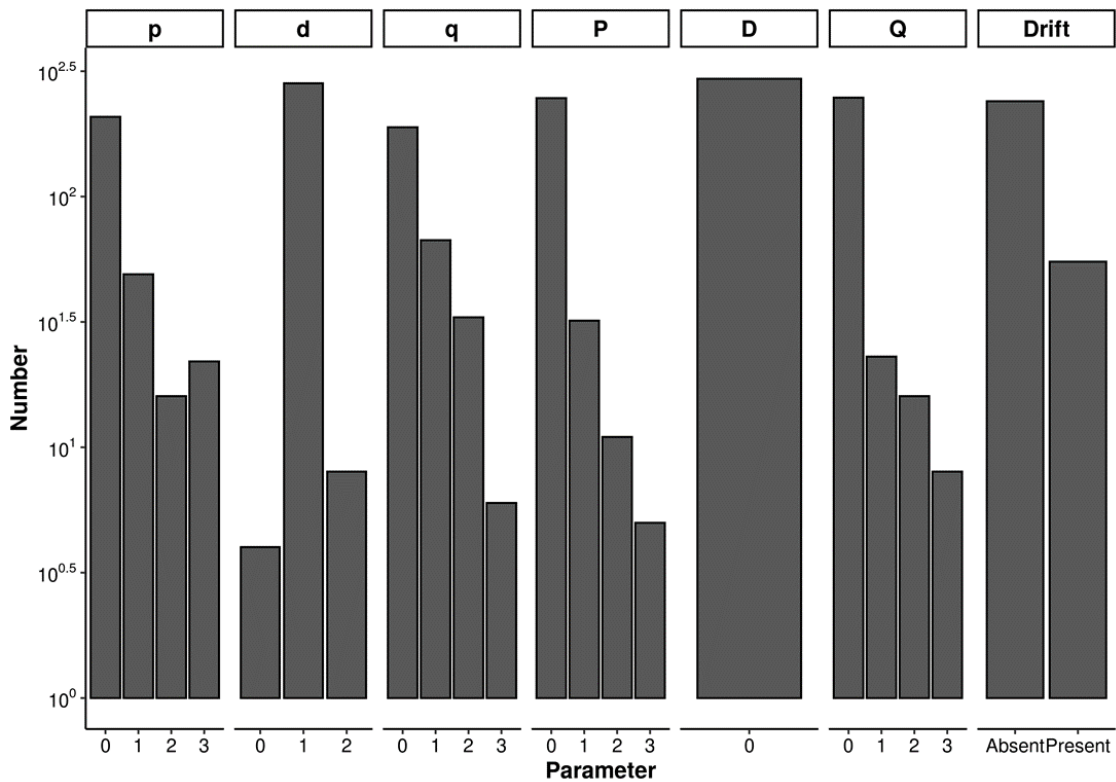


Figure 44. ARIMA specifications (Source: Author). The number of best fitting models per model parameter specification for auto-regressive (p , P), moving-average (q , Q), differencing (d , D) and random drift (Drift)

5.2.3 Time Series Outlier Analysis

Prior to the main analysis, a time series outlier analysis was conducted to confirm hurricane incident announcements as a suitable anchor point in the main model (Figure 45-Figure 48). This analysis was performed for hurricane incident announcements.

In Figure 45 the number of days between the end of the hurricane and the hurricane incident announcements was evaluated. There were not many damage announcements that were made during the hurricane. In Figure 45 the number of days between the end of the hurricane and the hurricane impact announcements

was also evaluated. It shows on the x-axis the days between hurricane incident announcement and end of the hurricane. The bars show the number of hurricane incident counts on the y-axis. Most firms announced hurricane damage of the last day of the hurricane or later (Figure 45).

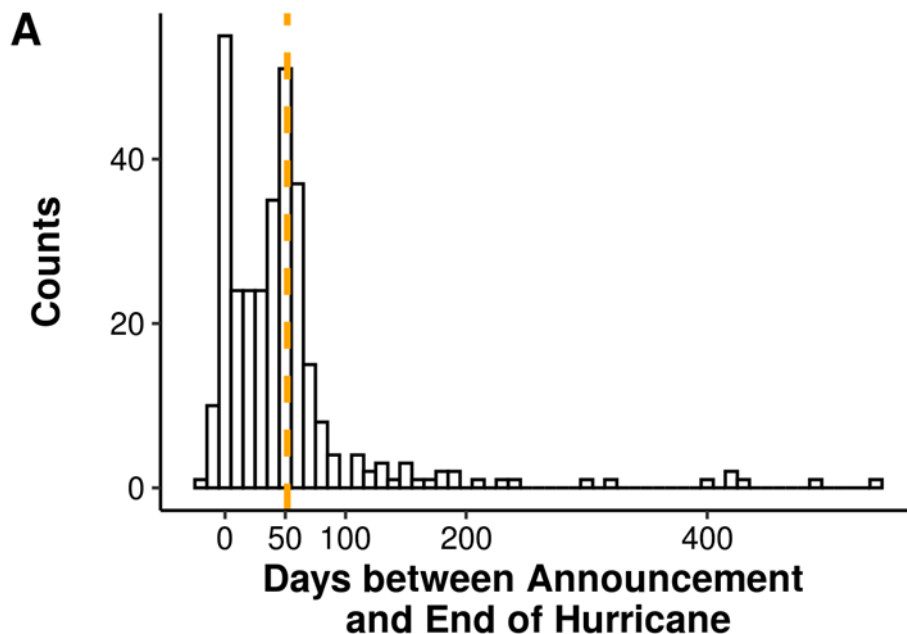


Figure 45. *Time Series Outlier Analysis (Source: Author)*

Figure 46 shows, per company, how many hurricanes share anchor A (a company's hurricane incident announcement date). This means that a company reports the damage of more than one hurricane on the same day. Having the same anchor for more than one hurricane results in higher uncertainty, because differentiating how much of the stock price reaction is due to which hurricane is more difficult. A substantial ratio of 53% of the announcement report damage from two or more hurricanes. This indicates that the damage allocation per hurricane on stock price might be challenging. Figure 46 shows the firms (x-axis) with the number of hurricane incident announcements on the y-axis. Panel C shows outlier from the date of announcement. In conclusion, companies often report joint damage resulting from more than one hurricane.

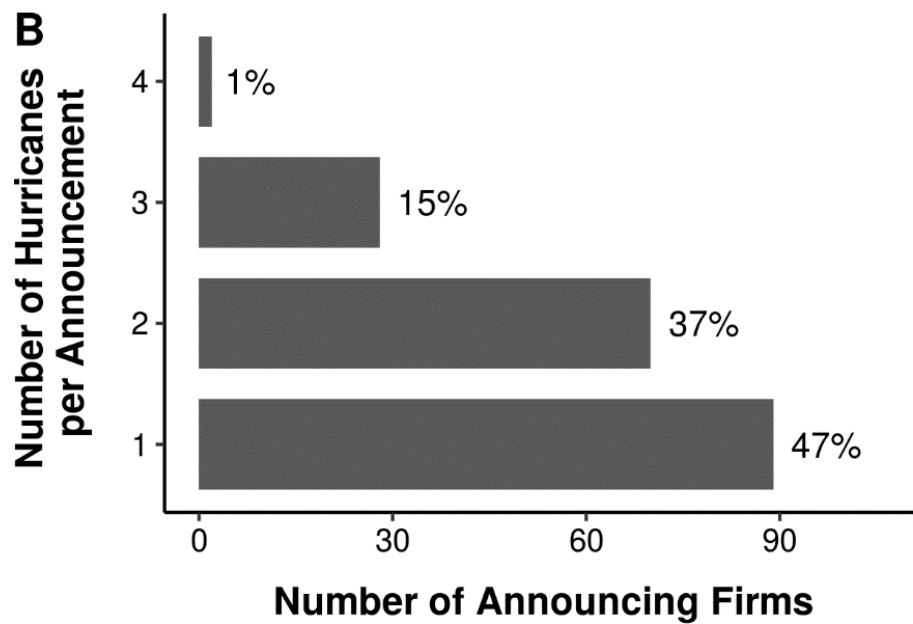


Figure 46. *Time Series Outlier Analysis (Source: Author)*

This analysis was used to detect the outliers within the overall time series and is a preparation for analysis D. Outliers to the time series were detected in 87% of the firms in scope (**Figure 47**). This indicates that the announcements are suitable anchors.

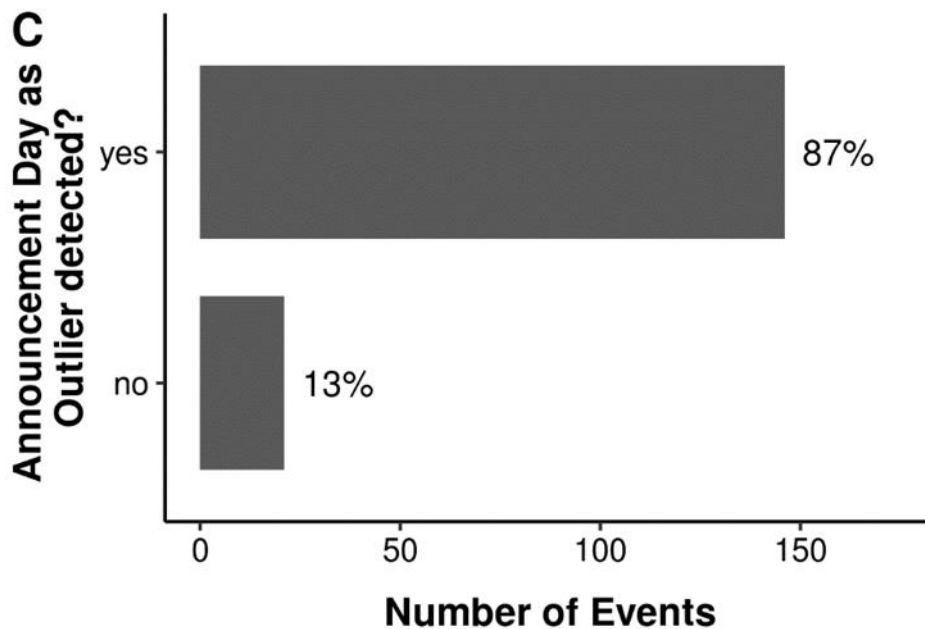


Figure 47. *Time Series Outlier Analysis (Source: Author). The diagram shows outlier from the date of announcement*

Figure 48 evaluates the interval between anchor and outlier. For most firms, the hurricane incident announcement and the outlier were on the same day or around the same time. This confirms that firms' announcements on hurricane incidents are suitable anchors.

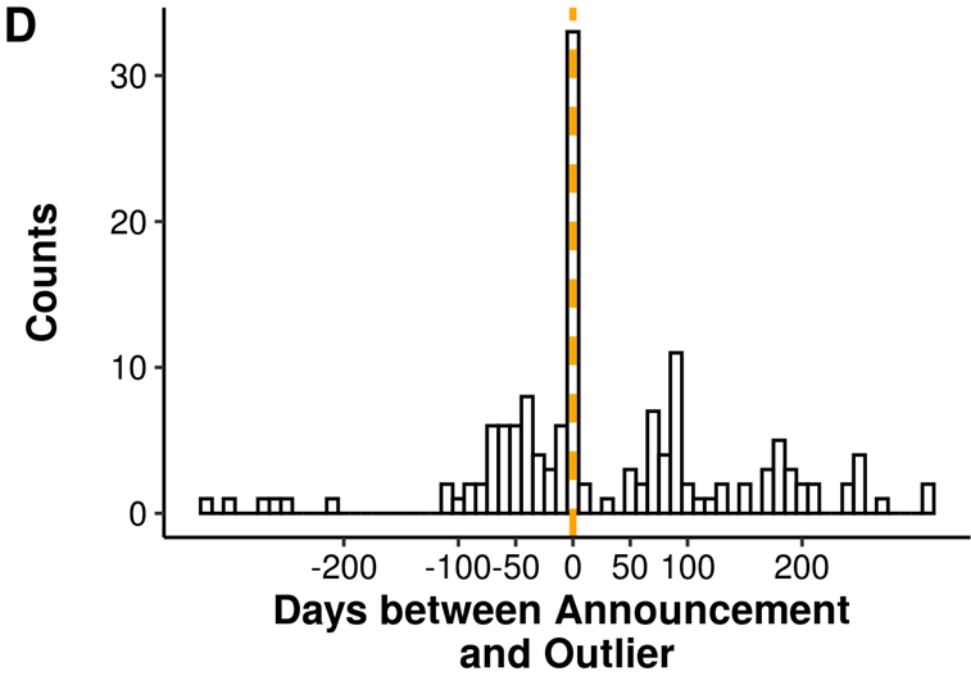


Figure 48. Time Series Outlier Analysis (Source: Author). The diagram shows the interval between anchor and outlier.

5.2.3.1 Hypothesis 1 and Sub-Hypotheses to H1

H1: A hurricane incident announcement/hurricane announcement has an effect on stock price.

H1a: A hurricane incident announcement/hurricane announcement has a short-term effect on stock price defined as a pulse function.

H1b: A hurricane incident announcement/hurricane announcement has a persisting effect on stock price defined as a step function.

H1c: A hurricane incident announcement/hurricane announcement has a transient effect on stock price defined as a transitory change function.

Hurricane incident announcements

Figure 49-Figure 53 provide an overview of the intervention analysis for the announcement date. Figure 49 shows the results of the number of likelihood ratio tests for three, six and nine months. The results indicate that for 25-31% of the announcing firms, hypothesis H1 is true as there is a statistically significant change in the time series due to the interruption by hurricane-related disruptions. This means for one third to one quarter of firms the hurricane was significant. On the other hand, between 69 and 75% of the announcement dates do not show a statistically significant reaction. The number of statistically significant likelihood ratio tests does not depend on the time horizon (3, 6 and 12 months) which indicates persistent interruptions. Figure 49 shows the number of Likelihood-Ratio-Tests (LRTs) per Firm. For each combination of firm and hurricane incident announcement, the ARIMA-intervention model with the lowest AIC is considered. If the p-value of the LRT comparing a null model with no intervention with the intervention is below the significance level of 0.05, then the modelled interruption is considered statistically significant (orange colour). The percentage number is the proportion of statistically significant LRTs per bar.

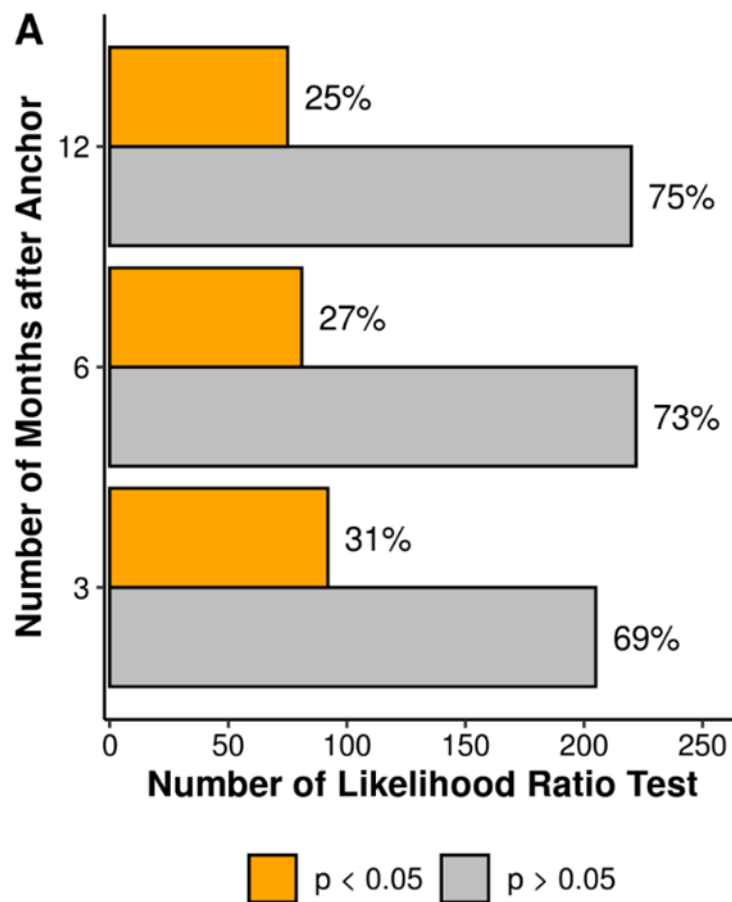


Figure 49. Results of the ARIMA-Intervention Model for hurricane incident announcements – anchor A (Source: Author)

Figure 50 provides further details on the announcement dates that show a statistically significant reaction. For each time horizon, the intervention is defined as a pulse, step or transitory change transfer function. The results show that independently of the time horizon, most interrupted time series are best described by a transitory change function (around 70%). Overall, of the firms that have a statistically significant reaction, most reactions fade over time. Step and pulse function cover each at around 15%. Therefore, changes as given by a step function are persistent. For short-term changes, as given by the pulse function, the results indicate that the chosen analysis framework is robust to choices regarding post-anchor time horizons. Figure 50 shows the transfer function and directionality of interruptions per firm type and hurricane incident announcement. Each time horizon adds up to 100%. For each time horizon the proportion of statistically significant LRTs that fit best are illustrated as the total bar for each of

the three transfer functions: step, transitory change and pulse. The proportion is also written as a percentage next to the bar. The bars indicate the best fitting transfer function of the model with a statistically significant LRT and lowest AIC for the particular firm and hurricane-related incidents. The proportions of negative reactions are illustrated by red bars, positive reactions are shown as green bars.

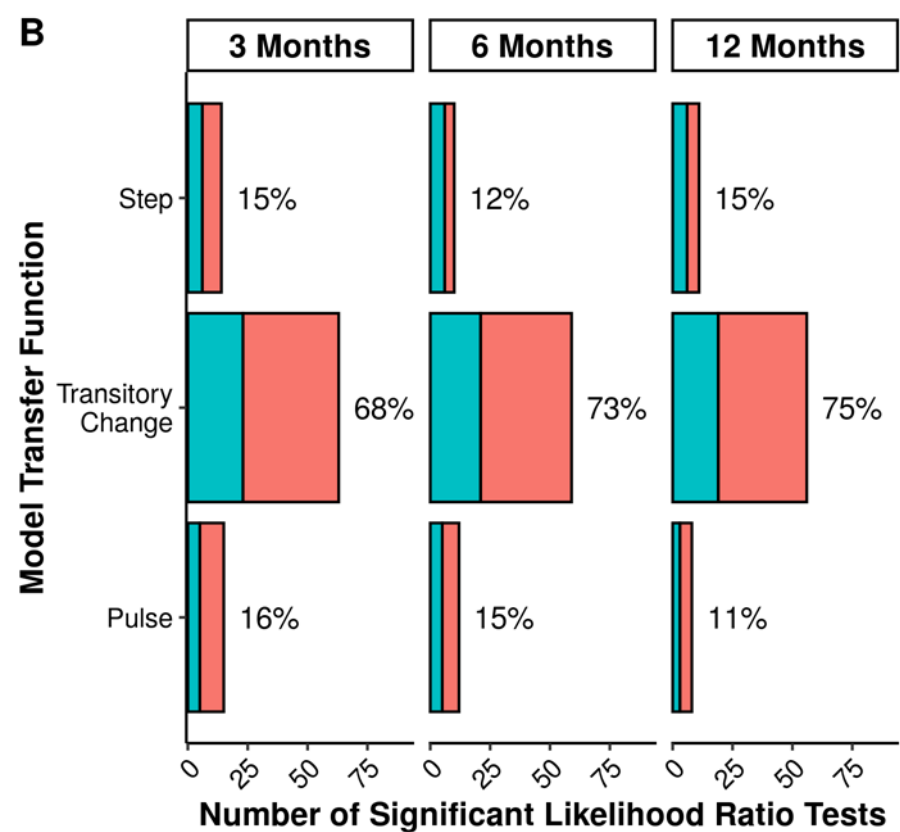


Figure 50. Results of the ARIMA-Intervention Model for hurricane incident announcements – anchor A (Source: Author)

Figure 51 summarises the relative effect changes observed due to the interruption. Positive as well as negative changes in the stock price time series after the anchor are detected. Persistent changes as given by the step function show the largest change, irrespective of time horizons. Concerning the transitory change, it appears that the effect changes decrease with an increasing post-anchor time period. However, this is not really the case because here the median change for the whole time series after the anchors is summarised. It can be noted that the positive stock price reactions due to disasters are similar in strength to the negative reactions and are stable over the time horizons. What might be noted

as well is that the reactions in the form of a transitory change function show the strongest positive as well as negative reactions across all time horizons. Figure 51 shows the strength of directionality of Interruptions per firm and hurricane incident announcement. The middle line is the 0 line. The further away the effect change, the stronger it is. The negative effect changes are on the left side and coloured in red. The positive effect changes are on the right side coloured in green.

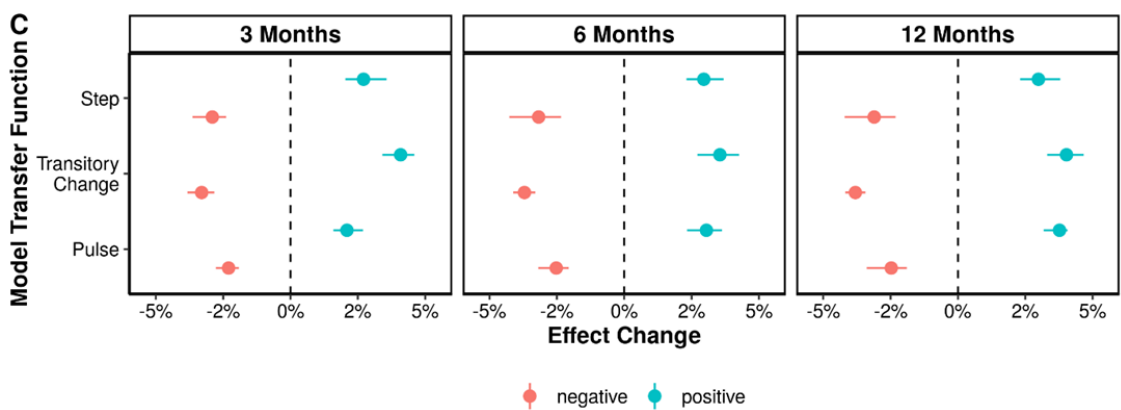


Figure 51. Results of the ARIMA-Intervention Model for hurricane incident announcements – anchor A (Source: Author)

In Figure 52 the effect changes of the transitory functions for the three time horizons are presented, visually presenting the curves. This clearly shows that positive as well as negative effect changes in stock prices decay over time – most decay even rather quickly. For the time period of three months, this process is not yet completed.

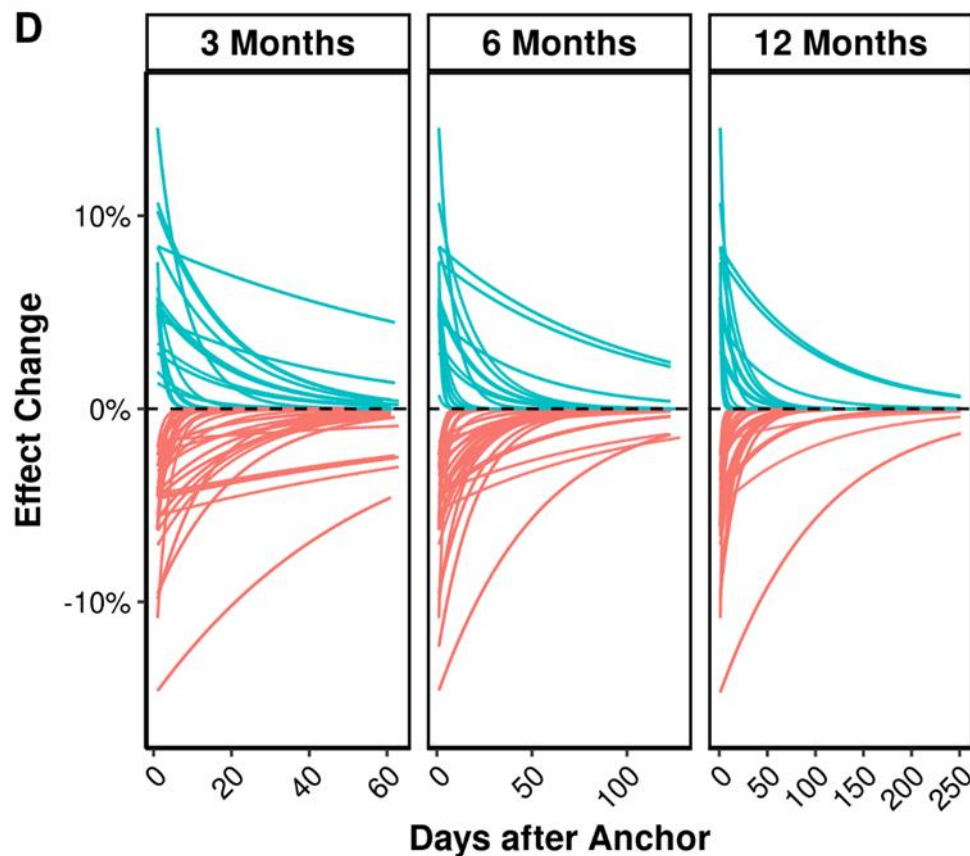


Figure 52. Results of the ARIMA-Intervention Model for hurricane incident announcements – anchor A (Source: Author)

In Figure 53 the omega coefficient of the transitory change transfer functions for the three time horizons is shown. The closer the omega coefficient comes to 1.0 the faster the effect fades (i.e. gets closer to the pulse function). The closer the omega coefficient is to 0.5 the closer it gets to a step function. The results show, for positive as well as negative reactions, a high omega co-efficient of around 0.8/0.9. This means that positive as well as negative stock price reactions due to hurricanes decay rather fast.

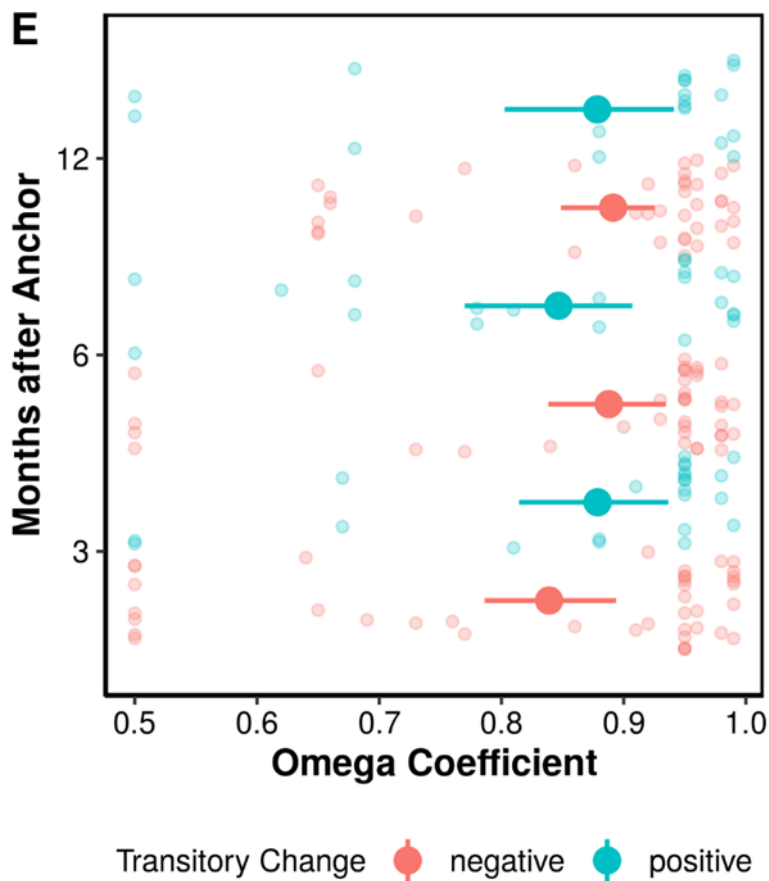


Figure 53. Results of the ARIMA-Intervention Model for hurricane incident announcements – anchor A (Source: Author)

General hurricane-related information

For all in-scope companies, all eight hurricanes are considered with their anchor B defined. Figure 54-Figure 56 present an overview of the intervention analysis for the reaction of announcing and non-announcing firms after anchor B. Figure 54 shows the reaction of announcing and non-announcing Firms after Anchor B. If the p-value of the LRT comparing a null model with no intervention with the intervention is below the nominal level of 0.05, then the modelled interruption is considered statistically significant (orange colour). The percentage number is the proportion of statistically significant LRTs per bar. The results indicate that around 21% of the reactions of announcing firms are statistically significant. For the non-announcing firms it is slightly less at around 18%. This means for non-announcing firms as well as announcing firms, for every group around 20% has a statistically significant stock price reaction due to released hurricane information.

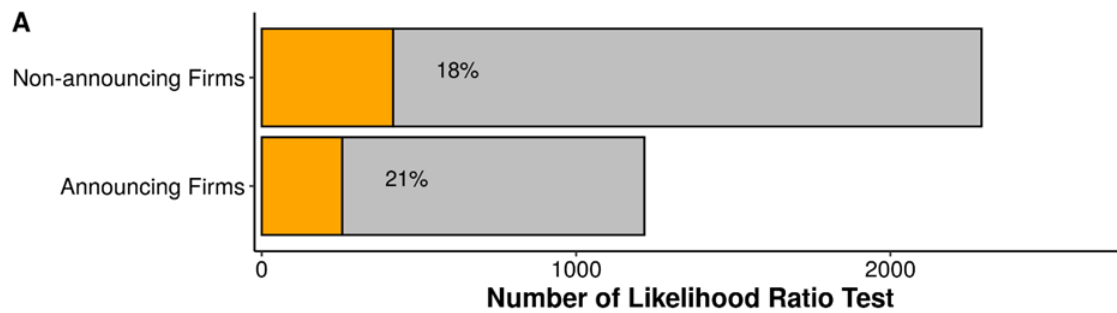


Figure 54. *Reaction of Announcing and Non-announcing Firms after Anchor B*
(Source: Author)

Figure 55 shows the more granular results of the LRT by breaking down the likelihood ratio for each of the six anchor B types for the reactions of the announcing and non-announcing firms. For the **announcing firms** the anchors with the highest number of statistically significant reactions are begin of hurricane and hurricane warning (23% each), followed by hurricane hitting land (21%), end of hurricane and after the hurricane (20%). With a big difference from the other anchors, the hurricane duration just shows significance in 10% of the cases. For the **non-announcing firms**, the results of the LRT per anchor are closer together. The highest LRT is found for the hurricane warning (22%), closely followed by the hurricane hitting land (20%), hurricane duration (18%), end of hurricane and after hurricane (17% each) and the begin of hurricane with 16%. It can be noted that all tested anchors led to a proportion of statistically significant reactions. Figure 55 shows the results of the ARIMA-Intervention Model for Hurricane Weather Forecasting (Part I). Number of Likelihood-Ratio-Test (LRT) per Firm Type and Weather Forecast Anchor. For each combination of firm and hurricane, the ARIMA-intervention model with the lowest AIC is considered. If the p-value of the LRT comparing a null model with no intervention with the intervention is below the nominal level of 0.05 then the modelled interruption is considered statistically significant (orange colour). The percentage number is the proportion of statistically significant LRTs per bar. Note: For every hurricane just one end, but for some hurricanes several beginnings and several warnings (Source: Author).

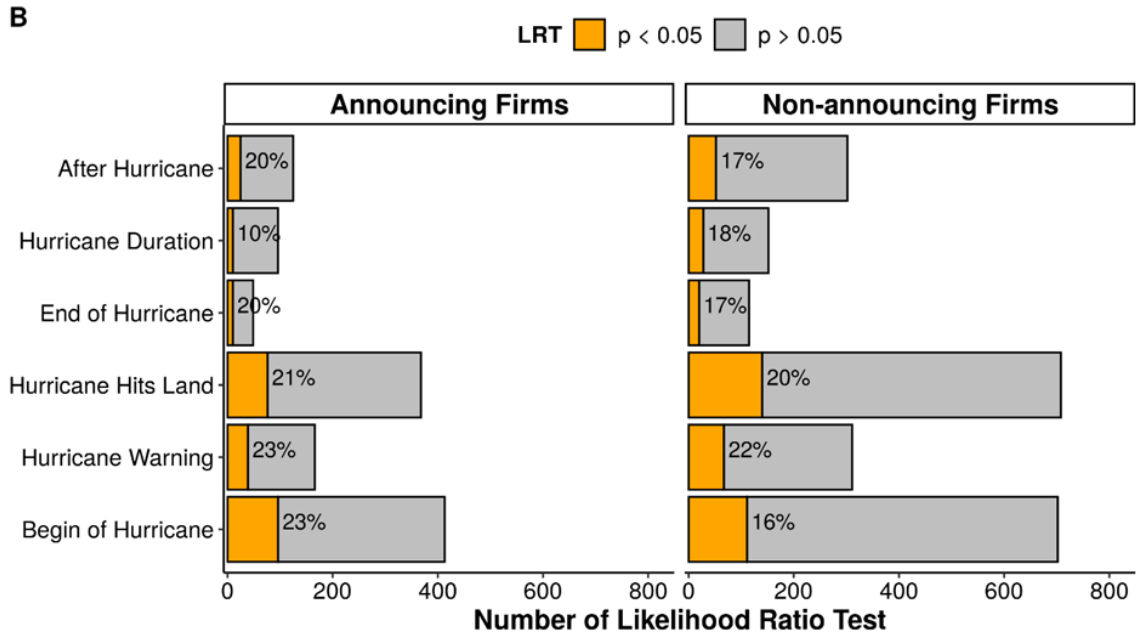


Figure 55. Reaction of Announcing and Non-announcing Firms after Anchor B

Figure 56 summarises the relative proportions of transfer functions per anchor. For each anchor per announcing and non-announcing firms, the interruption is defined as a function. For anchors B 1-4, being points in time, pulse and transitory function are applied; for anchors B 5-6, being intervals, the step function is applied. Overall, the reactions of announcing and non-announcing firms for all anchors tend to be more negative. The reactions for announcing firms are more negative than for the non-announcing firms across all anchor Bs. For most of the first four B anchors, namely begin of hurricane, hurricane warning, hurricane hits land and end of hurricane, the transitory change function provides more negative than positive significance compared to the pulse function. The highest proportion of negative reactions can be found when a hurricane hits land (for all firms and functions). A similar proportion of negative reaction is otherwise just found for the hurricane duration of announcing firms. Figure 56 shows the results of the ARIMA-Intervention Model for Hurricane Weather Forecasting (Part I). Directionality of Interruptions per Firm Type and Weather Forecast Anchor. Each bar adds up to 100%. A negative percentage means here that the proportion of the bar has a statistically significant LRT where the estimated effect has a negative coefficient. The colour indicates the best fitting transfer function of the

model with a statistically significant LRT and lowest AIC for the particular firm, hurricane and weather forecast anchor. Note: For every hurricane just one end, but for some hurricanes several beginnings and several warnings (Source: Author).

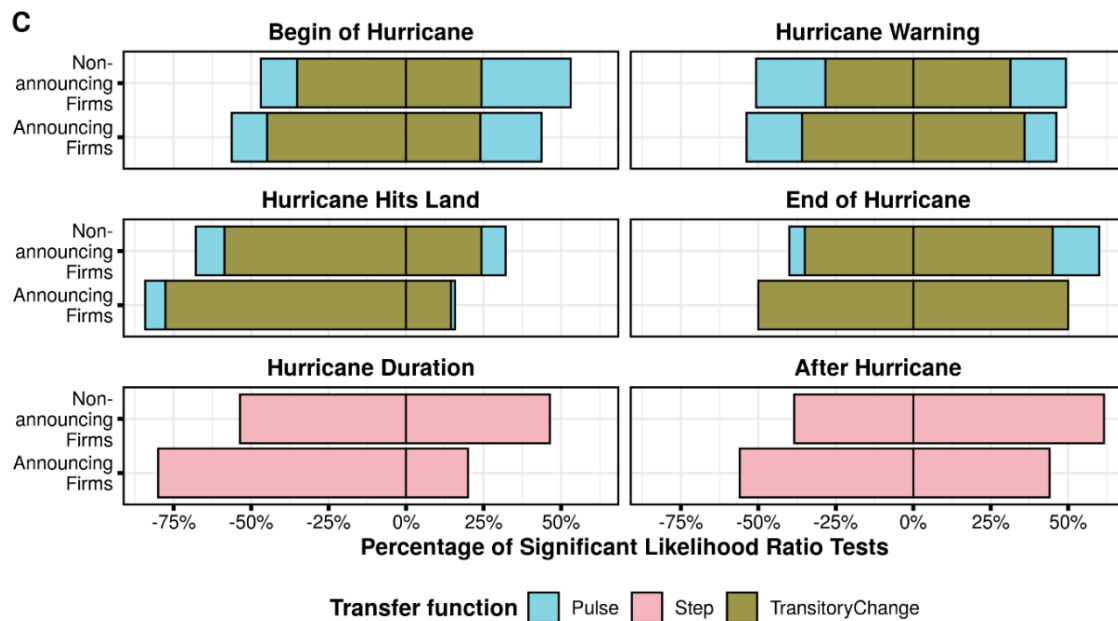


Figure 56. Reaction of Announcing and Non-announcing Firms after Anchor B (Source: Author)

More negative reactions though less frequent occurred for the begin of hurricane with the transitory function for all firms. A higher proportion of positive than negative reactions occurred for non-announcing firms at the end of the hurricane and after the hurricane. For the first four anchors the transitory function is the best fit for the majority of cases. For the begin of hurricane and hurricane warning there is also a 15-20% proportion where the pulse function fits best. The magnitude of effect changes and omega coefficient for the transitory change function in percentage is shown in Figure 57. When changes occur, the magnitude tends to be quite similar for negative and positive effect changes; there are some negative and one positive exception. Begin of hurricane for non-announcing firms with the pulse function has a strong negative reaction, the same applies for end of hurricane announcing firms and non-announcing firms (slightly less strong) for transitory change function. For after hurricane there is a strong negative as well as positive reaction for non-announcing firms. Figure 57 shows

the results of the ARIMA-Intervention Model for Hurricane Weather Forecasting (Part II). Effect Change per Firm Type and Weather Forecast Anchor. For each combination of firm and hurricane, the ARIMA-intervention model with the lowest AIC and statistically significant LRT, comparing the null model with no intervention to intervention defined by the anchor, is selected. The coefficient of the transfer function is then converted to an estimated percentage difference in stock price at the anchor point. For the transitory change function, the median of the first four days after the anchor is calculated.

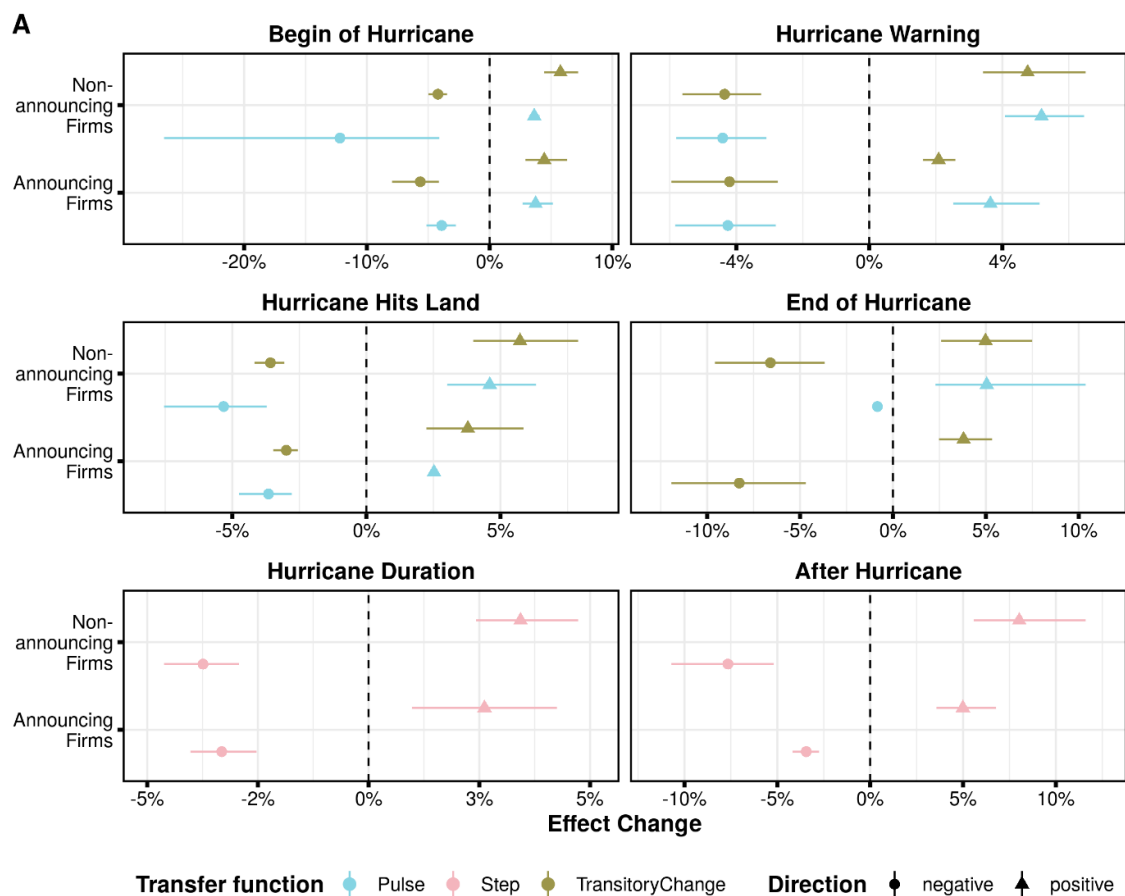


Figure 57. Reaction of Announcing and Non-announcing Firms after Anchor B - Effect change and omega coefficient (Source: Author)

Figure 58 describes the omega coefficient for the transitory change function. It needs to be noted that for nearly all cases, the omega coefficient is quite close to 1.0. This implies that positive as well as negative effects decay quite quickly. The fastest decay can be observed for the end of hurricane function, the only exception (one of the slowest decays) is the positive reaction of non-announcing

firms. Figure 58 shows the results of the ARIMA-Intervention Model for Hurricane Weather Forecasting (Part II). Omega Coefficient per Firm Type and Weather Forecast Anchor. For each combination of firm and hurricane, the ARIMA-intervention model with the lowest AIC and statistically significant LRT, comparing the null model with no intervention to intervention defined by the anchor, is selected. If the identified model uses a transitory change as the transfer function, then the identified omega coefficient determining the gradual increase (positive direction in green) or decrease (negative direction in red) is shown, and the mean estimated omega coefficient (+/- std. error) per firm type and weather forecast anchor is calculated and plotted in matching thick colours.

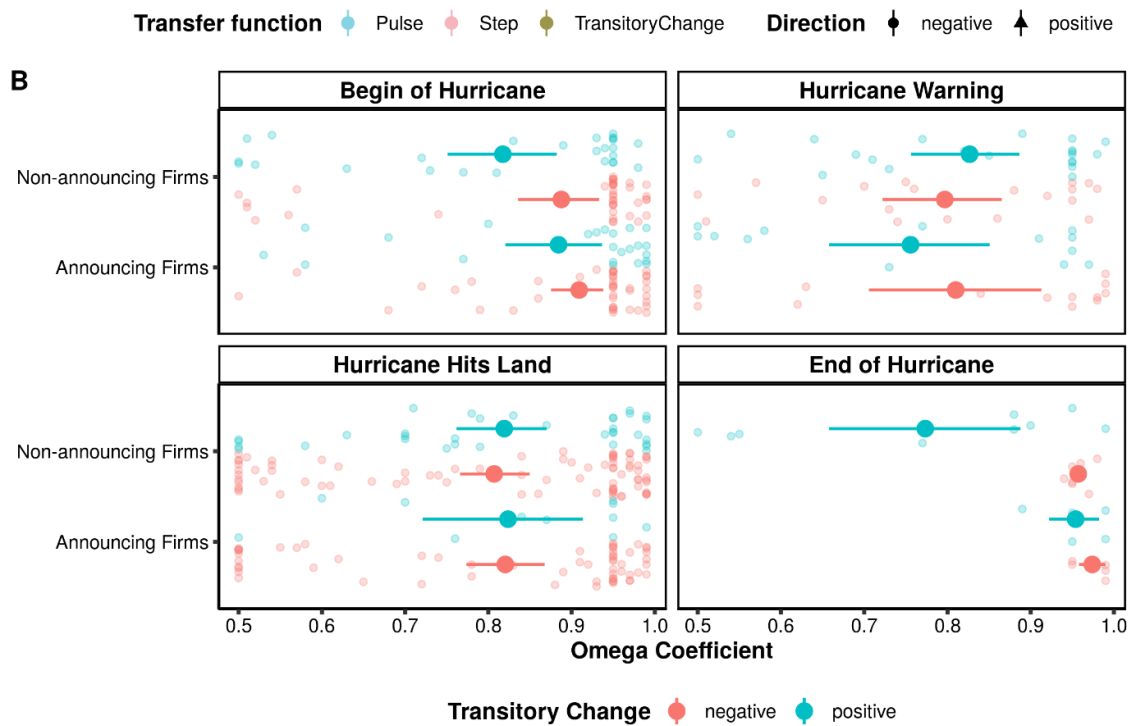


Figure 58. Reaction of Announcing and Non-announcing Firms after Anchor B - Effect change and omega coefficient (Source: Author)

To summarise the results regarding the first hypothesis: Hurricane incident announcements lead to significant reactions in around one third of cases. The reactions are mostly negative in the form of a transitory change function. Hurricane announcements lead to a significant reaction in around 20% of cases. It must be noted that there are slightly more significant reactions for announcing firms than for non-announcing firms. All tested anchors led to a proportion of

statistically significant reactions; however, dependent on the hurricane information anchor, the ratio of significant reactions ranges between 10 – 23% and also the patterns and direction vary. There are also more positive reactions than negative reactions for hurricane announcements and for the points in time, the transitory change function applies best.

5.2.3.2 Hypothesis 2

This hypothesis is just tested for hurricane incident announcements Anchor A.

The results of the intervention analysis are categorised by industry. It summarises the number of statistically significant Likelihood Ratio Tests (LRTs) per sector for each time horizon. Firstly, interruptions of the time series are persistent. Secondly, firms of all in-scope industrial sectors had statistically significant interruptions. After three months the ratio of firms with a statistically significant time series interruption ranges from 20% to 57%. According to this ratio, the technology sector suffers the most with more than 50%; however, the sector comprises less than 10 firms, therefore the reliability of this result is limited. 50% of consumer service, 36% of basic industries, 30% of consumer durables and 29% of capital goods firms show interruptions. Even the remaining sectors, i.e. consumer durables (23%) and health care (19%) have many firms affected. The industries according to the listing at the NYSE were applied (NYSE). When extending the time period to 6 or 12 months all industrial sectors still show interruptions; for some sectors the longer time horizon reduces the statistically significant reaction of firms by 10-20%. Basic industries and consumer durables show just a minimal change in proportions depending on the time horizon applied, which indicates a persistent effect (step change). Figure 59 shows the number of LRTs per industrial sector. For each combination of firm and hurricane incident announcement, the ARIMA-intervention model with the lowest AIC is considered. If the p-value of the LRT comparing a null model with no intervention with the intervention is below the nominal level of 0.05, then the modelled interruption is considered statistically significant (orange colour). The percentage number is the proportion of statistically significant LRTs per bar. The statistically significant and insignificant LRTs were plotted per industrial sector.

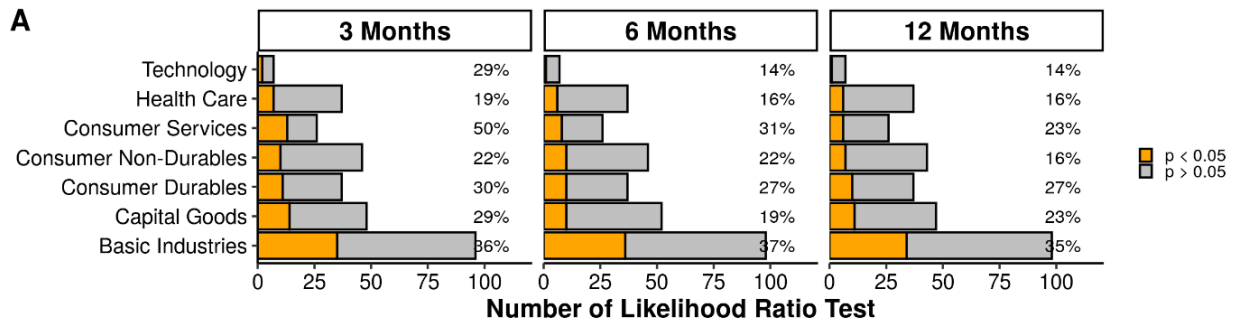


Figure 59. Intervention analysis: Insights regarding industries (Source: Author)

Figure 60 summarises the number of the best fitting transfer functions considering statistically significant interruptions across the time horizons per industrial sector. Negative LRT implies the direction of change. Negative as well as positive changes in stock prices are observed. Not only the number but also the directionality of change is independent of the post-anchor time period. Of note is the prevalence of transitory changes in basic industries, both negative and positive. Consumer services and capital goods (mostly transitory change) show more negative changes in stock price. Figure 60 shows the transfer function and directionality of interruptions per firm type and hurricane incident announcement. Each time horizon bar per sector adds up to 100%. For each time horizon the proportion of statistically significant LRTs that fit best are illustrated as the total bar per industry, consisting of the proportions of best-fitting three transfer functions: step (rose), transitory change (olive) and pulse (light blue). The proportions of negative reactions are illustrated by the bars left of the 0 line and the positive reactions to the right of the 0 line.

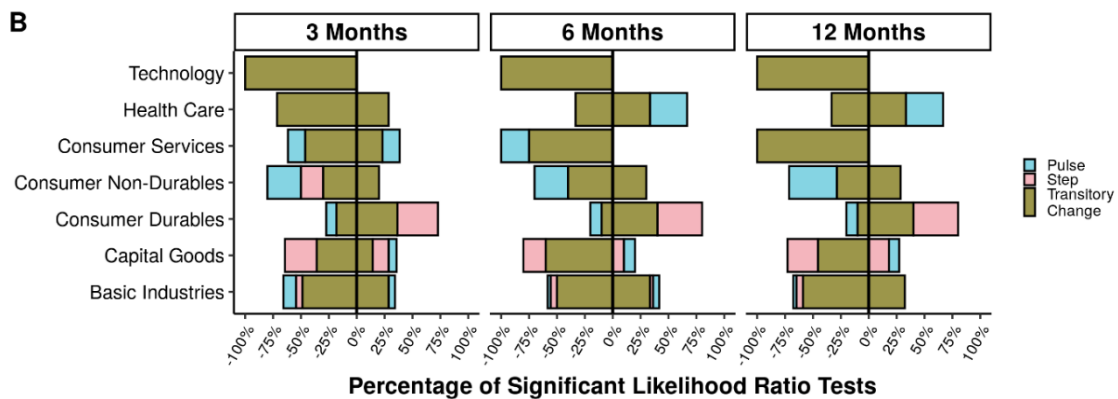


Figure 60. Intervention analysis: Insights regarding industries (Source: Author)

The magnitude of effect change, as a percentage, is shown in Figure 61. Please note that there are often only a small number of coefficient estimates per transfer function available (see small number of statistically significant LRTs per sector in Figure 59), resulting in large or even not estimable standard errors. Nevertheless, it is visible that when changes occur the magnitude is similar across positive and negative effect changes. Figure 61 shows the effect change of step, pulse and transitory function for the three time horizons per industrial sector. The effect changes left of the zero line have negative transfer function coefficients (circle shape) and right of the zero line have positive (triangle shape).

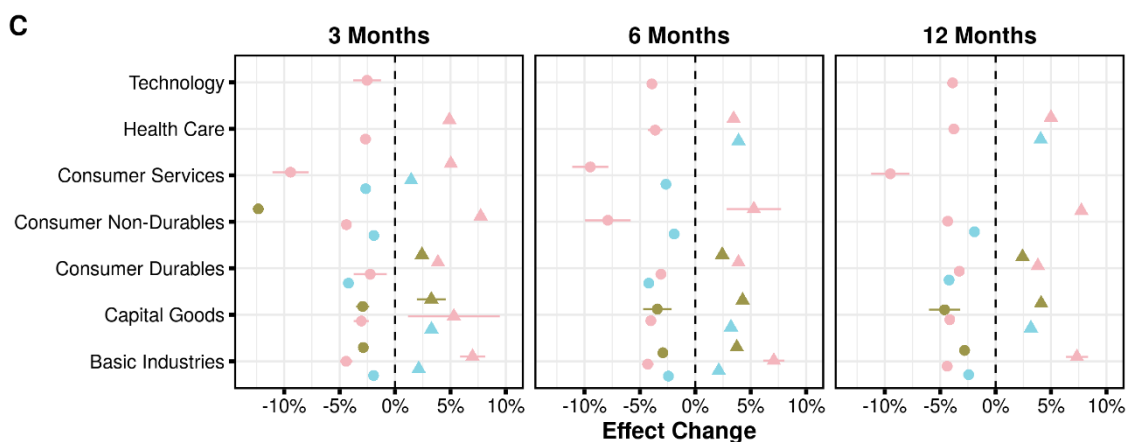


Figure 61. *Intervention analysis: Insights regarding industries (Source: Author)*

Figure 62 shows the omega coefficient of the transitory change transfer functions for the three time horizons per industry. The closer the omega coefficient comes to 1.0 the faster the effect fades (gets close to pulse function). The closer the omega coefficient is to 0,5, the nearer it gets to a step function.

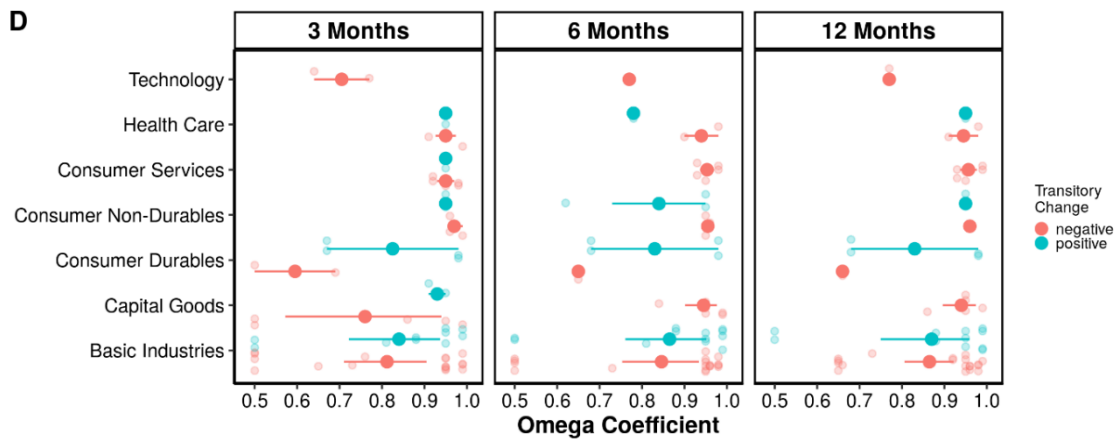


Figure 62. *Intervention analysis: Insights regarding industries (Source: Author)*

Overall, it can be noted that firms in all industrial sectors were affected; however, the impact in terms of extent, directionality and pattern mix differs between sectors.

5.2.3.3 Hypotheses 3 and 4

These hypotheses were just tested for hurricane incident announcements Anchor A. Figure 63 provides the results of the intervention analysis for the announcement as anchor per impact type (major SCD, major other damage, minor SCD and minor other damage). The results illustrate that all impact types show interruptions for all time horizons (between 16% and 38%). Major other damage and major SCDs show for all time horizons with around 30% being the highest ratio of interruption for all time horizons. It is notable that minor other damage had 34% interruptions of time series for the three months' time horizon, while for six and twelve months' time horizons it falls to around 20%. Minor SCDs and positive effect on demand show 20% interruptions for all time horizons. Figure 63 shows the number of LRTs for these groups: major other damage, major SCD; minor other damage, minor SCD and positive effect on demand. For each combination of firm and hurricane incident announcement, the ARIMA-intervention model with the lowest AIC is considered. If the p-value of the LRT comparing a null model with no intervention with the intervention is below the nominal level of 0.05 then the modelled interruption is considered to be

statistically significant (orange colour). The percentage is the proportion of statistically significant LRTs per bar.

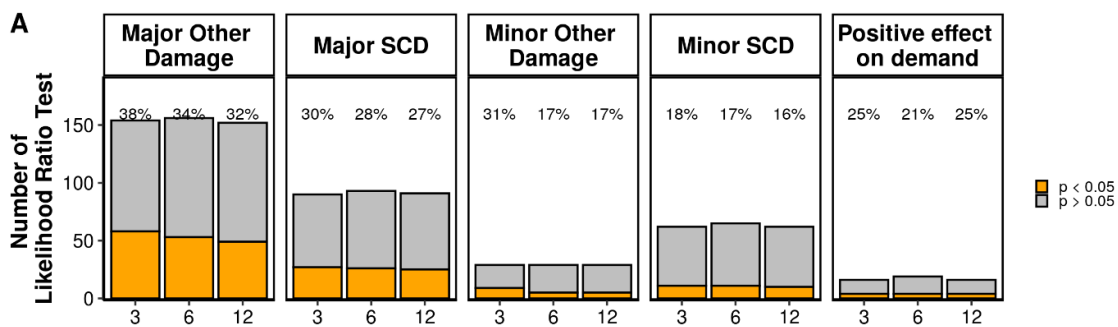


Figure 63. *Insights on impact (Source: Author)*

Figure 64 illustrates the best fitting transfer function for the statistically significant likelihood ratio tests. Figure 64 shows the transfer function and directionality of interruptions per firm type and hurricane incident announcement. Each time horizon adds up to 100%. For each time horizon the proportion of statistically significant LRTs that fit best are illustrated as the total bar per group consisting of the proportions of best fitting three transfer functions: step (rose), transitory change (olive) and pulse (light blue). The bars indicate the best fitting transfer function of the model with a statistically significant LRT and lowest AIC for the particular firm and hurricane-related incidents. The proportions of negative reactions are illustrated by the bars below the 0 line and the positive reactions above the 0 line.

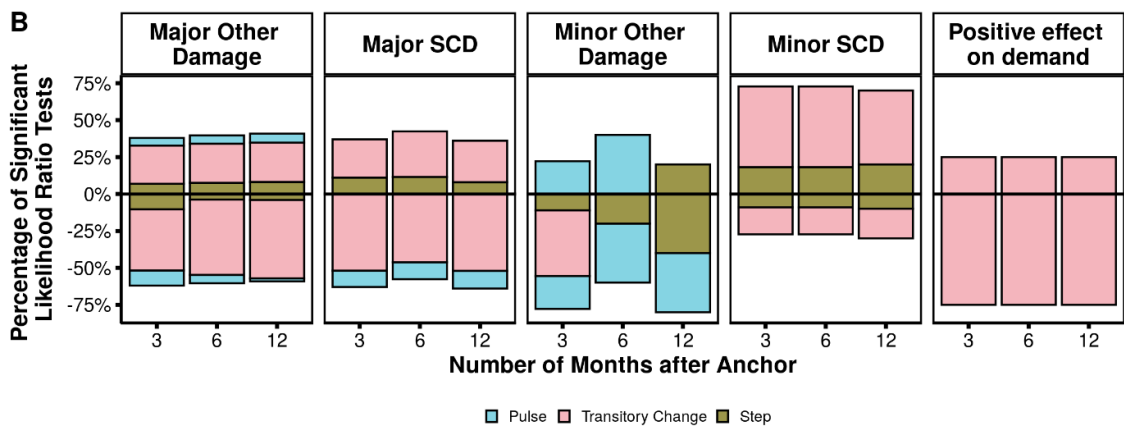


Figure 64. *Insights on impact (Source: Author)*

Here major damages show more negative effects of a transient nature on the stock price. Interestingly, minor other damages have the largest proportion of persistent large negative effects for the 12-month time horizon (negative step function) (Figure 65). Furthermore, minor SCD leads to a higher proportion of positive effects on stock prices with the second largest percentage change (Figure 65), while all positive effects on demand are short-lived. Figure 65 shows the effect change of step, pulse and transitory function for the three time horizons per group. The effect changes left of the zero line have negative transfer function coefficients (circle shape) and right of the zero line have positive (triangle shape) ones.

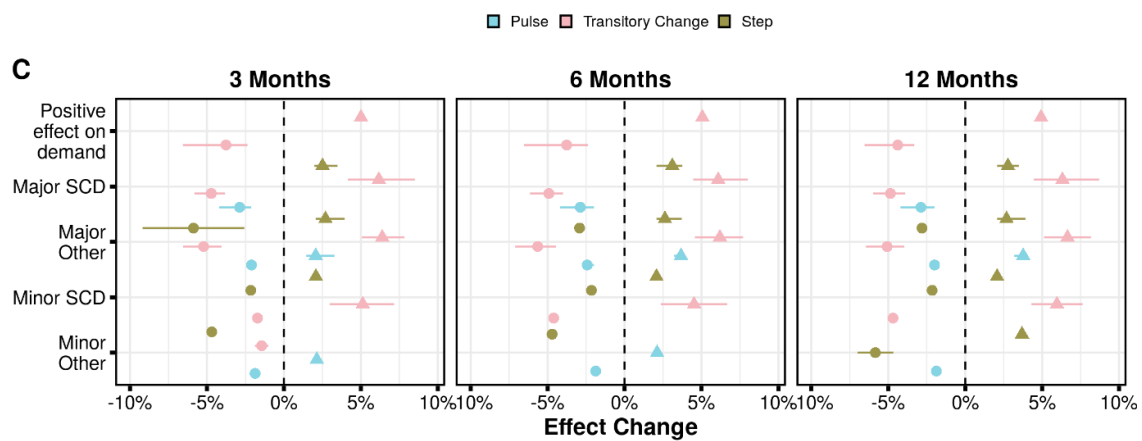


Figure 65. *Insights on impact (Source: Author)*

In conclusion, even though negative effects are more prevalent for major and minor other damages and major SCDs, these decay slightly faster than the positive effects (Figure 66). Figure 66 shows the omega coefficient of the transitory change transfer functions for the three time horizons per group. The closer the omega coefficient comes to 1.0 the faster the effect fades (gets close to pulse function). The closer the omega coefficient is to 0.5 the closer it gets to a step function.

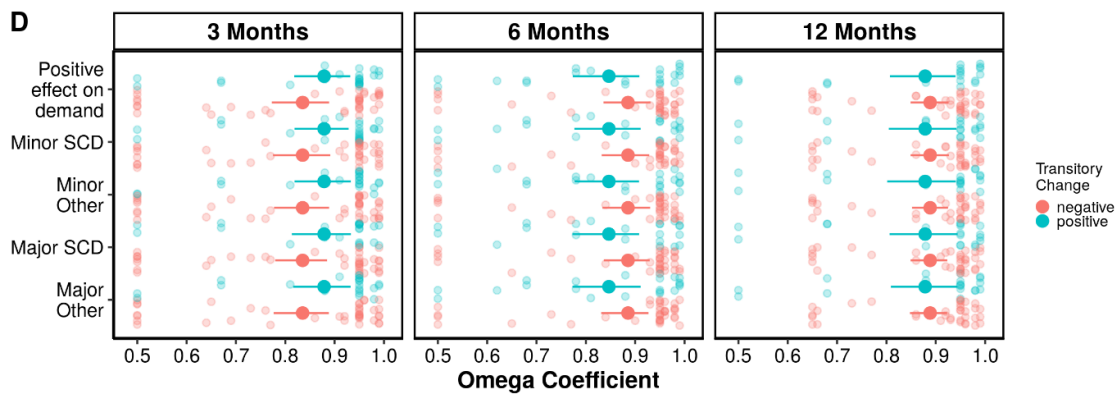


Figure 66. *Insights on impact (Source: Author)*

All impact type and extent mixes lead to a significant negative stock price effect, just minor supply chain disruptions cause a positive effect.

5.2.3.4 Hypotheses 5 and 6

These hypotheses were just tested for hurricane incident announcements Anchor A. The influencing factor categories overlap. The different factors, i.e. impact and impact + actual damage, show statistically significant interruptions of time series (Figure 67). Figure 67 shows the number of LRTs for impact, actual damage and preventive closure. For each combination of firm and hurricane incident announcement, the ARIMA-intervention model with the lowest AIC is considered. If the p-value of the LRT comparing a null model with no intervention with the intervention is below the nominal level of 0.05, then the modelled interruption is considered statistically significant (orange colour). The percentage is the proportion of significant LRTs per bar. The number of LRTs were plotted for impact, preventive closure + impact, actual damage + impact and actual damage + preventive closure + impact (further called groups). The descriptive analysis indicated that these were the combinations that occurred most and thereby provide sufficient data to test.

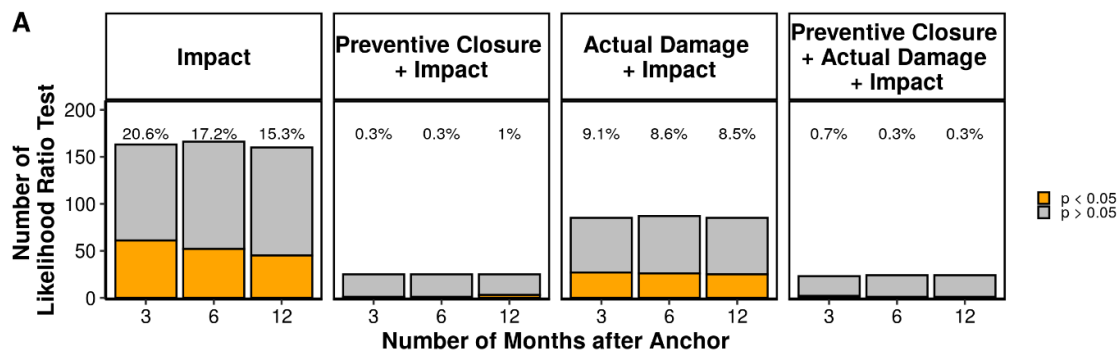


Figure 67. *Intervention analysis: Insights on the Intervention Analysis Preventive, Actual and Image (Source: Author)*

The best-fitting transfer function is the transitory change function for most cases (Figure 68). Figure 68 shows the transfer function and directionality of Interruptions per Firm Type and hurricane incident announcement. As seen in panel A, there are insufficient significant LRTs for the group's preventive closure + impact and preventive closure + actual damage + impact to do a further breakdown into positive and negative. Therefore, here just impact and actual damage + impact are shown in the further panels. Each time horizon adds up to 100%. For each time horizon the proportion of significant LRTs that fit best are illustrated as the total bar per group consisting of the proportions of best fitting three transfer functions: step (rose), transitory change (olive) and pulse (light blue). The bars indicate the best fitting transfer function of the model with a significant LRT and lowest AIC for the particular firm and hurricane-related incidents. The proportions of negative reactions are illustrated by the bars below the 0 line and the positive reactions above the 0 line.

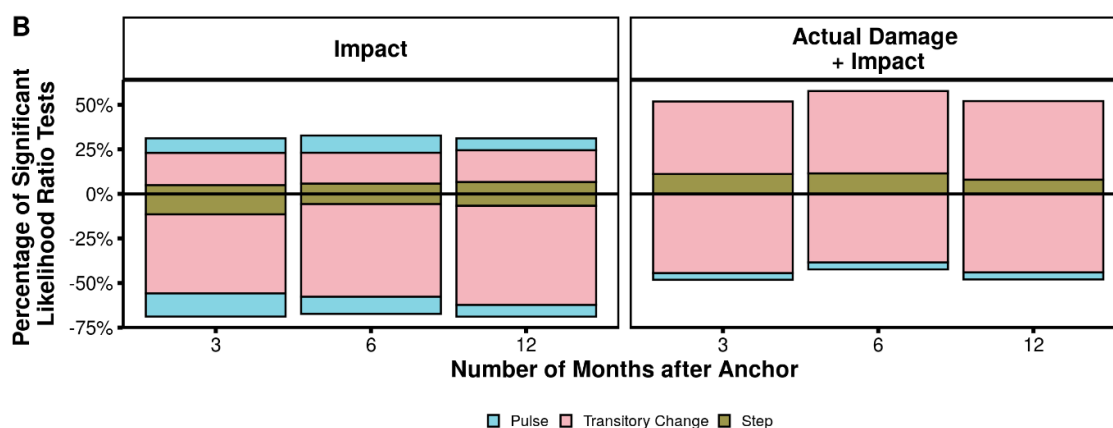


Figure 68. *Intervention analysis: Insights on the Intervention Analysis Preventive, Actual and Image (Source: Author)*

Impact on its own showed a higher rate of negative effects than in combination with actual damage. However, the relative change in stock price shows the same magnitude, irrespective of transfer function, when considering the 12-month period after the anchor. Even though impact alone had a higher rate of negative effects following a transitory transfer function (Figure 68), the decay of these effects is faster than for the positive ones after 6 or 12 months (Figure 70). Figure 69 shows the effect change of step, pulse and transitory function for the three time horizons per group. The effect change left of the zero line have negative transfer function coefficients (circle shape) and right of the zero line have positive (triangle shape).

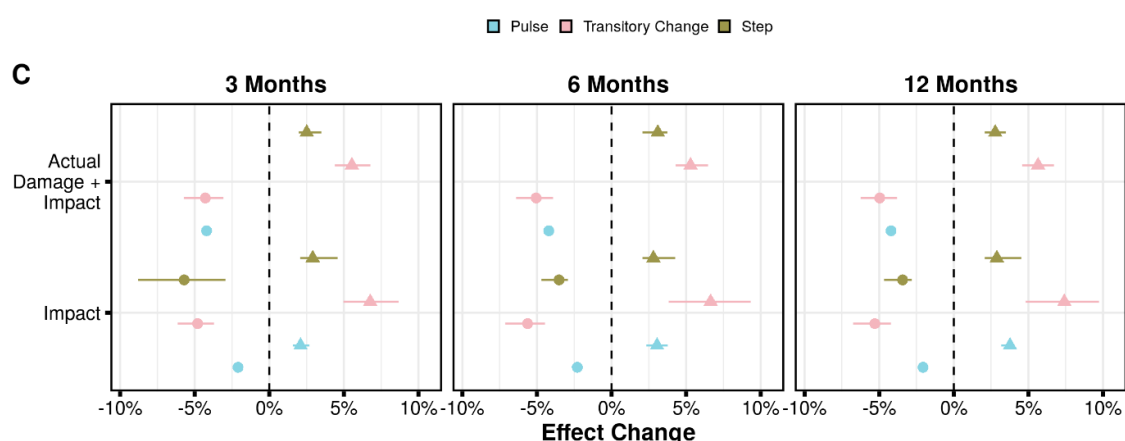


Figure 69. *Intervention analysis: Insights on the Intervention Analysis Preventive, Actual and Image (Source: Author)*

Figure 70 shows the omega coefficient of the transitory change transfer functions for the three time horizons per group. The closer the omega coefficient comes to 1.0 the faster the effect fades (gets closer to the pulse function). The closer the omega coefficient is to 0.5, the closer it gets to a step function.

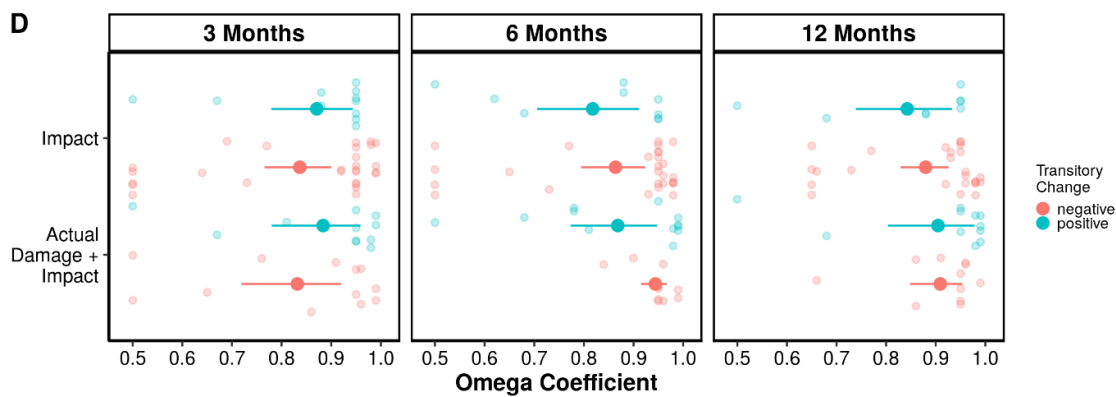


Figure 70. *Intervention analysis: Insights on the Intervention Analysis Preventive, Actual and Image (Source: Author)*

Announcements that include details on the actual damage led to more positive than negative reactions. Preventive closures rarely led to a significant reaction; however, this needs to be verified because insufficient data were available.

5.2.4 Summary of Main Model Results

An overview of the main model results per hypothesis is presented in Table 22. The results section`s main purpose is to describe the results.

For H1: Hurricane announcements and hurricane incident announcements have a significant effect on firm performance in 25-31% of cases. Most of these stock price effects are negative.

For H1 a,b,c: For the majority (around 70%) of cases, the transitory functions fit best. Positive as well as negative effect changes in stock prices decay over time.

For H2: All sectors are affected, however magnitude, directionality and pattern mix vary.

For H3 & H4: All impact types and extents are affected; however, magnitude, directionality and pattern mix vary. Around one quarter of incidents show significant stock price reactions for both SCDs and other damage. Other damage creates a higher proportion of significant reactions than SCDs. The information on impact is the biggest determinant for a significant stock price reaction when compared to information on damage or preventive closure. The extent of impact (major or minor) determines how high the proportion of significant stock price reactions is, though it does not necessarily influence the directionality in general, i.e., negative or positive reactions.

For H5: Firms providing details on the damage, suffer a lower proportion of significant reactions.

For H6: Preventive closures reduced the proportion of significant reactions to less than 1% of the incidents. Reporting on preventive closures apparently softens the effect of announcements on impact and damage. However, the finding must be confirmed as there was a lack of available data. Preventive closures reduced the proportion of significant reactions to less than 1% of the incidents.

Table 22 Main Model Results (Source: Author)

#	Hypothesis Topic	Hypothesis	Results Summary
H1	Stock Price Effect	Hurricane announcements as well as hurricane incident announcements cause a reaction in stock price	TRUE Hurricane announcements and hurricane incident announcements cause a significant effect on firm performance in 25-31% of cases.
H1 a,b,c	Transfer Functions	<p>H1a: A hurricane incident announcement/hurricane announcement has a short-term effect on stock price defined as a pulse function.</p> <p>H1b: A hurricane incident announcement/hurricane announcement has a persisting effect on stock price defined as a step function.</p> <p>H1c: A hurricane incident announcement/hurricane announcement has a transient effect on stock price defined as a transitory change function.</p>	<p>b is most TRUE</p> <p>For around 70% of cases, the transitory functions fit best.</p>
H2	Industrial Sector	H2: The industrial sector influences the stock price reaction due to a hurricane incident announcement.	TRUE All sectors are affected, however magnitude, directionality and pattern mix vary.
H3 & H4	Impact Type & Impact Extent	<p>H3: The impact type (supply chain disruption or other damage) influences the stock price reaction due to a hurricane incident announcement.</p> <p>H4: The extent of impact (minor or major) influences the stock price reaction due to a hurricane incident announcement.</p>	<p>H3 and H4 TRUE</p> <p>All impact types and extents are affected, however magnitude, directionality and pattern mix vary.</p>
H5	Actual Damage	H5: Actual damage influences the stock price reaction due to a hurricane incident announcement.	TRUE Firms providing details on the damage, suffer have a lower proportion of significant reactions.
H6	Preventive Closure	H6: Preventive closure influences the stock price reaction due to a hurricane incident announcement.	TRUE (to be confirmed due to little data) Reporting on preventive closures softens the effect of announcements on impact and damage.

6 Discussion

After the results were described in the previous section, in this discussion section the results are aimed to be explained and embedded in the existing literature. The sample population of the NYSE investigated differs from previous research.

Previously, supply chain research only examined firms reporting an SCD in their official announcements. The sample population investigated in this thesis includes all manufacturing companies, independently of whether there is information available on a hurricane-related damage or SCD. Of all 2,687 companies listed on the NYSE in the investigated timeframe, 625 (23%) meet the supply chain inclusion criterion. Publicly available information was reviewed per company and hurricane to record the first announcement of anticipated or past effects of a natural disaster. Therefore, not just the announcement of damage or disruption but also the duration of hurricanes could be applied as anchors in the time series model.

6.1 Discussion of Main Results

The discussion is structured along the hypotheses. Hypotheses 1 (incl. sub-hypotheses) is analysed as both anchor types are used as an anchor to model the effect on stock price per firm: hurricane incident announcements and hurricane announcements. For significant changes in stock prices the best fitting pattern, namely pulse, transitory change or step, for the time horizons spanning 3, 6 and 12 months after the anchor, is estimated. For hurricane incident announcements as well as for hurricane announcements the influence on the industrial sector was assessed. For hurricane incident announcements, additional factors such as impact, damage and preventive measures were evaluated for their influence. In this part of the analysis different hurricane announcement dates are used as anchors to model the effect on stock price: 1. Begin of hurricane, 2. Hurricane warning, 3. Hurricane hits land, 4. End of hurricane, 5. Hurricane duration and 6. After hurricane. The stock price development was tested for announcing and non-announcing firms per hurricane. The best fitting pattern for the reaction was determined. For anchors B1-4, that

are points in time, the pulse and transitory change was applied; for anchors B5-6, that are time intervals, the step function was applied.

6.1.1 Hypothesis 1: Hurricane Announcements

H1: A hurricane incident announcement/hurricane announcement has an effect on stock price.

H1a: A hurricane incident announcement/hurricane announcement has a short-term effect on stock price defined as a pulse function.

H1b: A hurricane incident announcement/hurricane announcement a persisting effect on stock price defined as a step function.

H1c: A hurricane incident announcement/hurricane announcement a transient effect on stock price defined as a transitory change function.

Hypothesis 1 states that hurricane incident announcements and hurricane announcements have a significant effect on stock price which is in alignment with the efficient market hypothesis (Kahneman and Tversky, 1973). Stock price allows the measurement of the subjective risk perceived by the shareholders in order to translate it into an objective risk view (Khan and Burnes, 2007, Zsidisin and Wagner (2010). The reaction patterns defined in the sub-hypotheses to H1 allow for estimating subjective and objective components.

For Hurricane Incident Announcements

H1 tested positive as around 30% of the announcing firms show a significant interruption associated with the hurricane incident announcement day in the time series (Figure 49-Figure 53). These interruptions are quite stable even when extending the time period from three to six or twelve months (Figure 50). These findings are in line with the efficient market hypothesis and are supported by findings from previous event studies that showed statistically significant reactions after announcements of SCDs and disasters (Caporale and Makarenko, 2019; Hendricks and Singhal, 2008, 2003; Zsidisin et al., 2016). Aligned with previous research findings, there are more negative than positive extreme values (Hendricks and Singhal, 2008, 2003). In this thesis it was detected that many of

the extreme values occurred when hurricane damage from two directly consecutive hurricanes were announced – mostly hurricanes Harvey and Irma; the companies were: CMG, AXE, CLW, VRTV, CSS and FTK. This happens because hurricane incident announcements are mostly made at the end of the hurricane season, often aggregating reports of multiple hurricane incidents.

Overall, the results of the intervention analysis provide insight that the transitory change function fits best in most cases (more than 60%). Even for the extreme values this is true with just one exception: ATI. As expected, the overall stock price reaction of firms was more negative (Hendricks and Singhal, 2003). Hurricanes cause a lot of destruction with e.g., Hurricane Harvey alone costing the US economy 125 billion USD (National Hurricane Center, 2018). The transitory change function indicates that there might be a component of overreaction in stock price – if the function approximates a pulse pattern. Absence of a pulse pattern indicates that the reaction is not solely an overreaction (Filbeck et al., 2016). The more abundant negative stock price effects disappear faster than the few positive reactions (Figure 51-Figure 53). The faster fading of negative effects may be due to hurricane damages being repaired and investors forgetting the incident over time. In conclusion, hurricane incidents are most likely to cause a strong negative sudden stock price reaction that fades over time, which is supported by previous research findings.

For Hurricane Announcements

H1 was tested positive for around 21% of the reactions of announcing firms and for 18% of the non-announcing firms. As announcements are tied to the hurricanes but not to the companies, it seems that investors, based on their intuition and/or past experience, can partially anticipate which companies will be suffering damage. Different hurricane information was tested in the form of different anchors: begin of hurricane, hurricane warning, hurricane hits land, end of hurricane, hurricane duration and after hurricane. All tested anchors led to a proportion of statistically significant reactions, indicating that all hurricane information is noted and reacted upon by shareholders. At the time of most hurricane announcements no damage to firms had yet occurred; however, the

fear of investors might lead to a “investors’ belief about future cash flows and risk not justified by the facts at hand as stated in Wurgler’s Theory: Investor Sentiment” (Baker and Wurgler, 2007, p.129). The reactions based on (at that point in time) unclear information might be explained by the enactment theory that could be used to explain the process of sense making of investors. These findings are also supported by the contagion theory, which indicates a spill-over of market reaction to companies that are located in the same area, even though these might not be affected at that point of time or possibly even not at all (Filbeck et al., 2016).

For announcing and non-announcing firms, the highest percentage of statistically significant reactions (23%) was found. This is in alignment with the efficient market hypothesis that investors react immediately to newly available information (Kahneman and Tversky, 1973). Even though the earliest information tested was “begin of hurricane” – this information means that the storm has reached a certain speed, but it still might be somewhere on the ocean far away from land. In contrast, the next point of time “hurricane warning” is tied to a location and it is the first time an imminent threat is quite certain; however, the extent of its damage is uncertain and therefore leads to overreactions (Filbeck et al., 2016).

Subsequently the results of the potentially influencing factors are discussed. In alignment with the enactment theory, the reactions differed based on the potentially influencing factors (Ellis et al., 2011). This is due to how investors make sense out of such a catastrophic event.

6.1.2 Hypothesis 2: Industrial Sectors

H2: The industrial sector influences the stock price reaction due to a hurricane incident announcement.

H2 can be confirmed. The percentage, directions and patterns of significant reactions differ between industrial sectors, which is in alignment with previous research that also found differences between industrial sectors (Worthington and Valadkhani, 2005). In this thesis, for the main analysis, the NYSE industrial sector classification was applied. However, even though there were differences,

generally all industrial sectors were affected, which aligned with other previous studies (Hendricks and Singhal, 2003; Liu et al., 2018). That the results differ between industrial sectors, is also aligned with the contingency theory, which states that contextual factors such as industrial sectors matter (Wagner and Bode, 2008).

For consumer non-durables, there are many interruptions following the pulse function. This indicates that investors react strongly, but the reaction normalises rapidly, indicating a possible overreaction or that investor's view recovery from the hurricane incident not as a long-term issue. Most firms in the consumer non-durables sector are food and beverage firms, some which produce short use packaging. Many of the goods can be destroyed or contaminated and investors are concerned about the destruction of goods and the hygiene of facilities. However, the short reaction of investors leaves the impression they are not sustainably concerned as they see it just as a short-term loss of product which is relatively easy to recover from. Interestingly, even though the strongest negative reactions were observed for this sector, there is just one negative extreme value and two positive extreme values. Reasons for the generally negative reactions might be that these consumer non-durables tend to be commodities that have little differentiation, a short product lifecycle and are replaced frequently. People buy these products wherever they are available; however, this availability is threatened by hurricanes as they might destroy products, disrupt logistics to stores and even online-deliveries, and lead to store closures. Shelf or, more generally, product availability is very important, because customers do not tend to wait for these articles, they buy alternatives. Thereby hurricanes are an imminent threat to consumer non-durables firms.

The only extreme negative value was from Anixter International Inc. (AXE), a company that supplies communications and security equipment, which is high value equipment that is sensitive to force and humidity. The firm reports the negative impact of hurricanes and earthquakes. Another firm in the home security area, Fortune Brands Home & Security Inc. (FBHS), in the basic industries sector, also had a negative reaction. The reason might be a drop in demand related to

the destruction of assets that would otherwise be equipped/protected with their products.

Both extreme positive values were observed at apparel companies (OXM and CHS). Oxford Industries, Inc. (OXM) was hit by both Hurricane Matthew and the recent bankruptcy filing by South Korea's Hanjin Shipping. The negative news was balanced by the information that the company will meet their financial targets despite these events, which probably led to the positive reaction from their shareholders.

The other firm, Chico's FAS, Inc. (CHS), with an extremely positive reaction, and also from the apparel sector, reported satisfactory results and liquidity despite hurricane impact. One of their brands did not perform according to expectation, but they provided a strategic plan; the performance was better than anticipated and shareholders were relieved.

Capital Goods show an interruption of 30% for the 3-month analysis; however, when observing 6 and 12 months, the number of companies showing a significant reaction drops to around 20%, indicating that the effect is not long-term. In conclusion, around 20% of capital goods firms show an interruption. Even though there are industries with a higher proportion of firms with an interruption, this sector has the second strongest negative reaction. Capital goods often produce large, heavy, technically complex, and expensive goods such as cars and defence machinery. Investors might react strongly to the destruction of inventory and products as these are of high value and can themselves cause quite substantial financial damage. In addition, the production plants for these goods tend to be technically complex and expensive so their repairs or even rebuilding would be expensive and probably time-consuming. Also paying the wages of skilled labourers and overheads for the time the production plants take to be repaired are costly. Finally, many of these firms are suppliers. Suppliers might have the risk of receiving fines for delivering late (especially when they have to deliver just in time) or losing their original equipment manufacturer (OEM) customers if they cannot deliver for extended periods. For high-value goods, transportation disruptions increase shipping costs for delivering on time.

A third of consumer durable firms show an interruption of time series. The stock price change is positive in the form of a step change for most firms, indicating that even though some investors react negatively to hurricane damage, the majority believe that firms benefit from increased demand. It seems that investors anticipate an increase in demand as consumers in the hurricane-affected regions might push demand because they need to replace damaged goods. If investors would just anticipate a short-term improvement, then a suitable transfer function would have been a pulse or transitory change.

For the sectors technology and healthcare the results do not allow for drawing a reliable conclusion from the modelling as the number of companies is too small.

Overall, the results indicate that hurricane incidents cause a significant reaction on stock price at a considerable number of firms. As the ratio of companies with interruptions of the time series per industry differs, this is an indicator that the industry matters and influences how likely a stock price reaction is after a hurricane-induced SCD. The industrial sectors' basic industries and capital goods seem to suffer the most: They showed the highest proportion of both significant reactions and negative reactions. Consumer services and consumer non-durables had a high proportion of negative reactions as well, but their proportion of significant reactions overall was lower.

Summarising the most extreme reaction: for the capital goods sector two negative extreme values (KEM and HY) and one positive extreme value (MDR) were observed. The KEMET Corporation (KEM) provided an announcement on preventive office closure due to hurricane Irma but no production closure. Probably they had a negative stock price reaction because shareholders were afraid of future damage or shareholders were generally not optimistic about the firm's future as the reaction was persistent (step function). The second extreme negative reaction happened to firm Hyster-Yale Materials Handling Inc. (HY), which designs, engineers, manufactures, sells and services a comprehensive line of lift trucks and aftermarket parts. A production plant was hit by hurricane Matthew affecting their financial results. However, the firm admitted that the negative results can be just partially justified by hurricane damage, implying

general firm performance or management issues. The combination of information probably led to the extremely negative shareholder response.

The only company that had a positive reaction was McDermott International Inc. (MDR). The firm announced the damage following a large delay, precluding a timely response by investors. Additionally, they announced that no damage on future income statements was expected, which led to a positive shareholder reaction.

A previous study found the following sectors are most sensitive to disasters: consumer discretionary, financial services and materials sectors (Worthington and Valadkhani, 2005). In this thesis the highest, i.e. the financial sector, is not considered as it does not have a significant supply chain (see scoping). This thesis finds a high proportion of interruptions and mostly negative reactions for consumer services (50%) and basic industries (36%) and thereby confirms these findings. Additionally, the sector consumer durables (30%) show a high proportion of interruptions and the sectors consumer non-durables and capital goods show predominantly negative effects. This thesis additionally shows that the primary pattern across industries is a transitory change function; however, the proportions of patterns vary between industrial sectors.

6.1.3 Hypotheses 3 and 4: Impact Type and Impact Effect Size

H3: The impact type (supply chain disruption or other damage) influences the stock price reaction due to a hurricane incident announcement.

H4: The extent of impact (minor or major) influences the stock price reaction due to a hurricane incident announcement.

These two hypotheses are discussed together because they were tested together. Hypothesis 3 states that the impact type (supply chain disruption and other damage) has an effect on stock price (Zsidişin et al., 2016). Similarly to previous SCM studies, this thesis found a stock price effect from SCDs and similarly to financial economics studies also found an effect from disasters (Donadelli and Lucchetta, 2013). For all impacts, 20-30% of the companies exhibit an interruption of the time series (Figure 63), thereby H3 is supported.

Interestingly the results showed that the type of impact e.g., SCD or other damage did not have as much influence on the stock price effect as the impact severity tested in H4. Hypothesis 4 states that the extent of impact influences the stock price effect. This is consistent with efficient market hypothesis which assumes that new information, such as news reports on the impact of SCD, will immediately have an effect on stock price (Fama et al., 1969). The major impact categories (major SCD and major other damage) lead to the highest proportion of firms with stock price interruptions. This result confirms the assumption that investors react immediately to this new information (Fama et al., 1969) and that, based on that news on smaller SCDs, investors react positively interpreting it as result of better SCRM (Ellis et al. 2011; Wagner and Neshat, 2012). The differences in reactions between impact type and extent are aligned with the signalling theory, which indicates that shareholders might have different perceptions of a firm based on its managerial responses (e.g. SCRM in place) and reward therefore minor supply chain disruptions and punish major supply chain disruptions (Marcus and Goodman, 1989).

Both categories show a negative transitory change with fast decreasing curve (Figure 64 and Figure 65). As the effects for both impact categories are similar, investors do not especially react to SCDs but just to major impact in whatever form. Between 32-38% of firms that reported major other damage show a stock price reaction; the majority of these are in the form of a transitory change function with a high omega coefficient (rising high but falling quickly). As the function is similar to a pulse function, there might be an overreaction component of the reaction. Other damage can be, for example, property damage and decrease in demand. The reaction might not be sustainable, because after the first shock investors might realize that the buildings are usually insured and the decrease in demand normalises for most goods when the disaster recovery is commencing. Major SCDs behave similarly to major other damage: around 30% of firms with a major SCD show a stock price interruption; however, these are stable over the time horizon. Based on TCE and the resource-based view, shareholders punished both a loss of resources and increased cost through major supply chain disruptions or other damage (Shi and Yu, 2013). The majority of the reactions are

negative and fit the transitory change function with a high omega coefficient. Major SCDs might be an indicator of the absence of or an inefficient SCM and might, therefore, be punished by investors (Ellis et al., 2011; Wagner and Neshat, 2012). The negative effect is confirmed by previous research (e.g. Hendricks and Singhal, 2005a, 2003; Zsidisin, 2016). The short duration of effect confirms some previous results of disaster research (Caparole and Makarenko, 2019), while conflicting with some supply chain research (Hendricks and Singhal, 2005a, 2003) that found a long-term effect. As major SCDs often last for a substantial amount of time, a longer reaction could have been expected. Maybe investors forget the incident over time or regard the incident as less threatening if they know the full damage assessment or the recovery works progress. In conclusion, even though negative effects are more prevalent for major and minor other damages and major SCDs, these decay faster than the positive effects. Generally, the ratio of firms with interruption stays stable, independently of the chosen time horizon. Furthermore, for all, the transitory change function fits best. This might indicate that either the strong negative reaction of investors is partially an overreaction, or the event will be forgotten after a while (Filbeck et al., 2016). The positive effect of interruptions might last longer as it might increase the shareholders' trust. Overall, some firms also benefit from hurricane incidents, which has been mostly overlooked in other research.

In summary: severity of the impact has more effect than the type of impact.

6.1.4 Hypothesis 5: Actual Damage

H5: Actual damages influence the stock price reaction due to a hurricane incident announcement.

Hypothesis 5 states that information on damage influences the stock price reaction. Announcements providing not just brief information on the impact but also detailed information on the damage led to a significant reaction in around 10% of cases. Interestingly most of these reactions were positive. In contrast, announcements containing just brief information on the impact resulted in

predominantly negative reactions in around 15-20% of cases. The more information, the lower the uncertainty (which naturally creates fear), implying a better insight into the damage and the efficiency of SCM (or whether it exists) by investors (Filbeck et al., 2016). In summary, providing details on damage reduces the likelihood of a stock price reaction and if there is a reaction it is more likely to be a positive one. This is aligned with the signalling theory that explains differences in reactions based on both the different perceptions of a firm and on the managerial responses, such as transparent communication (Marcus and Goodman, 1989).

6.1.5 Hypothesis 6: Preventive Closure

H6: Preventive closure influences the stock price reaction due to a hurricane incident announcement.

Hypothesis 6 assumes an influence of preventive closures of production facilities on the effect on stock price. Preventive closures were never reported on their own and reduced the proportions of significant reactions to less than 1% of the incidents. It is possible that reporting on preventive closures makes up for announcements on impact and damage. Preventive closures of production facilities are typically government ordered and apply to all companies in a region, or they are a risk management action to prevent more damage (Ellis et al. 2011; Wagner and Neshat, 2012). As seen from the results of testing hypotheses 3 and 4, investors appreciate SCRM that reduces SCDs. This might be explained by the signalling theory, which says that investors react on their perception of the managerial response to an event (Marcus and Goodman, 1989). Therefore, the market reacts less to hurricane incidents when preventive measures are announced as they are seen as effective managerial actions. Thus, preventive closures might reduce stock price effects. This is also aligned with the strategic choice theory, which states that managerial actions such as preventive closures could lead to less negative reactions (Wagner and Bode, 2008). It is also aligned with the shareholders belief in the high reliability theory and thereby that accidents are preventable, and therefore do not mind preventive closures.

6.1.6 Comparison of Hurricane Incident Announcements vs. General Hurricane Information

In this section for the first time, the effect after hurricane incident announcements is compared with the effect of hurricane announcements. At hurricane landfall (anchor B3), stockholders react to the information that the threat hurricane materialised. Investors react based on their expectation of whether a firm is affected and how severe that impact is. As for announcing firms, there is a high proportion of significant reactions for all anchor Bs, reflecting investors predicting damage. For the points in time, the transitory function is the best fitting function for the majority of data with high omega coefficients, implying strong but quickly fading reactions, indicating an overreaction component (Filbeck et al., 2016). During the hurricane, investors suffer from uncertainty, because time is needed for firms to assess the impact (Filbeck et al., 2016). This is reflected in the high proportion of negative reactions for announcing firms in the form of a step function. The long-lasting negative effect might be due to investors having to bear the uncertainty until the firms release information, which is in most cases the next quarterly or annual report. Investors react to the information provided by the announcement of a hurricane incident at the time of the announcement (anchor A). Interestingly, the transitory change function is most suitable, indicating an overreaction component to the announcement as well as a longer lasting effect. For hurricane incident announcements, investors seemed to reward companies for providing detailed information while punishing firms for providing just the minimum amount of information that is required by regulation. The more the results of the reaction of the analyses for anchors A and B mirror each other, the better the investors were anticipating the impact on the firm. There was a strong correlation between the results for both anchors. Certain industrial sectors provide more incident announcements, indicating that they experience more actual impact. Industrial sectors show different proportions, direction and/or strengths of reaction, indicating that investors react differently per industrial sector. Non-durables, basic industries and capital goods showed the most negative reactions. Investors might react more negatively for extended periods of time, due to potential impact (hurricane duration) as they lack information, than

they do to negative news knowing there is an impact (announcement of hurricane impact as anchor). Detailed information and preventive measures softened the investors' reaction considerably.

6.1.7 Overview over Use of Theory Explaining the Results

Several theories were used to deduce the hypotheses. Additionally, many of these theories as well as additional ones were used to make sense out of the results and are covered in the discussion section. Table 23 was created to provide an overview structured by the hypotheses that shows if and how the theories support this thesis' results. Most theories applied. However, Theory on the Economics of Natural Disasters did not apply, as there was no announcement, the majority of listed firms reacted upon. Also, Normal Accident Theory did not apply. As shareholders showed less negative or more positive reactions for companies with preventive closures or an effective SCRM, this indicates that shareholders do think that accidents are avoidable. Table 23 provides an overview over how the theories explain the results. The details on the theories that applied can be found in the respective discussion section.

Table 23 Theories Explaining the Results (Source: Author)

#	Hypothesis	Theory	Applies	Comment
H1	Stock Price Effect	Efficient Market Hypothesis	YES	Yes, shareholders reacted to hurricane announcements and hurricane incident announcements.
H1	Stock Price Effect	Theory on the Economics of Natural Disasters	NO	There were no announcements where the majority of the index reacted.

H1	Stock Price Effect	Normal Accident Theory	NO	Does not apply as investors differentiate between companies implementing preventive measures or not.
H1	Stock Price Effect	Contagion Effect	YES	Non-announcing companies showed stock price effects. However, announcing-firms have slightly more reactions.
H1	Transfer Functions	Investor sentiment	YES	Pulse functions and transitory change function with high omega coefficient. of non-announcing companies after hurricane announcement can be explained by investor sentiment
H1 a,b,c	Transfer Functions	Overreaction Hypothesis	YES	Companies with pulse function or transitory change function with high omega coefficient indicated overreaction.
H2,3, 4,5,6	All potentially influencing factors	Enactment Theory	YES	The reactions differed based on the potentially influencing factors. This is due to how investors make sense out of such a catastrophic event.

H2	Industrial Sector	Contingency Theory/ Strategic Choice Theory	YES	Results differed between industrial sectors, indicating that aligned with the contingency, contextual factors such as industrial sectors matter.
H3 & 4	Impact Type / Extent	Rational Pricing Theory	YES	Investors reacted to impact type and extent, indicating rational pricing.
H3 & 4	Impact Type / Extent	High Reliability Theory	YES	Positive reactions of shareholders on minor SCD and negative reactions on major SCDs indicate that shareholders believe in the prevention of accidents.
H3 & 4	Impact Type / Extent	Normal Accident Theory	NO	Investors made a difference between companies with minor and major SCD, which implies they believe that accidents are not inevitable.
H3 & 4	Impact Type / Extent	Signalling Theory	YES	Differences in reactions based on impact type/extent indicate that shareholders might have different perceptions of a firm based on the managerial responses (e.g. SCRM in place).

H3 & 4	Impact Type / Extent	TCE	YES	Differences in reactions based on impact type/extent indicate that shareholders are focused on minimizing cost and thereby reacting better to minor supply chain disruptions than to major ones.
H3 & 4	Impact Type / Extent	Resource-based View	YES	Differences in reactions based on impact type/extent indicate that shareholders see disaster damage as something that reduces the resources of a company and decreases its competitiveness, and explains a negative reaction by shareholders.
H5	Actual Damage	Signalling Theory	YES	Differences in reactions based on the different perceptions of a firm, based on the managerial responses (e.g. transparent communication).
H6	Preventive Closure	Contingency Theory/ Strategic Choice Theory	YES	Managerial actions such as the preventive closures led to less significant reactions.

H6	Preventive Closure	High Reliability Theory	YES	Less reactions by shareholders in the case of preventive closures indicate that they believe in the prevention of accidents.
H6	Preventive Closure	Normal Accident Theory	NO	Investors made a difference between companies with or without preventive closure.
H6	Preventive Closure	Signalling Theory	YES	Less reactions by shareholders in the case of preventive measures indicate a less negative view on managerial responses in terms of preventive closure.

7 Contribution

7.1 Contribution to Research Field

This thesis was conducted from a SCM perspective. The thesis brought together the three main concepts: Disasters, SCDs, and firm performance, connected these to one conceptual framework and thereby connected the SCM and financial economics literature.

SCDs caused by disasters are more severe in comparison to other causes. Therefore, this thesis focuses on disaster-induced SCDs, ensuring that their effect is not diluted by less severe causes such as small operational glitches (Hendricks and Singhal, 2003). The evaluation of the effect is extended to include

that of multiple hurricanes on multiple companies in various sectors, unlike in previous studies (Latour, 2001). Generally, this thesis is based on contingency theory, which has the central assumption that organisations have high efficiency and performance when firms consider the context and environment in which their strategy is designed and implemented (Chang et al., 2015). This thesis contributes to knowledge by answering the research question “What are the effects of supply chain disruptions due to hurricanes on stock price?” Analogous to the gaps defined in Section 2.5, the contributions made by this thesis will address aspects of conceptual, data-related and methodological issues.

This thesis contributes to supply chain research by further developing the understanding of how hurricane company announcements affect the stock price and how this is moderated by firm- or event-related factors. This contributes knowledge on how the supply chain risk posed by hurricanes can be better managed to reduce the impact on the company’s stock price. As there is little dedicated supply chain literature on the effect of SCDs on firm performance in general and specifically little research on disruptions caused by disasters, such as hurricanes, this thesis aims to contribute to this literature gap.

Another shortcoming of research so far is the preselection of companies, limiting the analysis to companies that announced they had been impacted by a disaster or SCD. This thesis includes non-announcing companies thereby a negative control is provided in the form of non-announcing firms. Furthermore, this thesis considers multiple potentially influencing factors by analysing the observed interruptions in stock price due to hurricanes: industrial sector, impact type, impact effect, information on actual damage and preventive closures of production facilities.

Additionally, different types of hurricane information are tested (for example: begin of hurricane, hurricane warning, hurricane landfall, end of hurricane, hurricane duration and after hurricane) to identify which information is the most relevant for investors. Most published studies investigate smaller stock exchanges, whereas this thesis provides an update with recent data from a large stock exchange, the NYSE. This is urgently needed as the frequency and impact

of natural disasters increase due to both climate change and the globalization of businesses (The Boston Consulting Group, Inc. 2013; The UN News, 2018). Hurricanes are confirmed to be the most prominent type of disaster, highlighting the importance of assessing related damages in one of the largest economies.

The manufacturing firms studied were all quoted on the NYSE.

Most of the existing studies are event studies assessing the impact of a disaster or SCD by estimating CARs, a form of linear regression analysis on stock price performance (Corrado, 2011). In this thesis, another type of regression model is applied, namely an intervention analysis or ITSA (Lopez Bernal et al., 2018). This method is a valid and appropriate alternative to traditional event study methods (Larcker et al., 1980). The stock price is a time series. An intervention analysis with an ARIMA model to account for autocorrelation, trend, seasonality and drift patterns is applied (Box and Jenkins 1970). Other advantages of this thesis' methodology are that longer term effects can be evaluated and the best fitting transfer functions are assessed. ARIMA models are a frequently used method to model and investigate interruptions and forecast financial data (Angadi and Kulkarni, 2015; Ariyo et al., 2014; Chung, Ip and Chan, 2009; Sengupta and Chaudhury, 2018). In conclusion, by using intervention analysis in combination with ARIMA modelling, the peculiarities of time series data are accounted for in the model, enabling not only the identification of a significant interruption but also its directionality and pattern by applying transfer functions (Box and Tiao, 1975). This study applied the ARIMA model to analyse the US consumer price index (Box and Tiao, 1975). This is a novel approach in the field of SCM research.

7.1.1 Confirming and Extending existing Research

7.1.1.1 Confirmation of Stock Price Reaction

This thesis confirmed the findings of previous studies regarding the effect of supply chain incident and disaster announcements on stock price. Previous studies found that supply chain incident announcements affect stock price – these are then major disruptions (Hendricks and Singhal, 2003, 2005a; Zsidisin et al., 2016). Other studies found that disaster incident announcements affect stock

price (Caporale and Makarenko, 2019). In alignment with these previous findings, this thesis' results have shown that hurricane incident announcements and hurricane announcements tend to lead to a significant reaction that is mostly negative. These results are in alignment with the efficient market hypothesis that the market reacts to new information (Fama et al., 1969).

For the first time the two anchors, i.e., hurricane incident announcements and hurricane announcements, were tested and the results compared with each other. A further original aspect of this study is the comparison of announcing firms and non-announcing firms as a negative control for the general hurricane information. Firms' stock prices are reacting to this general information of a hurricane, even before being affected or making announcements of damages. This implies that investors react to uncertainty, indicating a contagion effect (Bloise and Bornkamp, 1996; Filbeck et al., 2016). The results show that with regard to hurricane announcements, the proportion of negative reactions were higher for the announcing firms, implying that investors are already predicting which firms will be affected before they make hurricane incident announcements.

Another novelty of this thesis is the application of transfer functions to determine the pattern of the stock price reactions. The most common best fitting transfer function was the transitory change function. This implies the reaction lasts for a while; however, as there is a spike, this indicates an overreaction component based on the overreaction hypothesis. As a novelty, for ensuring robustness of results, testing was performed for three time horizons (3, 6 and 12 months). The results were observed to be consistent between the time horizons, implying that the results are stable.

In summary, hurricane incident announcements and hurricane announcements cause significant reactions that are mostly negative.

7.1.1.2 Clarifying the Influence of the Industrial Sector

Previous research found conflicting results. Some researchers found that the industrial sector does not influence stock price (Hendricks and Singhal, 2003 and Liu et al., 2018). In contrast, other researchers found that the industrial sector

does have an effect (Dietch and Corey, 2011; Donadelli and Lucchetta, 2013; Worthington and Valadkhani, 2005; Zhang et al., 2009). To clarify this conflicting information, the industrial sector was tested in this thesis. This thesis finds that all industries show a stock price effect due to hurricane incident announcements; however, the effect depends on the particular industry.

Most industries suffered predominantly negative effects; consumer services, consumer non-durables, capital goods and basic industries had the most negative effects. This is partially in line with a previous study that found that the most sensitive to disasters of any type are the consumer discretionary, financial services and materials sectors (Worthington and Valadkhani, 2005). That the capital goods sector is heavily affected is new. One reason for that might be that the industrial sector classifications applied vary. Not every study tests for capital goods as a category. Additionally, this thesis specifically tests the effect of hurricanes on different types of manufacturing firms, whereas most previous studies test for either disasters or supply chain disruptions in general. Probably capital goods are not very sensitive to general supply chain disruptions but more specifically to disaster-induced ones, as these can heavily damage the expensive physical assets in the production line.

Two industries were showing more positive effects: the healthcare and consumer-durables sectors. The healthcare sector typically showed increased demand after disasters as people are injured and need medical help. Additionally, disasters that cause flooding, such as hurricanes, increase the risk of the spread of diseases, for example due to rotting bodies in the water, thereby increasing the demand for healthcare products. The positive effects in the consumer-durables sector are probably also rooted in an increase in demand. The durable goods in hurricane-affected households such as furniture are typically of higher value and will usually not be replaced frequently. However, water damage forces households to make an unscheduled replacement. That certain industries may be benefitting from a disaster and therefore show more positive effects has also been observed in previous research (Dietch and Corey, 2011; Donadelli and Lucchetta, 2013; Worthington and Valadkhani, 2005; Zhang et al., 2009).

A novelty is the analysis of best fitting patterns per industrial sector. The finding is that even though the overall best fitting pattern is the transitory change function, the proportions of best fitting patterns differ between industries. In the following I will expand on the parts in the pattern mix that are not a transitory function.

From an SCRM perspective the pattern is most relevant for the capital goods and consumer non-durables sectors. The former shows mostly negative reactions and quite a proportion of these are lasting negative reactions in the form of step functions; the latter shows mostly negative reactions; part of these are pulse functions, and another part are step functions.

Looking at consumer services, there are positive and negative reactions in form of pulse functions, showing that some shareholders might overreact in good and in bad ways.

Consumer durables generally show a majority of positive reactions; of these reactions, most are step functions. This indicates that investors believe in a sustainable benefit from the hurricane incident – probably in the form of increase in demand. Health care also shows mostly positive reactions. A substantial number of these reactions are pulse functions which might indicate an overreaction.

In conclusion, companies from all sectors are affected but the reactions differ.

7.1.2 Adding to Existing Research

Previous research found there are factors that influence the stock price effect, and this thesis' results confirm that (Dietch and Corey, 2011). In the existing research some potentially influencing factors were just mentioned but have not been statistically tested yet: impact type and extent, actual damage and preventive closures. This thesis tested these factors statistically to see whether or not they influence the stock price effect.

7.1.2.1 Impact Type and Extent

So far just the effect of both major supply chain disruptions and major other damage has been tested – and that separately. This study enables a comparison

between both. It also enables a comparison between minor and major damage per impact type. The results confirmed the negative effect of major SCDs (Hendricks and Singhal, 2003) and generally major damage (Caporale and Makarenko, 2019). All impact types and extents lead to mostly negative reactions, apart from minor supply chain disruptions, which are the only impacts resulting in a positive reaction. This indicates shareholders' appreciation of effective supply chain (risk) management preventing worse damage.

Minor supply chain disruptions result in a positive reaction.

7.1.2.2 Actual Damage

The results indicate that providing information on damage leads to fewer share price reactions, less negative reactions and mostly positive reactions. This indicates that shareholders appreciate additional information as transparency reduces uncertainty for them. Uncertainty is a main driver for unjustified investors' reactions (Bloise and Bornkamp, 1996).

In conclusion, providing details on actual damage leads to less negative and mostly positive reactions.

7.1.2.3 Preventive Closure

The results show that firms providing information on preventive closures of production facilities are unlikely to have a stock price effect. This indicates that shareholders appreciate a proactive SCRM that prevents further, more severe damage (Papadakis, 2006). However, due to the small sample size for this particular factor, the results need to be confirmed by subsequent research.

In conclusion, companies providing information on preventive closures are unlikely to suffer a negative reaction.

7.2 Contribution to Practice

There are four main lessons for companies resulting from this thesis:

1. Hurricane risk must be actively managed by firms of all sectors
2. Hurricane risk preparation needs to be sector-specific
3. Firms should focus on managing supply chain disruptions

4. Firms need to communicate transparently

The subsections of this chapter are structured along these four key lessons.

7.2.1 Hurricane Risk Must be Actively Managed by Firms of All Sectors

The timeframe of this research, i.e. five years, included several hurricanes during which a considerable number of firms were hit by up to four hurricanes. This indicates that companies cannot avoid disasters, especially hurricanes.

Firms of all industrial sectors suffered negative stock price effects after hurricane incident announcements. The stock price effect is mostly negative described by a transitory function. Major supply chain disruptions, and both major and minor damage lead mostly to negative stock price reactions. Stock price is one way to measure firm performance, which a company's board is responsible for. Therefore, every company needs to recognize hurricanes as a risk that requires proactive risk management and preparations to be in hand for recurring damages or disruptions.

In conclusion, hurricanes occur frequently, and firms of all sectors are affected. Companies may not be able influence the likelihood of a disaster such as a natural catastrophe, but they are advised to actively manage hurricane risk to reduce the impact on their organisation.

7.2.2 Hurricane Risk Preparation Needs to Be Sector-specific

The results showed that firms of all industrial sectors suffered negative effects from hurricane incident announcements, mostly in form of a transitory function. As the stock price reactions differ between sectors, this indicates that specific preparation is required depending on the company's sector. Given the industry of a company, its management can anticipate, by using the results in this thesis, in order to estimate the extent, directionality and pattern of reaction for their company, dependent on its sector. This shows that, depending on the industry, investors have a different expectation of how severe or lasting the damage is.

Companies from the sectors of consumer non-durables, capital goods, and basic industries, and consumers themselves, are highly likely to have a negative stock price effect, indicating that especially these companies need to (pro)actively manage hurricane risk. The higher proportion of step functions of capital goods companies and also consumer non-durables show that several investors expect severe longer-term damage. Therefore, companies from these sectors need to be especially prepared. Two sectors showed more positive than negative reactions, i.e., the healthcare and the durables sectors, meaning that these must be least concerned.

This section shows that companies from all sectors need to manage hurricane risk; however, the preparation needs to be sector-specific.

7.2.3 Firms Should Focus on Managing Supply Chain Disruptions

Major SCDs, and major and minor other damage, cause mostly negative stock price reactions. The strong negative reactions indicate that shareholders see severe SCDs and generally other damage if minor or major as failure and punish the company accordingly, which is reflected in the stock price.

Just minor SCDs lead mostly to positive reactions. This should be an incentive for boards and senior management to focus on SCRM efforts. Investors solely reward for a functioning SCRM that prevents more severe disruptions and reduces SCDs from major to minor. By doing so companies able to reduce the SCD to a minor one, are likely to obtain mostly positive stock price reactions. Results indicate that proper SCRM decisions and efforts are valued. Even if these preventive measures lead to minor disruptions, such as preventive closures of production facilities, this does not seem to be punished by investors. As there was rarely a reaction, it seems that investors expect such measures as part of a proactive SCRM and therefore rarely react. This encourages supply chain managers to take preventive measures, even when these lead to a temporary disadvantage, to prevent worse damage, as well as encouraging boards and senior management to condone these preventive measures.

To summarise this section: Firms should focus their efforts on managing supply chain disruptions and do not need to be afraid of being punished by investors or closing down production sites as a mitigation measure.

7.2.4 Firms Need to Communicate Transparently

Not just SCRM but also corporate communication has an effect on the stock price reaction. This thesis assists listed firms in assessing their investors' reaction to different types of publicly available hurricane and hurricane incident information, given their industrial sector and timeframe. Not only that, but the results also provide the boards, communication departments and supply chain managers with which depth of information the market appreciates. Firms that are providing just the necessary, i.e., mandatory, information are punished by shareholders because the less information they have, the higher their uncertainty.

This thesis shows that investors do not just react to hurricane incident announcements that contain information on the damage to a firm, but also to hurricane announcements that are not related to a firm. At the point of a hurricane announcement, i.e. a hurricane warning or landfall, no firm is damaged yet, even though investors react to uncertainty.

If a company is not affected it might also communicate to reduce its investors' uncertainty. If hurricane announcements such as a hurricane warning or landfall are announced and at that point no company was damaged, the company might communicate its level of preparation for the hurricane. If the hurricane announcements are at a point where the hurricane has occurred, the company might communicate as soon as possible to their investors. It is sufficient when a hurricane is announced in the geographic proximity of a production site for the stock price to drop because shareholders are afraid of potential damage. Therefore, a company is advised to provide a negative announcement, if they are not affected, so their investors know. If a company is affected, it is advised to include detailed information in the hurricane announcement to reduce the investors' uncertainty and thereby have a less negative stock price reaction. Investors value a high level of detail and transparency on the actual damage in hurricane incident announcements and penalize a lack of transparency.

Overall, firms need to communicate in a transparent manner to reduce shareholders' uncertainty and build trust.

8 Limitations and Further Research Directions

This thesis applies a two-step approach consisting of the ARIMA Model and an ITSA to address the research question: “What are the effects of supply chain disruptions due to hurricanes on stock price?” There are limitations due to the available data, the research approach and the model itself, as well as general limitations and assumptions for this thesis. The timeframe for the regression analysis is tied (anchored) to the event date determined by the first hurricane incident announcement for a firm or the hurricane-related points in time and timeframes.

8.1 Limitations of the Data

The analysed intervals are one year prior to and one year after the anchor. Information may not be available for the entire chosen timeframe because the company just joined the NYSE, left the index or went through a merger or acquisition in that period. If the company data were available for less than 10% of the timeframe they were excluded as up until then the data can still be modelled well. Furthermore, the data of many companies (625 companies) were analysed to ensure that the results are meaningful. An initial analysis is performed on the availability of NYSE index and the respective stock price information (Figure 42 and Figure 43). The NYSE information for 2014-2018 and one year before and after is covered (Figure 32). In Section A of Figure 42, the timeframes of hurricanes are marked to demonstrate the necessity for a deeper analysis due to seasonality, for example. A causal relationship between each hurricane and Index performance cannot be established based on this data. Hurricanes often (especially in 2017) occur in proximity and therefore the stock price impact might not be completely separable. An overview of the sampling of firms based on the available stock price information is provided. Firms that did not provide enough stock price information (less than 10%) have been excluded. 95% of announcing firms and 92% of the non-announcing firms provide sufficient information and are therefore included in the subsequent analyses making bias or incompleteness of information unlikely (Figure 43). Data limitations were that in the technology sector there were just 10 companies in scope. The analysis of announcing firms

that had an interruption was providing too low a number of firms per sector, which makes the observations less reliable. This thesis is limited to the information disclosed. Firms might have not reported minor impact as it is voluntary for them - in contrast to firms with major impact. Therefore, the number of companies that suffer minor effect events go unreported. Firms also might not have provided information on damage, impact or preventive closures. Therefore, these events also go unreported and may be underestimated as factors.

8.2 Limitations of the Model

ARIMA models can be underpowered and susceptible to a false estimation of temporal patterns if the sampling period is too short and/or irregular (Box and Tiao, 1975). However, this is not an issue with the given outcome variable 'stock price' because the closing value on each trading day is measured per company during 2 months before the interruption. These provide up to 250 observations per announcement.

8.3 Limitations of the Research Approach

This thesis is a quantitative study that provides an indication of the correlation between hurricanes and stock price. It does not provide insights into the reactions of other firm performance aspects. The model also cannot deliver the evaluation of causal mechanisms. I spent the first 1.5 years attempting to access companies to study in-depth the financial and operational data of companies affected by hurricanes; however, the collection of a sufficient amount of data was not possible. Companies would reject talking about it or providing data as they felt as if they had failed and were concerned that talking about it might damage their reputation.

8.4 Outlook/Further Research

There are various possibilities for further research. This chapter is divided into two parts: 8.4.1 Further research that can be conducted with the current dataset and 8.4.2 Further research that requires additional data collection.

8.4.1 Further Research that can be Conducted with Current Dataset

8.4.1.1 Hurricane Announcement vs. Hurricane Incident Announcement per Industry

An analysis that was not conducted in thesis because it would have required significantly more computational power is testing the effect of the factor industrial sector (hypothesis 2) also for hurricane announcements. The analysis could be done as a next research step. The results could provide insights regarding the differences between how firms of different sectors react to different hurricane announcements such as a hurricane warning.

8.4.1.2 Announcing vs. Non-Announcing Firms per Sector (Manufacturing)

The above additional analysis of testing the industrial sector hypothesis (H2) per industrial sector would also enable another analysis: the comparison between announcing vs. non-announcing firms per hurricane announcement type per industrial sector.

8.4.1.3 Effect of Natural Disaster Incident Announcements on Stock Price

Data on all natural disaster incident announcements for the timeframe of five years was collected. All hypotheses could be tested for disaster incident announcements overall without further breaking them down into the different natural disaster types. A further breakdown into the disaster types with the data set is unfortunately not advised as there is insufficient data available to quantitatively analyse the disaster incident announcements per disaster type (apart from hurricanes).

An analysis of disaster announcements for overall natural disasters was not possible. Here, for hurricanes, the selected disaster announcements (hurricane announcements) were: hurricane warning, hurricane landfall etc. These points in

time are dependent on the disaster type (and also if the disaster can be anticipated), therefore disaster announcements of different disaster types can hardly be compared.

8.4.1.4 Testing the Influence of the Announcement Statement Type, Content or Source

The current dataset might allow researchers to test if the announcement statement type, content, or source influences the stock price effect. Obviously before conducting the analysis relevant research must be reviewed to have a sufficient base for the hypothesis.

8.4.2 Further Research that Requires Additional Data Collection

8.4.2.1 Identify other Potentially Influencing Factors

Additional potential influencing factors could be identified from the literature. It would make sense to test the ones where the previous research does not agree, the factors have not been statistically tested yet and the necessary data for statistical testing is available.

8.4.2.2 Comparing the Effects of Natural Disaster Incident Announcements on Stock Price between Markets for Firms of all Sectors

For further research potentially other interesting stock markets can be identified. The timeframe of five years seemed to be quite suitable; however, it is advised to collect the most recent data available (five years). Data for firms of all industrial sectors of the selected stock exchanges can be collected (not just from different types of manufacturing firms, as in this thesis). The effect of natural disaster incident announcement on stock price can be analysed per market and for all hypotheses generated in this thesis. Comparisons between the results from the different markets might provide insights on cultural differences, especially with regard to the perception of subjective risk. The increased population by not just including different types of manufacturing firms, might provide different insights and comparisons such as a comparison between manufacturing and logistics firms, and companies that do not have a significant supply chain.

8.4.2.3 Finding and Comparing the Effects of Natural Disaster Incident Announcement per Natural Disaster Type between Markets

This is an analysis that can be conducted with the data collected for the analysis described in Chapter 8.4.2.1. In this analysis it is advised to undertake a descriptive analysis for the natural disaster incident announcements per selected market. The purpose of these analyses is to find out which are the most dominant disasters per market which is a valuable insight in itself. Furthermore, this descriptive analysis is highly relevant to identify for which disaster type there is enough data to conduct a quantitative analysis. All hypotheses deduced in this thesis can be tested. If different markets allow the analysis for the same disaster type, a comparison can be made of all hypotheses.

8.4.2.4 Explore if there is Sufficient Data on Man-made Disasters Overall to Conduct Quantitative Analysis

Man-made disasters are different from natural disasters in many ways and this makes them partially more difficult to analyse in this context. Man-made disasters often span a longer timeframe. The most analysed man-made disaster is the terror attack on 9/11 that affected markets around the world. However, generally terror attacks are not significant enough to affect supply chains in a relevant manner. An interesting and growing area is that of cyber attacks directly targeting companies. The effects of cyber attacks on companies could be analysed and compared if enough data are found per stock exchange. Other man-made disasters that could be analysed are the effect of wars because fewer wars are happening, therefore it is advisable to analyse one war and analyse the effect of different announcements. One highly relevant example that will be elaborated on further is the current Ukraine war.

Two specific recent examples that would be highly relevant to research are given below:

8.4.2.5 COVID

The COVID_19 pandemic is probably the greatest natural disaster of the century, with global consequences, affecting all countries around the world. COVID was and still is a major threat to supply chains around the world. Studies could be

conducted to analyse for example the effect of globally relevant announcements. They could for example compare how the different markets react to one global announcement, e.g., from the WHO or UN, or on an announcement that reveals a new high of global infections or global death tolls. There could be analyses done per market on which announcement types, sources or content had the biggest effect. This could possibly also be compared between countries.

8.4.2.6 Ukraine War

The most significant man-made disaster in recent history is the Ukraine war, both the war itself and its consequences for the energy supply of various countries. The effect of announcements related to the war could be tested for various markets around the world (especially the European and Asian markets). This could include announcements such as major statements by Putin, the declaration that it is a war, involvement in the war of certain countries, announcements of penalties for Russia, major Russian conquests, or energy supply. There could be analyses done per market on which announcement types, sources or content had the biggest effect. This could possibly also be compared between countries. A comparison between countries dependent on Russia's energy supply and the ones that are not could also be made.

In summary, this thesis research methodology can be used to obtain many insights on disasters and disaster-induced supply chain disruptions globally especially if additional data are collected.

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APPENDICES

Appendix A Supply Chain Disruption Classification

The first column shows the dimension of the supply chain; the second column shows the exact occurrence; in the third and fourth columns classification and academic literature references are provided.

Table 24. *Supply Chain Disruption Classification (Source: Author)*

Classified by	Term used	Classification used	Reference
Risk Source (also called Responsibility / primary source)	Supply Chain Glitch	Internal, Customers, Suppliers, Others, Internal and supplier, Internal and customer, Internal and others, Customer and supplier, Supplier and other, Customer and other, None provided (the other category includes government, regulatory, and nature as sources of responsibility)	Hendricks and Singhal (2005)
	Supply chain vulnerability	Demand side, Supply Side, Supply chain structure	Wagner and Neshat (2012)
	Supply Chain Disruption	Internal, External, Natural Disaster	Macdonald and Corsi (2013)
	Disruption	Company-internal, customer-downstream, Supplier-upstream, Other). Internal: supply chain, External: Environmental	Kumar et al. (2015)
	Supply Chain Disruption	Internal, Supplier, Customer, Nature and Government	Hendricks and Singhal (2008)
	Supply Chain Disruption	Internal, external	Thun and Hoenig (2011)
	Supply Chain Disruption	internal sources, customers, suppliers. Other sources including multiple sources of responsibility, no source indicated.	Hendricks and Singhal (2009)
Risk Cause	Supply Chain Glitch	Internal, Customers, Suppliers, Others, Internal and supplier, Internal and customer, Internal and others, Customer and supplier, Supplier and other, None provided The other category includes government, regulatory and nature as sources of responsibility.	Hendricks and Singhal (2003)
	Supply Chain Disruption	Parts shortages, Ramping up and rollout problems, Order changes by customers, Various production problems, Development and engineering changes, Quality problems, Weather-related problems, Capacity and equipment problems, Information technology problems, Regulatory approval delays, Project and program delays, Construction problems, Reorganization delays, None provided	Hendricks and Singhal (2005)
	Supply Chain Disruption	Shortage, Customer-order related, Capacity, Production and planning, Quality, Product recalls, Financial, Infrastructure, Natural events, Worker issues, Others	Filbeck et al. (2016)
	Supply Chain Disruption	Parts Shortage, Changes by Customers, Production Problems, Ramp/roll-out Problems, Development Problems, Quality Problems	Hendricks and Singhal (2008)
	Supply Chain Disruption	Disruption due to parts shortages. Disruption due to order changes by customers. Disruption due to production problems. Disruption due to ramp-up and roll out problems. Other reasons and no reason given.	Hendricks and Singhal (2009)
	Supply Chain Glitch	Parts shortages, Order changes by customers, Production problems, Ramping up and rollout problems, Quality problems, Development and engineering changes, Weather related problems, Capacity and equipment problems, Information technology problems, Regulatory approval delays, Project and program delays, Construction problems, Reorganization delays, Cash and financial problems, None provided.	Hendricks and Singhal (2003)
	Supply Chain Disruption	Demand Side Supply Side Regulatory Legal and Bureaucratic Infrastructure Catastrophic Supply	Wagner and Bode (2008)
Disrupted Flow	Supply Chain Disruption	Demand-Side risks, Regulatory, legal and bureaucratic risks, Supply-Side risks, Infrastructural risks, Catastrophic risks	Zsidisin et al. (2016)
	Supply Chain Disruption	information flow, material flow, financial flow	Swierczek (2016)
Primary Location	Supply Chain Disruption	Supplier – upstream, Internal – company, Customer – downstream, Other	Filbeck et al. (2016)
By duration	Supply Chain Disruption	independent discrete disruptions/ dependent disruption, continuous disruption, complete disruption	Masih-Tehrani et al. (2011)
Others	Supply Chain Risk	Disruption, delays, system risk	Birkie (2016)
	Supply Chain Risk	Deviation, disruption, disaster	Dong (2006)
	Supply chain resilience	Turbulence, Deliberate Threats, External Pressures, Resource Limits, Sensitivity, Connectivity, and Supplier/Customer Disruptions.	Petit et al. (2013)

Appendix B Details on Event-related Factors

Details on Impact

NYSE listed firms have to disclose information on an ongoing basis: Annual reports on Form 10-K, quarterly reports on Form 10-Q and certain special events on Form 8-K and various other disclosure requirements.

The annual report Form 10-K provides an overview of the company's business and financial condition and audited financial statements (SEC, 2009). The form includes sections that require the firm to report on risk factors (Item 105 of Regulation S-K, § 229.105, Rule 421(d) of the Securities Act of 1933 (§230.421(d)) and market risk (SEC). The form requires quantitative and qualitative disclosures about market risk in item 7A (required by Item 305 of Regulation S-K, § 229.305).

Form 10-Q comprises unaudited financial statements and includes a continuing view of the company's financial position throughout the year and needs to be filed for the first three quarters of each year. Companies have to provide information on risk factors and information on any material changes on these as previously disclosed in the registrant's Form 10-K (§ 249.310). Companies also need to provide qualitative and quantitative information about market risk (305 of Regulation S-K § 229.305).

Form 8-K requires firms to report on a number of specified events (SEC, 2012). The form provides some event categories but basically has to be used by firms in the case of any material event, which would have a significant impact on the balance sheets, e.g. a major hurricane incident.

All SEC filings are publicly available in the SEC's EDGAR database.

Additionally, to the filings that have to be provided to the US regulator SEC, firms have to provide an annual report to the shareholders (SEC, 2014). This annual report tends to have a lower level of depth compared to the annual report that has to be submitted to the SEC. This report tends to include an opening letter from the Chief Executive Officer, financial data, results of operations, market

segment information, new product plans, subsidiary activities, and research and development activities on future programmes.

Another announcement of a major impact is the force majeure statement (Lexology, 2020). Since 9/11 many firms include force majeure clauses in their third-party contracts. These clauses define circumstances beyond the company's control inhibiting or even precluding fulfilment of contractual obligations. In these cases, firms may suspend, defer, or be released from their contractual duties without liability (BakerMcKenzie, 2020). Force majeure events can be grouped into economic force majeure, social force majeure and terrorist acts, and natural and technological disasters (Caporale and Makarenko, 2019). There are regulations on the timeliness to send such notice e.g. for sales of goods (N.Y. U.C.C. § 2.616; Cal. Com. Code § 2616; Tex. Bus. & Com. Code § 2.616; Fla. Stat. § 672.616). Punishments for non-compliance range from a waiver to delisting of the company. The contract interpretation is defined in the respective State law of the companies' headquarters. This results in jurisdictions varying in their treatment of such clauses. Negative returns were observed for most force majeure events on the day of the event, and for technological disasters up to ten days (Caporale and Makarenko, 2019).

Another case of major impact might be if companies hold back dividends to recover from natural disasters, e.g. the company Vale used their dividends to repair damage from a disaster in 2019 (Financial Times, 2019).

Details on Actual Damage

Examples are halted traffic due to flooded roadways and damaged infrastructure, suspended rail service and air traffic, closures of regional shipping terminals, ports and airports. These hurricane damages (especially flood damages) often result in major disruptions to procurement or distribution, leading to chaotic supply chains due to extra shipments and lower productivity. The supply chain disruptions may occur at the company itself, while transporting procured goods to the firms, or finished goods from the firm, or might even be external supply

chain disruption at a supplier. Generally, it is possible to distinguish between direct damages that are caused, e.g. by flooding in the affected areas, and indirect damage that consists of damage and costs outside of the flooded area, e.g. temporary buildings required that are outside the flooded area (Sebastian et al., 2017).

Details on Preventive Closure

Preventive closures are defined as closures of companies or infrastructure that are not due to actual damages. In the literature it is also often referred to as evacuation. “Evacuation is defined as the process of alerting, warning, deciding, preparing, departing and (temporarily) holding people, animals, personal belongings and corporate stock and supplies from an unsafe location at a relatively safer location given the actual circumstances.” (Sebastian et al., 2017). “(Evacuation) describes the complex interplay between formal evacuation decisions by the emergency management authorities and adoption of these instructions by local population and organizations.” (Sebastian et al., 2017). Evacuations serve the primary purpose of reducing loss of life (DeYoung et al., 2016). Evacuations can be classified depending on their temporal and spatial (Kolen, 2013) relationship to the threat, information used for the decision and the costs and benefits. In the case of hurricanes, the moment of onset of the evacuation and flood, the destination of evacuation (outside or inside of the flood zone) and the relationships with the first responders are examples of the defining characteristics of evacuations. Before the expected onset, it is a threat-driven response. This is based on the warning and results in preventive or vertical evacuation. After the expected onset of flood, it is an event-driven response, i.e., after and during exposure to flood. There are advised (voluntary) and mandated (i.e. ordered) evacuation/preventive closures. Evacuations are usually local depending on specific risks and circumstances (Sebastian et al., 2017). Evacuation decisions vary geographically.

Companies often close production facilities in the advent of hurricanes (Sebastian et al., 2017). If mandatory evacuation is not required, the decision to evacuate is

made by each firm depending on their own values, local circumstances and information at hand (DeYoung et al., 2016). Often companies evacuate before preventive evacuation was mandated or advised (voluntary). However, evacuations cost money, so companies need to balance risk mitigation to protect people and equipment and paying out money.

For major disasters such as hurricanes the government as well as companies take preventive measures such as preventive closures. Whereas this may be limited to adding shutters to your private home (DisasterSafety.org), the protection of entire communities requires flood prevention and closing of infrastructure. Individual companies have to close their own facilities either as part of a government issued preventive measure or because these structures are more vulnerable during normal operation or damage of the facilities if kept in operation would endanger the environment, workforce or other surrounding facilities. Examples of avoidable damages due to operations can be found in the scientific reports of hurricanes.

During hurricanes critical infrastructure is evacuated to limit damage. This might be communication, roads, shipping terminals and airports (Sebastian et al., 2017). The decision regarding which infrastructure is to be closed and when, is outside the control of companies forcing them to adjust their supply chain accordingly, if the firm is still operating.

Appendix C Figures showing Impact of Natural Disasters

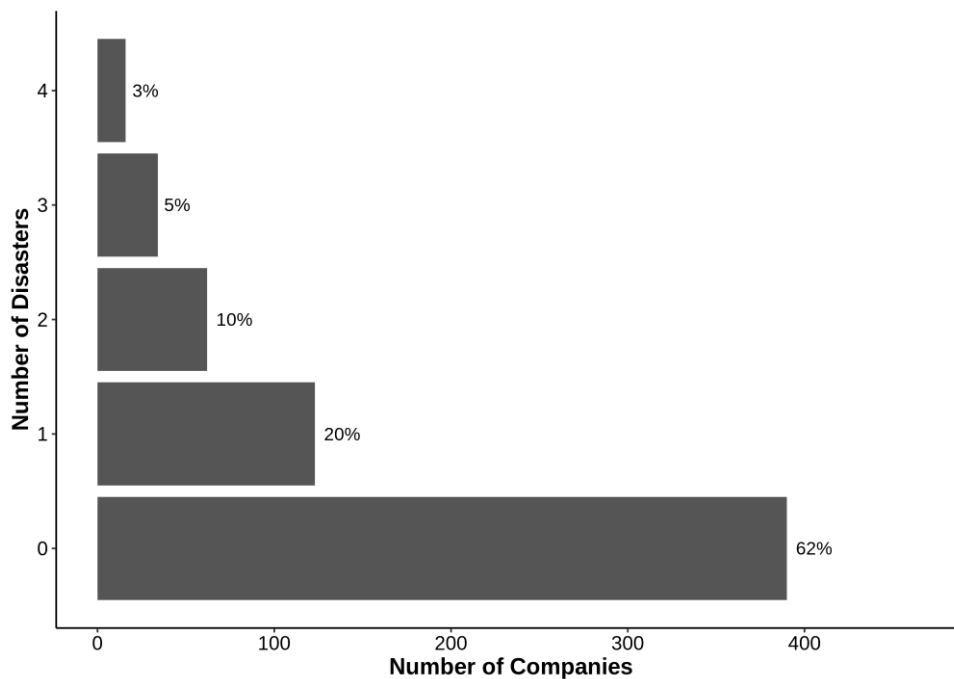


Figure 71. *Number of Announced Natural Disaster Incidents per Company (Source: Author)*

The number of announced natural disaster incidents per firm are shown on the y-axis. Per numerical category of reported natural disaster incidents, a bar graph shows the number of companies both as a percentage next to the bar representing the proportion of the companies and as an absolute number as shown on the x-axis.

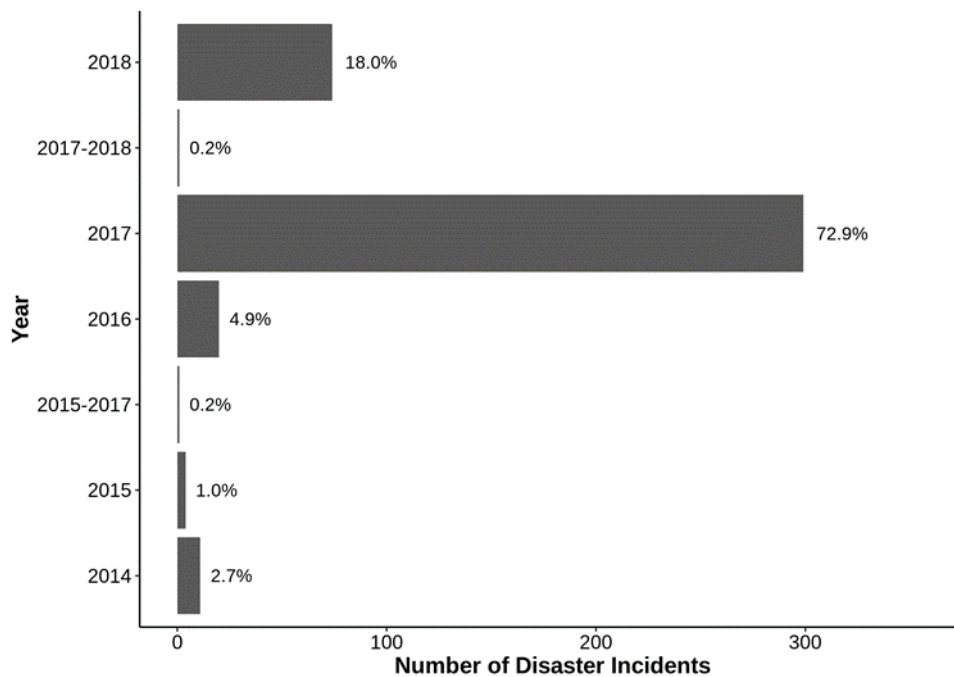


Figure 72. *Number of Announced Natural Disaster Incidents per year in 2014-2018*
(Source: Author).

The calendar year of incidents sorted chronologically is shown on the y-axis. There are spans of calendar years when required to cover incidents reported over timespans of more than one calendar year, i.e. droughts. Per year or years' timespan the bar graph shows the number of natural disaster incidents both as a percentage next to the bar representing the proportion of natural disaster incidents and as an absolute as shown on the x-axis.

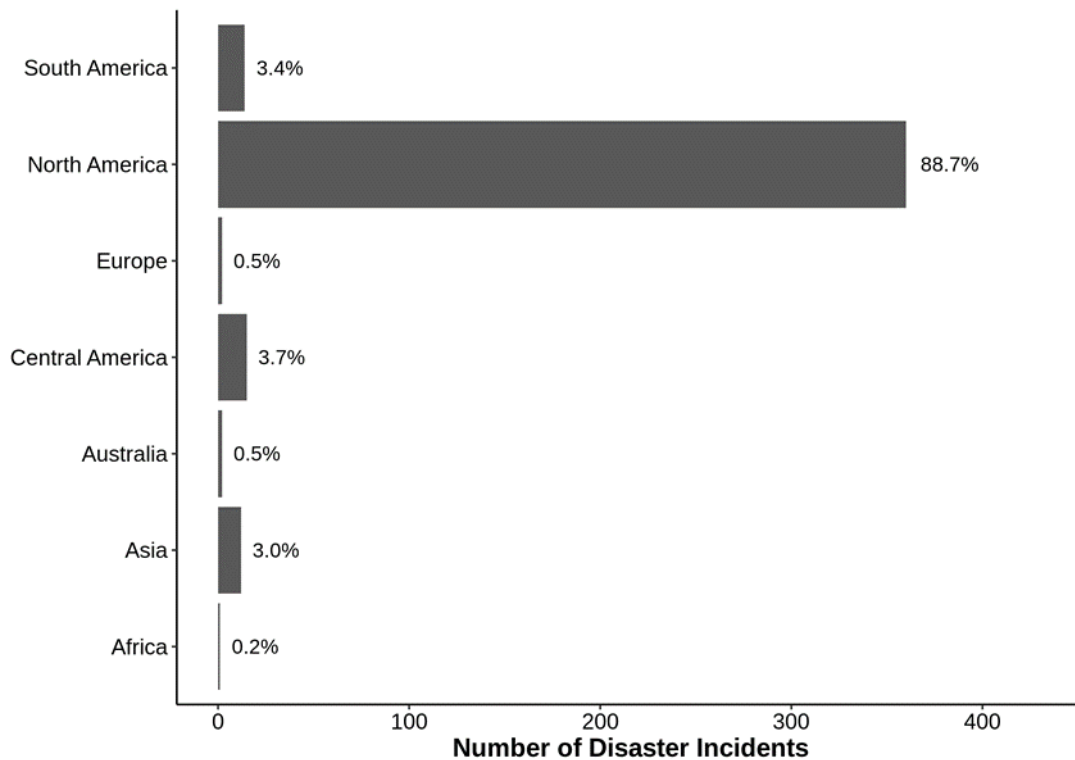


Figure 73. *Number of Announced Natural Disasters per Geographic Region in 2014-2018 (Source: Author)*

The continent where the natural disaster incident occurred is shown on the y-axis. Per continent bar graphs show the number of natural disaster incidents next to the bar representing the proportion of natural disaster incidents and as an absolute as shown on the x-axis.

Appendix D Introduction to ARIMA

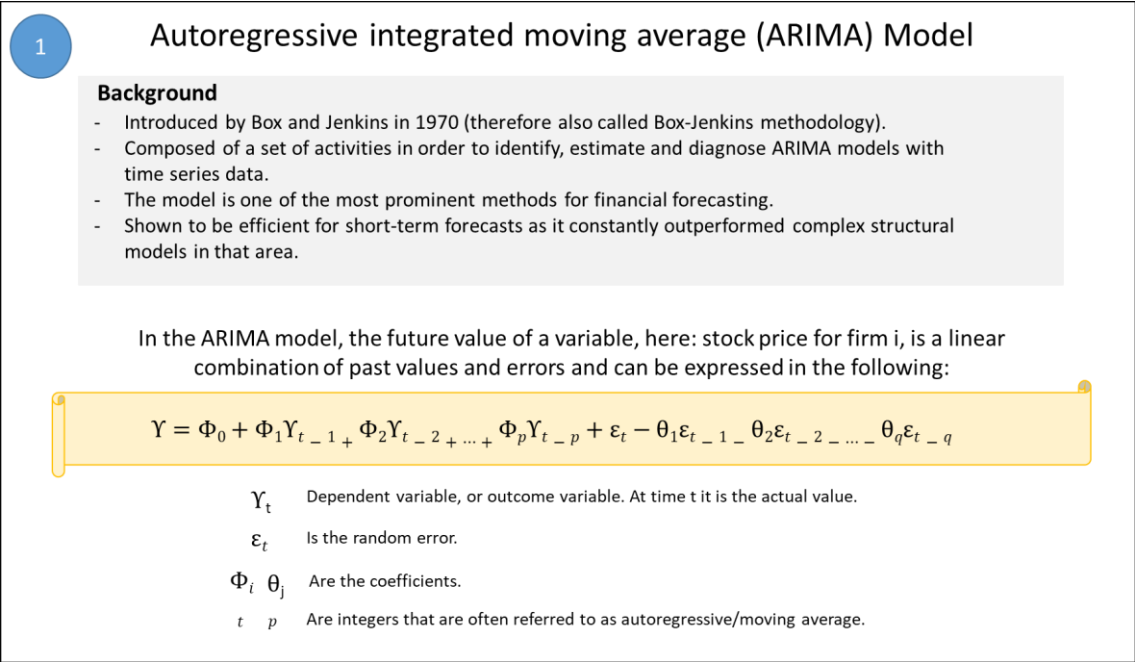


Figure 74. Introduction to ARIMA (Source: Author)

The schematic provides the background for the ARIMA model, below which the equation and its variables are displayed (for details on the model formulation see Box and Jenkins, 1970).

Appendix E Model Fitting and Selection Procedure

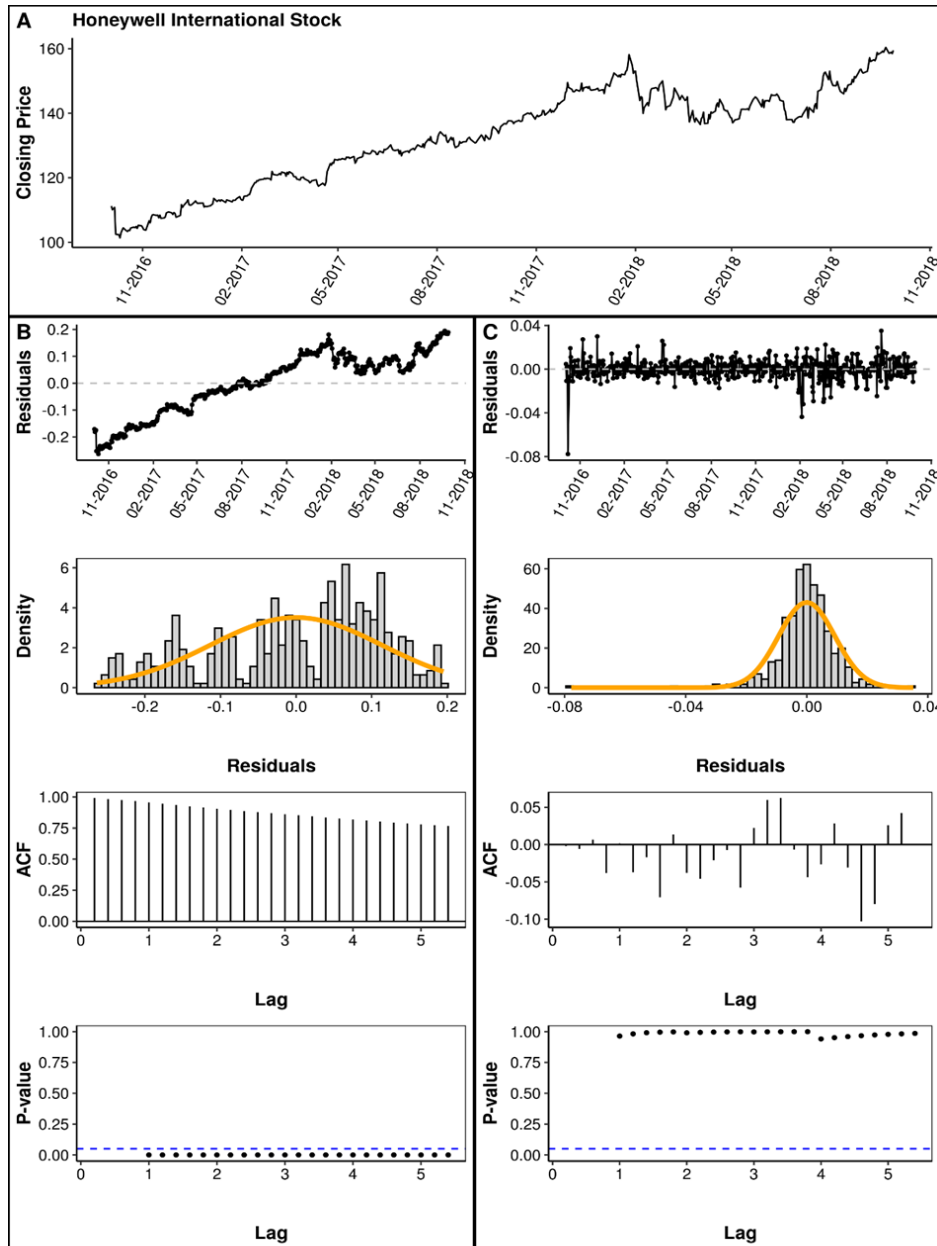


Figure 75. An overview of the model fitting and selection procedure (Source: Author)

This figure provides an overview of the model fitting and selection procedure and is illustrated with the stock price of the firm Honeywell International Inc. listed at the New York Exchange (Figure 75 A). The residuals in the linear model on the left follow a trend revealing autocorrelation (Figure 75 B,C). The residuals in the ARIMA model fluctuate around 0 with constant variance (C). The second graph

reveals that the residuals of the ARIMA model follow a normal distribution, thereby fulfilling the model assumption of normally distributed, homoscedastic errors in contrast to the errors of the simple linear model (Figure 75 C). Lastly, the Autocorrelation Function (ACF) should show no correlation between time lags and if fluctuations occur these should be close to zero without clear patterns. The residuals of the simple linear regression model show a strong correlation, even for large lag values and the Ljung-Box Test reveals that these correlations are significant (Figure 75 B). On the other hand, the autocorrelation function of the ARIMA has far smaller correlation values and based on the Ljung-Box Test, one can reject the hypothesis of autocorrelation (Figure 75 C).

Appendix F Origin of Hurricane Incident Announcement

Industry NYSE	ID	Company	Hurricane	Hurricane Incident Announcement Date	Statement	Info origin	Hurricane-related information
Health Care	ABBV	AbbVie Inc.	Maria	09.10.17	Company Statement	Company	Update on hurricane impact
Health Care	ABC	AmerisourceBergen Corporation	Harvey	19.09.17	Company Press Release	Company	Update on hurricane impact
Health Care	ABC	AmerisourceBergen Corporation	Irma	19.09.17	Press Release	Company	Update on hurricane impact
Health Care	ABC	AmerisourceBergen Corporation	Maria	05.10.17	News Article	Bloomberg	Update on hurricane impact
Consumer Non-Durables	ABEV	Ambev S.A. American Depositary Shares (Each representing 1 Common Share)	Harvey	01.03.18	Company Annual Results	Company	Announcement of Impact on financial statements
Consumer Non-Durables	ABEV	Ambev S.A. American Depositary Shares (Each representing 1 Common Share)	Irma	01.03.18	Quarterly and Annual Report	Company	Announcement of Impact on financial statements
Health Care	ABT	Abbott Laboratories	Maria	22.09.17	Damage Announcement	Startribune verified by Company	Confirmation of Damage
Consumer Durables	AIT	Applied Industrial Technologies, Inc.	Maria	17.08.18	Annual Report	Company	Announcement of hurricane impact
Capital Goods	ALV	Autoliv, Inc.	Harvey	26.10.18	Quarterly Report	Company	Announcement of Impact on financial results
Basic Industries	APD	Air Products and Chemicals, Inc.	Harvey	26.10.17	Quarterly Report	Company	Announcement of Impact on financial results
Health Care	APT	Alpha Pro Tech, Ltd.	Florence	05.11.18	Quarterly Report	Company	Announcement of Impact on financial results
Consumer Durables	ASH	Ashland Global Holdings Inc.	Harvey	01.09.17	Press Release	Company	Announcement of hurricane impact
Basic Industries	ASIX	AdvanSix Inc.	Florence	02.11.18	Quarterly Report	Company	Announcement of Impact on financial results
Basic Industries	ASIX	AdvanSix Inc.	Harvey	07.11.17	Quarterly Reports	Company	Announcement of Impact on financial results and operations
Basic Industries	ASIX	AdvanSix Inc.	Irma	07.11.17	Quarterly Reports	Company	Announcement of Impact on financial results and operations
Basic Industries	ATI	Allegheny Technologies Incorporated	Florence	23.10.18	Quarterly Report	Company	Announcement of Impact on financial results and operations

Consumer Non-Durables	ATR	AptarGroup, Inc.	Florence	02.11.18	Quarterly Report	Company	Announcement of Impact on financial results and operations
Consumer Non-Durables	ATR	AptarGroup, Inc.	Harvey	13.09.17	Investment analyst assessment	NASDAQ	Potential hurricane impact on financial statements
Basic Industries	AVD	American Vanguard Corporation (\$0.10 Par Value)	Harvey	05.11.18	Quarterly Report	Company	Announcement of Impact on financial results
Basic Industries	AVD	American Vanguard Corporation (\$0.10 Par Value)	Florence	05.11.18	Quarterly Report	Company	Potential hurricane impact on financial statements
Basic Industries	AVD	American Vanguard Corporation (\$0.10 Par Value)	Michael	05.11.18	Quarterly Report	Company	Potential hurricane impact on financial statements
Basic Industries	AVD	American Vanguard Corporation (\$0.10 Par Value)	Irma	05.11.18	Quarterly Report	Company	Potential hurricane impact on financial statements
Consumer Non-Durables	AXE	Anixter International Inc.	Harvey	24.10.17	Quarterly Report	Company	Announcement of Impact on financial results
Consumer Non-Durables	AXE	Anixter International Inc.	Irma	24.10.17	Quarterly Report	Company	Potential hurricane impact on financial statements
Basic Industries	AXTA	Axalta Coating Systems Ltd.	Harvey	05.09.17	Press release	Company	Announcement of response on hurricane
Consumer Durables	AYI	Acuity Brands Inc (Holding Company)	Maria	04.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Durables	AYI	Acuity Brands Inc (Holding Company)	Irma	04.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Durables	AYI	Acuity Brands Inc (Holding Company)	Harvey	04.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Durables	AZZ	AZZ Inc.	Harvey	25.09.17	Press release	Company	Announcement of Impact on financial statements and adjustment of earnings outlook
Consumer Durables	AZZ	AZZ Inc.	Irma	25.09.17	Press release	Company	Announcement of Impact on financial statements and adjustment of earnings outlook

Capital Goods	BA	Boeing Company (The)	Florence	11.09.18	Press Release	Company	Announcement of preventive closure
Basic Industries	BAK	Braskem SA ADR	Harvey	28.03.18	Annual Report and Management Report	Company	Announcement of Impact on financial statements and operations
Health Care	BAX	Baxter International Inc.	Maria	28.09.17	News Article	Dow Jones Newswires	Update on Hurricane impact
Consumer Durables	BC	Brunswick Corporation	Irma	27.09.17	Interview	Company	Update on Hurricane impact
Health Care	BCR	C.R. Bard, Inc.	Maria	02.11.17	Annual report	Company	Announcement of Impact on financial statements and operations
Health Care	BDX	Becton, Dickinson and Company	Maria	27.09.17	News article	Industry news	Update on Hurricane Impact
Health Care	BDXA	Becton, Dickinson and Company	Maria	27.09.17	News article	Industry news	Update on Hurricane Impact
Consumer Non-Durables	BERY	Berry Global Group, Inc.	Harvey	29.08.17	News article	Industry news	Update on Hurricane Impact
Consumer Durables	BMS	Bemis Company, Inc.	Maria	26.10.17	Quarterly Statement	Company	Announcement of Impact on financial results
Consumer Durables	BMS	Bemis Company, Inc.		26.10.17	Quarterly Statement	Company	Announcement of Impact on quarterly report
Consumer Durables	BMS	Bemis Company, Inc.		26.10.17	Quarterly Statement	Company	Announcement of Impact on quarterly report
Consumer Durables	BMS	Bemis Company, Inc.		26.10.17	Quarterly Statement	Company	Announcement of Impact on financial statements
Health Care	BMY	Bristol-Myers Squibb Company	Maria	25.09.17	News Article	Reuters.com	Update on Hurricane Impact
Miscellaneous	BRK.A	Berkshire Hathaway Inc.	Harvey	03.11.17	Quarterly Report	Company	Announcement of Impact on financial results and operations
Miscellaneous	BRK.A	Berkshire Hathaway Inc.	Maria	03.11.17	Quarterly Report	Company	Announcement of Impact on financial results and operations
Miscellaneous	BRK.A	Berkshire Hathaway Inc.	Irma	03.11.17	Quarterly Report	Company	Announcement of Impact on financial results and operations
Miscellaneous	BRK.B	Berkshire Hathaway Inc. New	Harvey	03.11.17	Quarterly Report	Company	Announcement of Impact on financial results and operations

Miscellaneous	BRK.B	Berkshire Hathaway Inc. New	Maria	03.11.17	Quarterly Report	Company	Announcement of Impact on financial results and operations
Miscellaneous	BRK.B	Berkshire Hathaway Inc. New	Irma	03.11.17	Quarterly Report	Company	Announcement of Impact on financial results and operations
Basic Industries	BRSS	Global Brass and Copper Holdings, Inc.	Maria	02.11.17	Quarterly Report	Company	Announcement of Impact on financial results and operations
Health Care	BSX	Boston Scientific Corporation	Maria	26.10.17	Quarterly Report	Company	Announcement of Impact on financial results and operations
Health Care	BSX	Boston Scientific Corporation	Harvey	26.10.17	Quarterly Report	Company	Announcement of Impact on financial results and operations
Health Care	BSX	Boston Scientific Corporation	Irma	26.10.17	Quarterly Report	Company	Announcement of Impact on financial results and operations
Consumer Non-Durables	BUD	Anheuser-Busch Inbev SA Sponsored ADR (Belgium)	Harvey	26.10.17	Quarterly Report	Company	Announcement of Impact on financial results
Consumer Non-Durables	BUD	Anheuser-Busch Inbev SA Sponsored ADR (Belgium)	Irma	26.10.17	Quarterly Report	Company	Announcement of Impact on financial results
Health Care	BVX	Bovie Medical Corporation	Harvey	02.11.17	Quarterly Report	Company	Announcement of Impact on financial results and update of earning expectations
Health Care	BVX	Bovie Medical Corporation	Irma	02.11.17	Quarterly Report	Company	Announcement of Impact on financial results and update of earning expectations
Consumer Non-Durables	CAL	Caleres, Inc.	Irma	21.11.17	Quarterly Report	Company	Announcement of Impact on financial results
Consumer Non-Durables	CAL	Caleres, Inc.	Maria	21.11.17	Quarterly Report	Company	Announcement of Impact on financial results
Consumer Non-Durables	CAL	Caleres, Inc.	Harvey	21.11.17	Quarterly Report	Company	Announcement of Impact on financial results
Capital Goods	CAT	Caterpillar, Inc.	Florence	17.09.18	News Article	News	Update on Hurricane Impact
Capital Goods	CBI	Chicago Bridge & Iron Company N.V.	Harvey	25.09.17	News Article	News	Announcement of permanent closure of facility due to hurricane

Basic Industries	CC	Chemours Company (The)	Florence	13.09.18	News Article	Industry News	Announcement of Planned shutdown of facilities
Basic Industries	CC	Chemours Company (The)	Harvey	02.11.17	Quarterly Report	Company	Announcement of Impact on financial results
Consumer Durables	CCF	Chase Corporation	Harvey	30.10.17	Annual Report	Company	Announcement of Impact on financial results and operations
Consumer Durables	CCK	Crown Holdings, Inc.	Florence	04.01.19	Research Report	Independent Investment Research Firm	Research Report on Impact on financial report
Consumer Durables	CCK	Crown Holdings, Inc.	Michael	04.01.19	Research Report	Independent Investment Research Firm	Research Report on Impact on financial statements
Basic Industries	CE	Celanese Corporation Series A	Harvey	29.08.17	Company Announcement	Company	Announcement of Impact on financial results
Consumer Services	CHS	Chico's FAS, Inc.	Harvey	21.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
				28.11.18	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Services	CHS	Chico's FAS, Inc.	Maria	21.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Services	CHS	Chico's FAS, Inc.	Irma	21.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	CLW	Clearwater Paper Corporation	Harvey	03.10.17	Press Release	Company	Announcement of Impact on financial statements
Basic Industries	CLW	Clearwater Paper Corporation	Irma	03.10.17	Press Release	Company	Announcement of Impact on financial statements
Basic Industries	CMC	Commercial Metals Company	Harvey	03.01.18	Earnings Call	Company	Announcement of Impact on financial statements in Earnings Call
Basic Industries	CMC	Commercial Metals Company	California Wildfire	03.01.18	Earnings Call	Company	Announcement of Impact on financial statements in Earnings Call

Basic Industries	CMC	Commercial Metals Company	Irma	03.01.18	Earnings Call	Company	Announcement of Impact on financial statements in Earnings Call
Health Care	CMD	Cantel Medical Corp.	Harvey	02.10.17	Statement of CEO	Company	Announcement of minimal operational disruption
Health Care	CMD	Cantel Medical Corp.	Irma	02.10.17	Statement of CEO	Company	Announcement of minimal operational disruption
Consumer Services	CMG	Chipotle Mexican Grill, Inc.	Harvey	24.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Services	CMG	Chipotle Mexican Grill, Inc.	Irma	24.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	CMI	Cummins Inc.	Harvey	30.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	CMI	Cummins Inc.	Irma	30.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Health Care	COO	Cooper Companies, Inc. (The)	Maria	10.10.17	Press Release	Company	Update on Manufacturing Facilities in Puerto Rico
Consumer Non-Durables	COT	Cott Corporation	Harvey		Press Release	Company	Update on Hurricane Harvey and Irma Effect
Consumer Non-Durables	COTY	Coty Inc. Class A	Florence	07.11.18	Quarterly Report	Company	Announcement of supply chain disruptions and Impact on financial statements
Capital Goods	CRH	CRH PLC American Depositary Shares	Harvey	21.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	CRH	CRH PLC American Depositary Shares	Irma	21.11.17	Quarterly Report	Quarterly Report	Announcement of Impact on financial statements
Health Care	CRHM	CRH Medical Corporation of Beneficial Interest	Irma	22.10.17	Quarterly Outlook	Company	Announcement of Impact on financial statements
Consumer Non-Durables	CRI	Carter's, Inc.	Harvey	26.10.17	Quarterly Report	Company	Announcement of Impact on financial statements

Consumer Non-Durables	CRI	Carter's, Inc.	Irma	26.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Health Care	CRY	CryoLife, Inc.	Harvey	11.10.17	Press Release	Company	Acquisition announcement of other firm and Announcement of Impact on financial statements
Health Care	CRY	CryoLife, Inc.	Irma	11.10.17	Press Release	Company	Acquisition announcement of other firm and Announcement of Impact on financial statements
Consumer Services	CSS	CSS Industries, Inc.	Harvey	07.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Services	CSS	CSS Industries, Inc.	Irma	07.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	CSTM	Constellium N.V. Ordinary Shares	Harvey	30.10.17	Analysis	Investment Firm?	Estimation of positive demand from investment firm
Consumer Durables	CTB	Cooper Tire & Rubber Company	Harvey	30.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Durables	CTB	Cooper Tire & Rubber Company	Irma	30.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Technology	CTS	CTS Corporation	Irma	06.02.18	Quarterly & Annual Report	Company	Announcement of Impact on supply chain
Technology	CTS	CTS Corporation	Maria	06.02.18	Quarterly & Annual Report	Company	Announcement of Impact on supply chain
Capital Goods	CX	Cemex, S.A.B. de C.V. Sponsored ADR	Harvey	30.04.18	Annual Report	Company	Announcement of Impact on financial statements
Capital Goods	CX	Cemex, S.A.B. de C.V. Sponsored ADR	Irma	30.04.18	Annual Report	Company	Announcement of Impact on financial statements
Consumer Non-Durables	DEO	Diageo plc	Irma	08.09.17	Interview	Industry website/ company interview	Announcement of Impact on operations/ buildings
Consumer Non-Durables	DEO	Diageo plc	Maria	26.07.18	Annual Report	Company	Announcement of Impact on

							financial statements
Consumer Non-Durables	DF	Dean Foods Company	Harvey	07.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Non-Durables	DF	Dean Foods Company	Irma	07.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	DHR	Danaher Corporation	Irma	15.11.17	Quarterly Report	Company/ Finance Website/ Interview	Announcement of Impact on financial statements/ operations
Capital Goods	DHR	Danaher Corporation	Maria	15.11.17	Quarterly Report	Company/ Finance Website/ Interview	Announcement of Impact on financial statements/ operations
Consumer Non-Durables	DIT	AMCON Distributing Company	Irma	08.11.17	Quarterly Report	Company	Announcement of Impact on financial statements/ operations
Consumer Non-Durables	DLA	Delta Apparel, Inc.	Matthew	06.02.17	Quarterly Report	Company	Announcement of Impact on financial statements/ operations
Consumer Non-Durables	DLA	Delta Apparel, Inc.	Florence	17.11.18	Quarterly and annual Report	Company	Announcement of Impact on financial statements/ operations
Basic Industries	DOOR	Masonite International Corporation Ordinary Shares (Canada)	Irma	18.09.17	Press Update	Company	Announcement of preventive closure
Consumer Non-Durables	DPS	Dr Pepper Snapple Group, Inc	Harvey	21.09.17	Announcement of lowering of profit forecast for the current fiscal year	Company	Announcement of Impact on financial statements
Consumer Non-Durables	DPS	Dr Pepper Snapple Group, Inc	Mexico Earthquake	21.09.17	Announcement of lowering of profit forecast for the current fiscal year	Company	Announcement of Impact on financial statements
Consumer Non-Durables	DPS	Dr Pepper Snapple Group, Inc	N/A	21.09.17	Announcement of lowering of profit forecast for the current fiscal year	Company	Announcement of Impact on financial statements
Consumer Services	DRI	Darden Restaurants, Inc.	Harvey	26.09.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Services	DRI	Darden Restaurants, Inc.	Irma	26.09.17	Quarterly Report	Company	Announcement of Impact on financial statements

Capital Goods	DRQ	Dril-Quip, Inc.	Harvey	06.09.17	Press release	Company	Announced the resumption of normal operations
Consumer Services	EAT	Brinker International, Inc.	Harvey	01.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Services	EAT	Brinker International, Inc.	Irma	01.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	ECL	Ecolab Inc.	Hurricane	05.09.17	Press release	Company	Announcement of Impact on financial statements and operations
Basic Industries	EMN	Eastman Chemical Company	Harvey	09.10.17	Press release	Company	Announcement of Impact on financial statements
Basic Industries	EMN	Eastman Chemical Company	Irma	09.10.17	Press release	Company	Announcement of Impact on financial statements
Capital Goods	EMR	Emerson Electric Company	Harvey	23.10.17	Press release	Company	Announcement of Impact on financial statements
Capital Goods	EMR	Emerson Electric Company	Irma	23.10.17	Press release	Company	Announcement of Impact on financial statements
Miscellaneous	ENR	Energizer Holdings, Inc.	N/A	15.11.18	Quarterly & Annual Report	Company	Announcement of Impact on financial statements
Consumer Durables	ETH	Ethan Allen Interiors Inc.	Harvey	12.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Durables	ETH	Ethan Allen Interiors Inc.	Irma	12.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	EVA	Enviva Partners, LP Common units representing limited partner interests	Florence	17.09.18	Press Release	Company	Announcement of Impact on financial statements and operations
Basic Industries	EVA	Enviva Partners, LP Common units representing limited partner interests	Michael	15.10.18	Press release	Company	Announcement of Impact on financial statements and operations
Capital Goods	EXP	Eagle Materials Inc	Harvey	25.10.17	Quarterly report	Company	Announcement of Impact on

							financial statements and operations
Capital Goods	EXP	Eagle Materials Inc	Florence	30.10.18	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	FBHS	Fortune Brands Home & Security, Inc.	Florence	25.10.18	Quarterly report	Company	Announcement of Impact on financial statements
Consumer Services	FBM	Foundation Building Materials, Inc.	Harvey	10.11.17	Quarterly report and annual predictions	Company	Announcement of Impact on financial statements and operations
Consumer Services	FBM	Foundation Building Materials, Inc.	Irma	10.11.17	Quarterly report and annual predictions	Company	Announcement of Impact on financial statements and operations
Capital Goods	FCAU	Fiat Chrysler Automobiles N.V.	Harvey	01.11.17	Press release	Company	Announcement of Impact on financial statements
Capital Goods	FCAU	Fiat Chrysler Automobiles N.V.	Florence	02.10.18	Press Release	Company	Announcement of Impact on financial statements
Capital Goods	FLS	Flowserve Corporation	Harvey	02.11.17	Quarterly report	Company	Announcement of Impact on financial statements
Health Care	FMS	Fresenius Medical Care AG	Maria	14.03.18	Annual Report	Company	Announcement of Impact on financial statements
Health Care	FMS	Fresenius Medical Care AG	Puebla Earthquake	14.03.18	Annual Report	Company	Announcement of Impact on financial statements
Health Care	FMS	Fresenius Medical Care AG	Maria	14.03.18	Annual Report	Company	Announcement of Impact on financial statements
Health Care	FMS	Fresenius Medical Care AG	Harvey	14.03.18	Annual Report	Company	Announcement of Impact on financial statements
Basic Industries	FTK	Flotek Industries, Inc.	Harvey	25.09.17	Update on next Quarterly report	Company	Announcement of Impact on financial statements and operations
Basic Industries	FTK	Flotek Industries, Inc.	Irma	25.09.17	Update on next Quarterly report	Company	Announcement of Impact on financial statements and operations

Capital Goods	FTV	Fortive Corporation	Florence	25.10.18	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	FUL	H. B. Fuller Company	Harvey	29.08.17	Press release	Company	Announcement of hurricane impact
Basic Industries	GCP	GCP Applied Technologies Inc.	Harvey	12.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	GCP	GCP Applied Technologies Inc.	Mexico Earthquake	12.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	GCP	GCP Applied Technologies Inc.	Maria	12.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	GCP	GCP Applied Technologies Inc.	Irma	12.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	GD	General Dynamics Corporation	Matthew	07.10.16	Press release , interview	Company	Announcement of impact on operations
Capital Goods	GE	General Electric Company	Florence	17.09.18	Press release , interview	Company	Announcement of impact on operations
Capital Goods	GEB	General Electric Company 4.875% Notes due October 15, 2052	Florence	17.09.18	Press release , interview	Company	Announcement of impact on operations
Consumer Services	GHC	Graham Holdings Company	Harvey	01.11.17	Quarterly report	Company	Announcement of Impact on financial statements
Consumer Services	GHC	Graham Holdings Company	Irma	01.11.17	Quarterly report	Company	Announcement of Impact on financial statements
Consumer Non-Durables	GIL	Gildan Activewear, Inc. Class A Sub. Vot.	Florence	01.11.18	Quarterly report	Company	Announcement of Impact on financial statements
Basic Industries	GLW	Coming Incorporated	Florence	17.09.18	Press release , interview	Company	Update on hurricane impact on operations
Consumer Durables	GNRC	Generac Holdings Inc.	Harvey	01.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Durables	GNRC	Generac Holdings Inc.	Irma	01.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Durables	GPK	Graphic Packaging Holding Company	N/A	23.10.18	Quarterly Report	Company	Announcement of Impact on

							financial statements
Basic Industries	GRA	W.R. Grace & Co.	Harvey	25.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	HMC	Honda Motor Company, Ltd.	Harvey	02.10.18	News Article, interview	Investment Website	Article on sales impact
Consumer Non-Durables	HOG	Harley-Davidson, Inc.	Harvey	05.09.17	Article	Wealth Management Company	Article on sales impact of disruptions
Capital Goods	HON	Honeywell International Inc.	Harvey	20.10.17	Article on different firms	Interview with company/ press release	Announcement of Impact on share price
Capital Goods	HON	Honeywell International Inc.	Irma	20.10.17	Interview, press release	Interview with company/ press release	Announcement of Impact on share price
Technology	HPE	Hewlett Packard Enterprise Company	Harvey	01.11.17	news article	Interview/ press release	Article on change of
Technology	HPQ	HP Inc.	Harvey	01.11.17	news article	Interview/ press release	Article on change of
Health Care	HRC	Hill-Rom Holdings Inc	Maria	11.10.17	press statement	Company	Update on hurricane damage
Technology	HRS	Harris Corporation	Irma	07.09.17	Press statement	Company	Announcement of preventive closure
Capital Goods	HUBB	Hubbell Inc	Harvey	15.11.17	News article	Interview with company	News article on restoration
Capital Goods	HUBB	Hubbell Inc	Maria	15.11.17	News article	Interview with company	News article on restoration
Capital Goods	HUBB	Hubbell Inc	Irma	15.11.17	News article	Interview with company	News article on restoration
Basic Industries	HUN	Huntsman Corporation	Harvey	28.08.17	Press release	Company	Update on Hurricane Impact
Capital Goods	HY	Hyster-Yale Materials Handling, Inc. Class A	Matthew	01.03.17	Quarterly Report	Company	Announcement of Impact on financial statements
Health Care	HYH	Halyard Health, Inc.	Harvey	12.09.17	Investor conference	Company	Announcement of Impact on operations
Capital Goods	HZN	Horizon Global Corporation	N/A	31.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations

Basic Industries	IP	International Paper Company	Harvey	15.09.17	Press release	Company	Announcement of Impact on financial statements and operations
Basic Industries	IP	International Paper Company	Florence	18.09.18	Press Release	Company Interview	Announcement of operational damage
Basic Industries	IP	International Paper Company	Irma	26.09.17	Industry Article	Industry	Announcement of Impact on financial statements and operations
Capital Goods	IR	Ingersoll-Rand plc (Ireland)	Maria	25.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Technology	ITW	Illinois Tool Works Inc.	N/A	24.10.18	Quarterly Report	Company	Announcement of Impact on financial statements
Health Care	JNJ	Johnson & Johnson	Harvey	17.10.17	Quarterly Report/ Earnings call/ interview	Company	Announcement of Impact on financial statements and operations
Health Care	JNJ	Johnson & Johnson	Maria	17.10.17	Quarterly Report/ Earnings call/ interview	Company	Announcement of Impact on financial statements and operations
Health Care	JNJ	Johnson & Johnson	Irma	17.10.17	Quarterly Report/ Earnings call/ interview	Company	Announcement of Impact on financial statements and operations
Capital Goods	KEM	KEMET Corporation	Irma	06.09.17	Press Release	Company	Announcement of Office Closure
Basic Industries	KMG	KMG Chemicals, Inc.	Harvey	01.09.17	Press Release	Company	Announcement of Impact on operations
Consumer Services	KR	Kroger Company (The)	Harvey	29.08.17	Press Release	Company	Announcement of store closures
Basic Industries	KRA	Kraton Corporation	Harvey	25.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	KRA	Kraton Corporation	Michael	15.10.18	Press Release; Interview	PR Newswire	Update on hurricane impact
Basic Industries	KRA	Kraton Corporation	Irma	25.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Durables	KS	KapStone Paper and Packaging Corporation	Florence	23.10.18	Quarterly Report	Company	Announcement of Impact on financial

							statements and operations
Consumer Durables	KS	KapStone Paper and Packaging Corporation	Michael	18.10.18	Press Release	Company	Update on Hurricane Impact
Consumer Durables	KS	KapStone Paper and Packaging Corporation	Matthew	07.02.18	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	LBY	Libbey, Inc.	N/A	31.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	LBY	Libbey, Inc.	N/A	31.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	LGL	LGL Group, Inc. (The)	Irma	21.03.18	Quarterly and annual Report	Company	Announcement of Impact on financial statements
Health Care	LLY	Eli Lilly and Company	Maria	29.09.17	News article	Company interview	Announcement of hurricane impact
Consumer Services	LOW	Lowe's Companies, Inc.	Florence	11.09.18	News article	News article, company interview	Announcement of Impact on sales
Consumer Services	LOW	Lowe's Companies, Inc.	N/A	21.11.17	News Article	Media, company interview	Announcement of Impact on financial statements
Consumer Services	LOW	Lowe's Companies, Inc.	N/A	21.11.17	News Article	Media, company interview	Announcement of Impact on financial statements
Basic Industries	LPX	Louisiana-Pacific Corporation	Florence	20.09.18	Press Release	Company	Announcement of mill closure
Basic Industries	LYB	LyondellBasell Industries NV Ordinary Shares Class A (Netherlands)	Harvey	28.08.17	News article, press release	News. Company press release	Announcement of shutdown of facilities
Basic Industries	MAS	Masco Corporation	Harvey	24.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	MAS	Masco Corporation	Maria	24.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	MAS	Masco Corporation	Irma	24.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	MPX	Marine Products Corporation	Irma	25.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations

Basic Industries	MLM	Martin Marietta Materials, Inc.	Harvey	02.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	MLM	Martin Marietta Materials, Inc.	Florence	06.11.18	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	MLM	Martin Marietta Materials, Inc.	Irma	02.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	MLM	Martin Marietta Materials, Inc.	Matthew	02.11.16	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	MTZ	MasTec, Inc.	Florence	02.11.18	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	MTZ	MasTec, Inc.	Michael	02.11.18	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Capital Goods	MDR	McDermott International, Inc.	Harvey	25.02.19	Quarterly and Annual report	Company	Announcement of Impact on financial statements
Consumer Services	MCD	McDonald's Corporation	Harvey	05.09.17	Article by investment firm	Investment firm	Estimation of Impact on financial statements
Consumer Services	MCD	McDonald's Corporation	Irma	05.09.17	Article by investment firm	Investment firm	Estimation of Impact on financial statements
Health Care	MDT	Medtronic plc. Ordinary Shares	Maria	06.10.17	Press Release	Company	Update on hurricane impact
Basic Industries	MOS	Mosaic Company (The)	Irma	11.09.17	Press Release	Company	Announcement of Hurricane Impact
Consumer Non-Durables	MYE	Myers Industries, Inc.	N/A	28.02.19	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	NCS	NCI Building Systems, Inc. New	Harvey	07.09.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Non-Durables	NKE	Nike, Inc.	Matthew	07.10.16	News Article	News, information from Nike	Announcement of preventive closure

Basic Industries	NPO	EnPro Industries Inc	Harvey	30.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	NPO	EnPro Industries Inc	Irma	30.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Health Care	NVS	Novartis AG	Florence	13.09.18	Industry Article	Industry Association, company information	Update on Hurricane Preparations
Consumer Non-Durables	NWL	Newell Brands Inc.	Harvey	06.09.17	Press Release	Company	Announcement of Impact on financial statements
Capital Goods	NX	Quanex Building Products Corporation	Harvey	13.09.17	Press Release	Company	Update on Hurricane Preparations
Capital Goods	NX	Quanex Building Products Corporation	Florence	12.12.18	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	OCIP	OCI Partners LP Common Units representing Limited Partner Interests	Harvey	06.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	OEC	Orion Engineered Carbons S.A	Harvey	02.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Durables	OI	Owens-Illinois, Inc.	Harvey	05.12.17	Press Release	Company	Announcement of Impact on financial statements
Consumer Durables	OI	Owens-Illinois, Inc.	Irma	05.12.17	Press Release	Company	Announcement of Impact on financial statements
Capital Goods	OII	Oceaneering International, Inc.	Michael	15.10.18	Press Release	Company	Update on Hurricane Impact
Basic Industries	OLN	Olin Corporation	Harvey	31.08.17	Press Release	Company	Declaration of Force Majeure
Basic Industries	OMN	OMNOVA Solutions Inc.	Harvey	28.09.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	OMN	OMNOVA Solutions Inc.	Irma	28.09.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations

Consumer Non-Durables	OXM	Oxford Industries, Inc.	Matthew	19.10.16	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Non-Durables	OXM	Oxford Industries, Inc.	Irma	05.12.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Non-Durables	OXM	Oxford Industries, Inc.	Harvey	05.12.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Non-Durables	PF	Pinnacle Foods, Inc.	Harvey	27.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Non-Durables	PF	Pinnacle Foods, Inc.	Irma	27.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Health Care	PFE	Pfizer, Inc.	Maria	25.09.17	Article	Pharma	Confirmation of plant damage
Health Care	PFE	Pfizer, Inc.	Florence	11.09.18	Press Release	Company	Announcement of operations shutdown prior hurricane
Consumer Durables	PGEM	Ply Gem Holdings, Inc.	Harvey	06.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Durables	PGEM	Ply Gem Holdings, Inc.	Irma	06.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Capital Goods	PGTI	PGT Innovations, Inc.	Irma	12.09.17	Business News Article	Information from company	Update on Hurricane Damage and Relief efforts
Consumer Durables	PKG	Packaging Corporation of America	Florence	25.11.18	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Technology	PNR	Pentair plc. Ordinary Share	Florence	23.10.18	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Technology	PNR	Pentair plc. Ordinary Share	Harvey	24.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations

Technology	PNR	Pentair plc. Ordinary Share	Harvey	24.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	POL	PolyOne Corporation	Harvey	26.01.18	Quarterly and Annual Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	PPG	PPG Industries, Inc.	Harvey	25.09.17	Press Release	Company	Update on hurricane and announcement of financial damage
Basic Industries	PPG	PPG Industries, Inc.	Mexico Earthquake	25.09.17	Press Release	Company	Update on hurricane and announcement of financial damage
Basic Industries	PPG	PPG Industries, Inc.	Maria	25.09.17	Press Release	Company	Update on hurricane and announcement of financial damage
Basic Industries	PPG	PPG Industries, Inc.	Irma	25.09.17	Press Release	Company	Update on hurricane and announcement of financial damage
Basic Industries	PQG	PQ Group Holdings Inc.	Harvey	08.09.17	Press Release	Company	Update on hurricane impact
Consumer Services	PRTY	Party City Holdco Inc.	Harvey	09.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Services	PRTY	Party City Holdco Inc.	Irma	09.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Non-Durables	REED	Reeds, Inc.	Harvey	05.12.17	Stock exchange news	Stock Exchange	Announcement of Impact on financial statements
Consumer Non-Durables	REED	Reeds, Inc.	Irma	05.12.17	Stock exchange news	Stock Exchange	Announcement of Impact on financial statements
Consumer Non-Durables	REV	Revlon, Inc. New	Harvey	03.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Non-Durables	REV	Revlon, Inc. New	Irma	03.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	RFP	Resolute Forest Products Inc.	Irma	02.11.17	Quarterly Report	Company	Announcement of Impact on financial statements

Basic Industries	RPM	RPM International Inc.	Harvey	04.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	RPM	RPM International Inc.	Maria	04.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	RPM	RPM International Inc.	Irma	04.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	RYAM	Rayonier Advanced Materials Inc.	Matthew	10.10.16	Press Release	Company	Announcement of resuming operations
Basic Industries	RYAM	Rayonier Advanced Materials Inc.	Irma	08.09.17	Press Release	Company	Announcement of preventive closure
Basic Industries	RYI	Ryerson Holding Corporation	Harvey	28.09.17	Press Release	Company	Announcement of Impact on financial statements
Basic Industries	RYI	Ryerson Holding Corporation	Irma	28.09.17	Press Release	Company	Announcement of Impact on financial statements
Consumer Durables	SAH	Sonic Automotive, Inc.	Harvey	11.10.17	Press Release	Company	Hurricane and Earnings Update
Consumer Durables	SAH	Sonic Automotive, Inc.	Irma	11.10.17	Press Release	Company	Hurricane and Earnings Update
Consumer Services	SHW	Sherwin-Williams Company (The)	Harvey	28.09.17	Press Release	Company	Announcement of impact on financial statements and adjustment of expectations
Consumer Services	SHW	Sherwin-Williams Company (The)	Maria	28.09.17	Press Release	Company	Announcement of impact on financial statements and adjustment of expectations
Consumer Services	SHW	Sherwin-Williams Company (The)	Irma	28.09.17	Press Release	Company	Announcement of impact on financial statements and adjustment of expectations
Basic Industries	SKY	Skyline Corporation	Florence	10.12.18	Investment Report	Investment Website	Announcement of Hedgefund interest
Basic Industries	SKY	Skyline Corporation	Michael	10.12.18	Investment Report	Investment Website	Announcement of Hedge Fund interest
Consumer Durables	SON	Sonoco Products Company	Harvey	18.10.17	Quarterly Report	Company	Announcement of Impact on financial

							statements and operations
Consumer Durables	SON	Sonoco Products Company	N/A	18.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Durables	SON	Sonoco Products Company	Maria	18.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Durables	SON	Sonoco Products Company	Irma	18.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Miscellaneous	SPB	Spectrum Brands Holdings, Inc.	N/A	23.11.18	Annual Report	Company	Announcement of Impact on financial statements and operations
Capital Goods	SPR	Spirit Aerosystems Holdings, Inc.	Matthew	01.02.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Technology	SPXC	SPX Corporation	Florence	01.11.18	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Capital Goods	SSD	Simpson Manufacturing Company, Inc.	Florence	29.10.18	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	SSD	Simpson Manufacturing Company, Inc.	Michael	29.10.18	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	SSL	Sasol Ltd. American Depositary Shares	Harvey	31.08.17	Press Release	Company	Announcement of preventive closure
Basic Industries	SSL	Sasol Ltd. American Depositary Shares	Nate	22.11.17	HQ Briefing	Company	Announcement of Impact on financial statements and project
Basic Industries	SSL	Sasol Ltd. American Depositary Shares	Irma	22.11.17	HQ Briefing	Company	Announcement of Impact on financial statements and project
Health Care	STE	STERIS plc Ordinary Shares	Harvey	01.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations

Health Care	STE	STERIS plc Ordinary Shares	Maria	01.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Health Care	STE	STERIS plc Ordinary Shares	Irma	01.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Non-Durables	STZ	Constellation Brands, Inc.	Harvey	05.01.18	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Non-Durables	STZ	Constellation Brands, Inc.	California Wildfire	05.01.18	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Non-Durables	STZ	Constellation Brands, Inc.	Irma	05.01.18	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	SUM	Summit Materials, Inc. Class A	Harvey	30.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	SUM	Summit Materials, Inc. Class A	Florence	06.11.18	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	SUM	Summit Materials, Inc. Class A	Irma	30.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Health Care	SYK	Stryker Corporation	Maria	23.10.17	Industry Article	New York Times	Update on hurricane impact
Basic Industries	SYT	Syngenta AG	N/A	14.02.19	Sustainability Report	Company	Hurricane Effect on Sustainability
Capital Goods	TDY	Teledyne Technologies Incorporated	Harvey	01.02.18	Annual Report	Company	Announcement of Impact on businesses
Consumer Non-Durables	THS	Treehouse Foods, Inc.	Florence	01.11.18	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Non-Durables	THS	Treehouse Foods, Inc.	Michael	01.11.18	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Non-Durables	TPR	Tapestry, Inc.	Harvey	07.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations

Consumer Non-Durables	TPR	Tapestry, Inc.	Typhoon N/A	07.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Non-Durables	TPR	Tapestry, Inc.	Irma	07.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Durables	TPX	Tempur Sealy International, Inc.	Harvey	02.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Durables	TPX	Tempur Sealy International, Inc.	Irma	02.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	TS	Tenaris S.A. American Depositary Shares	Harvey	28.08.17	Press Release	Company	Announcement of preventive evacuation
Basic Industries	TSE	Trinseo S.A. Ordinary Shares	Harvey	12.10.17	Quarterly and Annual Outlook	Company	Announcement of Impact on financial statements
Consumer Non-Durables	TSN	Tyson Foods, Inc.	Florence	13.09.18	Press Release	Company	Announcement of preventive closure
Consumer Non-Durables	TSN	Tyson Foods, Inc.	Irma	11.09.17	Press Release	Company	Announcement of preventive closure
Capital Goods	TTM	Tata Motors Ltd Tata Motors Limited	Irma	08.09.17	Press Release	Company	Announcement of preventive closure
Basic Industries	UFS	Domtar Corporation (NEW)	Florence	13.09.18	Industry Article	Investment Website	Update on Hurricane Damage
Basic Industries	UL	Unilever PLC	Harvey	19.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	UL	Unilever PLC	Irma	19.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Durables	UNVR	Univar Inc.	Harvey	29.08.17	Press Release	Company	Update on Hurricane Impact
Consumer Durables	UNVR	Univar Inc.	Irma	03.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	VMC	Vulcan Materials Company (Holding Company)	Harvey	01.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations

Basic Industries	VMC	Vulcan Materials Company (Holding Company)	Nate	16.02.18	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	VMC	Vulcan Materials Company (Holding Company)	Irma	01.11.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Capital Goods	VMI	Valmont Industries, Inc.	Harvey	18.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Capital Goods	VMI	Valmont Industries, Inc.	Irma	18.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Services	VRTV	Veritiv Corporation	Harvey	07.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Services	VRTV	Veritiv Corporation	Irma	07.11.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	VVV	Valvoline Inc.	Harvey	08.11.17	Quarterly and Annual Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	VVV	Valvoline Inc.	N/A	06.11.18	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	VVV	Valvoline Inc.	Irma	08.11.17	Quarterly and annual Report	Company	Announcement of Impact on financial statements and operations
Capital Goods	WBC	Wabco Holdings Inc.	Matthew	07.10.16	Article	Investment Website, Company information	Update on Hurricane Impact
Consumer Non-Durables	WCC	WESCO International, Inc.	Harvey	26.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Consumer Non-Durables	WCC	WESCO International, Inc.	Irma	26.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	WLK	Westlake Chemical Corporation	Harvey	11.08.17	Quarterly Report	Company	Announcement of Impact on financial

							statements and operations
Capital Goods	WOR	Worthington Industries, Inc.	Florence	26.09.18	Quarterly Report	Company	Announcement of Impact on financial statements
Capital Goods	WOR	Worthington Industries, Inc.	Irma	27.09.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Capital Goods	WOR	Worthington Industries, Inc.	Harvey	27.09.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Consumer Durables	WRK	Westrock Company	Florence	18.09.18	Press Release	Company	Update on Hurricane
Consumer Durables	WRK	Westrock Company	Michael	11.10.18	Press Release	Company	Update on Hurricane
Basic Industries	WST	West Pharmaceutical Services, Inc.	Harvey	26.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	WST	West Pharmaceutical Services, Inc.	Maria	26.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	WST	West Pharmaceutical Services, Inc.	Irma	26.10.17	Quarterly Report	Company	Announcement of Impact on financial statements and operations
Basic Industries	XRM	Xerium Technologies, Inc. New	Harvey	30.10.17	Quarterly Report	Company	Announcement of Impact on financial statements
Basic Industries	XRM	Xerium Technologies, Inc. New	Irma	30.10.17	Quarterly Report	Company	Announcement of Impact on financial statements