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COVID-19 Pandemic Effects in United Kingdom's stock market

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Dissertation as partial requirement for obtaining the Master's degree in Statistics and Information Management

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COVID-19 PANDEMIC EFFECTS IN UNITED KINGDOM'S STOCK MARKET

by

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Dissertation as partial requirement for obtaining the Master's degree in Statistics and Information Management, with a specialization in Risk Analysis and Management

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Abstract

Today, economic, natural and technological disasters, civil emergencies, disease epidemics yield an increasing concern about the world's economy. The first cases of COVID-19 started to appear in January 2020 in China and in 11th March was considered a pandemic. This pandemic is unique, in the sense that required some companies to reinvent their working methods, some to shut down their production for a certain time and in the worst cases file for bankruptcy.

In this work, we aim to study the possible effects of COVID-19 pandemic on UK's stock market. For this analysis we used daily data from FTSE All-Share between 1 January 2010 and 30 December 2020, COVID-19 daily total deaths and daily total cases, and also dummy variables based on a GARCH (1,1) regression model. The findings shows that the returns of FTSE All-Share during the COVID-19 pandemic were not affected significantly and that during this period we can see significant positive and negative effects during some specific fortnights. No significant evidence was found of a relationship between the rise in the number of cases/deaths per covid-19 and the daily index returns.

Keywords: COVID-19; UK; Extreme events; Financial Markets; Economic Crisis

Resumo

Atualmente, as catástrofes económicas, naturais e tecnológicas, as emergências civis e as epidemias são alvo de uma preocupação crescente sobre a economia mundial. Os primeiros casos de COVID-19 começaram a surgir em Janeiro de 2020 na China e a 11 de Março foi considerada uma pandemia. Esta pandemia é única, no sentido que exigiu que algumas empresas reinventassem os seus métodos de trabalho, que algumas encerrassem a sua produção durante determinado tempo e que, nos piores casos, declarassem falência.

Neste trabalho, pretendemos estudar os possíveis efeitos da epidemia de COVID-19 na bolsa de valores do Reino Unido. Para esta análise utilizámos dados diários do índice FTSE All-Share entre 1 de Janeiro de 2010 e 30 de Dezembro de 2020, o número total de mortes diárias e casos diários por COVID-19 e também variáveis dummy baseadas num modelo de regressão GARCH (1,1). Os resultados mostram que os retornos do FTSE All-Share durante a pandemia de COVID-19 não foram afetados significativamente e que durante este período podemos ver efeitos significantes positivos e negativos durante algumas quinzenas específicas. Não foram encontradas provas significativas de uma relação entre o aumento do número de casos/mortes por covid-19 e os retornos diários do índice.

Palavras Chave: COVID-19; Reino Unido; Eventos Extremos; Mercados Financeiros; Crise Económica

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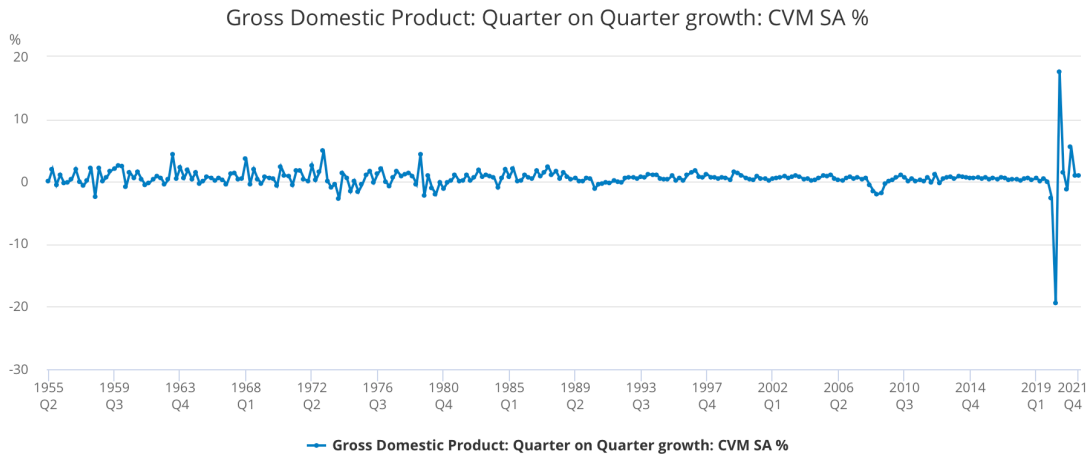
CHAPTER 1

INTRODUCTION

1.1 Background and Problem Identification

United Kingdom has strong political links with many countries, such as Group of Seven (seven of the most advanced economies), made up of the United States, Canada, France, Germany, Italy, Japan, and UK. UK is the sixth largest economy in the world with Gross Domestic Product (GDP) of 2,83 trillion dollars (comprising 3,3% of world GDP), ninth largest by purchasing power parity (PPP), and twenty second largest by GDP per capita.

The UK GDP experienced an increase every quarter from 1992 to 2008. In April 2008, however, it suffered a five-quarters decrease in its output (Graph 1). The Gross Domestic Product declined by 6% over this period (between the first quarter of 2008 and the second quarter of 2009) and, according to figures from the National Statistics Agency, it took five years to rebound to pre-recession rate. The UK economy is mainly powered by the services sector that contributes over 75% of its GDP, the second most prominent sectors being manufacturing and agriculture.



Graph 1 - Gross Domestic Product: Quarter on Quarter growth

Source: Office for National Statistics (https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/ihyq)

Financial markets react to major events. Some studies have focused on trying to understand what impact on the stock markets some events have, such as: disasters (Capelle-Blancard et al., 2010; Kowalewski and ëpiewanowski, 2020), sports (Edmans et al., 2007; Buhagiar et al., 2018), news (Solomon, 2012; Nguyen et al. 2014; Li, 2018),

environmental (Shelor et al.,1992; Carpentier and Suret, 2015; Guo et al., 2020), political events (Bash and Alsaifi, 2019; Shanaev and Ghimire, 2019; Škrinjarić, 2019) and health crisis such as epidemic/pandemic diseases, for example Severe Acute Respiratory Syndrome (SARS) outbreak (Lee and McKibbin, 2004; Nippani and Washer, 2004), Influenza outbreak (Barro, Ursua and Weng, 2020), Ebola Virus Disease (EVD) outbreak (Ichev and Marinč, 2018), among others.

An unexpected disease called coronavirus (COVID-19) has spread around the world since the end of 2019. Wuhan, a central city in China, announced the first case of COVID-19 on December 2019. The first three confirmed cases outside of Wuhan were on January 19th. To avoid the spread of epidemic, the Chinese government continued to implement different public health policies, such as travel restrictions, curfews and school closures. The virus, however, continued to spread as one of the highest infection rate viruses.

The UK confirmed the first two cases of the latest coronavirus on January 31st. On March 11th 2020, as the number of confirmed cases rose globally, the World Health Organization (WHO) announced the coronavirus outbreak to be a global pandemic. The main events relating to the COVID-19 outbreak are summarized in Table 1.

Dec. 31	WHO reports more than 2 dozen cases of pneumonia of unknown origin.
Jan. 11	First confirmed death from novel coronavirus reported in Wuhan, China.
Jan. 31	United Kingdom confirms the first two cases of coronavirus.
Mar. 8	UK records first 3 deaths.
Mar. 11	WHO considers COVID-19 a pandemic

Table 1- Main events relating to COVID-19

As of 23 of June, 2020, the number of global active confirmed cases surpassed 3.500.000, specifically, the UK passed the barrier of 300 000 cases and the number of cases continued to rise (WHO, 2020).Compared to other viruses, COVID-19 fatality risk is low, but its infection rate is relatively high (Table 2).

	Fatality rate (deaths/cases)	Infection rate (per infected person)
Ebola	50%	1.5-2.5
MERS	34.30%	0.42-0.92
SARS	10%	3
COVID-19	1%-3.4%	1.5-3.5
Seasonal flu	0.05%	1.3

Table 2 - Fatality Rates and Infection Rates of COVID-19 and Other Epidemics

Source: Asian development bank report No. 128 (https://www.adb.org/publications/economic-impact-covid19-developing-asia).

United Kingdom faced a major recessionary challenge regarding the effects of COVID-19 pandemic. There are some big companies whose business has been considerably affected by this pandemic, including Associated British plc, British Airways plc, Tesco PLC, Rolls-Royce Holdings plc, and Dyson Ltd. For instance, on the 22nd of March 2020, Associated British Foods plc had to close all stores in the UK, which represented 41% of its sales. On the other hand, due to the increasing demand for ventilators in the UK, some companies such as Rolls-Royce Holdings plc and Dyson Ltd. started to produce ventilators, which was a help to mitigate their lack of revenue during the pandemic.

Since public transit in Wuhan was halted on 23 January, a variety of papers have been released in the mainstream press reporting that COVID-19 is having a major effect on the economies of the countries affected. In The Economist, a report entitled 'Spread and Stutter' stresses that COVID-19 is a significant threat to the status of global markets. 'The Right Medicine for the World Economy' (The Economist) also reports that stock market prices have fallen as concerns intensify regarding the effects of the COVID-19 virus.

Coronavirus disease 2019 (COVID-19) has brought uncertainty in the global economy. When the pandemic first surged it was thought that only China's economy would be affected bringing several consequences to global economy, however, the situation turned out to be worst. This is noticeable in the MSCI World Index that fell 8% from the beginning of January until June 2020.

This study aims to examine the effect of COVID-19 disease on UK's stock market returns, additionally we will also examine the effects of daily cases and daily deaths on the UK stock market. Following the Chen, Tang, et al. (2009) 'The positive and Negative Impacts of the SARS outbreak: A case of the Taiwan Industries' paper, we think it would be interesting to make a similar type of analysis regarding the impact of COVID-19 on UK's stock market. In the next chapter we will refer to some studies that present evidence that, contrary to prevailing belief, viruses have not had negative impact in the stock markets while others present evidence that such impacts do exist and are statistically significant.

1.2 Study Objectives

As above mentioned, the main objective is to answer, "how was the UK stock market affected by the COVID-19 pandemic". To answer this question we first have to analyze the following questions "did COVID-19 impact the UK's stock market?" we aim to analyze the daily returns of FTSE All-Share in the period from January 2010 to January 2021, and see if this pandemic impacts the UK's stock market, "if so, what were the impacts" quantify the possible impact of this pandemic, "did COVID-19 had a momentarily impact on the UK's stock market?" and "if so, what were the impacts?" analyze and quantify in each fortnights if the returns differ from pre-pandemic average and try to find temporal events related to COVID-19 that coincide with those fortnights. Additionally, we will answer the questions "How does the number of daily deaths impact

the UK stock market prices?" and "How does the number of daily cases impact the UK stock market prices?". To answer this question, we aim to analyze the relation between daily returns of FTSE All-Share and the number of daily deaths/cases in the UK.

The rest of the paper proceeds as follows: on section 2 we present some relevant papers for this study that constitute the Literature Review, section 3 presents the data and methodology used, in section 4 we present the results and their discussion and finally in section 5 we present the conclusions.

CHAPTER 2

LITERATURE REVIEW

2.1 UK's stock market Origin

It was in 1968 that the first structured trading in marketable securities was heard of in London. All of this began when in that same year John Castaing published a list of stocks and asset prices designated at the time "The Course of the Exchange and other things". In 1761, about 150 stockbrokers founded a group/club to buy and sell shares at Jonathan's Coffee House. In 1773, the same group built their own house in Sweeting's Alley known as "New Jonathan's". However, members quickly renamed to "The Stock Exchange". (LSE, 2012a).

The London Stock Exchange opened its foreign market for growing companies, Alternative Investment Market (AIM), in 1995. The Stock Exchange Electronic Trading Service (SETS) was introduced two years later to offer the industry more speed and efficiency. LSE was listed as its own primary market in July 2001. A new international equity derivatives company, EDX London, was founded by the LSE in 2003. The LSE merged with Borsa Italiana in 2007, forming the London Stock Exchange Group (LSE, 2012a). Besides these important marks, stock markets reforms were also important. Due to the increase in market demand from an accumulation of steps in order to initiate a total change in the market structure, the day the London Stock Exchange rules changed, October 27, 1986, was named "Big Bang". The 1986 Big Bang marked the beginning of a chain of serious reforms, which saw the restructuring of the U.K. financial exchange (Yadav, P. K., & Pope, P. F, 1990; Peel et Al., 1993; Chambers, 2009).

In the U.K., there are several exchanges specializing in numerous trades, such as the International Financial Futures and Options Exchange (LIFFE), London Metal Exchange (LME) and Baltic Exchange. LIFFE started by trading future contracts and options with short-term interest rates, until it has merged with the London Traded Options Market (LTOM) in 1993, and increased the variety of products in its portfolio. The London Metal Exchange is an exchange for base and other metals futures contracts and options; and the Baltic Exchange, is a membership organization at the heart of the global maritime marketplace, that offers "*daily freight market prices*" and cost indexes of marine shipping. (LSE,2012a).

Today, at the heart of the global financial market, the London Stock Exchange is home to some of the world's biggest, most profitable and competitive companies. (LSE, 2012a). From over seventy countries, the Exchange is one of the most diverse of all stock exchanges in the world. The main market of the LSE is the biggest international market for the listing and trade of shares, debt and other instruments in the world.

The London Stock Exchange is nearly 300 years old, making it one of the world's oldest stock exchanges. The London Stock Exchange was founded in 1801 and is located in the City of London in the United Kingdom. (World Federation of Exchanges, 2012). As of March 2020, the Exchange had a market capitalization of US$3.332 trillion, making it the eighth-largest stock exchange in the world and the second largest in Europe.

During 1999, the London Stock Exchange had record volumes traded on the foreign and domestic exchange, with international business up 10,1% in value and domestic business up 36%. London experienced buoyant rate of trading in 1999, like many stock markets. A positive reminder of one of London's main strengths was the continuing expansion of its international market (LSE, 2012b). The overall volume of U.K equities traded during 1999 grew to 1.407 billion on the domestic market, from 1.037 billion in December 1998. The overall number of U.K. deals also soared to a record 20.929.000 up 29% from 16.220.000 deals in 1998 (81.644 a day on average). In 1999, all the big U.K. FTSE indexes set milestones.

The turnover volume hit 2.403 billion at the end of 1999, up more than 10,1% from 2.183 billion in December 1998. Over time, the number of listed firms on the LSE has not changed significantly. Based on the paper of Nyasha et Al. (2013) we were able to construct an updated table of the number of listed companies on the LSE and also draw some conclusions. The number declined to 2.778 in 2000 from 2895 in 1999, but bounced up to 2.927 in 2001. That number declined between 2001 and 2004, while it rose between 2005 and 2007. In 2007, the number of listed companies peaked, with 3.305 listed companies registered. As Nyasha et Al. (2013) analysed "*with the global financial crisis, the number of listed companies started its descent in 2008, recording 3.298 before further tumbling to 2.792 in 2009*". Since then, there has been a decrease in listed firms. The highest number of listed companies registered between 1999 and 2020 was in 2007, while

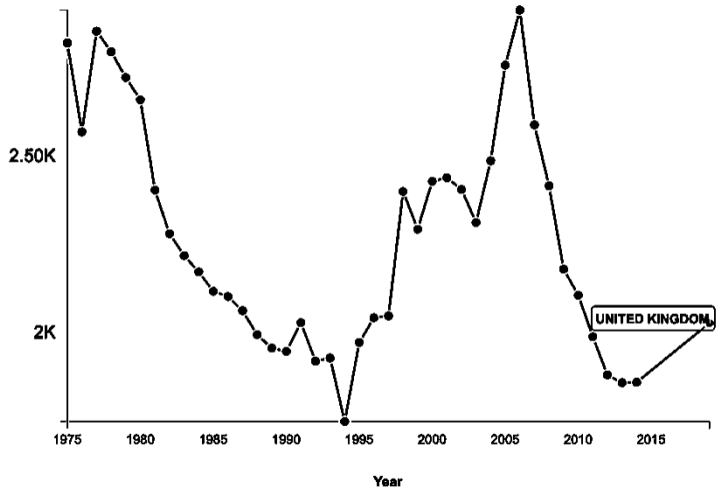
	1999	2000	2001	2002	2003	2004	2005	2006
Number of Listed Companies on the London Stock Exchange	2895	2778	2927	2880	2815	2681	2844	3088
	2007	2008	2009	2010	2011	2012	2013	2014
Number of Listed Companies on the London Stock Exchange	3305	3298	2792	2670	2594	2494	2448	2446
	2015	2016	2017	2018	2019	2020		
Number of Listed Companies on the London Stock Exchange	2365	2267	2038	2099	2055	1989		

Table 3 - Number of Listed Companies on The London Stock Exchange (1999-2020)

Source: London Stock Exchange. Report Highlights. Issuer List Archive (https://www.londonstockexchange.com/reports?tab=issuers)

the lowest number was recorded in 2020. Table 3 shows the number of listed companies on the LSE during the period 1999 to 2020.

The evolution of the U.K. stock market can also be seen in the number of domestic-listed companies. Between 1985 and 1998, the number of domestic firms listed in United Kingdom fluctuated around 2.000, rising to around 2.400 in 2002, declining marginally in 2003 before rising again in the following years, hitting a peak of around 2.920 in 2007. The number dropped steadily over the years from 2007 until it reached 2.000 listed companies in 2011. In 2019, U.K. registered 2.030 domestic-listed companies. United Kingdom experienced an year-on-year average number of domestic companies growth rate of -0,87% for the time period 1975 to 2019 (World Bank, 2020).



Graph 2 - Number of Domestic-Listed Companies on LSE (1975-2019)

Source: The World Bank

The London Stock Exchange (LSE) is the United Kingdom's main stock exchange where commodities, bonds and other financial instruments are exchanged on a day-to-day basis. The Financial Times Stock Exchange (FTSE) 100 Share Index is the dominant index of the LSE, containing 100 of the top blue-chip stocks. Apart from FTSE 100, LSE also has other known indexes, such as FTSE All-Share Index which includes approximately 600

of the more than 2.000 LSE-traded stocks, comprising at least 98% of the full market capitalization of all listed UK firms.

As its start in 1962, the FTSE All-Share Index was known as the FT Actuaries All-Share Index. In January 1984 and October 1992, respectively, the index was strengthened by the addition of two sub-indices, the FTSE 100 and the FTSE 250. (FTSE Russel, 2021)

Some authors, over the time, studied the primary factors that might have contributed to the variation of the volatility. Like the great crash of 1920, the financial world lived through hard times in 1987. In a matter of a few days, most financial markets lost around 30% of their value and trillions of dollars, thus leaving the "real economy" completely devastated for many years. The first day of this great collapse was a Monday and was therefore called Black Monday. (Sandoval and Franca, 2012)

As Bogle (2008) reported in his article, in just one day, the price of Dow Jones Industrial Average went from 2246$ to 1738$ ie, a drop of around 25%. Oberholzer and Boetticher (2015) in their paper concluded that Black Monday resulted in a "domino effect" in most of the global financial markets, with UK stock market value decreasing by about 26,4%.

From 1963 until late 2003, Engle (2004) analyzed the daily returns of the S&P 500 index. He refers to the October 1987 crisis as "the most dramatic event" and he also observes that volatility tends to be higher in markets that have seen a prolonged price fall. Next, Engle (2004) examined the sub-period after the 1987 crash which recorded "*low volatility period of the middle 1990s*", followed by "*a slow and steady stock price growth of equity prices*". As stock prices rose, uncertainty climbed, hitting extremely high levels from 1998 onwards.

We have seen tremendous volatility in the capital markets over the last two decades. In October 2008, credit flows froze, market confidence collapsed, and the economies of countries around the world plunged into recession one after another (Nanto, 2009). As a result, numerous economists and analysts were worried about the consequences of global contagion. The US economy was facing very tough times, and it did not take long for the consequences to extend to the rest of the global markets, given the national and foreign linkages of its financial sector, to jeopardize, for example, monetary union in Europe and the rest of the world, owing to the high convergence of world markets and the international nature of the financial services factor. As a result, the original US mortgage crisis developed into what came to be dubbed yet another "great recession" which led to drastic structural shifts in the world's main financial markets. The U.K., followed by the rest of Europe and then the developing markets, were the first to be impacted by the crisis due to its strong economic ties with the USA.

The study of the effect of financial crises is critical because crises are recurring phenomena that have significant implications on the real economy, especially "*in terms of loss of economic growth and employment, and increased risk for financial institutions*

that operate globally" (Horta, P., 2013). A lot of analysis and scientific data is available about how and when crises arise and are distributed through financial markets and regions. Lioui, A. (2009) reflected on the effect of the ban on short sales during the financial crisis on the uncertainty, skewness and kurtosis of 11 barred European shares, four European stock indices (CAC40, FTSE, DAX, IBEX 35) and two US indices (S&P 500, NASQAD). In an industry-sponsored report, Marsh and Niemer (2008) analyzed the comparative conduct of stocks that were subject to a short selling ban in 2008 by regulatory authorities in six countries, including the United States. Overall, Marsh and Niemer (2008) did not find any significant effect on the conduct of regular market prices from restricted short selling.

In his article, Chaudhury (2011) studied the effect of the 2008 financial crisis on "*the behavior of stock markets*" using daily returns for the 2007/2008 period of thirty-one large US stocks and the S&P 500. He concluded that "*unconditional mean daily returns declined fell to negative levels, unconditional volatility surged more than two hundred percent"*, market correlation weakened, and the value of market diversification improved in risk mitigation. Chaudhury (2011) also concludes that with the strong accumulated decreases in stock values, the average daily returns have declined dramatically, especially for the financial stocks that started at an "*early stage of the crisis*". The most notable effect of the recession, though, was on the unconditional standard deviation of daily returns, which brought the non-financial stocks up to "*more than three times the pre-crisis level*", "*four times for the S&P 500 and five times for the financial stocks*".

Using the Forbes and Rigobon (2002) concepts, Horta et al. (2010) found that the financial crisis of 2008 had contagious consequences on the European stock markets of the NYSE Euronext community (Belgium, France, the Netherlands and Portugal) as the association between the US returns and the indexes of the other four markets showed that both the US and the other markets went from a calm era to a crisis period. In the background of the 2010 European sovereign debt crisis, Horta, P. (2013) analyzed the same markets and discovered contagion effects from the Greek stock market to the Portuguese stock market, but not from Belgium, France and the Netherlands.

2.2 Economic and Stock Market Impacts of Health Crisis

In the past, the World Health Organization (WHO) has revealed numerous epidemics that have impacted the vast number of people and economies worldwide, such as Influenza, Ebola, Severe Acute Respiratory Syndrome (SARS), among others.

Many studies have analyzed the impact of epidemics on the economy and stock markets. These epidemics had a significant effect on the global economy, in fact, 5% of the US Gross Domestic Product (GDP) decreased due to influenza (Palese, 2004), furthermore, the EBOLA outbreak, which claimed the lives of over 11.000 people worldwide, cost the United States an estimated $53 billion in economic losses (Hai et Al., 2004). SARS-CoV

also had an economic impact in 2002, impacting over 8000 lives, reducing China's GDP by 1%, and contributing to a $54 billion global economic impact. (Peiris et Al. 2003)

An outbreak, generally referred to as the 'Spanish Flu', began during the last year of World War I in March 1918 and is estimated to have caused more than 50 million deaths worldwide. From September to November 1918, the first wave of Spanish flu proved much less fatal than the second wave that appeared in the world (Patterson and Pyle, 1991; Taubenberger and Morens 2006). A third wave was also witnessed by several nations in early 1919.

Barro, Ursua and Weng (2020) examined how GDP, stock prices and inflation across 43 countries have been impacted by the deaths from the Spanish flu pandemic. They concluded that in terms of the macroeconomic effects on GDP and consumption the pandemic "*may have been the fourth most important negative macroeconomic shock for the world since 1870*", going further they found that the pandemic reduced GDP and consumption by around 6,0% and 8,1% respectively. In relation to the impact on financial returns and inflation, they concluded that stock returns were "*negatively impacted by 26 percentage points and 19 percentage points, respectively*", whereas in this case the impact is of the pandemic as well as World War I deaths.

The experience in the United States, where growth resumed in March 1919, did not exactly fit the experience in Europe. Although describing the initial negative impact of the Spanish flu on Swedish capital income (but not earnings), Karlsson, Nilsson, and Pichler (2014) also found evidence of a persistent rise in poverty rates that persisted after 1920. The fact that the first two waves happened when World War I was still in progress, with the third wave emerging only a few months after the Armistice of 11th of November 1918, admittedly complicates any evaluation of the economic consequences of the Spanish Flu. The Spanish flu itself, however, seemed to have fueled such significant disruptions as those noted in Sweden and the United Kingdom (Economist, 1918a, 1918b).

Furthermore, using Weekly NYSE trading info, McTier, Tse and Wald (2013) analyzed the effect of influenza on financial markets. They concluded that for the United States, "*decreased trading, decreased volatility, decreased returns, and higher bid-ask spreads*" was correlated with a higher occurrence of flu. This paper claimed that flu may have an effect on financial markets performance by "*incapacitating key individuals, such as traders and market makers*", by impacting investors behavior, and by reducing economic activity expectations.

Through a number of possible scenarios (mild, moderate, extreme and ultra) that cover the history of influenza pandemics of the twentieth century, McKibbin and Sidorenko (2006) examined the effects of a pandemic influenza on the global economy. As McKibbin and Sidorenko reported faced with a pandemic influenza scenario, it would be expected that: (i) due to an increase in the number of deaths and sick people, a decrease

in the labor force in various sector in many countries; (ii) "*an increase in the cost of doing business*"; (iii) a sudden change in market preferences favoring sectors less vulnerable to the pandemic; and (iv) a constant re-evaluation of the risk of each country by investors based on government responses to the pandemic. The authors also state that even if the pandemic scenario was considered "moderate", the impacts on the overall growth levels of the economy would be quite high, it would cause the death of about 1,4 million people and reduce global GDP by about 0,8% (this is about US$ 330 billion) in economic output. If the pandemic represented a scenario called "ultra" then the impacts on the economy would also be greater. It would cause an estimated 142,3 million deaths and a reduction in global GDP of US$ 4,4 trillion.

The epidemic HIV/AIDS had it first diagnosed appearance in 1981 in United Stated, and it quickly dissipated around the world bringing serious consequences in global health. According to WHO in 1999, AIDS was the fourth biggest cause of death in the world and the first cause in Africa. Although 40 years have passed since the appearance of the first case of HIV, the disease remains a major public health problem and at the end of 2019 there were around 38 million people living with HIV.

Some studies such as Kambou, Devarajan and Over (1992), Cuddington (1993), Cuddington and Hancock (1994) and also Bloom and Mahal (1997) analyzed the economic impact of the AIDS epidemic. Kambou, Devarajan and Over (1992) in their study assumed that the AIDS epidemic affects the economy in the sense that it reduces the labour force and therefore also reduces production in the various economic sectors, more specifically a decrease in the economy of about 0,8% of the entire labor force. According to this reasoning they concluded that the decrease in the labor force resulted in a decrease in GDP of about -0,6% per year for countries on the African continent. Cuddington (1993) and Cuddington and Hancock (1994) studies focused on the epidemic in two countries severely affected by AIDS (Tanzania and Malawi) and concluded that this epidemic would negatively affect the average growth rate of GDP per capita by about 0,25 percentage points during the period year 2010. Bloom and Mahal (1997) studied "*51 developing and industrial countries*" (including United Kingdom) and again examined the claim that AIDS epidemic would "*slow the pace of economic growth*". Contrary to what was expected and seen in other studies about this epidemic, they concluded that despite the epidemic being very advanced and having already affected many countries, after "*controlling for standard influences on growth*", they did not find any evidence that the economies of the affected countries had reduced their growth between 1980 (1987) and the early 1990s compared to other countries less affected by AIDS. They also remark that they study indicates that there was more "*flash than substance to the claim that AIDS impedes national economic growth*".

Past studies by Keogh-Brown and Smith (2008), Beutels et al. (2009) and Lee and McKibbin (2004) studied the economic impact of Severe Acute Respiratory Syndrome (SARS). According to WHO, SARS was first reported in Asia in February 2003, and it quickly spread to 26 countries and it was contained in June 2003, that is 4 months later.

Beutels et al. (2009) used some metrics in his study of economic and social activities in order to try to estimate the impact of SARS in Beijing. They found significant correlation coefficients for "*leisure activities, local and international transport and tourism*" since much of this activity ended up being delayed or canceled. Keogh-Brown and Smith (2008) in their study used macroeconomic indicators to identify the possible effects of SARS in different countries. China and Hong Kong were claimed to have seen the largest losses, with Canada and Singapore experiencing smaller effects. The sectors most affected by the SARS investment epidemic were also considered restaurants, hotels, tourism, air transport and retail sales. Siu and Wong (2004) analyzed the spread of the disease in Hong Kong and its impact on the economy and concluded that the economic impact of SARS on "*consumption, tourism, and travel-related services turned out to be relatively short-lived*" and the response of the stock market reflected these behavior as well. Lee and McKibbin (2004) concluded that the impact of SARS on economy was significant and that it was not a consequence of the disease itself but instead the people's behavior associated with fear about the disease, which were ultimately reflected in the financial markets. They also conclude that the mitigation costs of a disease are much higher than the cost of a "*health budget for treatment of patients*".

Regarding the effects on stock markets, Nippani and Washer (2004) studied the impact of SARS on financial markets of the countries most affected by this pandemic, comparing the leading stock indices of these countries during the SARS outbreak period and the non-SARS period. The results show that there is no evidence that SARS negatively affected the main stock indices except in the case of China and Vietnam. The findings of this paper contradicted previous beliefs that SARS had had a huge and negative on economy on the affected countries. Also, Koo and Fu (2003) concluded in their study that regardless of the fears surrounding this disease about its possible effects on the economy, SARS had only "*limited and temporary economic impacts*". With the same approach but directed to a more particular market, Loh (2006) studied the "*impact of SARS on the performance and risk profiles of a set of airlines stock listed at the stock markets*" of the countries most affected by this pandemic and also concluded that there was no evidence that SARS had a negative impact on the returns of airline stocks.

The Middle East Respiratory Syndrome (MERS) is also a respiratory disease caused by a coronavirus. MERS appeared in 2015 in the Republic of Korea resulted in 38 deaths and about 16.000 people were in quarantine by December 2015. There is a lack of studies of the impact of this disease in the economy possibly due to the lower impact on public health compared to large epidemics/pandemics. However, Joo et al. (2019) studied the economic impact in the Republic of Korea of the MERS outbreak in the most affected economic sectors, tourism and travel-related service sectors. According to these authors MERS outbreak resulted in a 37,4% decrease in the number of visitors from June to September 2015 with an estimated total loss of 2,6 billion in the tourism sector.

All these studies and results demonstrate the impact that infectious diseases can have on the economy, causing significant economic losses in affected countries.

2.3 Economic and Stock Market Impacts of COVID-19

The latest reported pandemic, from Wuhan, China, is identified as a novel coronavirus (COVID-19), with the capacity to propagate from one human to another, it has spread almost all over the world and greatly impacted people's lives. On 17th of April 2020 more than 1.865.413 people were infected, and 110.008 deaths were recorded worldwide due to COVID-19 (Financial Times, 2020).

Following the lessons learned from the earlier SARS and MERS epidemics, researchers began proactive crisis response efforts in the most affected countries immediately after the onset of COVID-19. Studying the impact of COVID-19 is of the utmost importance, mainly since it first outburst in China, which is one of the most important economies in the world (ranked second worldwide for nominal GDP).

Each nation has locked down its industry and economies, people were forced to stay in their homes in order to avoid the transmission of COVID-19. Unemployment was a consequence of the lock down and the supply side, economic growth, the amount of tourism, and travel industry revenues decreased (Leduc and Liu, 2020).

Taking this into account, many studies have been carried out in order to study the impact of COVID-19 on the financial market. Among all these studies we have the studies by Nia (2020), Ali et Al. (2020) and Sharif et Al. (2020) who studied the impact of COVID-19 on the stock markets and concluded that the pandemic affected them negatively. Ali et al. (2020) reported that as the state of the pandemic worsened, more specifically the moment when COVID-19 evolved from epidemic to pandemic increased panic in global stock markets. Importantly, as Sharif et al. (2020) said " *COVID-19 risk is perceived differently over the short and the long-run and may be firstly viewed as an economic crisis*".

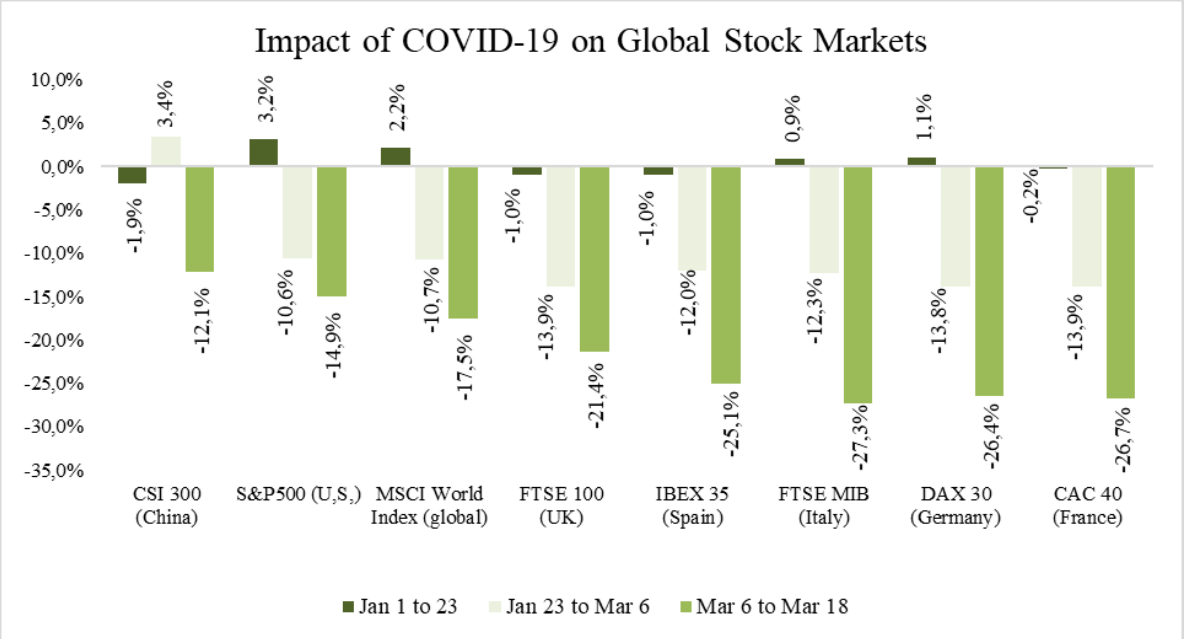
Goodell (2020) studied if COVID-19 can cause serious damage to the economic development worldwide and if it is expected to be a global problem. Slater (2020) also stated that COVID-19 had a tremendous impact on global stock markets. All financial markets had a big decrease in their prices, for example the Dow Jones Industrial Average (DJIA) was down by about 33% and the S&P 500 by about 29% between the periods of 31st of December 2019 and 20th of March 2020. (World Economic Forum, 2020), also FTSE 100 dropped about 24,8%. (The Guardian, 2020)

Burdekin (2020) also argued that the European and US stock markets responded significantly and negatively to the increasing death rates seen during the Spanish flu and discusses the theory that the higher death rates for Spanish flu affected the stock markets more broadly. However, in 1918, the European and more specifically, the American economy were still facing major wartime pressure. Due to this pressure it is possible that the economy was still suffering some disturbances or at least recovering from them, due

to the high ratio of deaths among the population, thus leading to a greater negative impact on stock markets.

Eichenbaum, Rebelo and Trabandt (2020) studied in their paper the "*interaction between economic decisions and epidemics*", and found that there is a clear relationship between the *"severity of the short-run recession caused by the epidemic and the health consequences of that epidemic*". Estrada, Park et al. (2020) estimated the economic impact on China's economic performance and they concluded that the public health crisis will reduce China's GDP from US$ 14,30 trillion dollars to US$ 10 trillion dollars between 2019 and 2020, respectively.

As Shehzad et al. (2020) reported the world's stock markets "*confronted an extreme collision in their market values*". After the outbreak of COVID-19, the stock value of the Standard & Poor (S&P) 500 index has plummeted by 30 per cent. The decrease in the market value of the world's most reputed stock indexes attributed to COVID-19 can be seen in Graph 3. The table suggests that the financial markets of Germany, France and Italy underwent an extreme decline of their market values during March. (Shehzad et al.2020)



Graph 3 - Decline in stock market values due to COVID-19

Adapted from Shehzad et al. (2020)

In comparison, the capital markets of the U.S. (S&P500), U.K. , Spain and China have dropped by 14,9 %, 21,4 %, 25,1 %, 14,7 %, and 12,1 % from March 6 to March 18, respectively. In addition to these variations, the MSCI World Index market value also fell by 17,5% relative to the same period.

Adam (2020) in his study compared the state of financial markets under pandemic COVID-19 circumstances and during the 2008 financial crisis and stated that they were on the verge of collapsing as they did during the financial crisis. Georgieva (2020) argued

that COVID-19 took the world closer to financial crises than the 2007-2009 Global Financial Crise. The Asian Development Bank has assessed that COVID-19 may have a global expense of $4.1 trillion (ADB, 2020).

Looking at literature and evidences about the effects of COVID-19 on stock markets, Baker, Bloom et al. (2020) compared the possible effects of this pandemic with other infectious diseases in the U.S.. The results showed that the Spanish Flu of 1918-19 had modest effects on the U.S. economy, that the 1957-1958 influenza pandemic impacted the economy and left some traces while the 1968 pandemic left no trace of its existence. Consistent with an event study, Ramelli and Wagner (2020) also examined the reaction of US companies to the COVID-19 pandemic (based on their pre-pandemic behaviour), and found that these firms had negative returns during the "incubation period" and also during the "outbreak period".

Zhang, Hu and Ji (2020) analyzed the possible impact of US' policy interventions, such as the decision to implement a "zero-percent interest rate" and "unlimited quantitative easing (QE), and how these policies create further uncertainty and will cause long-term problems into global financial markets. The results obtained by this author's also showed that "*global financial market risks have increased substantially in response to the pandemic*". Liu, Manzoor et. Al (2020) evaluated the immediate effect of the coronavirus outbreak on the stock markets of the most affected countries by this pandemic, including Japan, Korea, Singapore, the USA, Germany, Italy and UK. As in other studies, these authors concluded that the pandemic COVID-19 negatively and significantly affected the stock markets of all the affected countries. Furthermore, they also concluded that one of the determining factor for the propagation of this negative effect in stock markets is investors' feelings of panic/fear.

There is a common point between SARS' studies and COVID-19's papers, which is the fact that all authors consider important that we think not only of ways to avoid future public health problems but also financial issues.

2.3.1 Number of daily deaths and Daily confirmed cases VS Stock Markets

Some studies go further and study the impact of COVID-19 by analyzing a relationship between the number of deaths and the number of confirmed daily cases.

Al-Awdhi et al. (2020) studied the effects of the contagious diseases on the Chinese stock markets and for that they used two approaches. First, they used the daily growth total cases and concluded that there is a significant negative effect in the Hang Seng Index and Shanghai Exchange. The same conclusion was reached for the daily growth in total deaths caused by COVID-19. Chia et al. (2020) did the same exercise but with the Malaysian stock market returns and concluded that the number of daily deaths had no significant impact but the number of daily new COVID-19 cases had a significant, minimal negative impact on the returns on the indices. Following this order of reasoning, Zeren and Hizarci

(2020) studied the relationship between total number of daily cases and deaths with stock markets in China, South Korea, Italy, France, Germany and Spain (countries most affected by COVID-19). They concluded that there is a relation between the daily total deaths and all countries stock markets. COVID-19 daily total cases are also thought to have a long-term association with the financial markets of China, South Korea and Spain (SSE, KOSPI and IBEX35 respectively). . Due to this, considering the increasing evolution of COVID-19 (both in relation to the number of deaths and the number of cases) and also taking into consideration the results obtained by Zeren and Hizarci (2020), they conclude that "*investing in stock markets is not the best option for investors*". Liu et Al. (2020) already referenced in the previous sub-chapter, concluded that the number of confirmed cases of COVID-19 had a significant and negative impact on the major stock markets, especially the Asian stock markets which suffered large drops in returns.

In his study Ashraf (2020) also examined the impact of COVID-19 and for that they used the same measures as the afore mentioned authors and used the stock market returns of 64 countries, including the United Kingdom stock market (FTSE 100). They concluded that stock markets responded negatively to the increase in confirmed cases, that is " *stock markets returns declined as the number of confirmed cases increased*". They additionally concluded that the relationship between the number of deaths by COVID-19 and the returns of stock markets is not quite significant. In addition to these findings, the authors suggest that stock markets have a direct correlation and that this varies and depends on the time and severity of the pandemic.

Albulescu (2021) in his study used the S&P 500 to examine the effects of COVID-19 official announcements on financial volatility during the pandemic phase of the crisis. He concluded that new reported cases globally and in the US, increase stock market volatility and also that the death ratio (ratio between the number of daily reported deaths and the total infection cases) has a positive impact on volatility. It further concluded that global reported cases and deaths data has more impact on stock market prices than reported data at the US level. Xu (2020) also looked at the "dynamic responses of stock returns to unexpected changes in the COVID-19 cases", as well as the pandemic's unpredictability. He examined data from the Canadian and US stock markets and discovered that a spike in COVID-19 cases had a negative impact on the stock market in general.

CHAPTER 3

DATA AND METHODOLOGY

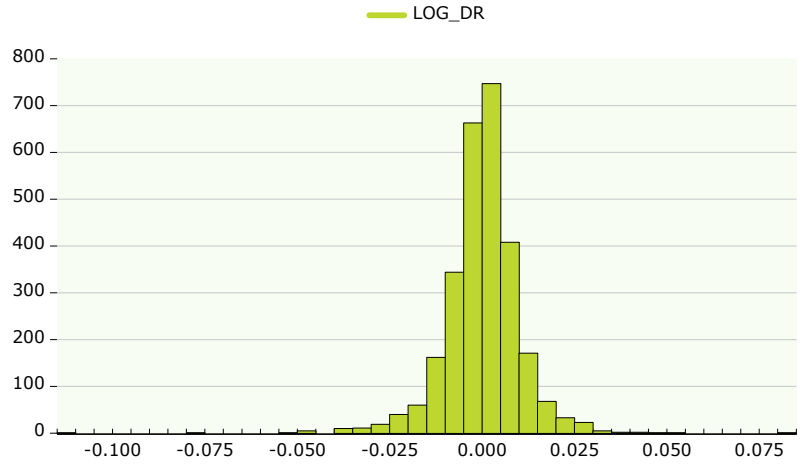
3.1 Data

Considering our research questions and in order to answer them, we have to consider what data we intend to access and how we need to manage it. Firstly, we will describe what data we decided to use in this thesis and secondly, we will describe the data treatment that was necessary to do in order to provide the best input for our variable's definition and model analysis.

Our sample consists of the daily quotes of the Financial Times Stock Exchange All- Share Index (FTSE All-Share), from January 2010 to January 2021, which covers both the FTSE 100 and the FTSE 250 indices, this allows us to have a representation sample for 98-99% of the UK market capitalization. This data was collected from Thomson Reuters Datastream and we extracted the adjusted daily closing price. The software used for the analyses that were carried out was EViews11SV. We used the data collected to calculate the log daily returns of the index:

$$R_t = \ln\left(\frac{I_t}{I_{t-1}}\right) \quad (1)$$

Where R_t is the daily return for FTSE All-Share on day t. I_t is the closing value for FTSE All-Share on day t and I_{t-1} is the closing value for FTSE All-Share on day t-1. The descriptive statistics for the FTSE All-Share return series are shown in Table 4.



Sample: 01/05/2010 12/30/2020

	Log_DR
Mean	0,000102
Median	0,000476
Maximum	0,084903
Minimum	-0,110836
Std. Dev	0,010142
Skewness	-0,708608
Kurtosis	13,28130
Jarque-Bera	12 472,34
Probability	0,000000

Table 4 - Descriptive statistics of returns of FTSE All-Share

There is a large difference between the maximum and minimum return of the index. The standard deviation for the period 2010-2020 is around 0,010. Mean is close to zero and positive which is expected for a time series of returns and can indicate that we are using

an appropriate time frame. There is also evidence of negative skewness, indicating that FTSE All-Share have asymmetric returns. The kurtosis exceeds the normal value of 3 demonstrating that the distribution of returns is heavy-tailed which is expected in financial returns time series. The return series is non-normal according to the Jarque-Bera test which rejects normality at the 1% level.

Data on the number of COVID-19 reported cases and deaths at the daily level was collected from the website https://coronavirus.data.gov.uk. For this, we only considered the working days. The descriptive statistics of these two metrics can be seen in Table 5.

Sample: 02/01/2020 12/30/2020

	Daily Deaths	Daily Cases
Mean	208,85	6 644,60
Median	59,00	1 805,00
Maximum	1 224,00	53 135,00
Minimum	0,00	0,00
Std. Dev	280,61	9 763,55

Table 5 - Descriptive statistics of returns of daily new deaths and daily new cases

As we can observe the mean of the daily deaths is 208,85, but we need to take into account that this has been observed since the beginning of the COVID-19, i.e. of the year 2020, which means that the minimum in both the daily deaths and new cases is 0 (the first recorded deaths in UK were in March). The maximum of daily new deaths registered is 1.224. The mean of the daily new cases is 6.644,60 and the maximum of daily new cases observed between January 2020 and December 2020 is 53.135.

3.1.1 COVID-19 Major Events in the UK

Since the beginning of the pandemic, many were the events that affected the world and more specifically the United Kingdom. In order to document events that may or may not have impacted stock markets, a timeline of COVID-19 events was carried out through the British Foreign Policy Group website complemented with other news published. (Annex 1)

December 2019

On 21st of December 2019 the first group of patients with a pneumonia of unknown origin was identified by Chinese epidemiologists, and on December 31, the Chinese authorities had already confirmed dozens of patients with this disease. China reported these cases to WHO, detected in Wuhan.

January 2020

On January 8, 2020 WHO sent a scientific team to China to help study the identified cases. The first death caused by this viral disease was reported on January 11,2020. According to WHO, the first cases detected outside China occurred in Japan, South Korea and Thailand on January 20th, 2020. Shortly thereafter, on January 23rd, 2020 Chinese

authorities closed Wuhan. At the end of January the first two positive cases of coronavirus appeared in the UK. WHO decided to consider a global health emergency due to the emergence of hundreds of cases in China. There have been 213 deaths to date and around 9.800 people infected worldwide.

February 2020

On the first week of February, the first positive coronavirus cases appeared in Spain and the first coronavirus death was reported outside China. United Kingdom gave indications for the English populations to leave China. On February 11th, the coronavirus disease was called COVID-19. To date there were 1.113 deaths in China and 44.653 active cases, while outside China there were 393 cases. On February 14th, France announced the first coronavirus death in Europe. In Italy, many cases of coronavirus began to emerge (+150. On February 29th, UK authorities reported the first cases of coronavirus disease originated in the UK. It was the worst week for global stock markets since the 2008 financial crisis.

March 2020

At the beginning of March, the United Kingdom began suffering more complications associated with the coronavirus, as it announced the largest increase in positive cases in one day (+34) and 6 deaths from COVID-19 with 373 currently positive cases. On March 11th, the US announced travel restrictions for European countries (except UK) for 30 days. It was also on this date that WHO declared COVID-19 a pandemic virus. Some of the UK's biggest sporting events have been postponed. On March 16th, Boris Johnson advises Britons to work from home and avoid pubs and restaurants in order to try to counter the pandemic's evolution. COVID-19 deaths exceed 55 in the UK and there are 1.543 confirmed cases. Schools in the UK closed indefinitely on March 18th. As of March 23rd, there were 270.000 positive cases and about 1.000 deaths worldwide. On March 25th, prince Charles tests positive for COVID-19. On March 27th, 2020, Prime Minister Boris Johnson and Health Secretary Matt Hancock test positive for coronavirus.

April 2020

In April, the number of positive cases in the world had already surpassed 1 million. Prime Minister Boris Johnson, on April 6, was admitted to the intensive care unit due to worsening symptoms. European air industry had decreased by 90% and the European finance ministers met to discuss the measures that would be taken to support the European economy. On April 9th, UK had the highest increase in deaths in 24 hours (+938) and the number of confirmed deaths worldwide was 100.000. UK Prime Minister recovered and was discharged from hospital on the 14th of April. In the last half of April, the number of confirmed cases in the world had already surpassed 2 million and deaths reached 200.000. UK started with the testing of vaccines in humans.

May 2020

On May 10th, the UK started to consider about a slow deconfinement, which included allowing outdoor physical exercise and returning to the workplace. It was also on this date that anyone traveling to the UK would need to undergo a 14-day quarantine period. As of May 21st, global coronavirus cases exceed 5 million. The UK government announced that schools would start to reopen in June.

June 2020

In the first half of June, some signs of improvement in the pandemic in the UK were felt, with a decrease in the number of infections/deaths daily. Globally, confirmed cases of COVID-19 exceeded the 7 million barrier. On June 17th, some sporting events start to return. On June 19th, UK ministers were accused of trying to cover up data on daily deaths by COVID-19, reporting lower figures than actual figures. Health authorities on June 24th warned of the second wave of the pandemic.

July 2020

On July 10th, UK rejected the offer to join Europe's vaccination program. WHO reported on July 18th the largest increase in COVID-19 cases in 24 hours since the start of the pandemic. At the end of July, UK imposed a lockdown in some areas of the North of England and also decided not to go ahead with deconfinement, having thus postponed the opening of some social spaces.

August 2020

The UK economy experienced a large decrease, of around 20,4% between the months of April and June, the biggest decrease on record. The government decided to change the way to count the number of deaths from coronavirus and so on this day the number of deaths had a decrease of 5.000 deaths.

September 2020

On 8th September the UK government declares that the coronavirus has so far, cost around 210 billion to UK. On September 9th, the UK launched yet another restriction prohibiting the gathering of more than 6 people, in an attempt to prevent a second wave of COVID-19. Confirmed coronavirus cases reach 30 million worldwide. The fear of a new confinement in the UK leads to a decrease in the price of the FTSE 100. On September 22nd, the UK registers the biggest growth in new confirmed cases and thus new containment measures come into force.

October 2020

On October 4th, the UK reports 22.961 more cases in 24 hours, but warns that this increase is due to a delay in notifications of confirmed cases in previous days. At the same time, Europe confirms 100.000 new cases within 24 hours for the first time. On October 30th WHO declared that "Europe is once again the epicenter of this pandemic". On October 31st the UK declares 4 weeks of national confinement in England, and on that same day the UK surpassed 1 million active cases of coronavirus.

November 2020

On November 9th, Pfizer announced that their vaccine is 90% effective, while UK vaccine experts said life should return to normal in the spring. On November 10th, the UK reported the highest death toll since May. On November 16th, Moderna studies proved that the vaccine produced by them had an effectiveness of 94,5%. On the same day, the United Kingdom placed an order for around 5 million doses of the Moderna vaccine.On November 20th, the UK's health minister announced to the country that the Pfizer vaccine

should start being administered next month. In the UK, confirmed cases exceeded 1,5 million. On November 30th, the final results of the tests carried out on the Moderna vaccine came out, proving an efficacy of 94%.

December 2020

By early December the UK death toll of COVID-19 had exceeded 60.000. The UK has also begun administering Pfizer/BioNTech vaccines in addition to clinical trials. In the last few days of December, the UK recorded more than 50.000 infections in 24 hours for the first time since the start of the pandemic. On December 30th, the UK government announced that it was prioritizing the first dose in order to contain the spread of the virus. On December 31st, the WHO lists the Pfizer/BioNTech vaccines for emergency use, causing countries to approve the use of the vaccines more quickly.

3.2 Variables

In order to analyse our data we defined variables that allow us to answer the research questions. Starting with the questions "Did COVID-19 impact the UK's stock market?" and "If so, what were the impacts?" we defined the variable $c_{1,t}$ (dummy variable that takes value of 1 if t belongs to the time after the 29th of January 2020 which is the day that UK confirmed the first two cases of COVID-19) and 0 otherwise. The variable $p_{x,t}$, where x=1,…,26 (where x=1 represents the first fortnight after 21st of December 2019 which is the day that China confirmed the first cases of COVID-19, x=2 represents the second fortnight, etc.), corresponds to the x dummy variables that take the value of 1 if t belongs to the time frame represented by x and allow us to answer the questions "Did COVID-19 had a momentarily impact on the UK's stock market?", and "If so, what were the impacts?". We will also try to relate these possible impacts to the COVID-19 calendar of events referenced

Finally, we have the variable daily_deaths that assumes the value of the daily number of deaths in the UK by COVID-19. Our study aims to study the impact of the number of deaths only on weekdays where market values are also recorded, so we took into account only the data of weekday deaths. This will allow us to answer the question"How does the number of deaths impact the UK stock market prices?". The same approach will be used for the daily_cases variable, to answer the question "How does the number of daily cases impact the UK stock market prices?"

3.3 Main Methodology

The most commonly used model for estimating an equation that relates one or more variables in econometrics is the ordinary least squares (OLS) model, but this model does not fit well to data that suffer from heteroscedasticity, i.e., data where there is an irregular pattern in the variance of the error term. Since in our study we are analysing stock returns, we allow variance of errors to be time dependent and therefore we need a model that allows heteroscedastic data. As Bollerslev (1986) studied, the ARCH (Autoregressive

Conditional Heteroskedastic) process that was introduced by Engle (1982) "*allows the conditional variance to change over time as a function of past errors*". There are already some studies that have demonstrated the usefulness and efficiency of modelling economic data with this ARCH, such as Engle (1983), Engle and Kraft (1983) and Coulson and Robins (1985). Bollerslev (1986) studied a more generalized process of ARCH, which is GARCH (Generalized Autoregressive Conditional Heteroskedastic), "*that allows a much more flexible lag structure*".

Given that some time series exhibit variable variance over time, a formula that would represent such processes mathematically could be given by:

$$\varepsilon_t = z_t \sigma_t \tag{2}$$

where ε_t denote the unexpected returns of the model, z_t is a white-noise process, and σ_t is a time-dependent standard deviation. The generalized ARCH, or GARCH (p,q), model of Bollerslev (1986) was arguably one of the most important parametrizations. (Balakrishnan, 2010). The standard deviation can be described by ARCH (p) model as

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \beta_i \sigma_{t-1} \tag{3}$$

Following the notation from (3) we can see that σ_t can also be defined by GARCH(p,q) where p is the order of ARCH terms (ε^2) and q is the order of GARCH terms (σ^2)

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-1}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-1}^2 \tag{4}$$

Where ε_{t-1}^2 are the squared unexpected returns for the previous period, α_0, α_i and $\beta_i > 0$ in order to guaranty that the conditional variance is strictly positive. Also $\sum_{i=1}^{q} \alpha_i + \sum_{i=1}^{p} \beta_i < 1$ should be verified in order to satisfy the stationary of the conditional variances.

Furthermore, the model GARCH (1,1) has been shown by Baillie & Bollerslev (1991) to fit well under financial time series, thus we choose this as our model. Therefore, we get the following GARCH (1,1) equation:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \sigma_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 \tag{5}$$

Where σ_t^2 and σ_{t-1}^2 are the variance of the index returns for day t and t-1 respectively, and α_0, α_1 and α_2 are the GARCH model coefficients.

In order to test and being able to answer our research questions we estimate the following regression equation using the Quasi-maximum likelihood method studied by Bollerslev and Wooldridge (1992):

$$r_t = b_0 + \sum_{x=1}^{x} b_x A_{x,t} + \varepsilon_t \quad (6)$$

$$r_t = b_0 + B_t + \varepsilon_t \quad (7)$$

Where r_t represents the daily log return of the FTSE All-Share index between t-1 and t, where $A_{x,t}$ is a dummy variable that takes the value 1 when the day t belongs to a certain time frame represented by x and 0 otherwise and where B_t represents a numeric variable at day t.

3.4 Hypothesis

In order to answer the first research questions which are "Did COVID-19 impact the UK's stock market?" and "If so, what were the impacts?" we have to test the hypothesis that pre COVID-19 daily returns differ from daily returns during the COVID-19 period as such we will have to estimate the following equation:

$$r_t = b_0 + b_1 c_{1,t} + \varepsilon_t$$

Considering the second question "Did COVID-19 had a momentarily impact on the UK's stock market?" and "If so, what were the impacts?" we sequentially test whether the return of each fortnight differ from pre COVID values. The estimated equation will be:

$$r_t = c_0 + \sum_{x=1}^{26} c_t p_{x,t} + \varepsilon_t$$

We will also test whether the daily returns of FTSE-All Share differ considering the number of daily deaths/daily new cases in order to answer the question "How does the number of deaths impact the UK stock market prices?" and "How does the number of daily cases impact the UK stock market prices?", by estimating the following equations:

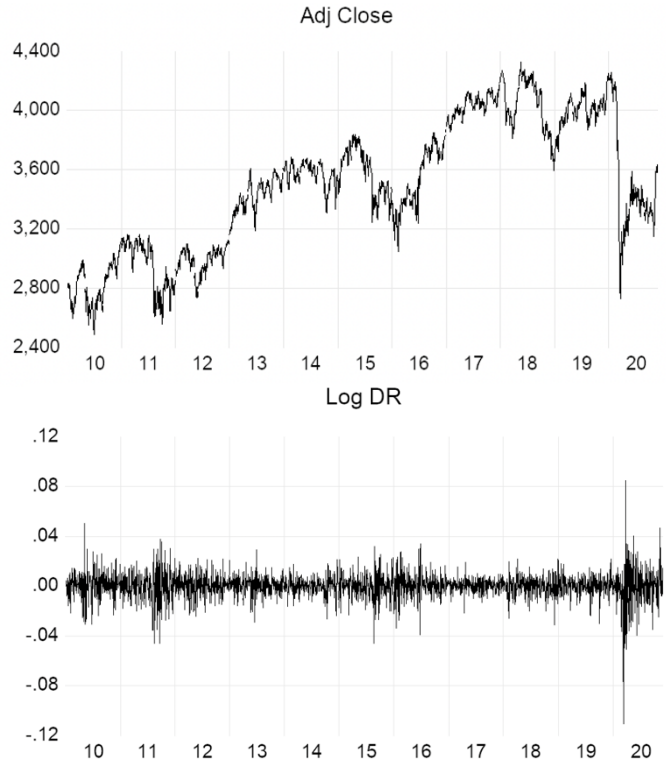
$$r_t = d_0 + d_1 \text{daily\_deaths}_t + \varepsilon_t$$

$$r_t = f_0 + f_1 \text{daily\_cases}_t + \varepsilon_t$$

CHAPTER 4

RESULTS AND DISCUSSION

Before analysing the results from the GARCH (1,1) model we decided to do a preliminary analysis based on the graph of the daily values of the FTSE All-Share Index and on the graph of the log daily returns of this same index. Analysing Graph 4 a), we can see that until January 2020, the FTSE All-Share prices were successively increasing, starting at around £2400 and reaching £4400 in 2019, but with the starting of the year 2020 it decreased about 35%, to prices between £2500 and £3500. Looking at Graph 4 b) it appears that returns start to be more volatile from the second half of March 2020. These observations may indicate a possible impact of COVID-19.



Graph 4 - Daily FTSE All-Share stock market index. a) display daily observations on the price of the FTSE All-Share index, over the period January 2010 through December 2020. b) display the daily return of the FTSE All-Share index, over the period January 2010

Taking this into account, we will analyse for each objective question the respective coefficients and analyse whether they are statistically significant. Taking into account the results in Table 6, we can see that for the variable c_1 (that helps us to answer the questions "Did COVID-19 impact the UK's stock market?" and "If so, what were the impacts") we have a coefficient that it is not statistically significant at 1%, 5% and 10% level and for that reason we do not reject H_0, which means that we cannot assume that there is sufficient statistical significance to affirm that the COVID-19 impacted the UK stock market

returns. These results are in line with Nippani and Washer (2009), that contrarily toother authors that studied the impact of SARS on financial markets, concluded that there was no evidence that this epidemics had negative effects on most financial markets. Considering the COVID-19 studies, our results differ with the ones from Nia (2020), Ali et al. (2020) studies that conclude that this pandemic negatively affected the stock markets. However, it should be noted that these studies were done with shorter time frames (around 3 months) than the one used in our study, thus this may be a possible explanations of the results differences. For instance, Koo and Fu (2003) concluded that the SARS epidemic had limited and temporary economic impacts, which leads us to the next research question in order to try to find a a momentarily impact.

Variable	Coefficient
c	0,000391***
c1	-0,000546

Notes: ***,**,* denote significance at 1%, 5% and 10% respectively.

Table 6 - GARCH Output: Variable c1

Using the same approach for the second and third research questions "Did COVID-19 had a momentarily impact on the UK's stock market?", "If so, what were the impacts?" and taking into account the variables defined before (p_t), we obtain the results in Table 7. The only variables for which the p-value is statistically significant at 1%, 5% and 10% confidence level are p_5, p_6, p_{19}, p_{23}, this might mean that for these fortnights the UK stock market was affected by COVID-19 events. Variables p_5 and p_6 present a negative coefficient of -0,014385 and -0,04273 respectively, which means that there is a negative and statistically significant impact on these respective fortnights. We can say that the return for fortnight p_5 (recalling 5 fortnights after the day China confirmed the first case of COVID-19, 21st December) is 1,4 percentage points lower than the return seen in the pre-COVID-19 period. Looking at the table in Annex 1, we can observe that in fortnight 5 several events may be linked to this variation, such as the appearance of the first case of coronavirus disease originating from the UK, or even the fact that the United Kingdom recorded the largest increase in new cases to date. We can reach the same conclusion for variable p_6, the return for the fortnight is 4,3 percentage points lower than the return seen in the pre-COVID-19 period. Referring again to the table in Annex 1, we can see that during the sixth fortnight the WHO declared COVID-19 a pandemic which greatly alarmed the stock markets. Other events included one of the biggest sporting events in UK being postponed and some lockdown measures being applied creating some panic in the country. For variable p_{19} we can also observe a statistically significant negative impact with a coefficient of -0,007016, i.e. fortnight 19 has a return of 0,7 percentage points below the pre-covid period, however this difference is smaller than that presented in fortnights 5 and 6. Analysing Annex 1 we can observe that in these two weeks signs of a new lockdown started to appear and the United Kingdom registered the highest growth of new confirmed cases. We can observe that in p_{23} (representing the days between 5th of November 2020 and 18th of November 2020) we have a significant and positive impact in the UK stock market comparing with pre COVID-19 period with a further 1 percentage point return. In these two weeks the first news about the vaccination began to appear.

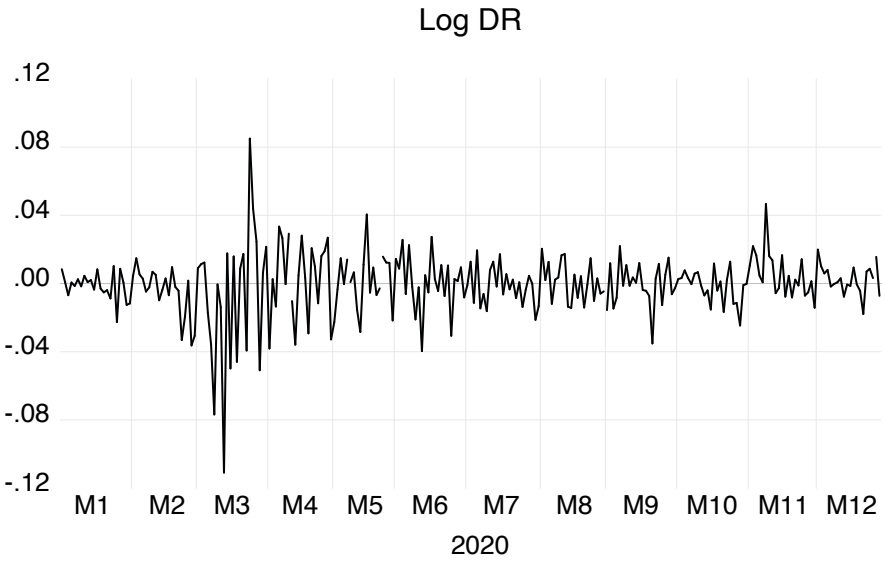
Pfizer first announced that their vaccine was 90% effective, while studies by Moderna confirmed a vaccine effectiveness of 94,5%. Although the UK has seen the highest number of deaths since May 2020 also during these two weeks, news came out that the UK had already ordered 5 million vaccines from Moderna and that vaccination would start in December. The arrival of this news probably brought a relief in investors' expectations.

Variable	Coefficient
c	0,000406***
p1	-0,000655
p2	0,000515
p3	-0,002271
p4	-0,000668
p5	-0,014385***
p6	-0,04273***
p7	0,006714
p8	0,004726
p9	-0,001535
p10	0,003966
p11	0,001227
p12	-0,000085
p13	-0,003223
p14	0,000131
p15	-0,000907
p16	-0,000761
p17	-0,001719
p18	-0,000402
p19	-0,007016***
p20	0,001439
p21	-0,002434
p22	-0,000639
p23	0,010402***
p24	0,001565
p25	0,00082
p26	-0,00116

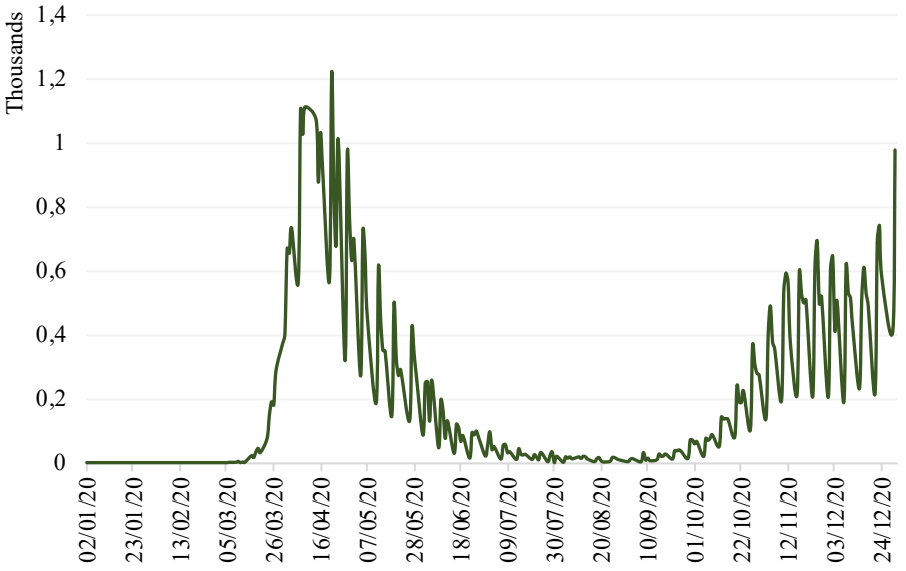
Notes: ***,**,* denote significance at 1%, 5% and 10% respectively.

Table 7 - GARCH Output: Variable pt

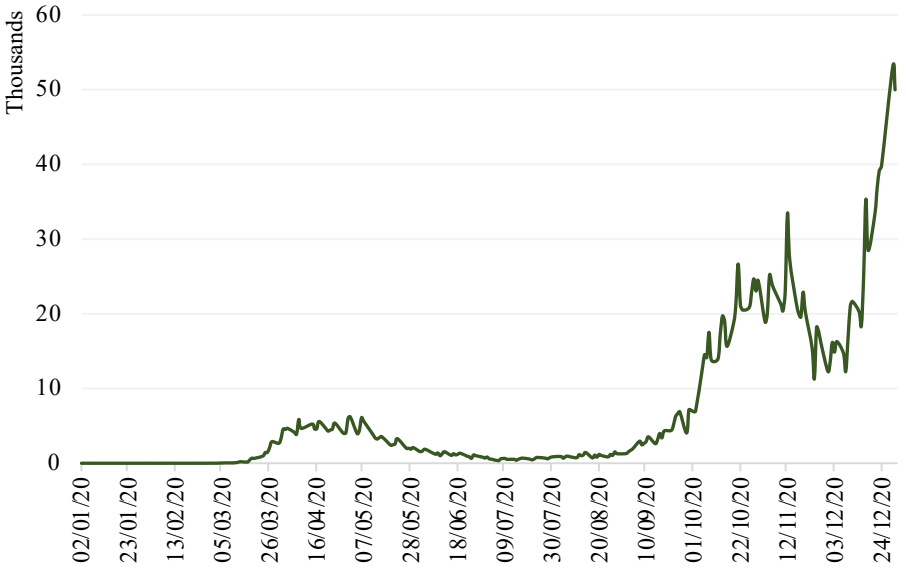
In order to be able to pre-analyse whether there might be any relationship between the number of daily deaths/daily cases and the daily returns of the FTSE All-Share we have made 3 graphs. Graph 5 shows the daily returns of the index for the interval from 01/02/2020 to 30/12/2020. Graph 6 shows the daily deaths recorded by COVID-19 and Graph 7 shows the daily confirmed cases of COVID-19. The figures suggest that daily returns are related to the daily confirmed deaths caused by COVID-19 since the index returns start to be more volatile as the growth of confirmed deaths starts to increase. This is only visible in the first rise in the number of deaths between March and April, and from October onwards the same conclusion cannot be drawn. Regarding the number of new daily confirmed cases, there does not appear to be any relationship with the daily index returns.



Graph 5 - Daily returns of the FTSE All-Share index



Graph 6 - Daily confirmed COVID-19 deaths



Graph 7 - Daily confirmed COVID-19 cases

Regarding the question "How does the number of deaths impact the UK stock market prices?" and its regression coefficients observed in Table 8, we can confidently say that the daily number of deaths has no relevant statistical impact on the average daily return, since the daily_deaths coefficient has no statistical significance at the 1%, 5% and 10% levels. This contrasts with the results obtained by Al-Awdhi et al. (2020) and Zeren and Hizarci (2020) which suggest a statistically significant impact of the number of daily deaths on the stock market returns. On the other hand, it further provides more support to the results obtained and discussed by Chia et al. (2020) and Ashraf (2020).

Variable	Coefficient
c	-0,000661
daily_deaths	-0,000005

Notes: ***,**,* denote significance at 1%, 5% and 10% respectively.

Table 8 - GARCH Output: Variable daily_deaths

With respect to the question "How does the number of daily cases impact the UK stock market prices?" we can also conclude, by observing the reported coefficients of Table 9 and statistical significance of these coefficients, that the daily number of deaths has no impact on the average daily return. These results go in opposition of former research by Al-Awdhi et al. (2020), Chia et al. (2020), Zeren and Hizarci (2020) and Ashraf (2020) which have all obtained statistical significance of the number of daily cases on the stock market returns. This fact can possibly be explained by the time frame used for the research and the fact that the number of daily cases could have had a momentarily impact on the stock market and thus early research would get a significant coefficient for its impact on returns. (Can also be possibly explained by different methodologies).

Variable	Coefficient
c	-0,000300
daily_cases	0,000000

Notes: ***,**,* denote significance at 1%, 5% and 10% respectively.

Table 9 - GARCH Output: Variable daily_cases

CHAPTER 5

CONCLUSION

This work aimed to study the impact of COVID-19 pandemic on the UK stock market. In order to carry out this study, three main ideas were used: (i) analysis of the FTSE All-Share returns over the long-term, i.e. using a time window of about one year, (ii) analysis of the returns on the index over the short-term, in order to analyze momentary impacts and (iii) analysis of the impact of the number of deaths and confirmed cases on the FTSE All Share returns. Giving the scale of this COVID-19 pandemic and the uncertainty it has brought to the economy, we need to think about ways to avoid public health crises and also possible financial crises. Using daily stock market returns and time frame dummies, we found no significant permanent impacts related with the persistence of COVID-19, we found, however, momentarily impacts on some fortnights where some significant COVID related events occurred, which may suggest, at least to some extent, a potential correlation between significant COVID-19 events and UK stock market returns. Using daily COVID-19 confirmed cases and deaths since the beginning of February 2020 we examined the possible effects of these two measures on the UK stock market. We found no significant evidence that daily confirmed deaths and cases impacted the daily returns of stock market. However, this conclusion contradicts other studies which have found statistical significance between the number of daily cases and deaths on the stock market returns.

It is important to keep in mind that even though our methodology seems the most appropriate, it has its own limitations. These limitations range from the fact that we are not able to isolate the possible effect of COVID-19 from other impacts, such as the possible effect of BREXIT, to the fact that when this study was done, COVID-19 had not yet ended, and many restrictions and lockdowns were yet to take place around the world. We believe that this work brought some relevant questions to be answered by future studies such as trying to understand if the different results we obtained in comparison to past literature can be the result of just using a different time frame, or even try to study the impact of COVID-19 on the volatility of the UK stock market rather than daily returns. It could also be interesting to apply this same study to the MSCI World Index, in order to try to broaden the scope of the study to developed countries, as a whole.

We believe that wthis thesis contributes to the scientific community in the following ways, firstly, we contribute to studies examining the impact of major events on financial markets, but specifically the impact of health crises on stock markets. Secondly, due to COVID-19 pandemic being such a recent event there is a scarce existing literature about

its effects. Thirdly, to the best of my knowledge no other study focused on the UK stock market, even more general studies used the FTSE 100 while we will be using FTSE All-Share in order to get a better representation of the whole UK stock market.

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Annex 1 – Timeline COVID-19

px	Date	Event
p1	**21st Dec 2019**	First group of patients with a pneumonia of unknown origin identified by Chinese epidemiologists
	31st Dec 2019	Chinese authorities confirmed they were treating dozen of patients with these pneumonia of unknown origin.
		China reports to WHO the confirmed cases of pneumonia, detected in Wuhan.
	8th Jan 2020	The Chinese government agrees to accept a WHO scientific team to assist their own researches.
p2	**11th Jan 2020**	Chinese state media reported the first known death from an illness caused by the virus
	20th Jan 2020	According to WHO, the first cases detected outside China occurred in Japan, South Korea and Thailand.
p3	**23rd Jan 2020**	Chinese authorities closed Wuhan, trips out of the city were cancelled and public transports within the city were suspended.
	29th Jan 2020	First two positive cases of coronavirus appeared in the UK.
	30 th Jan 2020	WHO decides to consider a global health emergency due to the emergence in the UK.
	31st Jan 2020	213 deaths to date and 9.800 people infected worldwide.
	1st Feb 2020	The first positive cases appeared in Spain
	2nd Feb 2020	The first death of coronavirus is reported outside China
	4th Feb 2020	The UK give indications for the citizens to leave China.
p4	**11th Feb 2020**	The disease is named COVID-19.
		1.113 deaths in China and 44.653 active cases, while outside China there is 393 cases
	14th Feb 2020	France announces the first coronavirus death in Europe.
p5	**23rd Feb 2020**	Many cases begin to emerge in Italy (+150)
		Italy introduces strict restrictions
	29th Feb 2020	UK authorities reported the first case of coronavirus disease originated in the UK.
		The worst week for the global stock markets since 2008 financial crash
		The WHO raises the coronavirus alert to the highest level
	4th March 2020	United Kingdom announced the largest increase in positive cases in one day (+34)
p6	**10th March 2020**	6 deaths from COVID-19 with 373 currently positive cases in the UK
	11th March 2020	US announced travel restrictions for European countries (except UK) for 30 days.
		Stock markets continued to crash.
		WHO declared COVID-19 a pandemic virus
	13th March 2020	UK's biggest sporting events have been postponed
	16th March 2020	Boris Johnson advises Britons to work from home and avoid pubs and restaurants in order to try to counter the pandemic's evolution
		The UK's death toll rises to 55, with 1,543 confirmed cases, though it is believed 10,000 people have already been infected.
	17th March 2020	France has already had 6.500 infected people and 140 deaths and that is why it imposed the lockdown.
		Travel restrictions start in Europe for 30 days
	18th March 2020	The UK government announce that schools in the UK will be shut down from Friday until further notice.
p7	**20th March 2020**	The UK government ordered the closure of pubs, restaurants, gyms and other social spaces across the country.

		The chancellor announces to the country that the government will pay around 80% of the wages of workers affected by the pandemic.
	23rd March 2020	Prime Minister Boris Johnson says that Britons should only go outside for reasons of extreme necessity. For those who do not comply with these restrictions there will be police measures.
		There were 270.000 positive cases and about 1.000 deaths worldwide
	25th March 2020	Prince Charles tests positive for the coronavirus.
	27th March 2020	Prime Minister Boris Johnson and Health Secretary Matt Hancock test positive for coronavirus
p8	**2nd April 2020**	Number of positive cases in the world had already surpassed 1 million
	6th April 2020	Prime Minister Boris Johnson was admitted to the intensive care unit due to worsening symptoms
	7th April 2020	European finance ministers met to discuss the measures that would be taken to support the European economy
		The European air industry had decreased by 90%
	9th April 2020	UK has the highest increase in deaths in 24 hours (+938)
	10th April 2020	the number of confirmed deaths worldwide surpasses 100.000
	14th April 2020	UK Prime Minister recovered and was discharged from hospital
	15th April 2020	The number of confirmed cases in the world has already surpass 2 million
p9	**23rd April 2020**	UK started with the testing of vaccines in humans
	25th April 2020	Worldwide COVID-19 deaths reach 200,000.
p10	**10th May 2020**	UK starts to think about a slow deconfinement, which includes allowing outdoor physical exercise and returning to the workplace
		UK government announces that anyone traveling to the UK will need to undergo a 14-day quarantine period.
p11	**21st May 2020**	Global coronavirus cases exceed 5 million
	24th May 2020	UK government announces that schools will start to reopen in June.
	1st June 2020	UK records lowest increase in COVID-19 daily deaths and infections since the end of March.
p12	**9th June 2020**	UK records lowest daily COVID-19 death toll since March 22nd, with 55 deaths.
		Confirmed cases of COVID-19 exceed the 7 million barrier, worldwide.
p13	**17th June 2020**	Some sporting events start to return, such as the English Premier League football.
	19th June 2020	UK ministers are accused of trying to cover up data on daily deaths by COVID-19, reporting lower figures than actual figures.
	24th June 2020	Health authorities warn of the second wave of the pandemic.
		Volunteers from the UK, Brazil and South Africa begin to receive injections of the vaccine developed by the University of Oxford.
p14	**10th July 2020**	UK rejects the offer to join Europe's vaccination program.
p15	**18th July 2020**	WHO reports the largest increase in COVID-19 cases in 24 hours since the start of the pandemic.
p16	**30th July 2020**	UK imposed a lockdown in some areas of the North of England
	31st July 2020	UK government decides not to go ahead with the deconfinement, having thus postponed the opening of some social spaces.
p17	**12th August 2020**	UK economy experienced a large decrease, of around 20,4% between the months of April and June, the biggest decrease on record.
		The government decided to change the way to count the number of deaths from coronavirus and so on this day the number of deaths has a decrease of 5.000 deaths.
p18	**8th September 2020**	UK government declares that the coronavirus has so far, cost around 210 billion to UK

	9th September 2020	UK launched yet another restriction prohibiting the gathering of more than 6 people, in an attempt to prevent a second wave of COVID-19
p19	**18th September 2020**	Confirmed coronavirus cases reach 30 million worldwide
	19th September 2020	British doctors are thus warning the UK government of tighter restrictions as the pandemic evolves
	21st September 2020	The fear of a new confinement in the UK leads to a decrease in the price of the FTSE 100
	22nd September 2020	UK registers the biggest growth in new confirmed cases and thus new containment measures come into force
p20	**4th October 2020**	UK reports 22.961 more cases in 24 hours, but warns that this increase is due to a delay in notifications of confirmed cases in previous days
p21	**9th October 2020**	Europe confirms 100.000 new cases within 24 hours for the first time
p22	**30th October 2020**	WHO declared that "Europe is once again the epicenter of this pandemic"
	31st October 2020	UK declares 4 weeks of national confinement in England
		UK surpasses 1 million active cases of coronavirus
p23	**9th November 2020**	Pfizer announced that their vaccine is 90% effective
		UK vaccine experts said life should return to normal in the spring
	10th November 2020	UK reported the highest death toll since May.
	16th November 2020	Moderna studies proved that the vaccine produced by them had an effectiveness of 94,5%
		United Kingdom placed an order for around 5 million doses of the Moderna vaccine.
	18th November 2020	Update on the efficacy of the Pfizer and BioNTech vaccine, which goes from 90% to 95%
p24	**20th November 2020**	UK's health minister announced to the country that the Pfizer vaccine should start being administered next month.
	22nd November 2020	In the UK, confirmed cases exceeded 1,5 million.
	30th November 2020	final results of the tests carried out on the Moderna vaccine came out, proving an efficacy of 94% and it was also indicated that the people who participated in the tests of this vaccine had not developed any serious disease.
p25	**3rd December 2020**	UK death toll of COVID-19 had exceeded 60.000
	8th December 2020	UK has also begun administering Pfizer/BioNTech vaccines in addition to clinical trials
p26	**28th December 2020**	Uk reports over 40,000 cases in 24 hours for the first time since the start of the pandemic.
	29th December 2020	UK recorded more than 50.000 infections in 24 hours for the first time since the start of the pandemic
	30th December 2020	UK government announced that it was prioritizing the first dose in order to contain the spread of the virus.
	31st December 2020	WHO lists the Pfizer/BioNTech vaccines for emergency use, causing countries to approve the use of the vaccines more quickly.