Effects of Natural Disasters on the U.S. Stock Market

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ABSTRACT

Natural disasters are unpredictable and uncontrollable by humans and result in huge damage to personal property. Natural disasters have an impact in many areas of the economy, including financial markets. A stock market is a public entity for the trading of company stock (shares) and derivatives at an agreed price. There are now stock markets in virtually every developed and most developing economies, with the world's largest markets being in the United States. When a natural disaster happens, there are many consequences such as destruction of factories, delay or cancellation of the delivery of goods, etc. Therefore if the impact of a natural disaster is large enough, financial markets will be affected. This effect can be direct or indirect. This study will use daily return stock share prices to create portfolios of different sectors of the market to study the effect of natural disasters on different sectors of the market. Also, a correlation study will investigate the correlativity between different sectors in short run after a natural disaster to understand the indirect effects of natural disasters on different sectors of U.S. market.

KEYWORDS

Natural Disaster, Stock Market, Sector Portfolio, Cor-relativity

1 MOTIVATION

The goal of this study is to investigate the effects of natural disasters happened in the U.S. on its financial market. The effects were observed separately on different sectors of the market. This study is designed to discover the patterns of change in different market sectors tracked by S&P 500 and to create a simple portfolio of the highest impacted sector, in order to spot the change caused in that sector due to other sectors during the period of the disaster.

This project also includes a visualization package that enables researchers to select among various natural disasters occurred in the last 10 years and to see different related graphs and test different hypotheses.

2 RELATED WORK

Chen [1] worked on finding relations between the stock performance in Taiwan and the political events in the country. When market-adjusted techniques are applied, seemingly Taiwan's stock market often reacts to the occurrences of political incidents with a significant abnormal price performance. Perveen and Rahman [4] examined the impact of fiscal and monetary policies on the stock prices of the financial sectors of Pakistan. The results showed that those policies have significant impact on the stock prices and can exhibit a positive or negative correlation. For example, money supply and GDP growth rate portray a remarkable positive impact but tax revenues and interest rates show a negative effect on the stock market. Kongprajya [3] investigated the performance of Thai stock exchange with political news. This study proved that returns appear to be negative on the day in which unfavorable news was released and the opposite occurs on the day in which favorable news was released.

These stock market uncertainties also emerge from geopolitical events. Some recently published articles have studied this phenomenon. Tielmann and Schiereck [7] found an overall negative effect of the Brexit referendum on the stock prices of European logistics companies. Schiereck et al. (2016) [5] explained that the change in banks' stock prices can be linked with Brexit and was more substantial than the effect caused due to Lehman's bankruptcy. Seetharam[6] believed that companies' adaptive capacity is a key component determining the extent to which they will be affected by the start of natural disasters. He studied daily U.S. stock data and their reactions to the top 122 natural disasters happened in U.S. from 1980 to 2014. The results showed that affected companies had stock market valuations which were 0.3 to 0.7 percentage points lower than those of unaffected firms. The research estimates the total loss of the exposed companies to be 9 to 22 million dollars while more significant losses appear long after the exact day the disaster happens. Seetharam[6] concludes that the largest negative impacts mostly happen in the window of 6 days before and 20 days after the disaster. Furthermore, koerinadi et al.[2] observe the effects of international natural disasters on their domestic stock market returns and also on different industries' returns. They found that earthquakes, hurricanes and tornadoes are likely to affect the market returns negatively while floods, tsunamis and volcanic explosions are probable to have positive impacts on the market. koerinadi et al.[2] point out that the positive effect might be due to macroeconomics events independent from the disasters or that the disasters are not negatively effective enough to influence the market returns. Overall, the conclusion is natural disasters are likely to affect construction industry positively while they are more probable to affect travel industries negatively. Moreover, the results encourage investors to take long positions in construction and material industries and short positions in travel industries shortly after natural disasters strike.

Our study utilizes beneficial points from each of the related studies mentioned while being dissimilar to every single one of them in several aspects. First, we have used the financial data of U.S. stock market and a data set of natural disasters happened in the U.S., both from 2001 to 2021. Second, we studied three major types of disasters i.e. drought, wildfire and storm. Third, we created a visualization toolkit showing impact of those natural disasters on different sectors and correlation of other sectors with the highest impacted sector. This toolkit also presents different market sectors'

price change in a given time span to help researchers investigate and test their hypotheses more conveniently.

3 PROBLEM DEFINITION

Given a Natural Disaster in the last 10 years, our task is to analyze the impact of that Natural Disaster on the U.S. Stock Market, specifically in the following 2 ways,

(1) By what degree did the Natural Disaster impacted each industry.
(2) For the industry that was impacted the most, what part was played by the other industries on that impact.

The companies listed in the U.S. stock market was clustered into 8 industry groups.

The remainder of the paper is divided as follows, section 4 discusses the datasets we used for the study. Section 5 details the methodology we performed, after which section 6 discusses the Visualization toolkit we developed to provided candid and simple visualizations for our project. Further, section 7 delineates the results we obtained from our study and finally section 8 concludes with additional future work that can be rendered to extend this study. Additionally, in appendix A, additional details regarding the Visualization Toolkit that we developed are presented.

4 DATASETS

There are numerous sources of datasets such as Datahub for stock market value. Moreover, There are various datasets representing natural disasters happened in the U.S. in the past years which can be used to study their effects on the U.S. stock market. emdat provides useful datasets for this purpose.
To understand how natural disasters affect the market, a number of analyses can be done on different datasets to eliminate the effect of how the categories are defined. The general rules should be extendable and verified by different sources of data. However, for our project we took into consideration the following 2 datasets,

(1) Warton CRSP dataset for stock market data
(2) EM-DAT Natural Disaster Dataset

The Warton CRSP dataset is part of the Warton Research Data Service.The Center for Research in Security Prices, LLC (CRSP) which maintains the most comprehensive collection of security price, return, and volume data for the NYSE, AMEX and NASDAQ stock markets. Additional CRSP files provide stock indices, beta-based and cap-based portfolios, treasury bond and risk-free rates, mutual funds, and real estate data. For this project we used last 10 years' daily stock market data using the REST APIs provided by Warton Research Data Service.

Additionally, EM-DAT (Emergency Events Database), is an initiative aimed to rationalise decision making for disaster preparedness, as well as providing an objective base for vulnerability assessment and priority setting. EM-DAT contains essential core data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present. For this project we used the last 10 years' data regarding the Natural Disasters that happened in the U.S.
The datasets being real world datastes contained noise which would had negatively impacted our study. Thus, we took certain steps to clean the datasets as detailed in the section titled Data Preparation.

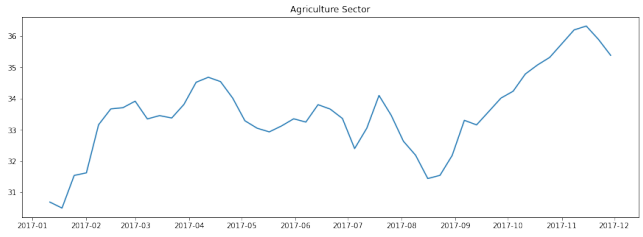

Figure 1: Weekly Return Index for the Agriculture sector for 2017

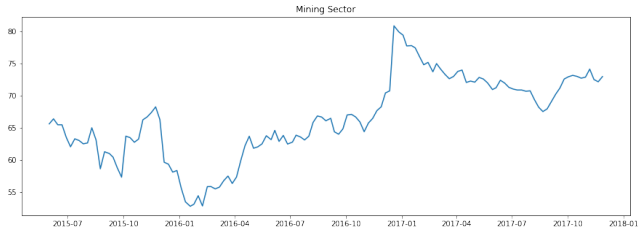

Figure 2: Weekly Return Index for the Mining sector for 2015-2018

5 METHODOLOGY

The methodology included

(1) Data preparation
(2) Creating Portfolios Companies' Industry
(3) Filter the Natural Disasters
(4) Finding the Impact of the Disaster on Different Sectors
(5) Analyzing the correlativity of different sectors with the highest impacted sector

5.1 Data Preparation

For retrieving the Stock Market Data, we utilized the REST APIs provided by Warton Research Data Service. We ran a SQL query on the dataset and stored the relevant daily stock market data for the last 10 years.
The real-world datasets contain noises, missing values and could not be used directly. We firstly processed the data to take care of the noises, missing values and outliers. For processing the data, we initially deleted the rows that had NULL values. Secondly, we extracted the exact data fields that could be used for our analysis. For this study we considered the following attributes,

- date
- siccd
- permno
- ticker
- MarketCap
- prc

Where, ticker is the Symbol Variable Name, siccd is the Standard Industrial Classification Code, permno is the permanent number

assigned to each company that allows us to track each company regardless of name or ticker changes, and prc is the Closing Price.

The daily stock market data includes small companies, whose share price and market capital is low. As part of our study we found that records these companies substantiated to the most amout of noise. Thus, in order to redress this problem, as the next step we filtered the entire dataset to only contain records for companies whose market capital is more than 10 Million Dollars. Doing this effectively decreased the noise present in the dataset. The Market Cap (MC), is defined as follows,

$$MC = PRC \times SHROUT \tag{1}$$

Where, PRC is the Closing Price and SHROUT is Number of Shares Outstanding

For this study we considered the weekly average stock data instead of the daily stock data. Thus, we took the corresponding value of the first day of each week when the stock market is open. Figure 1 and 16 shows the corresponding graphs for the Agriculture and Mining sector for a specific period of time.

We used more than one attributes to be able to conduct this study. Therefore, after preparing each dataset in the previous step, we needed to merge the useful features of each industry group together and create a unified one that enables us to analyse the data and achieve interesting insights which were previously hidden in it.

For the Natural Disaster Dataset, we firstly cleaned the data by deleting the rows that had invalid values in any column. Then we filtered the dataset to get the records for the last 10 years. After which, we extracted the following columns to be used in this study,

- Name
- Disaster Type
- Start Date
- End Date
- Total Adjusted Insured Damages

5.2 Creating Portfolios Companies' Industry

For creating sector portfolios of the companies we used the help of the SICCD code. Standard Industrial Classification Code (SICCD) is used to group companies with similar products or services. The Standard Industrial Classification Manual contains descriptions of categories recognized by the U.S. Government. SIC Code is an integer between 100 and 9999. The first two digits refer to a major group. The first three digits refer to an industry grow up. All four digits indicate an industry. Missing SIC Codes are set to 0. Most Nasdaq SIC codes have only the first three digits; CRSP has added a fourth digit of zero. Using the first two digits we divided the companies into 8 industry sectors, namely,

- agriculture
- mining
- construction
- manufacturing
- transportation
- wholesale
- retail
- public administration

Additionally, we used the weighted (Market Capital) average of stock prices as the sector portfolio return index.

5.3 Filter the Natural Disasters

Firstly we, sorted the Natural Disasters based on the adjusted insured damages. We used the adjusted insured damages instead of the absolute insured damages or total damages because of the following reasons,

(1) Absolute insured damages takes into account the inflation over the years. Thus, it works as a check to effective comparison between the severity of two natural disasters.
(2) Total Damage attribute is an educated guess whereas, Insured damages renders a more accurate measurement of the monetary loss occurred due to the natural disaster than the Total Damage attribute.

Secondly, we grouped the disasters into different disaster types

- Drought
- Wildfire
- Storm
- Flood
- Biological

Finally, we used the start and end date for the duration of analysis on the market.

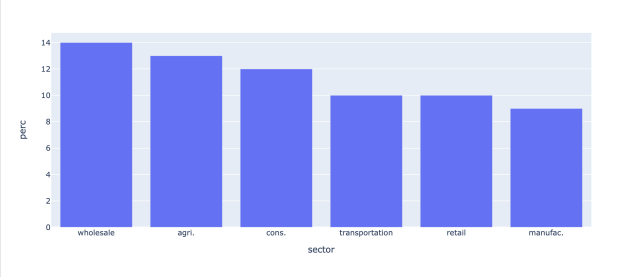

Figure 3: Impact Level of 2021 Storm Ida on Different Sectors of the U.S. Financial Market

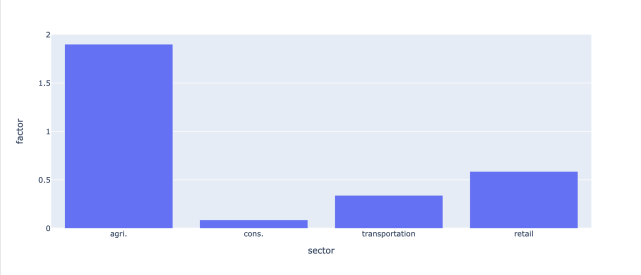

Figure 4: Correlation Factors Between the Wholesale Sector and Other Sectors of the Market After Storm Ida

5.4 Impact of the disaster on different sectors

Given a natural disaster, we tried to find the impact of the considered disaster on different industry sectors. Firstly, we considered the time period t_d as follows,

$$t_d = NaturalDisasterlength + kmonths \quad (2)$$

The buffer period of k months was chosen to be 2, as studies [6] have shown that maximum fluctuation in the stock market occurs in the 20 days window following the disaster.

After which, based on return index for each sector the impact of disaster is calculated with following formula,

$$Impact = \frac{I_{max} - Imin}{I_{max}} \quad (3)$$

Where Imax is the maximum return index of the industry sector during the considered period. and Imin is the relevant minimum return index of the industry sector.

Finally, we plotted the data for each industry sector in a bar chart. The bar charts for different disasters as shown and discussed in the Results section of this paper.

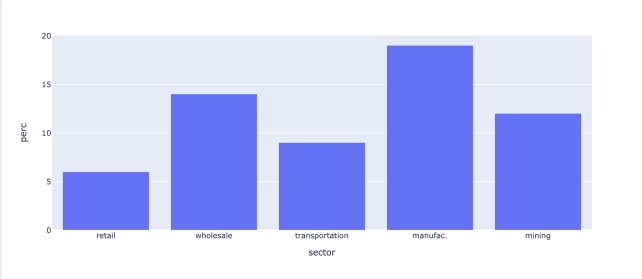

Figure 5: Impact Level of 2012-2013 North America Drought on Different Sectors of the U.S. Financial Market

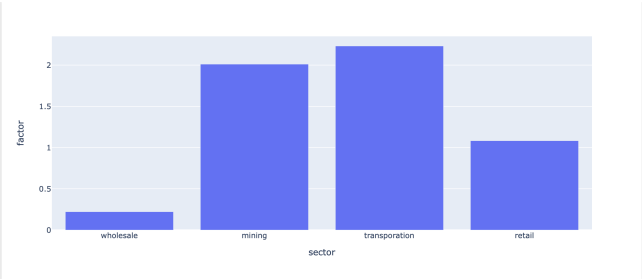

Figure 6: Correlation Factors Between the Manufacturing Sector and Other Sectors of the Market After 2012-2013 Drought

5.5 Correlativity Analysis on the Highest Impacted Sector

Given the highest impacted sector (I), we tried to create a portfolio of the industry in order to study the impact of other industries on sector I. We used linear regression to create the portfolio and then validated the model using the R2 Score. To do this we followed the following steps,

(1) Divided the weekly stock data into two sets, $Dataset_{train}$ and $Dataset_{testing}$.
(2) From $Dataset_{train}$, we considered the dependent variable (Y) as the values of sector I, and the independent variable vector (X) as the weekly stock data of all the other sectors.
(3) We took the set of sectors (S) with the highest correlation coefficients (B).
(4) To verify the model we tested the model with the $Dataset_{testing}$ and checked that the R2 score is reasonable.

Thus, by performing the above steps we created a portfolio of the industry I as follows,

$$I = [B] \times [S] \quad (4)$$

Where, I is the highest impacted sector, S is the set of Industries with the highest correlation coefficient and B is the vector of corresponding correlation coefficients

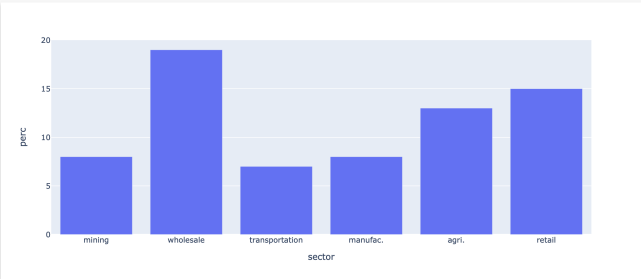

Figure 7: Impact Level of 2017 California Wildfire on Different Sectors of the U.S. Financial Market

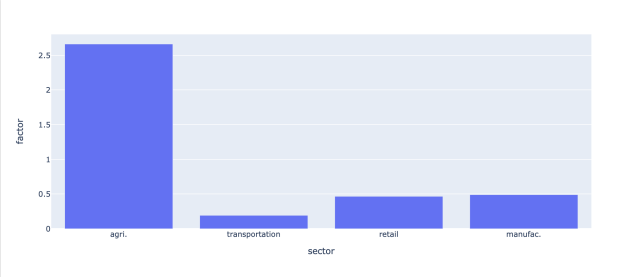

Figure 8: Correlation Factors Between the Wholesale Sector and Other Sectors of the Market After 2017 California Wildfire

6 VISUALIZATION TOOLKIT

Checking hypotheses for researchers can be time consuming task. The process of verifying or rejecting any hypothesis has many steps from preparing and cleaning the data to creating portfolios and running the experiments. This process is more challenging in the

Table 1: Disaster Details for One Example of Drought, Storm, and Wildfire

Disaster Type	Name	Location	Adjusted Insured Damage	Start Date (mm/dd/yyyy)	End Date (mm/dd/yyyy)	Considered End Date (mm/dd/yyyy)
Drought	North America Drought	Illinois	$18.88B	06-01-2012	12-01-2012	02-01-2013
Storm	Tropical Storm 'Ida'	Louisiana	$36.0B	08-26-2021	09-02-2021	11-02-2021
Wildfire	Tubbs, Atlas, Nuns Fires	California	$10.61B	06-01-2017	12-31-2017	03-02-2018

realm of finance and financial market data as the data entries are unpredictable, not cleaned, and nor prepared. There seems to be a need for a proper toolkit that allows researchers to easily get results on some experiments and be able to verify or reject any possible explanation in search of new findings.

Therefore, in order to candidly present our findings, as part of this project we developed a rich Visualization toolkit that can be used to get plots for studies pertaining to the change of the financial market due to a specific natural disaster. This visualization will be specifically useful in determining whether a correlation exists given a hypothesis. Details on how this interactive toolkit is developed and some snapshots from it is included in the Appendix A.

7 RESULTS

Table 1 shows an example for each of the three major natural disaster categories including their type, name, location, adjusted insured damage, start date, end date, considered end date which is 2 months after the actual end date. We have considered 2 months after the end of the disaster to be able to capture all the possible impacts because actual impacts will appear long after a disaster happens as Seetharm[6] mentions as well.

Figure 3 shows the impact the 2021 Storm Ida had on the U.S. stock market. From figure 3, it is evident that the wholesale sector was highly impacted followed by the agriculture and construction sector. From figure 4, we can conclude that the agriculture sector contributed immensely towards the impact of the wholesale sector.

Figure 5 shows the Impact of 2012-2013 North American Drought on the U.S. stock market for different industry sectors. It is evident that the manufacturing sector was impacted the most followed by the wholesale sector. Furthermore, from figure 6, it is evident that mining sector and transportation sector had more contribution towards the change in the manufacturing sector than the wholesale sector's contribution, even though the total impact on the wholesale sector was the 2^{nd} highest. Additionally, the conclusions adheres to the assumption that transportation and mining are more related to manufacturing industry compared to the relation of wholesale industry with the manufacturing industry.

Figure 7 shows the impact the 2017 California Wildfires had on the U.S. stock market. From figure 7, it is evident that the wholesale sector was the highest impacted followed by the retail and agriculture sector. The conclusion is valid based on the assumption that due to Wildfire the agriculture sector was very much devastated which in turn impacted the wholesale sector. From figure 8, it is candid that indeed the agriculture sector played the major role towards the impact in the wholesale sector.

8 CONCLUSIONS AND FUTURE WORK

In this study we studied the impact of U.S. Natural Disasters on U.S. stock market. This study used daily return stock share prices to create portfolios of different sectors of the market to study the effect of natural disasters on different sectors of the market. Also, a correlation study was performed to investigate the correlativity between different sectors in short run after a natural disaster to understand the indirect effects of natural disasters on different sectors of U.S. market. This study can be further extended by considering the following,

- The impact of Natural Disasters occurring in other parts of the world on the U.S. stock market.
- In this study we only considered three major categories of natural disasters i.e. drought, wildfire, and storm. It would be riveting to take other types into account as well.
- This study did not include the impact of companies with lower market capital, thus it would be interesting to analyze the impact such companies can have on the entire sector.
- For this study we only considered the Closing price of the market. In future, we can extend this study to include other important variables in the Stock Market like the Volume Traded, opening price and bid number.

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Figure 9: Visualization Toolkit Header

A VISUALIZATION TOOLKIT DETAILS

For developing this useful toolkit we used the Dash library of Python as the backend service. Dash is a Open Source Python library for creating reactive, Web-based applications. Dash started as a public proof-of-concept on GitHub. Dash is a user interface library for creating analytical web applications. Those who use Python for data analysis, data exploration, visualization, modelling, instrument control, and reporting will find immediate use for Dash. Figure 9 shows the header used in this web app.

The toolkit is interactive, as shown in figure 10. There are 3 selection criteria:

- Disaster Type
- Sectors
- Date Range

With Disaster Type, one can see the examples of impacts of natural disasters on the market. These are pre-calculated analysis done on the market.

Sectors and Date Range will determine the portfolio return index of which industry and for which duration should be drawn. This can help researchers to look into the variations of the market for any period and quickly verify or reject hypotheses. Figures 11, 12, 13, 14, 15, 16, and 17 show the return index figures for 7 different sectors for the duration period of California Wildfire. As shown in these figures, With the help of cursor, one can get the exact value for the return index for every entry.

Thus, the user would be able to select a Natural Disaster type, the date range and the industry sector and would be able to get the corresponding plots to test their hypothesis and perform various studies.

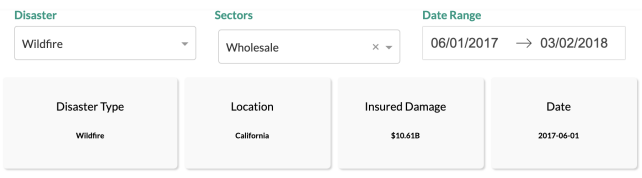

Figure 10: Interactive Selection Menu In Interactive Visualization Toolkit

Figure 11: Retail Weekly Return Index for the Selected Time Period From the Toolkit

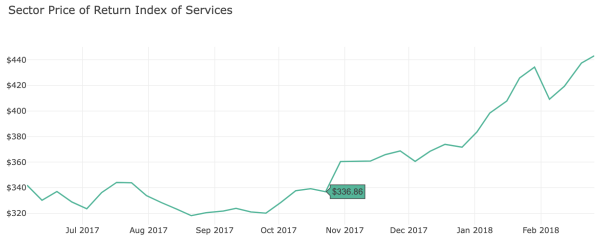

Figure 12: Services Weekly Return Index for the Selected Time Period From the Toolkit

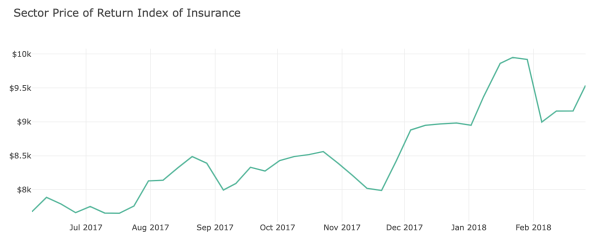

Figure 13: Insurance Return Index for the Selected Time Period From the Toolkit

Figure 14: Wholesale Return Index for the Selected Time Period From the Toolkit

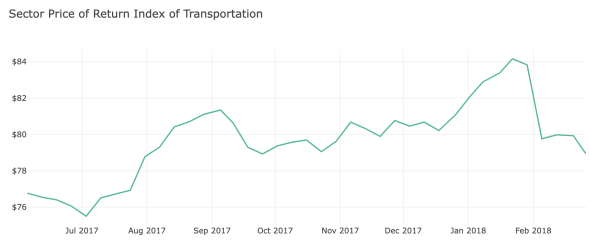

Figure 15: Transportation Return Index for the Selected Time Period From the Toolkit

Figure 16: Mining Return Index for the Selected Time Period From the Toolkit

Figure 17: Manufacturing Return Index for the Selected Time Period From the Toolkit