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THE IMPACT OF COVID-19 ON STOCK PRICES: EVIDENCE FROM THE U.S. STOCK MARKET

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ABSTRACT

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This study examines the impact of the COVID-19 pandemic on the U.S. stock market using event study methodology. The stock markets are divided into two industries: technology and transportation. The effects are studied separately, and the results are compared. The event day selected in this study is the 13th of March 2020, when the national emergency related to COVID-19 was announced in the U.S. The investors' reactions are analysed within the event window, which starts ten days before the event and lasts ten days after the event. Additionally, the sensitivity analysis, which studies how much the event day selection affects the results, is made.

The empirical results of the study show that the COVID-19 impacted stock prices in the U.S. significantly. The technology companies were not affected on the event day, but the average abnormal returns of transportation companies on the event day were significantly negative, -1,636 %. The cumulative average abnormal returns within the event window were 7,662 % for the technology companies and -7,908 % for the transportation companies. So, the technology industry was impacted positively, while the transportation industry was impacted negatively. The sensitivity analysis shows that the event day selection strongly affects the results, which indicates that the event study methodology might not be the best choice for this situation. It was observed that the long duration of the event and the impacts of other events decreases the applicability of event study methodology and, therefore, the reliability of the results of this study.

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Tämä tutkielma tutkii COVID-19 pandemian vaikutuksia osakkeiden hintoihin Yhdysvaltojen osakemarkkinoilla tapahtumatutkimuksen avulla. Osakemarkkinat on jaettu kahteen toimialaan, teknologiaan ja kuljetukseen. Vaikutuksia tutkitaan molemmille toimialoille erikseen, jonka jälkeen tuloksia vertaillaan. Tapahtumapäiväksi on valittu 13 maaliskuuta 2020, jolloin Yhdysvalloissa julistettiin kansallinen hätätila koronavirukseen liittyen. Sijoittajien reaktioita tutkitaan tapahtumaikkunan sisällä, joka alkaa kymmenen päivää ennen tapahtumaa ja päättyy kymmenen päivää tapahtuman jälkeen. Lisäksi herkkyysanalyysi, joka tutkii kuinka paljon tapahtumapäivän valinta vaikuttaa tuloksiin, tehdään.

Tutkimuksen empiiriset tulokset osoittavat, että COVID-19 pandemia vaikutti osakkeiden hintoihin Yhdysvalloissa merkittävästi. Teknologiayritykset eivät olleet vaikutuksen alaisia tapahtumapäivänä, mutta kuljetusyritysten keskimääräiset epänormaalit tuotot olivat tapahtumapäivänä negatiiviset, -1,636 %. Kumulatiiviset keskimääräiset epänormaalit tuotot tapahtumaikkunassa olivat teknologiayrityksille 7,662 % ja kuljetusyrityksille -7,908 %. Teknologia-ala siis hyötyi tilanteesta, kun taas kuljetusala kärsi siitä. Herkkyysanalyysi osoittaa, että tapahtumapäivän valinta vaikuttaa tuloksiin todella paljon, mikä indikoi, että tapahtumatutkimus ei välttämättä olisi paras mahdollinen valinta kyseiseen tilanteeseen. Menetelmän käytön osalta havaittiin, että tapahtuman pitkä kesto sekä muiden tapahtumien vaikutukset vaikeuttavat tapahtumatutkimuksen metodologian soveltamista ja näin heikentävät tämän tutkimuksen tulosten luotettavuutta.

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"A journey well shared is a journey well enjoyed" - Unknown

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On the 18th of May 2021 in Vantaa,
Hanna Fagerholm

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1. INTRODUCTION

The great depression in 1929, Black Monday in 1987, the dot-com bubble burst in 2001, the financial crisis in 2008, and the COVID-19 pandemic in 2020. What is combining these events is the significant and rapid fall of stock prices – a stock market crash. The topic is highly fascinating to both academics and practitioners. From a market efficiency point of view, the only thing that can cause a stock market crash is a disclosure of some new critical information. However, even today's modern analyses cannot entirely explain what information caused the past crashes. There could be one big reason or many reasons affecting at the same time before and during the crashes. Nevertheless, the one thing is known; the stock market crashes are big, the declines in stock prices could be massive, and their effects in financial markets are significant. (Chen 2021; Sornette 2017; Bierman 1998)

This study examines the impact of COVID-19 on the United States stock market. The topic is critical as this was an abnormal situation in stock markets, and its effects could have been substantial. The impact of COVID-19 on stock prices has been studied much in China, but there are also many indications that the effects are global (Liu, Manzoor, Wang, Zhang & Manzoor 2020; Chaudhary, Bakhshi & Gupta 2020; Topcu & Gulal 2020). Mazur, Dang, and Vega (2020) discuss one of the biggest crashes in stock market history.

1.1. Background of the study

Torales, O'Higgins, Castaldelli-Maia, and Ventriglio (2020), and Poudel and Subedir (2020), consider the impact of COVID-19 on mental health. The virus is forcing people to keep social distance, which directly affects physical health. Also, the situation is causing stress, anger, and fear all around the world. The increasing number of COVID-19 cases in medical centres could cause problems in managing other health issues at the same level as before the pandemic. Richards, Anderson, Carter, Ebert, and Mossialos (2020) state that the impact of COVID-19 on cancer care has been significant in many countries. There are delays in diagnoses, the capacity for surgeries has been decreased, and systematic treatment is facing issues. Brewer and Gardiner (2020) studied the impact of COVID-19 on household incomes. The incomes have decreased, and the probability of taking loans has increased during the pandemic.

COVID-19 has impacted society in many ways. Among these effects, it has also impacted businesses and stock prices globally. He, Sun, Zhang, and Li (2020) found that COVID-19 negatively impacted the Chinese stock market. Similarly, Al-Awadhi, Alsaifi, Al-Awadhi, and Alhammadi (2020) noticed that the Chinese stock market was impacted, and traditional industries like traveling were impacted mostly. In turn, the situation brought new opportunities to modern high-tech companies, and the stock prices were positively affected. Shen and Zhang (2020) found that the prices of so-called “stay-at-home” stocks increased during the COVID-19 pandemic while the prices of “go-outside” stocks decreased. Thorbecke (2020) and Baek, Mohanty, and Glambosky (2020) studied the impact of COVID-19 on the U.S. stock market. They found similar results to China; traditional sectors were suffered most, and some modern sectors got benefits. Also, the volatility of the U.S. stock market increased.

1.2. Research questions and hypotheses

This study aims to examine the impact of COVID-19 on the U.S. stock market using event study methodology. The event study methodology focuses on studying the effect of some significant event on stock prices in the short-term (MacKinlay 1997; Wells 2004).

The research questions of the study are:

- *How can stock market crashes be studied using event study methodology?*
- *How can event study methodology use to study the impact of COVID-19 on stock markets? What are the results?*

The study focuses on two different industries, technology and transportation. The impacts are studied differently, and the results are then compared. The event day was set for the 13th of March 2020, when the national emergency related to COVID-19 was announced in the U.S.

According to MacKinlay (1997), the null hypothesis of event studies is that the event has no significant impact on stock prices. Fama (1960) and Malkiel (2003) state that in efficient markets, new information immediately affects stock prices. Thus, when the information of COVID-19 has spread, the impact on stock prices should appear. The previous studies have shown that traditional industries, like transportation, have been more sensitive to the news of COVID-19 than modern industries, like technology, and the differences were significant (He et al. 2020; Al-Awadhi et al. 2020; Thorbecke 2020). Consequently, the first and the second hypotheses of this study are:

H1: COVID-19 positively impacts stock prices in the technology industry.

H2: COVID-19 negatively impacts stock prices in the transportation industry.

Fama (1997), and De Bondt and Thaler (1985), suggest that investors tend to overreact to unexpected news and events. The studies state that the overreaction can cause short-term anomalies, but the anomalies are weak and tend to disappear rapidly in the long run. Based on these findings, the third hypothesis of this study is:

H3: The reactions are high after the event day, but they disappear rapidly within the event window.

1.3. Research method and data

This study implements quantitative research methodology, an event study methodology. The event study examines the short-time behaviour of stock prices around a specific event. The methodology was born with the idea that in efficient capital markets, the effects of a certain event can be seen immediately in stock prices. The study process is quite simple; the first step is to select the event day in which the information of the event has come to the markets. After that, the normal returns are estimated. Once the normal returns are estimated, the abnormal returns can be calculated, and if the abnormal returns occur, these could be linked to the event. The methodology's problem is that it cannot differ the impacts of other events; other events could also cause abnormal returns of the stocks during the same period. (MacKinlay 1997; Wells 2004; Kothari & Warner 2007)

To perform an event study, the information of the event is needed. As COVID-19 is a pandemic and information about it has come in many parts, the event day selection is difficult. However, on the 13th of March 2020, U.S. President Donald Trump declared a national emergency in the U.S. to fight against the COVID-19 outbreak (Alvarez 2020). This event day is used in this study as it is an observable event relative to COVID-19. Also, the days week before an event are analysed using sensitivity analysis for examining how much the event day selection affects the results. Furthermore, the data of stock market prices is required. The U.S. stock market data is used and, more specifically, two sectors, namely technology and transportation industry. The stock market data is collected from Datastream.

The U.S. stock market was selected as it is the leading stock exchange globally, with almost 56 percent of the shares listed there in January 2021. The U.S. stock exchanges, The New York Stock Exchange (NYSE), and the NASDAQ are the biggest stock exchanges worldwide. (Statista 2021) Moreover, when almost 56 percent of all the shares globally are listed in the U.S. stock exchanges, it is clear that the stock market crashes in the U.S. affect globally. Also, one of the most followed stock indices, the Standard and Poor's 500 index (S&P 500 index), is listed in the U.S. stock exchange. The index includes the 500 largest companies in the U.S. stock market, and many funds are intended to follow the performance of the S&P 500 index. (Kenton & Boyle 2020) This study uses the S&P 500 index as a market index.

Figure 1 illustrates the S&P 500 index price and returns development from February 2019 to March 2020. From February 2019 to January 2020, the index price has been increased quite constantly, and the daily returns have been evenly below five percent. In February

2020, the index price began to decrease heavily, and the daily returns started to be more volatile. The price reduced by more than 1 000 $ only in one month, and the daily returns for both directions were even ten percent.

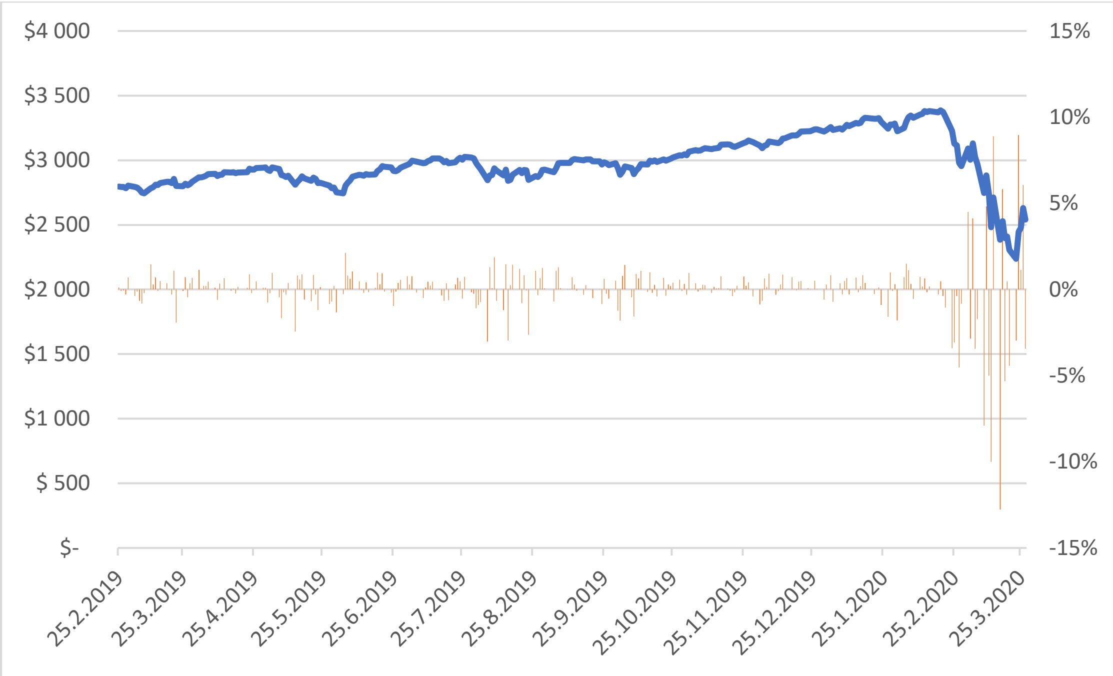

Figure 1. S&P 500 index price ($) and returns (%) from February 2019 to March 2020. (Datastream)

1.4. Theoretical framework

The purpose of the theoretical framework (figure 2) is to support the empirical part of the research. The first part of the theoretical framework is COVID-19 since it is the factor that is assumed to cause an impact on stock markets. The second part is the event study methodology, as it is used to study the impact of COVID-19. The last part of the theoretical framework is the stock market because it is the study's objective. These variables are linked together as it is assumed that COVID-19 causes impacts on the stock market, and the impacts are studied with event study.

Figure 2. Theoretical framework.

1.5. Limitations of the study

The limitations of this study are mostly related to the methodology. The event study methodology needs an exact day for the event to study the reactions. The selection of an exact event day is difficult in COVID-19, and the choice affects the data and the results. Even if there is more than one event day selected in this study, the days are limited to five, and the other days are not included. Also, the event study methodology studies the short-term impacts, so the results are not useful when considering the long-term effects. The problems with an event study are considered more in section 2.4.4.

Moreover, the study is limited to one country. The impacts are not studied in other regions, and the results are useful in the U.S. only. Besides, the study included only two stock groups, technology and transportation, and hence the results are not directly generalizable for other industries.

1.6. Structure of the study

The study is divided into six sections. After the introduction chapter, the structure is as follows. In the second section, the theoretical framework is introduced. The chapter includes the definitions of pandemic and COVID-19 followed by the theory of efficient market hypothesis. Also, the event study methodology with the formulas is introduced, and the problems related to the methodology are considered. In the third section, the literature review is presented. The literature review chapter aims to present the previous studies related to event study and COVID-19, especially to the impacts of COVID-19 on stock markets.

The fourth section starts the empirical part of the study. In the fourth chapter, the case COVID-19 in the U.S. is presented, and the stock market data for studying the impacts is shown. Also, the data processing is presented in this chapter. In the fifth section, the empirical results are presented for the technology and transportation companies. Also, the results are compared with the S&P 500 index movements, and the sensitivity analysis is done. Lastly, a discussion of the results is made. In the sixth section, the conclusion of the study is done. In this chapter, the answers to the research questions and hypotheses are shown, and the reliability of the results is analysed. After that, the ideas for further research are presented.

2. THEORETICAL FRAMEWORK

The event study methodology is used to study the effect of some significant event on stock market prices. It enables researchers to include a non-numeric factor in the study, as the events can be related to, for example, environmental emergencies. The event study methodology is based on calculating normal returns: how much the stock has returned before an event in relation to market index returns. Then, when the event happens, the actual returns can be compared to normal returns, and the effect of an event can be calculated. (Wells 2004; MacKinlay 1997) This study uses the event study methodology as it aims to examine the impact of a health emergency in stock markets, and the methodology fits perfectly to this need. Some earlier studies have also used the same methodology, and the results are useful (He et al. 2020; Shen & Zhang 2020).

2.1. Pandemic

On the 11th of March 2020, World Health Organization (WHO) announced that "COVID-19 could be characterized as a pandemic” (WHO 2020a). The definition of a pandemic is unclear, and it has changed over time (Doshi 2011). According to Kelly (2011), the traditional definition of a pandemic is "an epidemic occurring worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people." The problem of this classical definition of a pandemic is that it contains nothing about the population immunity or infection difficulty. By following the classical description, pandemics would occur every year. According to WHO (2010), "a pandemic is the worldwide spread of a new disease"; "An influenza pandemic occurs when a new influenza virus emerges and spreads around the world, and most of the people do not have immunity." Many of the past pandemics have been originated from animals.

Morens, Folkers, and Fauci (2009) discuss the definition of a pandemic in their article. They also see that the definition of a pandemic is unclear, and different definitions vary quite much. Some of the descriptions consider only the "level of explosive transmissibility," while some also consider the disease difficulty. The researchers tried to describe pandemics by finding similarities between past pandemics. When discussing the previous pandemics, these criteria are often fulfilled: "wide geographic extension, disease movement, high attack rates and explosiveness, minimal population immunity, novelty, infectiousness, contagiousness, and severity."

Maher and Bellizzi (2020) state that the discussion of a pandemic definition started seriously in 2009 after the novel H1N1-virus was announced as a pandemic. The old definition was unclear, and it needs to be revised. The new description outlined four required elements of a pandemic, which are: "new emerging virus, no or little population immunity, high morbidity and mortality, and spreads easily between humans."

2.2. COVID-19

On the 31st of December 2019, WHO's country office in China reported the "viral pneumonia" cases in Wuhan, China. On the same day, WHO's Epidemic Intelligence from Open Sources (EIOS) reported the group of pneumonia cases caused by an unknown virus in Wuhan. Later, on the 9th of January 2020, WHO reported that the cases are caused by a novel coronavirus, and the outbreak of the virus started. On the 13th of January, The Ministry of Public Health in Thailand reported that they had found the novel coronavirus in Thailand. That was the first registered virus case outside of China. On the 11th of February, WHO named the novel coronavirus as COVID-19. On the 7th of March, the total number of COVID-19 cases in the world surpassed 100 000 and quite quickly after that, on the 4th of April, the reported cases in the world surpassed 1 million. (WHO 2020c) Figure 3 illustrates new confirmed COVID-19 cases by regions from January 2020 to April 2021. The virus started to spread quickly after March 2020, and the two regions with most of the cases are the Region of the Americas and the European region. New daily confirmed cases were their highest on the 20th of December 2020 when the total cases were more than 800 000 worldwide.

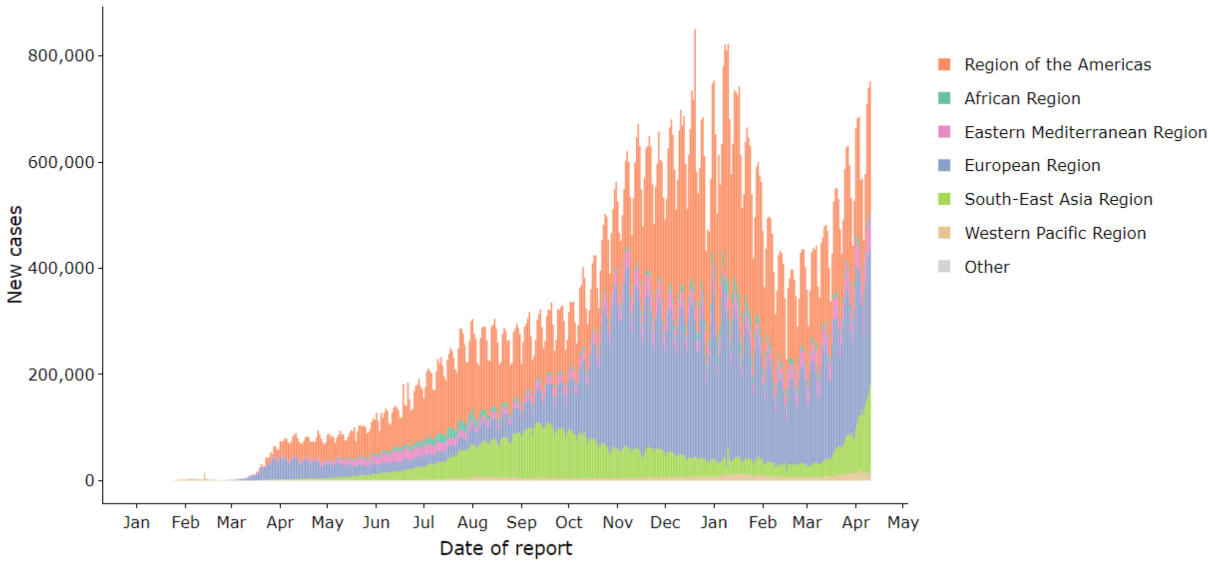

Figure 3. New COVID-19 cases by regions. (WHO 2021)

COVID-19 is a disease caused by a novel coronavirus, which causes symptoms to most of the carriers. Generally, people infected with COVID-19 will recover without hospital treatment, but older people and persons included in the risk group are more likely to need special treatment. COVID-19 impacts differently between different people, but the most common symptoms are fever, cough, and sleepiness. There are also some less common symptoms, for example, loss of taste and smell. The severe symptoms that could need hospital treatment include breathing difficulty, chest pressure, and difficulty in speech or movement. (WHO 2020a)

2.3. Efficient market hypothesis

Event study methodology assumes markets to be efficient (Wells 2004). The efficient market hypothesis was developed by Eugene Fama, and it was accepted by other economists about a generation ago. It was commonly believed that the security markets effectively reflect the information about the entire stock markets. (Malkiel 2003) According to Fama (1960), the hypothesis is based on the fact that the securities' buyers believed that the security's price is higher than its current purchasing price, and the sellers believed that the current selling price is higher than the actual price of the security.

The efficient market hypothesis assumes markets to be efficient all the time, which means that the current market prices reflect all the information available at present. When new information arrives, the news will spread rapidly to the whole market, and the information cause changes in stock prices immediately. That is why the analysis based on public information does not help investors find undervalued stocks and make better profits than the randomly selected stocks on the market do. Therefore, unskilled investors who do nothing but buy a randomly chosen portfolio will get the same returns as professional investors. In efficient markets, the individual investor cannot continuously get a better return than the market gets. It is impossible to make profits with skills. (Fama 1960; Malkiel 2003)

The efficient market hypothesis is based on the idea of a random walk, which means that all the followed price changes represent the random anomaly of the previous prices. In efficient markets, it means free information flow, when the allowable news is reflected immediately to the stock prices. It is assumed that tomorrow's price changes are caused only by the information available tomorrow, and it is different from the price changes today. Because news is unpredictable, the price changes of stocks need to be unreliable and random as well. As a result, stock prices reflect all the information available at present. (Malkiel 2003)

2.3.1. The forms of efficiency

The efficient market hypothesis defines three different forms of efficiency in the markets. The weak form, in which all the information about past market prices is reflected directly in the security prices. In other words, the technical analysis based on the previous prices is not useful in the weak form of efficiency. The semi-strong form, in which all the public information is reflected directly to the security prices. Therefore, the analysis which is based on public information is not profitable. The strong form, in which all possible information is reflected directly in the security prices. Even the analysis, which is based on internal data, is not helping the investor. (Fama 1960)

The original efficient market hypothesis met some critics from other researchers. The critic was related to the cost of information in the markets, which was one of the most important things with the hypothesis. For example, according to Grossman and Stiglitz (1980), the cost of information in efficient markets always needs zero. In the real world, that is not true, which means that the efficient market hypothesis is partially incorrect. (Fama 1991)

Fama (1991) reformed the hypothesis due to criticism, which caused changes in efficiencies forms in the markets. In the weak form, the content changed, and in the semi-strong and strong form, Fama changed only the header, not the content. The weak form was replaced with the tests of return predictability. The weak form considered only historical price series, whereas the reformed version considered the historical data better by considering stock returns and interest rates also. The semi-strong form was replaced with the event study, and the strong form was replaced with the tests of private information.

At the beginning of 2000, economists started to believe that price changes are somehow predictable. They said that the future stock prices could be predicted with the stocks' past values and fundamental factors. These new ideas make it possible to think that the individual investor could earn better returns than the market. The efficient market hypothesis was challenged by new theories that consider that the psychological and behavioural elements also affect stock prices. (Malkiel 2003)

2.3.2. Criticism towards the efficient market hypothesis

The efficient market hypothesis states that the stock prices are unpredictable regardless of time and markets. In the real world, there is some evidence of situations in which the markets are inefficient and the equity prices predictable. Malkiel (2003) divides these situations into three groups: short-term anomalies with investors underreaction, long-run return reversal, and seasonal and day-of-the-week patterns. For example, Lo and MacKinlay (2008) found that daily stock prices correlated with each other. Shiller (2003) found that behavioural factors affect stock prices. Fama and French (1988), as well as Poterba and Summers (1988), found that the prices are correlated negatively in the long run. Haugen and Lakonishok (1988) found higher returns in January, and French (1980) and Hawawini and Keim (1995) found that the returns are depending on the day-of-the-week.

2.4. Event study methodology

Figure 4 summarises the process of an event study methodology. The first step is the event selection, followed by the selection of companies involved. After that, the calculation of normal and abnormal returns can be done. Finally, the calculation of the statistical significance of the results is made.

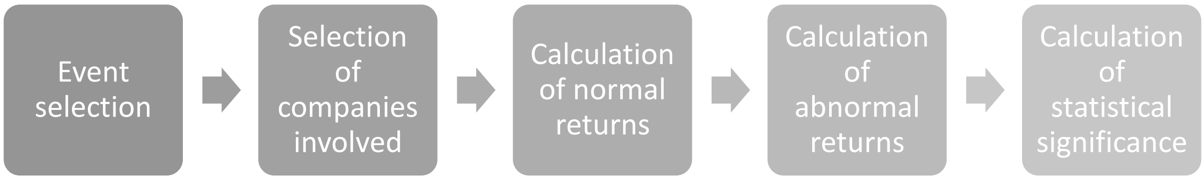

Figure 4. Event study process. (Based on MacKinlay 1997)

The first step, event selection, includes the selection of an event window also. Typically, the event window covers ten days before the event, the event day, and ten days after the event. Before the event window, there is usually 250 days long estimation window in which the normal returns are calculated. (Vaihekoski 2016) The event window and estimation window are shown in figure 5. Usually, the most challenging part of the event study methodology is to choose the right event day because the information of the event can come to markets in many parts in several days. It could also be hard to differentiate a specific event from other events occurring at the same period. (MacKinlay 1997; Wells 2004) After the event is selected, the examined companies must separate before the study can be accomplished. The first step is to identify the companies under the influence and then define criteria based on which they are chosen. (Wells 2004)

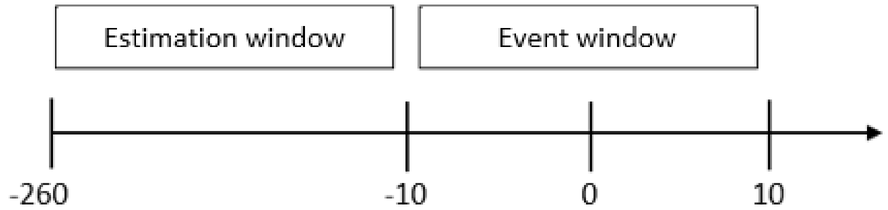

Figure 5. Estimation window and event window. (Based on Vaihekoski 2016)

According to MacKinlay (1997), there are several ways to perform an event study, but the general flow of the analysis is similar. This study follows mostly the analysis flow as presented by MacKinlay. To study the impact of a certain event on stock prices, the abnormal returns need to be calculated. They are calculated with the difference between realized returns and normal returns. For company i and event day t, the abnormal returns are:

$$AR_{it} = R_{it} - E(R_{it}|X_t), \tag{1}$$

in which AR_{it} is abnormal returns, R_{it} is realized returns, and $E(R_{it}|X_t)$ is normal returns from the period t.

2.4.1. Normal returns

According to Wells (2004), there are many ways to calculate the normal returns, such as mean adjusted model, market-adjusted model, and market model. The mean adjusted model uses the daily mean return from the estimation window, and this average could be compared to realised returns in markets. The idea behind the market-adjusted model is similar to the mean-adjusted model, but the mean is calculated from the market prices in the market-adjusted model. However, the market model differs from previous models because it also considers the risk of returns. The market model considers the firm's beta, which indicates the stock risk compared to market risk. Stock’s beta one indicates the mean risk, whereas the beta above one indicates a higher risk, and beta below one indicates a lower risk.

As stated by MacKinlay (1997), the normal returns could also be calculated with Capital Asset Pricing Model (CAPM) or Arbitrage Pricing Theory (APT). CAPM calculates the normal returns with stock's covariance with the market portfolio. In turn, in APT, the normal returns are modelled with the linear combination of stock risk factors. However, MacKinlay states that these models do not increase the model's value. The problem with CAPM is that the study could be susceptible to CAPM restrictions. In APT, the risk factors behaviour is similar to markets, so these factors increase the model's explanatory power very little. Because of these things, the normal returns are calculated with the market model in this study.

The market model combines any of the stock's returns with the returns of the market portfolio. The market model is:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \tag{2}$$

$$E(\varepsilon_{it} = 0) \qquad var(\varepsilon_{it}) = \sigma_E^2,$$

in which R_{it} is stock returns on the period t, R_{mt} is market returns on the period t, and ε_{it} is an error term, which is assumed to be zero. α_i, β_i, and σ_E^2 are the model's parameters. The goodness of the market model is that the model removes returns depending on changes in markets. That decreases the variance of abnormal returns and increases the ability to see the effects of events in stock prices. (MacKinlay 1997)

2.4.2. Abnormal returns

In the market model, the abnormal returns are:

$$AR_{it} = R_{it} - \alpha_i - \beta_i R_{mt}, \tag{3}$$

in which AR_{it} is the abnormal returns. When all the abnormal returns of each stock are calculated, the average abnormal returns could be calculated. The average abnormal returns are:

$$AAR_t = \frac{1}{N}\sum_{i=1}^{N} AR_{it}, \tag{4}$$

in which AAR_t is the average of abnormal returns, and N is the number of events (MacKinlay 1997).

Whereas the abnormal returns are studied in a single day, the abnormal returns could be examined for a certain period. In cumulative abnormal returns, the returns are aggregated over time. The cumulative abnormal returns are (MacKinlay 1997):

$$CAR_i(t_1, t_2) = \sum_{t\,=\,t_1}^{t_2} AR_{it}, \tag{5}$$

in which $CAR_i(t_1, t_2)$ is the cumulative abnormal returns in a specific period. The cumulative average abnormal returns can be calculated using cumulative abnormal returns. The cumulative average abnormal returns are (MacKinlay 1997):

$$CAAR(t_1, t_2) = \frac{1}{N}\sum_{i=1}^{N} CAR_i\,(t_1, t_2), \tag{6}$$

in which $CAAR(t_1, t_2)$ is the cumulative average abnormal returns in a specific period.

2.4.3. Statistical significance

The statistical significance of estimates in the event study could be tested with various test statistics. In this study, the statistical significance testing follows MacKinlay (1997) and Vaihekoski (2016). When testing the statistical significance of average abnormal returns, the null hypothesis is that the event has no impact on stock returns. The test statistic is:

$$\theta_1 = \frac{\sqrt{N} \times AAR_t}{\sqrt{\sigma^2(AR_{it})}} \sim N(0,1), \tag{7}$$

in which N is the number of events, AAR_t is the average abnormal returns, σ^2 is variance, and AR_{it} is abnormal returns. In the case of cumulative abnormal returns, the test statistic is:

$$J_1 = \frac{CAR(t_1, t_2)}{\sqrt{\sigma^2(t_1, t_2)}} \sim N(0,1), \tag{8}$$

in which $CAR_i(t_1, t_2)$ is the cumulative abnormal returns in a certain period. The variances in formula denominators are calculated with:

$$\sigma^2(t_1, t_2) = \frac{1}{N^2}\sum_{i=1}^{N}(t_2 - t_1 + 1)\sigma^2(t_1, t_2). \tag{9}$$

2.4.4. Problems with an event study

The main problems with an event study are related to the methodology's assumptions and its violation. The first problem is related to the identification of the event day. An event study methodology assumes that the event day can be found without uncertainty. Especially in this study, the information of the event has come in parts, and there is uncertainty in the event day identification. (MacKinlay 1997) The second problem of the methodology is linked to the beta. The market model depends on the stock's beta, and the beta is assumed to be a constant and perfect estimator for the future.

Nevertheless, empirical studies have shown that the beta is not stable over time. The study's object could also impact the stock returns and change the stock's beta. The beta represents the relationship between stock return and return of the market portfolio; macroeconomic factors like changes in interest rates will impact beta. The third assumption is related to the fact that when analysing a dataset that is large enough, irrelevant factors could be filtered away. In this situation, changes in stock prices could be linked only to a specific event. If the irrelevant factors could not be filtered, the studied impact could be incorrect and insignificant. (Wells 2004; Vaihekoski 2016)

The other possible problem with an event study could be the trading activity. In an event study, the daily prices are often taken from the closing price, which is the day’s last trade. However, because of nonsynchronous trading activity, the last trade of the day happens at a different time each day. This could include biases for the study, but the biases are only minimal when studying the actively traded stocks. (MacKinlay 1997) Also, an event study methodology assumes that the samples of a study are independent. This assumption could be violated more likely when the research focuses only on one industry, especially for insurance and banking. (Wells 2004)

3. LITERATURE REVIEW

This part of the study focuses on discovering the earlier studies of a similar topic. The first section presents the impact of emergencies on stock markets. The purpose was to find the studies that have used event study as a methodology and studies that have examined the stock market crashes. The second section of this part presents the previous studies that focus on the impact of COVID-19 on stock markets. The keywords to find these studies from databases were “COVID-19,” “stock markets,” and “event study.” The databases used in this study were LUT Primo and Google Scholar. The searches gave thousands of articles related to these topics, but the papers selected in this study were mainly used event study methodology. This literature review considers about 20 previous research.

3.1. The impact of emergencies on stock markets

The impact of unexpected emergencies on stock markets has been studied much, and there are many references that significant events affect the stock prices. The events are mostly related to terror attacks, extreme weather conditions, and other major disasters. Nikkinen, Omran, Sahlström, and Äijö (2006) examined how the September 11 attacks in 2001 affected the equity markets. They studied 53 different stock markets and found that the attacks increased the markets' volatilities significantly. Also, the increase of short-time negative returns was substantial, but the markets recovered quickly. Lanfear, Lioui, and Siebert (2018) studied the impact of extreme weather events in the U.S. on the country's stock market. The research included several hurricanes from 1990 to 2017, and it found strong abnormal returns on stock markets during and after the storms. Kaplanski and Levy (2010) examined how aviation disasters affected the NYSE Composite Index. They found that aviation disasters impacted significantly negatively on stock prices in two days. The average market loss was about 60 billion dollars per aviation disaster. The study shows that the impacts were smaller in big and stable firms’ stocks. Kaira, Henderson Jr., and Raines (1993) examined the Chernobyl nuclear accident's impact on the U.S. power utility share prices. They found that the share prices reacted negatively to the disaster even if there are no direct connections between Chernobyl and power utilities in the U.S. The adverse reactions of the share prices were based only on market expectations.

Al-Rjoub (2009) studied the effects of Mexico's Tequila crisis in 1994, the Asian/Russian crisis in 1997-1998, the Iraq war in 2004, the local financial crisis in 2005, and the global financial crisis in 2008-2009 on Jordanian stock market. The study found that the stock market returns were significantly negative during financial crises. Surprisingly, the returns were substantially positive during the Iraq war. Other studied events had no significant impact on Jordanian stock market returns. However, changes in volatility during the events were related to expectations; if the expectations were pessimistic, the volatility decreased, and if the expectations were optimistic, the volatility increased. The financial crises in 2005 and 2008-2009 had no significant impact on Jordanian stock market volatility.

Righi and Ceretta (2011) examined the impact of the Greek crisis on stock market volatility and risk in Germany, France, and England. They found changes in market volatilities and covariances after the crisis. Also, the changes in market risks were significant as the risk increased during the crisis but decreased to the lower level after the crisis's peak.

3.2. The impact of COVID-19 on stock markets

The use of a global health event as an emergency to study stock market reactions has risen during the COVID-19 pandemic. He et al. (2020), Al-Awadhi et al. (2020), and Shen and Zhang (2020) studied the impact of COVID-19 on the Chinese stock market. He et al. (2020) split their study into several different industries on the Chinese stock market and found that the various sectors reacted differently to the outbreak of COVID-19. They noticed that the COVID-19 affected the traditional industries, like transportation and mining, negatively and the modern industries, like high-tech and healthcare, positively. The effect was also different in different stock exchanges – negative in the Shanghai Stock Exchange and positive in the Shenzhen Stock Exchange. In the whole Chinese stock market, the reaction has been negative as most of the sectors suffered from the pandemic. Similarly, Al-Awadhi et al. (2020) found that the outbreak of COVID-19 impacted most negatively the transportation industry as its stock returns were worse than the market during the study. In turn, the technology and medicine sectors performed better than the market during the study. However, China's massive economy with substantial supporting resources recovered partially quickly from the harmful effects of COVID-19 (He et al. 2020). Shen and Zhang (2020) split the Chinese stock market into two groups in their study. Stay-at-home stocks included the firms whose products or services are assumed to be consumed at home, and go-outside stocks included the firms whose products or services are considered to be finished outside. The study found no significant negative impact of COVID-19 on the stay-at-home stocks, and in fact, the cumulative abnormal returns were positive for these stocks during the pandemic. Moreover, as can be assumed, the impact of COVID-19 was significantly negative for the go-outside stocks, and the cumulative abnormal returns decreased during the pandemic.

Similar results are also founded in the U.S. Thorbecke (2020) studied the impact of COVID-19 on the U.S. economy by focusing on stock prices. The study used several macroeconomic factors and found the expected results. The sectors that suffered mostly from COVID-19 included, for example, airlines, tourism, and oil. Thorbecke thought that these sectors would not recover until the pandemic is over. Also, the sectors that benefited were not surprising. These sectors included, for example, electronic entertainment, biotechnology, and software. Baek et al. (2020) studied the effect of COVID-19 on U.S. stock market volatility. The study showed that the volatility increased in defensive sectors like telecom and decreased in aggressive sectors like business equipment. The volatility increasing is linked to the increased risk in these industries. The study also found that the volatility was more sensitive to the effects of COVID-19 than macroeconomic factors.

Alam, Alam, and Chavali (2020) and Anh and Gan (2020) studied the effect of COVID-19 lockdown on different stock markets. Alam et al. (2020) examined the effect of lockdown in India and split the study into two periods: the pre-lockdown period and the post-lockdown period. In the pre-lockdown period, the impact was negative because the investors were panicking. In turn, in the post-lockdown period, the effect was positive, and the markets started to recover from the shock gradually. Anh and Gan (2020) investigated the impact of lockdown in Vietnam and found similar results. In Vietnam, the increasing number of

COVID-19 cases and the pre-lockdown period caused a significantly negative effect on the stock prices. The most substantial effect was seen in the financial sector. However, in the post-lockdown period, the impact was positive for the entire stock market in Vietnam.

Kumar and Kumara (2020) studied the stock market performance in India during the COVID-19 pandemic. They split the study into pre and post COVID-19 periods and analysed the correlations between stock and equity market growth. The changes in the correlations and market capitalization were significant. Travel, entertainment, oil, and gas industries suffered the most significant impact of COVID-19 as the stock prices of these industries decreased by about 40 percent. Surprisingly, the losses in the IT sector are also significant as some of the stock prices dropped much. However, there were also some gainers of the situation, for example, healthcare, telecom, and banking.

Liu et al. (2020) and Chaudhary et al.(2020) examined the impact of the COVID-19 outbreak in different countries. Liu et al. (2020) took 21 leading stock indices into their study from several countries, including, for example, Japan, the USA, and the UK. The stock markets

reacted strongly and negatively to the COVID-19 outbreak in all the countries. The countries in Asia were affected mostly by the pandemic as in these countries, the negative abnormal returns were more significant than in other countries. The study also found the adverse effects between the number of COVID-19 cases and stock prices. Chaudhary et al. (2020) studied the impact of COVID-19 in 10 leading countries based on GDP. They found that the daily mean returns from January 2020 to June 2020 were negative in all the markets, but the second quarter of the period showed some positive mean returns. However, the market volatility remained higher than in regular times, also in the second quarter of the study period.

While Liu et al. (2020) and Chaudhary et al. (2020) examined the impact of COVID-19 on major stock indices, Topcu and Gulal (2020) investigated the effect of COVID-19 on emerging stock markets. The study included four regions, South America, Middle East, Europe, and Asia. They found negative impacts in all areas, but the impacts fallen to the end of the study period. In this study, the highest effect was seen in the Asian region, and in

Europe, the impact was the lowest. Waheed, Sarwar, Sarwar, and Khan (2020) analysed the Pakistani stock market and found an adverse result of COVID-19's impact on developing markets. They found that the effect is adverse in emerging markets, which means that they could benefit from this situation. The benefits are linked to the relief packages for small businesses and the opportunity to take a low-interest rate loan and grow a business.

According to previous studies, significant events affected stock markets. The impact of COVID-19 on stock markets has been studied in many countries, and the results are similar. As could be expected, the pandemic impacted negatively on stock markets, and some industries have suffered more than others. The traditional sectors, for example, traveling, were suffered the most. On the other hand, the situation has brought modern and high-tech industries opportunities, benefiting the pandemic. However, the trend in equity markets around the world has been decreasing during the COVID-19. Table 1 shows the conclusion of earlier results.

Table 1. Conclusion of earlier results.

Authors (year)	Object	Split	Result
He et al. (2020)	China	Several industries	Negative -> traditional, Positive -> modern
Al-Awadhi et al. (2020)	China	Several industries	Negative -> transportation, Positive -> technology and medicine
Shen and Zhang (2020)	China	Stay-at-home and go-outside stocks	Negative -> go-outside, No impact/small positive -> stay-at-home
Thorbecke (2020)	The U.S.	Several industries	Negative -> airlines, tourism, and oil, Positive -> electronic entertainment, biotechnology, and software
Baek et al. (2020)	The U.S.	Several industries	Volatility decrease -> aggressive sectors like business equipment, Volatility increase -> defensive sectors like telecom
Alam et al. (2020)	India	Pre-lockdown and post-lockdown	Negative -> pre-lockdown, Positive -> post-lockdown
Anh and Gan (2020)	Vietnam	Pre-lockdown and post-lockdown	Negative -> pre-lockdown, Positive -> post-lockdown
Kumar and Kumara (2020)	India	Several industries	Negative -> travel, entertainment, oil, gas, and IT, Positive -> healthcare, telecom, and banking
Liu et al. (2020)	Different countries		Negative -> all countries, Most negative -> Asia
Chaudhary et al. (2020)	Different countries		Negative -> all countries
Topcu and Gulal (2020)	Emerging stock markets		Negative -> all countries, Most negative -> Asia, Least negative -> Europe
Waheed et al. (2020)	Pakistan		Emerging markets could benefit from this situation

4. CASE DESCRIPTION AND DATA

This chapter focuses on the case of this study. Firstly, the development of the COVID-19 in the U.S. is shown. The analysis concentrates on the beginning of the COVID-19 spread as the event day is set there. After the case presentation, the event day selection is justified. Finally, the data of the study and the data processing are presented.

4.1. COVID-19 in the U.S.

Figure 6 illustrates the timeline of the COVID-19 in the U.S at the beginning of 2020. The first COVID-19 case in the U.S. was reported on the 20th of January with a person who arrived from Wuhan on the 15th of January (Washington State 2019-nCov Case Investigation Team 2020; Baker 2020). On the 6th of February, a woman died in San Francisco, and the test results showed that the woman was infected with the COVID-19. That was the first death linked to the COVID-19 in the U.S. (Fuller, Baker, Hubler & Fink 2020; Moon 2020). On the 13th of March, President Donald Trump declared a national emergency in the U.S. to fight against the COVID-19 outbreak. The declaration meant that the Federal Emergency Management Agency (FEMA) would get the coordinator role for coronavirus response since that day. The appointment also freed up billions of dollars from federal funds to fight against the pandemic. (Alvarez 2020) The cumulative number of COVID-19 cases in the U.S. crossed 100 000 cases on the 27th of March and 1 million cases on the 28th of April (CDC 2021). On the 12th of April 2021, there were about 31 million reported cases and about 562 thousand registered deaths caused by the COVID-19 (New York Times 2021).

COVID-19 spreads primarily through droplet infection when the sick person sneezes or coughs. The general guidelines for preventing the spread of the virus include, for example, washing hands and maintaining the distance for other people. Many countries have also exercised the restrictions of movements and the distancing measures, called lockdown, to slow the spread of COVID-19. The lockdown period in the U.S. started in March 2020. (World Health Organization 2020b; New York Times 2020)

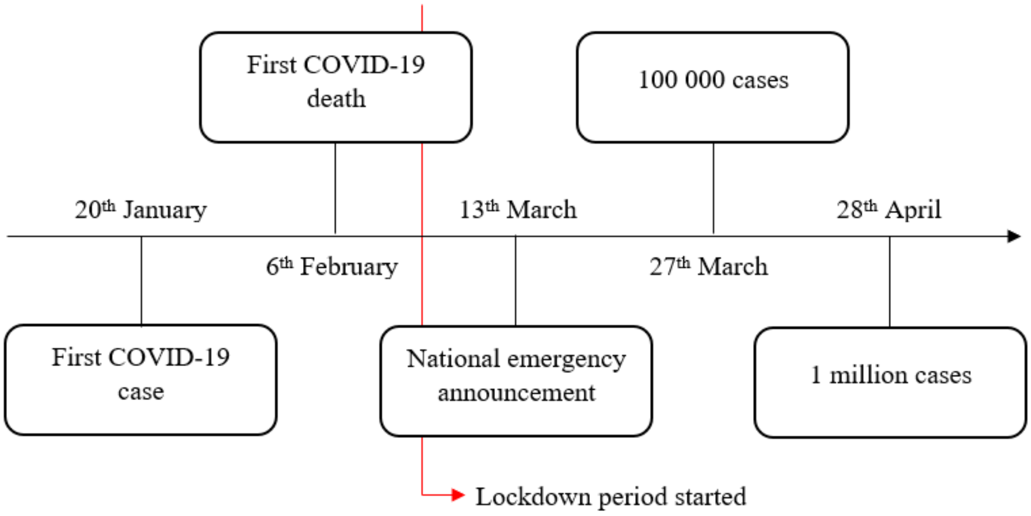

Figure 6. Timeline of the COVID-19 in the U.S. around the event date.

4.2. Event day selection

An event day selection is one of the most challenging parts of the event study methodology, especially in this study. The information related to COVID-19 (the spread of the virus) has come in many parts, and there is no one day or even one month when the information came to the markets. When looking at figure 1 in section 1.3, the highest variation of the S&P 500 index took place in March 2020, and therefore the event window will be located to this period. The event day is set to be the 13th of March 2020 because, on this day, the national emergency related to COVID-19 was declared in the U.S. Also, five days before this day are studied with the sensitivity analysis because the selection of an event day is not precise. The sensitivity analysis aims to decrease the event day selection margin of error and study how much the event day variations impact the results.

4.3. Data

Previous studies have shown that COVID-19 positively impacted modern industries and negatively impacted traditional industries (He et al. 2020; Al-Awadhi et al. 2020). Because COVID-19 has impacted different industries differently, the industries are studied separately in this study. The industries involved are technology and transportation to represent modern and traditional stock groups, respectively. The technology group includes 20 large technology companies in the U.S. stock market, and the transportation group includes all the 20 companies from the Dow Jones Transportation Average (DJTA) index. The stocks included in each group are presented in appendices 1 and 2. Dow Jones Transportation Average is the oldest stock index in the U.S. stock market, and hence it fits perfectly to reflect the traditional group of this study (Kenton 2020).

The adjusted closing price is used to calculate the stocks' historical returns as it considers the corporate actions such as stock splits or dividends and is, therefore, better than the "normal" closing price (Ganti & Scott 2020). The study sample includes the estimation window and the event window, so the stock market data for 40 stocks is collected and analysed from February 2019 to March 2020. Also, information of the market return is needed. This study's market return is the S&P 500 index, which includes the 500 largest companies in the U.S. stock market by weighted market capitalization (Kenton & Boyle 2020). The daily adjusted closing prices of the stocks and the closing prices of the S&P 500 index were collected from Datastream.

4.4. Data Processing

To calculate the normal and abnormal returns of the stocks, the actual daily returns need to be calculated. According to Wells (2004), the calculation of stocks' daily returns as a percentage should be done using natural logarithms instead of simple percentage changes to avoid the bias of arithmetic anomaly. If the stock price has increased on day one and decreased on day two to the same level as on day one, the average returns of these two days need to be zero. That is why the calculation of stocks' daily returns has been done with the following formula:

$$r_t = ln(\frac{P_t}{P_{t-1}}), \tag{10}$$

in which r_t is the daily return in percent, P_t is the day's adjusted closing price and P_{t-1} is the previous day's adjusted closing price.

After the daily returns (%) were calculated, alpha (α) and beta (β) could be estimated. Next, the normal returns could be calculated with the market model (formula 2). After the normal returns were estimated, the abnormal returns were calculated with the difference between actual returns and normal returns. Finally, the average abnormal returns (AAR), cumulative average abnormal returns (CAAR), and the test statistics could be estimated.

5. RESULTS

In this section, the empirical results are shown. Firstly, the average abnormal returns (AAR) and the cumulative average abnormal returns (CAAR) are presented. The average abnormal returns illustrate the abnormal returns daily from day -10 to 10, while the cumulative abnormal returns sum the returns for different periods within the event window. After that, the sensitivity analysis, which compares the AAR and CAAR values for different event days, is made. Finally, the discussion of the results is done.

When looking at the results of abnormal and cumulative abnormal returns, it must be considered that the positive abnormal returns do not directly mean that the stock has made profits. The abnormal returns are calculated using the market index, the S&P 500 index. If the market index has been decreased and the single stock has been decreased less than it normally decreased in relation to the market index, the abnormal returns are positive. Generally, if the abnormal returns are positive, the stock has made better profits than the market index has made, including the stock's beta in the calculation. As shown in chapter 1.3, the price of the S&P 500 index decreased much in March 2020, so the stocks could have been done high positive abnormal returns even though the stock price has been reduced in this period.

5.1. Average abnormal returns (AAR)

Table 2 shows the average abnormal returns (AAR) of technology and transportation companies around the event day. The average abnormal returns of technology companies were not significant on the event day, and no effect is observed. In turn, the average abnormal returns of transportation companies on the event day were significantly negative, -1,636 %, and it seems that Trump's announcement of a national emergency affected immediately to the returns of transportation companies.

After the event day, the average abnormal returns of technology companies were significantly positive. The positive values were seen on days 1, 3, 4, 5, and 6, which means that the investors of technology companies reacted positively to the event. However, the reaction came with a little delay. From day 7, the average abnormal returns of technology companies started to be significantly negative. In transportation companies, the average abnormal returns after the event day varied more, and there was no such a trend. Roughly, the average abnormal returns were negative at first, and after that, they started to be positive.

Before the event day, there were also some significant average abnormal returns of both groups. The values were mostly positive to the technology companies and negative to the transportation companies. These results indicate that the investors reacted to the event before it actually happened, but the reactions were smaller than after the event.

Table 2. Average abnormal returns (AAR) and significance of the results (t-value). An asterisk indicates a result that can be considered statistically significant.

	TECHNOLOGY		TRANSPORTATION	
Event day	**AAR**	**t-value**	**AAR**	**t-value**
-10	1,163 %	4,3994*	-0,414 %	-1,2381
-9	-0,874 %	-3,3052*	-4,679 %	-13,9892*
-8	-0,291 %	-1,0990	0,226 %	0,6772
-7	-0,798 %	-3,0179*	-1,817 %	-5,4314*
-6	0,498 %	1,8852	-2,567 %	-7,6740*
-5	0,370 %	1,4013	1,752 %	5,2395*
-4	2,253 %	8,5202*	0,426 %	1,2723
-3	-0,057 %	-0,2169	0,061 %	0,1827
-2	0,902 %	3,4131*	0,730 %	2,1842*
-1	1,599 %	6,0478*	-1,471 %	-4,3990*
0	0,061 %	0,2293	-1,636 %	-4,8906*
1	1,430 %	5,4070*	4,137 %	12,3713*
2	-0,506 %	-1,9122	-3,864 %	-11,5528*
3	2,586 %	9,7796*	-5,643 %	-16,8718*
4	1,055 %	3,9908*	-0,205 %	-0,6137
5	1,398 %	5,2889*	3,408 %	10,1913*
6	3,206 %	12,1255*	3,482 %	10,4101*
7	-2,889 %	-10,9255*	3,717 %	11,1152*
8	-2,313 %	-8,7485*	2,273 %	6,7966*
9	-0,933 %	-3,5286*	-4,063 %	-12,1479*
10	-0,200 %	-0,7546	-1,765 %	-5,2763*

Significance level: *5 %.

5.2. Cumulative average abnormal returns (CAAR)

Table 3 shows the cumulative average abnormal returns (CAAR) of technology and transportation companies for different periods within the event window. Around the event day, from day -1 to 1, the cumulative average abnormal returns of technology companies were significantly positive, 3,089 %. It seems that the investors of technology companies reacted rapidly to the event even if the reaction at the event day was not significant. For the same period, the cumulative average abnormal returns of transportation companies were also positive, 1,031 %, which indicates that the shareholders' reaction was positive around the event day. However, the reaction was negative on the event day.

After the event day, from day 1 to 10, the cumulative average abnormal returns of technology companies were significantly positive, 2,835 %, which shows that the shareholders of technology companies reacted positively to the event in the longer term. Furthermore, the cumulative average abnormal returns of technology companies from day 1 to 5 were huge, 5,963 %, only in five days, which confirms that the positive reaction right after the event day was significant. In turn, the cumulative average abnormal returns of transportation companies from day 1 to 5 were significantly negative, -2,166 %, which indicates that the negative reaction of transportation companies' investors continued after the event day. The result for the period from day 1 to 10 was not significant and cannot be considered. These findings mean that the null hypothesis of no significant effect is rejected. The results support the first and the second hypotheses that COVID-19 positively impacts the technology companies and negatively the transportation companies. Though the results do not support the third hypothesis that the reactions are high after the event day, but they disappear rapidly within the event window. The significant reactions can also be seen in later days.

Before the event day, from day -10 to -1, the cumulative average abnormal returns of technology companies were significantly positive, 4,766 %. For the same period, the cumulative abnormal returns of transportation companies were significantly negative, -7,751 %. The reactions before the actual event were significant, and the directions were the same as after the event day.

Table 3. Cumulative average abnormal returns (CAAR) and significance of the results (t-value).

	TECHNOLOGY		TRANSPORTATION	
Event day range	**CAAR**	**t-value**	**CAAR**	**t-value**
[-10,-1]	4,766 %	5,7010*	-7,751 %	-7,3288*
[-5,-1]	5,067 %	8,5711*	1,498 %	2,0034*
[-1,1]	3,089 %	11,6842*	1,031 %	3,0816*
[0,0]	0,061 %	0,2293	-1,636 %	-4,8906*
[0,1]	1,490 %	3,9855*	2,502 %	5,2896*
[1,5]	5,963 %	10,0866*	-2,166 %	-2,8960*
[1,10]	2,835 %	3,3907*	1,479 %	1,3983

Significance level: *5 %.

Figure 7 illustrates the development of the cumulative average abnormal returns (CAAR) of technology (green) and transportation (red) companies within the event window day by day. Before day -5, the cumulative average abnormal returns of technology companies were close to zero, so the technology companies gave quite normal returns. After day -5, the cumulative average abnormal returns started to increase significantly, and investors' positive reactions started to show. On day 6, they were as much as 13,996 %. However, on day 10, on the closing day of the event window, the cumulative average abnormal returns of technology companies were 7,662 %. In transportation companies, the cumulative average abnormal returns were below zero within the whole event window, but the trend is quite similar to technology companies. The returns decreased heavily in the early days, but after that, the development was quite stable until the event day. After the event day, they started to vary more, and the closing cumulative average abnormal returns for the transportation companies were -7,908 %. The difference between technology and transportation companies' CAAR on day 10 was about 16 %, clearly showing the difference between them.

Figure 7 also shows the cumulative returns of the S&P 500 index (grey). The cumulative returns of the S&P 500 index were highly negative within the event window, and it seems that the index returns varied much. The CAAR of technology and transportation companies seemed to be more stable than the S&P 500 index returns, and the CAAR values did not strictly follow the index movements. However, in the big picture, some indications indicate that the abnormal returns of technology and transportation companies followed the S&P 500 index; the returns for both (positive and negative) directions were lower at the start, but some days after the event, they started to increase. The transportation line followed the S&P 500 index straighter than the technology line.

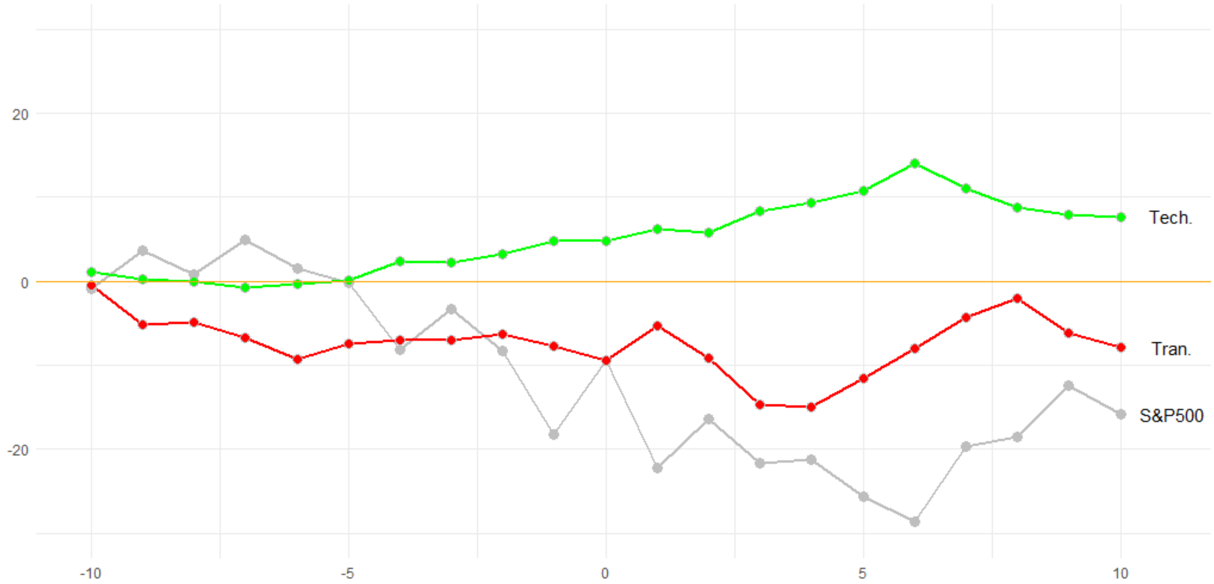

Figure 7. Cumulative average abnormal returns (CAAR) and cumulative returns of S&P 500 index (%).

5.3. Sensitivity analysis

The purpose of a sensitivity analysis is to study how much the event day selection affects the results. In this study, there was much uncertainty related to the event day selection as the information of the COVID-19 has come in many parts in many days and even in many months. Though, the national emergency announcement due to the COVID-19 pandemic was selected. The sensitivity analysis considers the actual event day, the 13th of March 2020, and five other weekdays before the actual event.

Table 4 shows the sensitivity analysis results for the average abnormal returns (AAR) on the event day. It seems that the event day selection highly affected the results of technology companies. The average abnormal returns on the event day varied between -0,219 % and 2,611 %, but what is more important, the significance of the results varied highly. Only three of the results could be regarded as significant when a significance level of 5 % is used. The highest positive and significant average abnormal returns of technology companies were seen on the 9th of March.

Furthermore, the event day selection affected more the results of transportation than technology companies. In transportation companies, the average abnormal return varied between -3,545 % and 4,540 %. Also, the significance of the results differed, and there were only three significant results. The highest positive and significant average abnormal returns of transportation companies were seen on the 11th of March.

Table 4. Sensitivity analysis for AAR on the event day.

	TECHNOLOGY		**TRANSPORTATION**	
Event day	**AAR**	**t-value**	**AAR**	**t-value**
6.3.2020	0,448 %	1,7160	-3,545 %	-3,4351*
9.3.2020	2,611 %	9,9975*	-0,625 %	-0,6071
10.3.2020	-0,219 %	-0,8377	2,881 %	2,7936*
11.3.2020	1,041 %	3,9718*	4,540 %	4,3820*
12.3.2020	1,851 %	7,0358*	1,489 %	1,4177
13.3.2020	0,061 %	0,2293	1,479 %	1,3983

Significance level: * 5 %.

The event day selection also impacted cumulative returns much. Table 5 shows the sensitivity analysis results for the cumulative average abnormal returns (CAAR) from day 1 to 10 for different event days. The CAAR of technology companies decreased with later event days. When the event day was the 6th of March, the cumulative average abnormal returns were 11,823 %, and when the event day was the 13th of March, they were 2,835 %. Also, the significance of the results varied as the results were more significant in the early days. However, all the results stayed below the 5 % significance level, making them meaningful.

In transportation companies, the situation was different. The cumulative average abnormal returns increased significantly when using later event days as they were negative with early days and positive with last days. Furthermore, the significance of the results varied substantially as only three of the results were significant. Thus, the event day selection played a massive role when studying the cumulative average abnormal returns of transportation companies.

Table 5. Sensitivity analysis for CAAR from day 1 to 10.

	TECHNOLOGY		TRANSPORTATION	
Event day	**CAAR**	**t-value**	**CAAR**	**t-value**
6.3.2020	11,823 %	14,3294*	-3,545 %	-3,4351*
9.3.2020	12,685 %	15,3610*	-0,625 %	-0,6071
10.3.2020	9,528 %	11,5311*	2,881 %	2,7936*
11.3.2020	5,969 %	7,2052*	4,540 %	4,3820*
12.3.2020	3,008 %	3,6152*	1,489 %	1,4177
13.3.2020	2,835 %	3,3907*	1,479 %	1,3983

Significance level: *5 %.

5.4. Discussion of the results

Overall, the results of the study show that the COVID-19 impacted the stock market in the U.S. When studying the average abnormal returns on the event day, there was no effect in technology companies, and there was a negative effect in transportation companies. It means that the investors of transportation companies believed that the event affects negatively to the performance of transportation companies immediately. Similarly, He et al. (2020) found that the average abnormal returns of transportation companies were significantly negative on the event day in China. The impacts seem to be similar in the U.S.

After the event day, the abnormal returns of technology companies started to be significantly positive. Firstly, these positive abnormal returns indicate that the shareholders of technology companies reacted to the event with a delay. According to Fama (1970) and Malkiel (2003), the markets are efficient only if the stock prices entirely reflect all information available at any time. It means that when new information arises, the stock prices are assumed to react immediately. Therefore, the technology companies' stock market in the U.S. seemed inefficient as the reaction was no immediate.

Secondly, the positive abnormal returns after the event day could indicate delayed information, which means that some additional information about the event came after the actual event. In this case, the delayed information is possible as many of the news related to the COVID-19 were published after the national emergency announcement. Thus, it seems that the daily abnormal returns behaved accordingly when new information arises. However, on day 7, the abnormal returns of technology companies changed radically as they started to be significantly negative. It is difficult to deduce what caused this. Maybe the investors got some new information related to the event, or maybe the abnormal returns just began to reduce after the high positive abnormal returns before. Probably, the changes were due to an unstable situation in the U.S. stock market in which the daily returns varied much in all the industries. In transportation companies, the abnormal returns were mostly negative first after the event but started to be positive later. The reasons for these changes are assumed to be the same as in technology companies. Though, the variation in transportation companies' abnormal returns was higher than technology companies, which indicates that the transportation industry was more likely to be affected by COVID-19.

There were also some significant abnormal returns before the event day, for example, positive abnormal returns of technology companies and negative abnormal returns of transportation companies on day -1. Firstly, the results indicate that there was some information related to the event available on the markets before the actual event, and the shareholders were able to react beforehand. According to Fama (1970), the significant abnormal returns before the event day can be linked to the fact that the investors have got some information from other sources, like the internet. In this study, the information of the event may have come in many parts, and the reaction before the actual event is obvious. If the COVID-19 cases have increased and the situation worsened, the shareholders could forecast the upcoming national emergency. Moreover, according to Fox and Duster (2020), the Senate Minority Leader and other senators have sent the public letter to President Trump in which they ask Trump to announce a national emergency in the U.S. a few days before the announcement. That can be one reason for the early reactions of investors of technology and transportation companies.

Secondly, the early reactions indicate about impacts of other events. As there were significant reactions before any information had been published about the national emergency, it seems that there were some other things affected. The event studied in this study might have been only one event among others, and all the reactions around it might have been random. It is difficult to say in which event the investors reacted within the event window. However, the daily abnormal reactions were higher after the national emergency announcement than before it, which means that the impact of the event cannot invalidate entirely.

When studying the cumulative average abnormal returns, the technology industry faced positive returns, and the transportation industry faced negative returns. The reaction of technology companies' shareholders around the event day, from day -1 to 1, was significantly positive even if the reaction on the event day was not significant. It is not surprising that the significant reaction was dated for days -1 and 1 as there has been much information in many days, and the reaction has been hard to time to the exact event day. There could also have been other events affecting at the same time impacting the cumulative abnormal returns of this study. Similarly, the reaction of transportation companies' investors around the event day differs from the even day's one. There was a significantly negative reaction on the event day but a significantly positive reaction from day -1 to 1. The result indicates that the situation in the U.S. stock market was unstable, and the returns varied much daily. The reactions to the actual event may be hard to see in the short term.

However, the cumulative abnormal returns in a longer period within the event window illustrate the overall impacts better. For example, the cumulative abnormal returns of technology companies for five days after the event day were 5,963 %, while the abnormal returns of the transportation companies were -2,166 %. Also, the cumulative abnormal returns ten days before the actual event were significantly positive, 4,766 %, for the technology companies and negative, -7,751 %, for the transportation companies. As mentioned above, there was some information available before the event, and the upfront reactions can be considered significantly. The directions of the upfront reactions were the same as after the event, and therefore they help strengthen the overall picture of how the different sectors reacted to the situation. The situation can also be seen in figure 7; the cumulative abnormal returns were positive for the technology companies and negative for the transportation companies within the almost entire event window.

Generally, the abnormal returns of the transportation companies varied more than the technology companies, but in the big picture, the abnormal returns of transportation companies were negative. It could be roughly said that the technology companies got benefits from this situation while the transportation companies harmed. Correspondingly, Thorbecke (2020) found that the COVID-19 impacted positively on electronic and software industries and negatively on the airlines and tourism industries in the U.S. The overall findings are reasonable as it could be assumed that the technology companies can perform their daily tasks almost normally. They could also bring opportunities to this situation, for example, with the live streaming programs. The technology industry is the one that helps other industries to continue their daily processes by replacing the normal on-site task with innovations. Schaefer, Nair, and MacMurray (2020) conclude that "technology will continue to play a massive role in the COVID-19 pandemic." Simultaneously, the transportation companies cannot even perform their daily tasks completely as the traveling has stopped almost completely.

Furthermore, He et al. (2020) and Al-Awadhi et al. (2020) found that the COVID-19 impacted positively on modern industries like technology and negatively on traditional industries like transportation in China. Shen and Zhang (2020) noticed that the impacts were positive on the go-outside stocks and negative on the stay-at-home stocks. These results are also consistent with this study if the technology companies' stocks are considered to consume at home, like streaming services, and the transportation companies' stocks are considered to consume outside, like airlines. These findings of this study are somehow generalizable, and it could be assumed that the companies who sell products that are not location-dependent, such as outdoor sports material, could benefit from the situation.

Altogether, what needs to be remembered is that the entire market gave negative returns. However, when comparing the returns of technology companies to the market index, the decrease was smaller, and the abnormal returns turned out to be positive. The technology companies returned better than before when considering the movements of the S&P 500 index. In turn, the transportation companies made lower returns than normal relative to the S&P 500 index, which means that the abnormal returns were negative.

6. CONCLUSIONS

The objective of this study was to examine the impact of COVID-19 on the U.S. stock market. The study was motivated by the new stock market situation and the earlier results, which showed that the impacts were significant worldwide. The U.S. stock markets were split into two sectors, technology and transportation, and the impacts were studied differently in the short term. The results were then compared, indicating how modern industries, like technology and traditional industries, like transportation, differed from each other. Finally, several event days were studied using sensitivity analysis to examine how much the event day selection affected the results.

6.1. Answers to the research questions and hypotheses

The first research question was:

- *How can stock market crashes be studied using event study methodology?*

The literature review focused on answering this research question. The previous studies showed that the event study methodology is a widely used methodology to examine the impacts of significant events on stock markets and stock market crashes. Earlier results indicated that the event study methodology could be used to study stock market crashes in the short term, especially when the information of the event has come to markets within a short period of time. If the event is long-term, the event day selection could be difficult, but the event study methodology could still be used. In this case, the most relevant single event of the long-term event can be selected, and the event day is set there. The second research question was:

- *How can event study methodology use to study the impact of COVID-19 on stock markets? What are the results?*

To answer this question, earlier results were analysed, and this study was undertaken. Previous studies showed that the impact of COVID-19 on stock markets could be examined using event study methodology. However, the event day selection could be difficult as the COVID-19 is a long-term event. The selected days differed a little between the earlier studies. Mostly, the days of some significant announcements related to COVID-19 or the lockdown period starts were used. After the event day selection, the short-term impacts were studied, and they seemed to be significant.

When considering this study, the event day selection was the most difficult part of the process. The event day was set to the day when the national emergency was announced in the U.S. as it was a major announcement related to COVID-19 in the middle of all the other news relative to the same topic. The results were significant, and it seems that the event study methodology can be used to study the impact of COVID-19 on stock markets. However, the event day selection could be difficult as the information has come to the markets in many days. The event day selection could affect the results much.

Previous studies showed that COVID-19 impacted stock markets worldwide. The impacts were studied much in different countries, but the results were similar. COVID-19 impacted all the stock markets somehow. The most common outcome was that modern industries, like high-tech, were positively affected, and traditional industries, like transport, were negatively affected by COVID-19. Earlier results also showed that COVID-19 impacted negatively on go-outside stocks and positively on the stay-at-home stock. Additionally, the effect of COVID-19 on stock prices seemed to be negative on pre-lockdown periods and positive on post-lockdown periods. Moreover, different countries were also impacted differently as the most negative impact was seen in Asia, and the least negative impact was seen in Europe. Finally, some studies showed that the reaction in emerging markets is different, and they could benefit from this situation.

The results of this study showed that COVID-19 impacted the U.S. stock market. The stock markets were split into two sectors, technology and transportation, and it seems that these industries reacted differently to the event. On the event day, there was no effect on technology companies, and there was a negative effect on transportation companies. When studying the impacts cumulatively, there was a positive impact in technology companies and a negative impact in transportation companies within the almost whole event window. It means that the technology industry benefited, and the transportation industry suffered from this situation. The sensitivity analysis showed that the event day selection affected much the results of this study in both AAR and CAAR analysis. The impacts were considerably higher with some days, and the significance of the results varied a lot.

The first hypothesis of this study was:

H1: COVID-19 positively impacts stock prices in the technology industry.

The results of this study suggested the first hypothesis. The positive reactions were quickly seen when studied the average abnormal returns. Moreover, the cumulative average abnormal returns were highly positive, clearly showing the positive reaction of technology companies' investors for a longer period. The second hypothesis of this study was:

H2: COVID-19 negatively impacts stock prices in the transportation industry.

The second hypothesis was also suggested by the results of this study. The average abnormal returns of transportation companies varied more than technology companies, and the AAR results were not that clear. However, the cumulative average abnormal returns of transportation companies were highly negative, indicating the negative reaction of transportation companies' shareholders. The third hypothesis of this study was:

H3: The reactions are high after the event day, but they disappear rapidly within the event window.

The results of this study did not suggest the third hypothesis. The reactions were high in both stock groups rapidly after the event. However, the reactions were also high at the end of the event window. It means that the investors reacted to the event also in the long term, which was not predicted.

6.2. Reliability of the results

The findings of this study indicate that the event study methodology might not have been the best choice to study the impact of COVID-19 on the U.S. stock market. The first issue was related to the impact of other events. The abnormal returns on the event day did not differ significantly from other day's abnormal returns, which suggests that the event studied in this study was not that meaningful. The stock prices also behaved uncertainly outside the event day, recommending that the other events simultaneously impacted stock prices. The event study methodology cannot differ the impact of these events.

The second problem was related to the duration of the event. There were significant impacts on the event day and right after that, suggesting that the event affected the stock prices. However, there were also significant impacts before the event and at the end of the event window, which indicates that the impacts of COVID-19 on stock prices in the U.S. were long-term. As the event study methodology focuses on studying the short-term impacts, it does not perfectly fit to study the long-term event. Consequently, these two things lower the reliability of the results.

Nevertheless, even if there was only one event selected, the objective of this study was to examine the impacts of COVID-19 on the U.S. stock market as a whole. As it seemed that other events affected stock prices simultaneously, it could be assumed that these other events were mostly related to COVID-19. When making this assumption, the results of this study are mostly reliable, and it could be said that COVID-19 impacted much the U.S. stock market, and the situation was highly unstable. The impacts seemed to be long-term, making cumulative abnormal returns more truthful than the daily abnormal returns.

6.3. Suggestions for further research

This thesis examined the impact of COVID-19 on the U.S. stock market, but only on two groups, technology and transportation. It would be interesting to study other industries, such as the medical sector, as this situation could positively impact the sector. Also, the study focused only on the U.S. stock market, so it would be beneficial to expand the research area. Some earlier studies have shown that the impacts of COVID-19 were smaller in Europe than in other areas, and it would be interesting to study the differences between countries in Europe. Even if Europe seemed to be affected less, the differences within Europe could be significant.

Besides, as one of the biggest problems with this study was to select the exact event day, it needs to be considered if other research methodologies could be used to study the same stock groups. It would be beneficial to choose the research methodology created to study the long-term impact as it seems that COVID-19 is more permanent than rapidly disappearing.

REFERENCES

Al-Awadhi, A. M., Alsaifi, K., Al-Awadhi, A. & Alhammadi, S. (2020) Death and Contagious Infectious Diseases: Impact of the COVID-19 Virus on Stock Market Returns. *Journal of Behavioral and Experimental Finance* 27.

Al-Rjoub, S. A. M. (2009) Business Cycles, Financial Crises, and Stock Volatility in Jordan Stock Exchange. [www document]. [Accessed 30.11.2020]. Available https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1461819

Alam, M. N., Alam, M. S. & Chavali K. (2020) Stock Market Response During COVID-19 Lockdown Period in India: An Event Study. *Journal of Asian Finance, Economics and Business* 7, 131–137.

Alvarez, P. (2020) Here's What Trump's Coronavirus Emergency Declaration Does. [www document]. [Accessed 6 November 2020]. Available https://edition.cnn.com/2020/03/13/politics/states-coronavirus-fema/index.html

Anh, D. L. T. & Gan, C. (2020) The Impact of the COVID-19 Lockdown on Stock Market Performance: Evidence from Vietnam. *Journal of Economic Studies*.

Baek, S., Mohanty, S. K. & Glambosky, M. (2020) COVID-19 and Stock Market Volatility: An Industry Level Analysis. *Finance Research Letters* 37.

Baker, M (2020) When Did the Coronavirus Arrive in the U.S.? Here's a Review of the Evidence. [www document]. [Accessed 6 November 2020]. Available https://www.nytimes.com/2020/05/15/us/coronavirus-first-case-snohomish-antibodies.html

Bierman, H. (1998) The Causes of the 1929 Stock Market Crash. *Contributions in Economics and Economic History*.

Brewer, M. & Gardiner, L. (2020) The Initial Impact of COVID-19 and Policy Responses on Household Incomes. *Oxford Review of Economic Policy* 36, 1, 187–199.

Centers for Disease Control and Prevention (2021) Trends in Number of COVID-19 Cases and Deaths in the US Reported to CDC, by State/Territory. [www document]. [Accessed 22.3.2021]. Available https://covid.cdc.gov/covid-data-tracker/?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcoronavirus%2F2019-ncov%2Fcases-updates%2Fcases-in-us.html#trends_dailytrendscases

Chaudhary, R., Bakhshi, P. & Gupta, H. (2020) Volatility in International Stock Markets: An Empirical Study During COVID-19. *Journal of Risk and Financial Management* 13, 9.

Chen, J. (2021) Stock Market Crash. [www document]. [Accessed 1 February 2021]. Available https://www.investopedia.com/terms/s/stock-market-crash.asp

De Bondt, W. F. M & Thaler, R. (1985) Does the Stock Market Overreact? *The Journal of Finance* 40, 3, 793–805.

Doshi, P. (2011) The Elusive Definition of Pandemic Influenza. *Bull World Health Organ* 89, 532–538.

Fama, E. F. (1960) Efficient Market Hypothesis'. Doctoral Dissertation, Ph. D. Dissertation, *University of Chicago Graduate School of Business*.

Fama, E. F. (1991) Efficient Capital Markets: II. *The Journal of Finance* 46, 5, 1575–1617.

Fama, E. F. (1997) Market Efficiency, Long-Term Returns, and Behavioral Finance. *Journal of Financial Economics* 49, 283–306.

Fama, E. F. & French, K. R. (1988) Permanent and Temporary Components of Stock Prices. *Journal of Political Economy*, 96, 2, 246–273.

Fox, L. & Duster, C. (2020) Schumer, Other Senators to Ask Trump to Issue National Emergency Declaration for Coronavirus. [www document]. [Accessed 26 March 2021]. Available https://edition.cnn.com/2020/03/11/politics/schumer-coronavirus-emergency-declaration/index.html

French, K. R. (1980) Stock Returns and the Weekend Effect. *Journal of Financial Economics*, 8, 1, 55–69.

Fuller, T., Baker, M., Hubler, S. & Fink, S. (2020) A Coronavirus Death in Early February Was 'Probably the Tip of an Iceberg'. [www document]. [Accessed 6 November 2020]. Available https://www.nytimes.com/2020/04/22/us/santa-clara-county-coronavirus-death.html

Ganti, A. & Scott, G. (2020) Adjusted Closing Price. [www document]. [Accessed 8 March 2021]. Available https://www.investopedia.com/terms/a/adjusted_closing_price.asp

Grossman, S. J. & Stiglitz, E. J. (1980) On the Impossibility of Informationally Efficient Markets. *The American Economic Review* 70, 3, 393.

Haugen, R. & Lakonishok, J. (1988) The Incredible January Effect: The Stock Market's Unsolved Mystery. Homewood, IL: Irwin.

Hawawini, G. & Keim, D. B. (1995) On the Predictability of Common Stock Returns: World-Wide Evidence. *R. Jarrow et al. Eds., Handbooks in OR & MS*, 9, 497–544.

He, P., Sun, Y., Zhang, Y. & Li, T. (2020) COVID-19's Impact on Stock Prices Across Different Sectors – An Event Study Based on the Chinese Stock Market. *Emerging Markets Finance and Trade* 56, 10, 2198–2212.

Kaira, R., Henderson Jr., G. V. & Raines, G. A. (1993) Effects of the Chernobyl Nuclear Accident on Utility Share Prices. *Quarterly Journal of Business and Economics* 32, 2, 52–77.

Kaplanski, G. & Levy, H. (2010) Sentiment and Stock Prices: The Case of Aviation Disasters. *Journal of Financial Economics* 95, 2, 174–201.

Kelly, H. (2011) The Classical Definition of a Pandemic is Not Elusive. [www document]. [Accessed 6 November 2020]. Available https://www.who.int/bulletin/volumes/89/7/11-088815/en/#:~:text=A%20pandemic%20is%20defined%20as,are%20not%20considered%20pandemics.

Kenton, W. (2020) Dow Jones Transportation Average (DJTA). [www document]. [Accessed 1 February 2021]. Available https://www.investopedia.com/terms/d/djta.asp

Kenton, W & Boyle, M. J. (2020) S&P500-Index – Standard & Poor's 500 Index. [www document]. [Accessed 1 February 2021]. Available https://www.investopedia.com/terms/s/sp500.asp

Kothari, S. P. & Warner, J. B. (2007) Econometrics of Event Studies. *Handbook of Empirical Corporate Finance* 1, 3–36.

Kumar, M. P. & Kumara, N. V. M (2020) Market Capitalization: Pre and Post COVID-19 Analysis. *Materials Today: Proceedings.*

Lanfear, M.G., Lioui, A. & Siebert, M. G. (2018) Market Anomalies and Disaster Risk: Evidence from Extreme Weather Events. *Journal of Financial Markets* 46.

Liu, H., Manzoor, A., Wang, C., Zhang, L. & Manzoor, Z. (2020) The COVID-19 Outbreak and Affected Countries Stock Market Response. *International Journal of Environmental Research and Public Health* 18, 8.

Lo, A. W. & MacKinlay, A. G. (2008) A Non-Random Walk Down Wall Street. Princeton: Princeton University Press.

Mackinlay, A. C. (1997) Event Studies in Economics and Finance. *Journal of Economic Literature* 35, 1, 13–39.

Maher, O. A. & Bellizzi, S. (2020) Pandemic Declaration, Definition Versus Process. *Public Health* 185, 265.

Malkiel, B. G. (2003) The Efficient Market Hypothesis and Its Critics. *The Journal of Economic Perspectives* 17, 1, 59–82.

Mazur, M., Dang, M. & Vega, M. (2020) COVID-19 and the March 2020 Stock Market Crash. Evidence from S&P1500. *Finance Research Letters.*

Moon, S. (2020) A Seemingly Healthy Woman's Sudden Death is Now the First Known US Coronavirus-Related Fatality. [www document]. [Accessed 6 November 2020]. Available https://edition.cnn.com/2020/04/23/us/california-woman-first-coronavirus-death/index.html

Morens, D. M., Folkers, G. K. & Fauci, A. S. (2009) What Is a Pandemic? *The Journal of Infectious Diseases* 200, 7, 1018–1021.

New York Times (2020) See How All 50 States Are Reopening (and Closing Again). [www document]. [Accessed 9 November 2020]. Available https://www.nytimes.com/interactive/2020/us/states-reopen-map-coronavirus.html

New York Times (2021) Covid in the U.S.: Latest Map and Case Count. [www document]. [Accessed 12 April 2021]. Available https://www.nytimes.com/interactive/2020/us/coronavirus-us-cases.html

Nikkinen, J., Omran, M. M., Sahlström, P. & Äijö, J. (2006) Stock Returns and Volatility Following the September 11 Attacks: Evidence from 53 Equity Markets. *International Review of Financial Analysis* 17, 27–46.

Poudel, K. & Subedir, P. (2020) Impact of COVID-19 Pandemic on Socioeconomic and Mental Health Aspects in Nepal. *International Journal of Social Psychiatry* 66, 8, 748–755.

Poterba, J. H. & Summers, L. H. (1988) Mean Reversion in Stock Prices: Evidence and Implications. *Journal of Financial Economics*, 22, 1, 27–59.

Richards, M., Anderson, M., Carter, P., Ebert, B. L. & Mossialos, E. (2020) The Impact of the COVID-19 Pandemic on Cancer Care. *Nature Cancer* 1, 565–567.

Righi, M. B. and Ceretta, P. S. (2011) Analyzing the Structural Behavior of Volatility in the Major European Markets During the Greek Crisis. *Economics Bulletin* 31, 4, 3016–3029.

Schaefer, A., Nair, S. & MacMurray, D. (2020) COVID-19: Technology Sector Perspectives. [www document]. [Accessed 16 April 2021]. Available https://assets.ey.com/content/dam/ey-sites/ey-com/en_ca/topics/technology-sector/pdf/ey-covid-19-technology-sector-perspectives-v7.pdf?download

Shen, D. & Zhang, W. (2020) Stay-at-Home Stocks Versus Go-Outside Stocks: The Impacts of COVID-19 on the Chinese Stock Market. *Asia-Pacific Financial Markets*.

Shiller, R.J. (2003) From Efficient Markets Theory to Behavioral Finance. *Journal of Economic Perspectives*, 17, 1, 83–104.

Sornette, D. (2017) Why Stock Markets Crash: Critical Events in Complex Financial Systems. *Princeton Science Library*.

Statista (2021) Distribution of Countries with Largest Stock Markets Worldwide as of January 2021, by Share of Total World Equity Market Value. [www document]. [Accessed 18 February 2021]. Available https://www.statista.com/statistics/710680/global-stock-markets-by-country/

Thorbecke, W. (2020) The Impact of the COVID-19 Pandemic on the U.S. Economy: Evidence from the Stock Market. *Journal of Risk and Financial Management* 13, 233.

Topcu, M. & Gulal, O. S. (2020) The Impact of COVID-19 on Emerging Stock Markets. *Finance Research Letters* 36.

Torales, J., O'Higgins, M., Castaldelli-Maia, J. M. & Ventriglio, A. (2020) The Outbreak of COVID-19 Coronavirus and Its Impact on Global Mental Health. *International Journal of Social Psychiatry* 66, 4, 317–320.

Vaihekoski, M. (2016) Rahoitusalan sovellukset ja Excel. Helsinki. Talentum Pro.

Waheed, R., Sarwar, S., Sarwar, S. & Khan, M. K. (2020) The Impact of COVID-19 on Karachi Stock Exchange: Quantile-on-Quantile Approach Using Secondary and Predicted Data. *Journal of Public Affairs* 20.

Washington State 2019-nCov Case Investigation Team (2020) First Case of 2019 Novel Coronavirus in the United States. [www document]. [Accessed 6 November 2020]. Available https://www.nejm.org/doi/10.1056/NEJMoa2001191#article_references

Wells, W. (2004) A beginner's Guide to Event Studies. *Journal of Insurance Regulation* 22, 4, 61–70.

World Health Organization (2010) What is a Pandemic? [www document]. [Accessed 7 November 2020]. Available https://www.who.int/csr/disease/swineflu/frequently_asked_questions/pandemic/en/

World Health Organization (2020a) Coronavirus. [www document]. [Accessed 7 November 2020]. Available https://www.who.int/health-topics/coronavirus#tab=tab_1

World Health Organization (2020b) Coronavirus Disease (COVID-19): Herd Immunity, Lockdowns and COVID-19. [www document]. [Accessed 9 November 2020]. Available https://www.who.int/news-room/q-a-detail/herd-immunity-lockdowns-and-covid-19

World Health Organization (2020c) Timeline: WHO's COVID-19 Response. [www document]. [Accessed 6 November 2020]. Available https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline?gclid=CjwKCAjw8-78BRA0EiwAFUw8LNs_WmsLL8rGpqjlnc1xAV55XxoYglmSjV62cN0gyP8hiOhFO9plVxoCNY0QAvD_BwE#!

World Health Organization (2021) COVID-19 Explorer. [www document]. [Accessed 12 April 2021]. Available https://worldhealthorg.shinyapps.io/covid/

APPENDICES

Appendix 1. Technology companies included in this study.

Number	Company	Ticker
1.	Adobe Inc.	ADBE
2.	Alphabet Inc.	GOOG
3.	Amazon.com, Inc.	AMZN
4.	Apple Inc.	AAPL
5.	AT&T Inc.	T
6.	Broadcom Inc.	AVGO
7.	Cisco Systems, Inc.	CSCO
8.	Comcast Corporation	CMCSA
9.	Facebook, Inc.	FB
10.	International Business Machines Corporation	IBM
11.	Intel Corporation	INTC
12.	Mastercard Incorporated	MA
13.	Microsoft Corporation	MSFT
14.	Netflix, Inc.	NFLX
15.	NVIDIA Corporation	NVDA
16.	Oracle Corporation	ORCL
17.	PayPal Holdings, Inc.	PYPL
18.	Salesforce.com, Inc.	CRM
19.	Verizon Communications Inc.	VZ
20.	Visa Inc.	V

Appendix 2. Transportation companies included in this study.

	Company	Ticker
1.	Alaska Air Group, Inc.	ALK
2.	American Airlines Group Inc.	AAL
3.	Avis Budget Group, Inc.	CAR
4.	C.H. Robinson Worldwide, Inc.	CHRW
5.	CSX Corporation	CSX
6.	Delta Air Lines, Inc.	DAL
7.	Expeditors International of Washington, Inc.	EXPD
8.	FedEx Corporation	FDX
9.	J.B. Hunt Transport Services, Inc.	JBHT
10.	JetBlue Airways Corporation	JBLU
11.	Kansas City Southern	KSU
12.	Kirby Corporation	KEX
13.	Landstar System, Inc.	LSTR
14.	Matson, Inc.	MATX
15.	Norfolk Southern Corporation	NSC
16.	Ryder System, Inc.	R
17.	Southwest Airlines Co.	LUV
18.	Union Pacific Corporation	UNP
19.	United Airlines Holdings, Inc.	UAL
20.	United Parcel Service, Inc.	UPS