A pandemia COVID-19 e o seu impacto na volatilidade dos mercados financeiros europeus

Dissertação de Mestrado

Inês Teves Santos

Mestrado em

Ciências Económicas e Empresariais

Ponta Delgada
2023

A pandemia COVID-19 e o seu impacto na volatilidade dos mercados financeiros europeus

Dissertação de Mestrado

Inês Teves Santos

Orientadores

Prof. Doutor Tiago Mota Dutra
Prof. Doutor João Carlos Aguiar Teixeira

Dissertação submetida como requisito parcial para obtenção do grau de Mestre em Ciências Económicas e Empresariais, com especialização em Finanças e Contabilidade.

RESUMO

A volatilidade dos mercados financeiros é uma área de estudo altamente investigada ao longo dos anos por académicos. Diferentes fatores influenciam a volatilidade dos mercados financeiros, entre os quais, o sentimento de medo por parte dos investidores.

A pandemia COVID-19 desencadeou uma onda de pânico global, a qual foi causada pelo medo despertado pela incerteza associada ao surto da doença SARS-CoV-2. Em simultâneo, o confinamento que existiu em diversos países, associado a esta pandemia, conduziu à suspensão total de diferentes setores, o que se refletiu nos mercados financeiros.

Nesta dissertação estudamos o impacto da COVID-19 nos mercados financeiros europeus. Com o objetivo de avaliar o seu impacto, recorrermos ao uso de uma regressão linear através do método dos mínimos quadrados. No entanto, uma vez que os erros obtidos desta regressão são homoscedásticos e autocorrelacionados, optámos por seguir para o método dos mínimos quadrados generalizados. A regressão teve em conta as variáveis de número de casos diários de COVID-19 e o rácio de morte diário – sendo estes os parâmetros da COVID-19 estudados.

Os estimadores obtidos pela regressão linear demonstraram que, de facto, os parâmetros da COVID-19 impactaram o índice de volatilidade, com especial efeito no início da pandemia – desde o início de janeiro até ao final de maio de 2020. Das duas variáveis, associadas à pandemia, utilizadas, apenas o rácio de mortalidade teve impacto na variável dependente – índice de volatilidade, VSTOXX. Também concluímos que o período do confinamento não impactou a volatilidade dos mercados, sendo que foi no início da pandemia que foi registado um maior nível de impacto. Ainda chegamos à conclusão de que se perspetivarmos a pandemia no seu período completo até ao final de 2022, as variáveis da COVID-19 não tiveram tanto impacto na volatilidade do mercado, uma vez que houve outras variáveis que tiveram maior influência em certos períodos, como é o caso do conflito armado entre a Rússia e a Ucrânia.

Palavras-chave: COVID-19; Mercados financeiros; Volatilidade.

ABSTRACT

The volatility of the financial markets is an area of high interest in the finance world. It is known that, in fact, there are different factors that influence the volatility of the financial markets, such as the investors' sentiment of fear.

The COVID-19 pandemic caused panic towards people around the world, mostly caused by the unknown feeling instigated by the outbreak of this disease. Simultaneously, the lockdown, which caused a total suspension of different sectors, had a real impact on the financial markets.

In this dissertation we studied the impact of the COVID-19 on the European financial markets. In order to evaluate the impact, we aimed to resource to an OLS regression. Nevertheless, since the errors were homoscedastic and autocorrelated, we opted to follow a different approach, producing a GLS regression. The regression had as variables related to the pandemic the number of daily cases of COVID-19 and its daily death ratio.

The unbiased estimators showed us that, in fact, the COVID-19 parameters had impact on the volatility index, especially in the beginning of the pandemic – from the January until the end of May of 2020. From the two COVID-19 parameters we used, only the death ratio had shown some impact on the dependent variable – volatility index, VSTOXX. We also got to the conclusions that the pandemic did not impact the volatility of the European markets in the lockdown period, while in the beginning of the pandemic it had. When we look at the entire period of the pandemic, until the end of 2022, we can see that the pandemic did not have a great impact on the volatility of the European financial markets, since there are other factors that started to play a bigger role in the impact of the markets – such as the Russia-Ukraine war.

Keywords: COVID-19; Financial markets; Volatility.

DEDICATÓRIA

Aos meus pais, que tudo fazem por mim.

AGRADECIMENTOS

Desde já e de uma forma mais generalizada, queria agradecer a todos aqueles que de alguma forma neste último ano me ajudaram a concluir a minha dissertação – quer através da motivação que me foi fornecida, quer através da ajuda prestada,

Um especial agradecimento aos meus orientadores – Prof. Doutor Tiago Dutra e Prof. Doutor João Teixeira – por todo o auxílio que me foi oferecido e pela prontidão em que o mesmo me foi dado. Agradeço ainda a orientação, os ensinamentos e a exigência que foram importantes ao longo destes meses.

À minha família – de sangue e de coração –, também o meu muito obrigada por tudo. Pela ajuda e pela paciência. Pela motivação e pelas palavras sábias nos momentos certos.

Estes últimos meses foram, sem dúvida alguma, desafiantes. Embora nem todo o percurso tenha sido fácil, posso dizer que foi ótimo, sendo que conseguir obter novas competências, assim como desenvolver as que já possuía. Importa ainda referir toda a aprendizagem que obtive sobre o universo dos mercados financeiros, ao longo da investigação e escrita da dissertação. Claramente posso afirmar que estes meses foram enriquecedores em todos os aspetos.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BLUE – Best Linear Unbiased Estimator
EPU – Economic Policy Uncertainty
EU – European Union
GLS – Generalized Least Squares
IMF – International Monetary Fund
OLS – Ordinary Least Squares
SD – Standard Deviation
US – United States
VIX – Volatility Index
VSTOXX – Volatility of Euro Stoxx 50 index
WHO – World Health Organization

CHAPTER I – INTRODUCTION

The volatility of financial markets has been studied for years, and it is still a central topic to academics (Kalotychou & Staikouras, 2009). According to Peters (1996), people are influenced by what has happened, which means that the future expectations are highly correlated with the individuals' recent experiences. The same happens with the expected value of financial assets that are affected by the past volatility. According to that, and to even more, a lot of different authors are spending time analysing the different effects and reasons for the volatility of the financial markets, especially when it comes to study the volatility impacts on crisis times, as we will see next.

There are some different academic researches that aim to study the existent relation between the volatility and financial crisis. Caporale *et al.* (2006), for example, examined the international volatility transmission of the 1997 South East financial crisis with the purpose of investigating how financial crises spread between countries. A lot of other authors have analysed the volatility of financial markets during the period of the 2008 global crisis. According to Reuters (2008), it was the biggest crisis to happen in the world ever since the Great Depression.

Schwert (2011) studied how the volatility has changed overtime – since the 19th century – and analysed what was expected to happen in the following months after crisis, ever since the high volatility levels during times of crisis captured the attention of the public. Bartram & Bodnar (2009) did an analysis of the effect of the 2008 financial crisis on global equity markets and its components, including the return volatility measures across regions and across sectors, in which was possible to verify higher levels of volatility right after the outbreak of the crisis. Those kinds of studies are made for different regions and countries, all over the world, for example, Rastogi (2015) has studied the impact of the financial crisis in the volatility in emerging economies such as Singapore, China, Brazil, Argentina, Malaysia, and South Korea. Singhania & Anchalia (2013) studied its impact in the Asian markets like Japan, China, and India. Assaf (2016) studied the volatility of the markets of Middle East and North Africa before and after the 2008 crisis. Slimane *et al.* (2013) studied the 2008 financial crisis impact in the volatility behaviour and transmission on the European markets.

With one of the most recent events that happened in the world – the COVID-19 pandemics – a lot of academics started to study the impact of the outbreak of this disease in the financial markets. About this disease, it is important to mention that on January 30th of 2020 the Director-General of the World Health Organization (WHO) declared the novel coronavirus outbreak a health emergency of international concern and on 11th March of 2020 WHO made the assessment that COVID-19 could be characterized as a pandemic, recognizing that COVID-19 was not just a public health crisis but one that would affect every sector (World Health Organization, n.d.). According to the same source, on March 13th of 2020 the Director-General of WHO declared that Europe had become the epicentre of the pandemic, which means that China was no longer considered the epicentre.

The COVID-19 had a lot of impacts in different industries in 2020, especially due to the lockdown and the fear that got installed on the population by that time. One of those sectors is undoubtably the financial sector, which caught the attention of various academics that proceeded to study the impact of the COVID-19 on the financial markets, resourcing to different components to elaborate those studies.

For example, So *et al.* (2021) studied the impact of COVID-19 on the connectedness of the Hong Kong financial market, using network analysis based on correlations and partial correlations of 100 stock returns listed in Stock Exchange of Hong Kong to perceive those impacts. Zhang *et al.* (2020) realized a study with the aim to discover the general pattern of country-specific risk and systematic risks in the global financial markets, by analysing the volatility and the correlation to study the patterns of stock market reaction to the outbreak of COVID-19 pandemic. Haroon *et al.* (2021) had examined the nature of time-varying systematic risk for both Islamic and non-Islamic sectoral indices during COVID-19.

A lot of other academics had presented studies where they analyse the impact of COVID-19 on the financial markets, but it is incontestable the fact that the component of the volatility in the financial markets' world was one of the most appealing to those studies. Benzid & Chebbi (2020) studied the impact of COVID-19 on the volatility of the exchange rates on the USD/GBP, USD/EUR and USD/CNY and Choi (2022) studied the dynamic connectedness between the volatility of different markets – South Korea, Japan, China, and the United States. Other authors like Chowdhury & Abedin (2020) and Albulescu (2021) studied the impact of the announcement of COVID-19 new daily cases and deaths on the volatility of the financial markets.

In this study we focused on the impact of COVID-19 in the financial markets' volatility – to be more precise, the European financial markets. Therefore, we elaborate a linear regression that is able to determine the impact of our independent variables –

number of reported new daily cases of COVID-19, the daily death ratio, and the Economic Policy Uncertainty (EPU) index – in the dependent one, the VSTOXX (Volatility of Euro Stoxx 50 index).

According to what was previously exposed, this dissertation brings some new highlights to the literature, once we measure the impact of the COVID-19 in financial markets resourcing to the volatility index of STOXX-50, in order to estimate the impact of the pandemic, specifically in European markets. Besides that, we make a little closure about the impact of the pandemics in different periods of time, in order to understand in which period, the COVID-19 uncertainty had more influence on the volatility.

We had got to the conclusions that the announcement of deaths, reflected on the daily death ratio, caused impact on the volatility of the European financial markets, whereas the announcement of new cases had no impact on the volatility. Aside with these findings, we also got to the conclusion that the COVID-19 factors had impacted the volatility index, but only in the beginning of the pandemic, since as the time passed by, other events started to become more relevant on the volatility behaviour.

This thesis is subdivided in five different chapters. Besides this present chapter, we integrated a Chapter II, where we perform a literature review about the main themes of this thesis – financial markets, volatility, and COVID-19. In the third chapter the variables used in this essay are presented and analysed. In Chapter IV we present the methodology that is used on this dissertation, so that, in chapter V we expose the obtained results. We conclude this thesis in chapter VI – Conclusion.

CHAPTER II – LITERATURE REVIEW

The financial markets are a very important indicator of the worldwide finance and economy. In this section it is intended to make a literature review of what academics have studied and published about this theme. We enhance the studies that include the volatility of the markets and the ones that approach the European financial markets. Only then we are able to review the literature related with the main theme of this dissertation – the impact of COVID-19 on the financial markets.

Therefore, this chapter is subdivided in four subchapters. The first one is more general – we begin to approach the financial markets, as a whole. In the second subchapter we talk about the European financial markets and then in the third subchapter we present the volatility in the financial markets. In the final subchapter, we approach the impact of COVID-19 on the financial markets.

2.1 Financial markets

The financial markets are composed by formal and informal institutions which are continually evolving (Bailey, 2005). Still according to Bailey (2005), the financial markets aim to facilitate the exchange of assets. It matters to also refer that a great part of the financial sector activity occurs on financial markets, where securities are traded without capital flowing to firms (Bond *et al.*, 2012).

Peters (1996) pointed out that there is a feedback effect that is largely ignored, especially on the financial markets – the fact that people are influenced by what happened in the past and that influence their future expectations. This same author states that it is the new information, that is received, that move the financial markets' prices, considering that in the efficient markets, the prices reflect known information and, also, the fairness of the prices is guaranteed by the investors – they distinguish key information, separating it from not so important information.

This way, the financial markets play an important role as an information provider. As an example, Bodie *et al.* (2018) abord the fact that the stock prices reflect investors' valuation of companies' prospects – including the current and the future ones. Therefore, when the market is more optimistic about the company, its share prices will get higher, and the opposite happens when the market is more pessimist.

Greenwood & Smith (1997) states that the financial markets also play a central role in what concerns to economic development which leads to the formation of new markets. The fact is that the financial intermediation, that occurs in those markets, can have an impact on economic growth by acting on the saving rate, on the fraction of saving channelled to investment, or on the social marginal productivity of investment (Pagano, 1993).

2.2 The European financial markets

Europe is considered by Bekaert *et al.* (2013) the region in the world that has done more efforts to reassure the integration of its economies. In fact, with the foundation of the European Union (EU), the European countries that are part of the EU started to reinforce the process of economy integration, with the free flow of goods, services, capital, and people – which also resulted in a higher level of stock market integration, not only in EU but, also in other world regions (Aslam *et al.*, 2021).

In pair with the EU, the introduction of the Euro is considered one of the most important events for the financial markets all around the world (Bartram *et al.*, 2007). Besides that, and according to the same authors, the adoption of a common currency for the countries that integrate the Euro-zone had, as a consequence, the convergence of those countries' interest rates and the elimination of the exchange rate risk had impacted on the dependence of markets within the Euro area.

Bartram *et al.* (2007) refer that the elimination of the exchange risk inside the Euro area reduced the remaining differences of investment and consumption in that area. As a result, there are less regional discrimination and preferences between these countries. Attending what has been stated, Bartram *et al.* (2007) conjectured that the Euro appearance created a higher degree of dependence between the equity markets of the Euro area countries.

It is important to refer that, according to Baele (2005), there is a strong positive connection between the sensitivity of local returns to common shocks and the degree of financial integration.

2.3 The volatility of the financial markets

Volatility is considered the event of unexpected changes in the price of the financial markets' trades (Bhowmik & Wang, 2020). According to Danielsson *et al.* (2018), the financial market volatility affects economic decision, especially when it is differentiated to what it was expected to be. Granger & Poon (2001) state that the financial market volatility is an important input for investment and financial market regulation.

The volatility plays an important role on the financial markets. The fact is that, according to Kalotychou & Staikouras (2009), volatility commonly happens with unexpected news' arrival, being a side effect of it – or, in other words, the response of the financial markets to that news. Bhowmik & Wang (2020) also add that the financial markets' volatility can be considered the reflection of the deviation of the expected future value of assets, and it can be explained by the measures of variability, variance, or standard deviation. The volatility has a lot of impacts on financial markets, and it is important to refer that it doesn't matter if we are talking about high or low volatility, because both of them affect the financial markets participants' decisions (Danielsson *et al.*, 2018). Nevertheless, the high volatility is, commonly associated with future uncertainty in the traditional finance theory (Danielsson *et al.*, 2018).

Studies of financial assets return volatility are one of the most important themes in modern financial research, once volatility has a big influence on the investment behaviour of the different financial market participants (Bhowmik & Wang, 2020). Kalotychou & Staikouras (2009) also adds that traders quote options in terms of volatility instead of price, since an option's implied volatility is a more useful measure of its relative value.

Financial markets have had changes in the volatility levels over the years (Shiller, 1988). In the modern world, characterized by its context of economic globalization, the stock markets have started to show even higher degrees of volatility with unprecedent oscillations that causes a raise on uncertainty levels and risk of the market (Bhowmik & Wang, 2020).

Poon (2005) states that volatility leads to an increasing level of uncertainty and risk of the stock market. To control the levels of volatility it is important to measure accurately the volatility of stock index returns. It is notable that, although volatility is related to risk, they are not exactly the same thing – volatility is the measure of uncertainty while risk is related to an unwanted outcome (Poon, 2005).

Volatility is one of the most used methods of quotation of the financial markets, once volatility is used for the discovery of the efficient prices (Kalotychou & Staikouras, 2009). To analyse the volatility on different financial markets, we can use volatility indexes. The most known volatility index is the CBOE Volatility Index of the Chicago Board Options Exchange (VIX), which estimates the expected volatility of the S&P 500 Index (Chicago Board Options Exchange, 2018).

Ahoniemi (2008) have remarked that when the VIX is very high, it commonly means that markets are pessimistic. Dennis *et al.* (2006) found that the VIX fluctuations are substantial to predict the future index return volatility. Since its creation, it has been seen as a good index to predict the future volatility. By the use of historical data volatility, VIX index reaches higher levels during times of financial stress (Fleming *et al.*, 1995).

Aside the VIX index, there are some other indexes that measure the volatility in different markets. In Europe, for example the most used volatility indexes are VSTOXX and the German index, VDAX (Fahling *et al.*, 2019). The VSTOXX measures the volatility of Euro Stoxx 50 index, which tracks the biggest and most traded companies from the Eurozone while VDAX is constructed to measure the volatility of the Germany market DAX.

2.4 The COVID-19 and the volatility of financial markets

According to the World Health Organization, the COVID-19 is an infectious disease caused by SARS-CoV-2 and it first appeared in Wuhan, China in November of 2019 (World Health Organization, 2023). On January 30th of 2020, the WHO declared that the COVID-19 outbreak was a public health emergency of international concern and, later, on March 11th of 2020 the WHO declared the coronavirus disease as a pandemic due to its alarming levels of spread and severity (World Health Organization, n.d.). By the time of this communication, and according to the same source, the Director-General had declared that the countries should take urgent and aggressive action towards this pandemic.

The first place that went to lockdown due to COVID-19 disease was Wuhan on January 21st of 2020 (The American Journal of Managed Care, 2021). But the fact is that it quickly spread to other continents like Europe and America and by March 2020, Italy was already considered the pandemics epicentre (Horowitz, 2020).

According to Elliot (2020), by the time it got clear that COVID-19 was not confined to China and there would be more economic effects widespread in many different countries, economists, central banks, and finance ministries believed that the coming shock in the economy, would be sharp but short in time, so that, the activity would have a rapid recovery. Still according to Elliot (2020), the COVID-19 has had an effect on both supply and demand, due to the fact that entire countries were in lockdown by that time, so that the factories and offices were shut, leading to an output fall, as consequence. On the other hand, consumers were isolated at their homes, so they didn't buy as much goods and services as they used to.

It is important to refer that the restrictions that were verified while traveling – for both domestic and international flights– as well as the interruption on the supply chains were crucial to lead to the forecasts of the future existence of an economic crisis by international agencies, such as International Monetary Fund (IMF) (Aslam *et al.*, 2021). But, as imaginable, not all sectors were affected negatively due to the pandemic – sectors like pharmaceuticals and biotechnology obtained substantial growths (Chundakkadan & Nedumparambil, 2022).

According to Mazur *et al.* (2021), the stock market crash that occurred in March of 2020 happened because of the low degree of consumer spending in the different industries, leading to firms revise their earnings prospects, since they would be lower than previously expected. This had as consequence the fall of stock prices around distinct markets.

The fact is that in March of 2020 occurred one of the biggest stock market crashes, as a consequence of the COVID-19 pandemic and the governments' responses to it (Mazur *et al.*, 2021). As it was previously stated, by the time of the COVID-19 outbreak, when whole industry sectors around the world got shutten, there were predictions of a possible new economic crisis (Aslam *et al.*, 2021). Haroon & Rizvi (2020) determined that the panic caused by media frenzy and the pursuit for breaking news is associated with increased volatility in financial markets. The COVID-19 panic affected the world economy as a whole, causing negative impact on trade and tourism (Albulescu, 2020).

According to Diebold & Yilmaz (2012) and Aslam *et al.* (2021), during crisis, the financial markets' volatility commonly has a sudden increase and spills over across markets. In what concerns to the COVID-19 pandemic itself, the uncertainty caused by it resulted in high volatility and unpredictability in the markets (Zhang *et al.*, 2020).

Chundakkadan & Nedumparambil (2022) had discovered that the attention given to COVID-19 had a negative impact on the sentiment among market participants, and consequently had led to a depression in the markets. According to the same authors this negative sentiment caused high volatility on the markets, as well.

Wang & Enilov (2020) have got to a conclusion that COVID-19 did influence the stock market returns' movement, finding evidence of causality from COVID-19 to stock market returns in France, Germany, Italy, Canada, and United States.

As it was already reported, a lot of academics studied the impact of the COVID-19 on the financial markets. For example, Lúcio & Caiado (2022) studied how the COVID-19 pandemics affected volatility of some of the S&P 500 Industries, using clusters mechanisms, while Shezad *et al.* (2021), between other findings, analysed the impact of different groups of countries' economic slowdown on the US volatility. Wang *et al.* (2022) studied volatility spillovers and time-frequency dynamic of the biggest financial markets of the world since the COVID-19 outbreak, discovering that the US and United Kingdom's markets are spillovers transmitters, and the others are receivers.

Yousef (2020) studied the impact of COVID-19 on the stock market volatility, using variables associated with the COVID-19, like the number of daily new cases and its growth rate, the EPU index and the prices of Oil and Gold with the aim to evaluate the relation of those with the standard deviation of the indexes of different stock markets. That study led to the conclusion that the COVID-19 did indeed impact the volatility – given by the standard deviation – of the stock markets.

Engelhardt *et al.* (2021) investigated the relationship between the market volatility, COVID-19 cases growth rate and the level of trust of the different countries and found that there was a general increase in the level of volatility during the COVID-19 pandemics. Chaudhary *et al.* (2020) studied the impact of COVID-19 on the volatility of the stock markets on the 10 countries with bigger value of GDP in the world, getting into the conclusion that the virus had a positive impact on the volatility. Chowdhury *et al.* (2022) made a study of the impact of the COVID-19 and the changes of EPU on the stock markets' volatility of the United States, getting to the conclusion that those markets are highly sensitive to this pandemic.

Albulescu (2021) developed a study where the main purpose was to find if the COVID-19 had influenced the United States financial markets' volatility. On that study, Albulescu used an Ordinary Least Squares (OLS) regression to verify the impact of variables like number of daily reported new cases of COVID-19, the fatality ratio of that disease and the EPU index, on the VIX – volatility measure of the S&P 500. The main result was that the COVID-19 variables had positive impact on the volatility index.

In sum, one of the most important components of the financial markets is, undoubtably, the volatility. Volatility, according to different academics is a mechanism that is used to find efficient prices, not forgetting that prices reflect the investors valuation of the market. It matters to refer that in times of crisis the prices are highly affected – in efficient markets the prices reflect the known information – which is reflected on the volatility. It should also be remembered that the COVID-19 pandemic was considered a crisis and, according to some authors that had already studied this pandemic, it had a general influence on the markets. In this dissertation it was studied the impact of the coronavirus disease on the volatility of the European financial markets.

CHAPTER III – VARIABLES AND DATA ANALYSIS

In this chapter we describe the variables that are used in this study, with the purpose of forecasting the impact of COVID-19 in the European financial markets. Alongside with the description of the variables, we also make a slight analysis of the data, using graphics to demonstrate the growth of those during the period of the pandemic time.

Considering that the final aim of this dissertation is to study the impact of COVID-19 on the European financial markets, the independent variable used in this thesis is the volatility index for European options, most known as the VSTOXX. The independent variables, that represent the impact of COVID-19 on the volatility, are the reported new daily cases of COVID-19 and the death ratio of this same disease. We also use the Economic Policy Uncertainty index as an independent variable. The selection of those variables was made with the purpose of analysing how much the COVID-19 factors influenced the volatility of the financial markets, and we included the EPU index with the aim to see if that factor can improve our results.

3.1 Variables

In the first place, it is important to state that the COVID-19 pandemics first appeared in November of 2019 in Wuhan and, even though the disease was stabilized by 2023, it is still important to reflect about its effects in the different sectors around the world, including the finance sector. As it has been exposed before, the main point of this dissertation is the study of the effects of COVID-19 in the European financial markets.

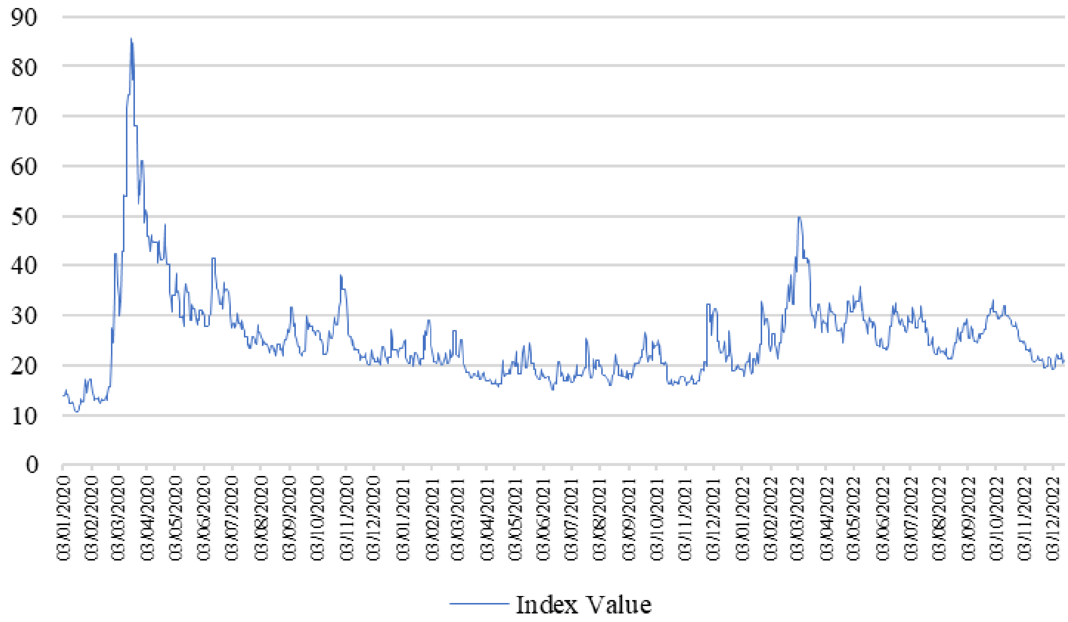
In this study, we focus on the timeline between January 3rd of 2020, and December 14th of 2022.

It should be noted that, according to Qontigo (2023a), the volatility is the most used measure of the level of uncertainty in certain markets. In accordance with that, the dependent variable, as it was mentioned before, is the Euro Stoxx 50 Volatility Index, commonly referred as VSTOXX. This is an index composed by 50 stocks, representing the 50 largest companies of the 20 biggest sectors in terms of free-float market capitalization in the Euro Zone (Qontigo, 2023b). That volatility index measures the implied variance across all options of a given time to expiry and it was developed by Goldman Sachs and Deutsche Börse (Qontigo, 2023a).

In the Figure 1, it is possible to visualize the growth of the VSTOXX on the COVID-19 timeline used in this study. The VSTOXX had reached its peak on March 16th of 2020.

In that same day it was announced 12.976 new cases of COVID-19 and 730 deaths – the number of deaths was the highest number by that time. The death ratio on March 16th of 2020 had reached 3,80% - also the highest level by then. After this peak, the VSTOXX started to normalize on the following months, by getting lower. In June of 2020 it already got back to its normal values.

Figure 1. VSTOXX index value over time



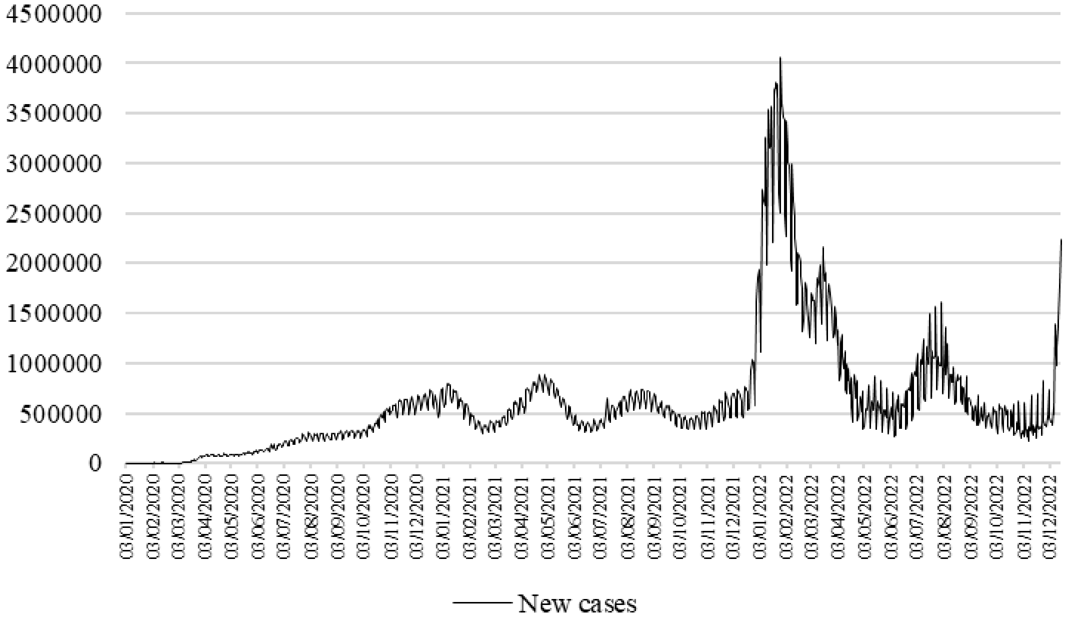
Source: Qontigo

One other variable used in this study, as an independent variable, is the worldwide reported daily new cases of COVID-19 by the WHO. This variable is a COVID-19 measure that was used to estimate the impact of this disease on the financial markets' volatility.

As it is shown on Figure 2, it is possible to visualize the growth of the daily cases of COVID-19 all over the world – between January 3rd of 2020 and December 14th of 2022.

Even though VSTOXX index had reached its highest level in March of 2020, that was not the same time when the number of cases got to its peak. The fact is that it was on January 26th of 2022 that the number of reported new cases reached the number of 4.053.592, being the maximum number of daily cases ever reached until nowadays.

Figure 2. New reported daily cases of COVID-19 over time



Source: World Health Organization (WHO)

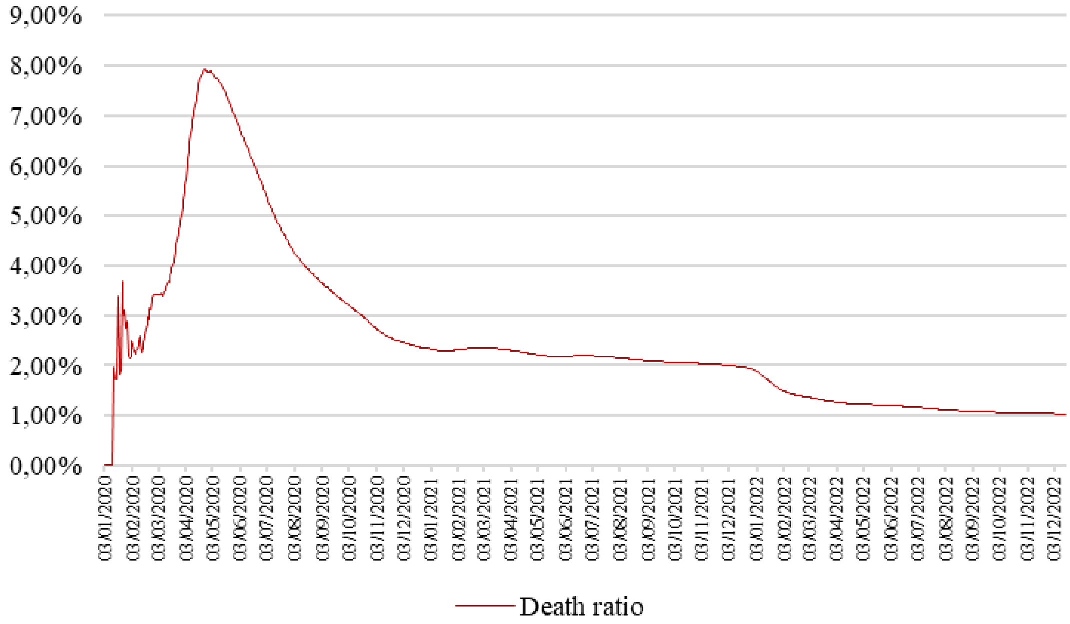
Such as the reported new daily cases of COVID-19, we also analysed the daily death ratio of COVID-19. To use this measure, it was necessary to take in account that, according to the OPAS (2020), the death ratio is calculated as specified in the equation (1).

$$Death\ ratio\ per\ infection\ (\%) = \frac{Number\ of\ deaths\ per\ infection}{Number\ of\ infection\ cases} \times 100 \quad (1)$$

Therefore, we proceeded to the calculation of the death daily ratio, according to the reported daily new cases and reported daily deaths caused by COVID-19, resourcing to the data available on the website of WHO. The daily ratios are represented on the graphic disposed in Figure 3. In this figure we can see that the maximum value of the ratio was verified on April 24th of 2020 with a percentage of 7,94%.

After the death ratio reaches its maximum value, it starts to decline until the present. Should be noted that the decline is more expressive until the end of 2020. That can be explained by the fact that the total number of registered cases of COVID-19 keeps getting higher, so the new deaths start to have less impact in the ratio.

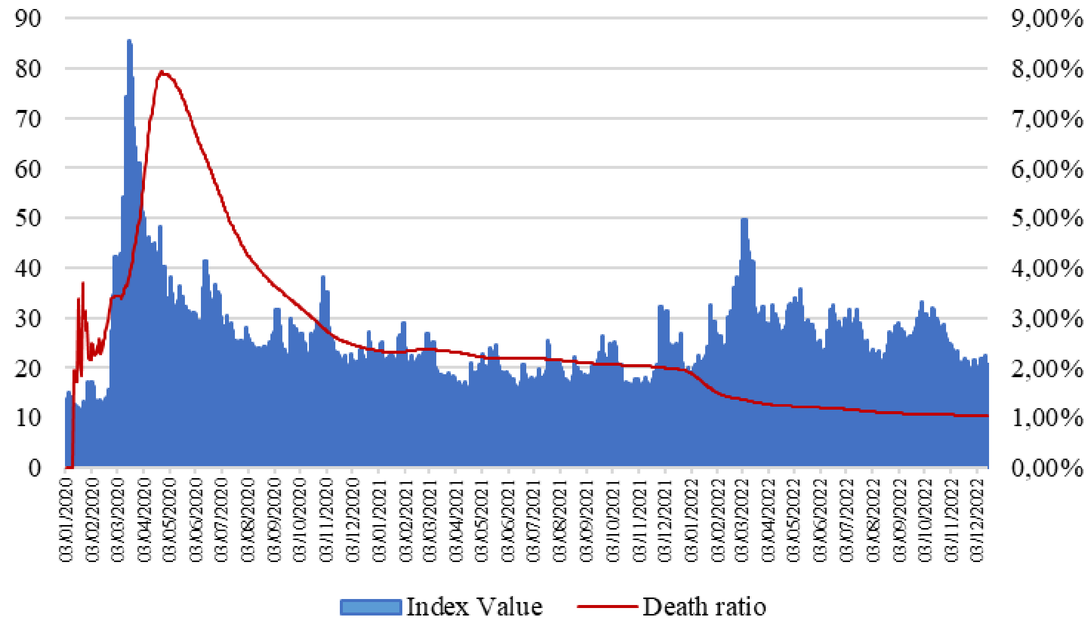
Figure 3. Daily death ratio caused by COVID-19 over time



Source: World Health Organization (WHO)

In the Figure 4, it is possible to visualize the joint behaviour of the death ratio variable and the VSTOXX values. The peak of those variables happened around the same time – in the beginning of the COVID-19 pandemic. After they reached those peaks, both variables started to decline. Along with those facts, we can see that there might be a correlation between these two. Only in 2022 they started to have different behaviours – the VSTOXX started to show higher values, what might be explained by the Russia-Ukraine war. That being said, by the visualization of the Figure 4, we can perceive that the COVID-19 impact on the volatility was more significant until the end of 2021.

Figure 4. Death Ratio and VSTOXX value over time



Source: World Health Organization (WHO) and Qontigo

One other variable studied in this dissertation is the EPU index and it should be noted that we had in account the global EPU values.

The EPU index is measured by taking in account three different types of underlying components: quantifying newspaper coverage of policy-related economic uncertainty; the second is basically reports by the Congressional Budget Office, which are made upon lists of temporary federal tax code provision; and, for last, the third component draws on the Federal Bank Reserve of Philadelphia's Survey of Professional Forecasters (Economic Policy Uncertainty, 2012).

According to Hartwell (2018), volatility is related to market uncertainty and macroeconomic conditions.

Baker *et al.* (2016) stated that the policy uncertainty is highly correlated with stock price volatility in higher levels and diminished investment and employment in policy-sensitive sectors, such as health care, finance, and infrastructure construction. Baker *et al.* (2016) also refers that higher policy instability and uncertainty in the US and Europe in recent years caused potential harm in macroeconomic performance. It is also stated that effects of policy uncertainty are shown on cross-sectional structure of stock price volatilities, rates of investment and employment levels of growth.

According to Pastor & Veronesi (2012), the government policy changes are responsible for the rising of stocks volatility and also for a higher correlation across companies, as long as the policy changes are the same for all. The same authors state that the bigger is the uncertainty, the bigger will be the magnitude of the impacts in the volatility.

Although the EPU of European countries, by itself, isn't a great addition in forecasting volatility of European markets, when the United States' EPU is added to the model, it achieves higher forecasts accuracy (Mei *et al.*, 2018). Also, the EPU index can improve the prediction for the European markets during recessions and expansions, according to the same author.

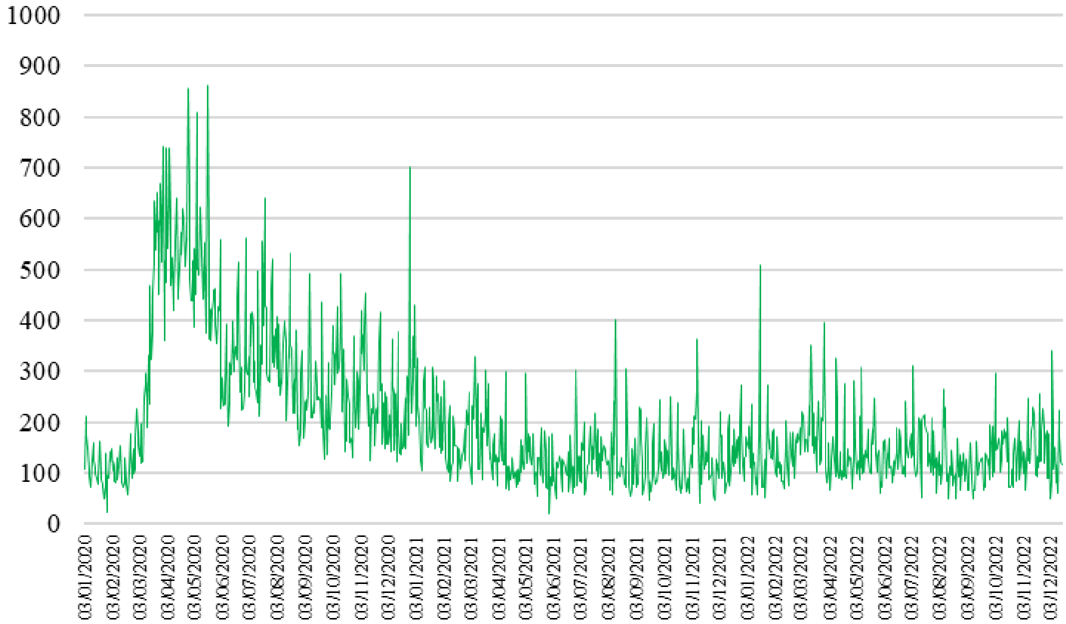
In what concerns to the pandemic caused by the coronavirus, Baker *et al.* (2020) have already obtained evidence that the COVID-19 pandemic has created a massive uncertainty shock. That shock is even larger than the one that was caused by the financial crisis of 2008.

In the Figure 5, it is possible to verify the development of the EPU index values over the pandemic time, more precisely, between January 3rd of 2020 and December 14th of 2022. The EPU had reached its higher level on May 17th of 2020 – by the time when the lockdown ended or was close to its ending for most European countries. It is important to mention that, in that day, the EPU index had reached the value of 861,1 – the greatest of all time, ever since the creation of this index.

Around June of the same year, the EPU index started to normalize its values, since it started to decline. It should be noted that the growth of this index from the beginning of January of 2020 until its peak in May was relatively accentuated.

It is also possible to visualize that it was in the beginning of the COVID-19 pandemic that the EPU index had registered higher levels – between the middle of March until the end of May, the lowest level registered was 323,71 on March 16th of 2020. After this period of higher levels, the EPU index value started to decrease, except for some very specific days, when it was registered some higher values.

Figure 5. Daily EPU index



Source: Economic Policy Uncertainty (EPU)

Those different variables that have been presented in the prior paragraphs were important to this case study. Firstly, to analyse the volatility, it was mandatory to have in account the VSTOXX index as a volatility variable related to the European financial markets. Then, to measure the impact of the COVID-19 pandemic, it was also required to use COVID-19 variables, so that, the announcement of new cases and of the death ratio were used in order to evaluate the impact and, also, to see which one had more influence on European markets. Besides that, it was added one other variable: the EPU index. This addition was made, to have a control variable, which is already known to be highly related to the volatility indexes, just how it was shown before.

The data used for this study was exported from official founts – WHO, Qontigo and the EPU websites. In the Table 1, the four variables taken in account in this study are presented such as its descriptions, the purpose of each of them on this dissertation, and for last the sources from where the data was taken.

Table 1. Variables' description

Variables	Description	Purpose	Font
VSTOXX	Stock index composed by 50 stocks from 11 countries of Eurozone that shows up its implied volatility.	Dependent Variable. Study the impact that the other variables have in this index.	Qontigo
Daily COVID-19 reported cases	The number of global cases of COVID-19 that were announced daily by the World Health Organization (WHO).	Verify if the reported cases of COVID-19 had any reflection in the European Volatility index.	World Health Organization (WHO)
Daily death ratio of COVID-19	The number of deaths due to COVID-19 that were daily announced by the World Health Organization (WHO) divided by the daily COVID-19 reported cases.	Verify if the reported deaths of COVID-19 impacted the VSTOXX.	World Health Organization (WHO)
EPU	Index that measures the global Economic Policy Uncertainty.	Verify the impact on the VSTOXX caused by EPU.	Economic Policy Uncertainty (EPU)

3.2 Descriptive statistics

With the aim to compare different periods of COVID-19 pandemic – the entire period between the beginning of 2020 and the end of 2022, the start of the pandemic and the first lockdown period –, it was decided to use four different periods of time. The first one, that contemplates the entire period, goes from January 3rd of 2020 to December 14th of 2022. The second contemplates the start of the pandemic and lockdown periods and goes from January 3rd of 2020 to May 29th of 2020. For last, the two other periods are divided by the beginning of the pandemic – we decided to use a period that started 2 months before the beginning of lockdowns in Europe and ended one month after the beginning (January 13th of 2020 to April 9th of 2020) – and the lockdown period (March 16th of 2020 to May 15th of 2020).

In the Table 2, it is possible to visualize the descriptive statistics of the variables on the different timelines, such as the mean, standard deviation (SD), minimum and maximum value.

Table 2. Statistic data

		Mean	**Standard Deviation**	**Minimum**	**Maximum**
03/01/2020 - 14/12/2022	VSTOXX	25,43	9,09	10,69	85,62
	New cases	587 989	591 689	0	4 053 592
	Death Ratio	2,52%	1,62%	0,00%	7,94%
	EPU	184,61	119,21	22,25	807,66
03/01/2020 - 29/05/2020	VSTOXX	33,01	18,62	10,69	85,62
	New cases	37 266	38 495	0	108 185
	Death Ratio	4,58%	2,43%	0,00%	7,94%
	EPU	310,05	206,73	22,25	807,66
13/01/2020 - 09/04/2020	VSTOXX	34,10	22,52	10,69	85,62
	New cases	16 883	25 609	0	80 380
	Death Ratio	3,47%	1,28%	1,72%	6,77%
	EPU	238,71	197,45	22,25	807,66
16/03/2020 - 15/05/2020	VSTOXX	45,37	13,82	27,67	84,80
	New cases	65 685	20 663	12 976	89 049
	Death Ratio	6,52%	1,49%	3,80%	7,94%
	EPU	517,34	97,23	323,71	807,66

During the entire period of COVID-19 that was taken in account, it is possible to see that the maximum of all variables, except the reported new cases, was reached during the beginning of the pandemics and the lockdown periods. It was also in that period that the SD got higher values for all the variables. The fact is, as it was seen before, this period was remarked by the uncertainty and the fear sentiment.

The volatility index registered a mean value of 25,43 throughout the pandemic. During the lockdown period it registered a higher mean value – of 45,37 –, although the highest value reached was not registered in that period. The EPU index had a similar performance with the VTOXX – the mean value throughout the COVID-19 pandemic was 184,61 and in the lockdown period the mean value was substantially bigger – 517,34. The maximum of the reported new daily cases was of 4.053.59 new cases, and it was reached only in 2022. The death ratio has a mean value of 2,52% and it was in the period comprehended between the beginning of the pandemic and the end of the first lockdown that it reached higher values – the maximum was 7,94%. In what concerns to the minimums, they were all registered in the beginning of the COVID-19 pandemic – to be more precise, in January of 2020.

To conclude, it should be noted that the chosen variables for this study have the aim to evaluate the impact of the coronavirus pandemic on the European financial markets. In this study different timelines were used with the aim to differentiate the period of time when the COVID-19 had more influence on the European volatility index. In this chapter it was indicated how the different variables are important to the model, according to the main purpose. From the descriptive statistics, it was already possible to understand that in the five first months of 2020, almost every variable had reached its peaks.

CHAPTER IV – METHODOLOGY

In this chapter we present the different tests that we have done to study the impact of the COVID-19 in the European financial markets' volatility. The methodology used has the main purpose of verifying if the COVID-19 did, in fact, impact the volatility of those markets and, if that was the case, what was the magnitude of the impact of the COVID-19 variables.

In addition, we also wanted to verify if those variables had more impact in the beginning of the pandemics, during the lockdown period, or if there was no difference between those distinct periods. Besides that, we also built a regression of the pandemic time until the moment of this study – the end of 2022.

That being said, we elaborated a regression with the variables – the dependent variable is the volatility index, and the independent variables are the reported daily cases and the death ratio of COVID-19, and the global EPU index. For the regression we use two different methods: the Ordinary Least Squares and the Generalized Least Squares.

4.1 Ordinary Least Squares

To study the impacts that COVID-19 had on the volatility of the European financial markets, we use the OLS regression methodology, with the aim to measure the impact.

The OLS method, according to Chumney & Simpson (2006), is one of the most common methods of analysis that are used in the world.

These kinds of models, according to Zdaniuk (2014), assume that the analysis is reflected on a model that describes the relationship between one or more explanatory variables and a continuous or at least interval outcome variable that minimizes the sum of square errors. The error is nothing more than the difference between the actual and the predicted value of the outcome variable. The OLS's most common analytical method is the linear regression. The estimators that are obtained with this method are known as the least-squares estimators (Gujarati, 2003).

This methodology also has some assumptions that are important to mention. The first assumption is that the expected value of the error (ϵ_t) is 0. The second is that there is no autocorrelation between the errors, because if the opposite happens it means that the parameter estimates will be inefficient. The third and last assumption is that the errors must be homoscedastic (Chumney & Simpson, 2006). It is also important to refer that the opposite of homoscedasticity – heteroscedasticity –, arises when the error variance changes across the sample (Hendry, 1995).

The violation of the assumption of no autocorrelation between the errors doesn't affect the unbiasedness of the OLS regression estimators, but it still affects their efficiency. When the model fails the homoscedasticity assumption, it means that the variance is not constant and the derivation does not hold, leading to biased estimates of the variances of each of the estimated parameters (Pindyck & Rubinfeld, 1991).

One of the main aims of the linear regression, resorting to OLS method, is to verify if those variables are or are not significant to the model. Therefore, the test hypothesis can be written in the following way:

$$H_0: The\ model\ doesn't\ explain\ the\ volatility\ of\ the\ European\ financial\ markets$$

$$H_1: The\ model\ explains\ the\ volatiity\ of\ the\ European\ financial\ markets$$

If we reject the null hypothesis (H_0), it means that the model is significant and can, indeed, explain the volatility of the European financial markets. We also use this test of hypothesis to verify if each variable is significant to the model, by themselves.

Alongside with the analysis of the significance of the models, we must make the model estimation, but it only can be done if the variables are significant to the model. The β values determine the impact that the different variables had on the volatility of the European financial markets and whether the impact is positive or negative. The α is nothing more than the interception of the model.

The last point we seek to analyse with this regression is the quality of adjustment. The quality of adjustment is given by the R^2 coefficient. The coefficient goes from zero to one and it represents how much the model explains the dependent variable – the volatility index, VSTOXX.

The estimation is made in accordance with the equations (2), (3), (4) and (5). It should be noted that *VSTOXX* stands for the volatility index, *CovCases* for the reported daily cases of COVID-19, *DeathRatio* for the death ratio of the COVID-19 and *EPU* for the Economic Policy Uncertainty index. It should also be taken in account the fact that we are comparing the VSTOXX index with the COVID-19 and uncertainty data of the prior day. The ϵ_t stands for the error term of the regression.

$$VSTOXX_t = \alpha + \beta_1 . CovCases_{t-1} + \epsilon_t \quad (2)$$

$$VSTOXX_t = \alpha + \beta_1 . DeathRatio_{t-1} + \epsilon_t \quad (3)$$

$$VSTOXX_t = \alpha + \beta_1 . CovCases_{t-1} + \beta_2 . DeathRatio_{t-1} + \epsilon_t \quad (4)$$

$$VSTOXX_t = \alpha + \beta_1 . CovCases_{t-1} + \beta_2 . DeathRatio_{t-1} + \beta_3 . EPU_{t-1} + \epsilon_t \quad (5)$$

For convenience, we will further refer to equations (2), (3), (4) and (5) as Model 1, Model 2, Model 3 and Model 4, respectively.

In the first model, our aim is to know if the number of reported daily new cases of COVID-19 had any impact in the VSTOXX performance and how big was that possible impact. Albulescu (2020) had stated that the number of cases had impacted the United States financial markets' volatility. In this thesis, we want to verify if the same has succeeded in the European financial markets and that way we can perceive if the behaviour of European markets, in terms of volatility, was similar to the United States financial markets' behaviour.

In the Model 2, we studied the impact of another COVID-19 variable – death ratio. In this model we are studying the impact of the COVID-19, but we had the aim to verify if there is any variation on the impact of this variable towards the variable of number of cases. This way, after we do both regressions, we might discover which of the factors had more impact in the Europeans' behaviour toward the financial markets.

After analysing both variables separately, we pretend to observe if using them together might improve the regression results in what concerns to the impact on the VSTOXX values. That being stated, in the Model 3 we aim to understand whether the COVID-19 variables had impacted the volatility index or not.

In the fourth, and last, model, as it was already mentioned, we added another variable that is not directly related to the COVID-19 pandemic – the Economic Policy Uncertainty index. We already discussed how that variable is related to the volatility, especially in crisis times, time when it usually has a positive correlation with volatility. We also shall not forget that the EPU reached its highest levels during the pandemic. This way, we believe that this variable might improve the results obtained in the OLS regression.

Getting back to the OLS methodology, as it was already mentioned, the OLS has some assumptions that should be verified, such as that there should be no autocorrelation between the errors and that the errors should be homoscedastic, as well.

To verify the first presented assumption – no autocorrelation between the errors –, we realized the Durbin-Watson test. The Durbin-Watson is the most used test to detect serial correlations, which is the ratio of the sum of squared differences on successive residual to the residual sum of squares (Gujarati, 2003).

To attest the homoscedastic assumption, we applied the Breusch-Pagan test to the data obtained by the OLS regression. This model is presented as a test for heteroscedastic disturbances in a regression linear model, using the Lagrangian multiplier test (Breusch & Pagan, 1979).

One of the ways to proceed when there are signals of heteroscedasticity is to compute some feasible Generalized Least Squares (GLS) estimator in an attempt to capture the efficiency of GLS.

4.2 Generalized Least Squares

The OLS estimator is only efficient amongst the linear unbiased estimator if the errors of the linear regression are homoscedastic and if they are not autocorrelated (Cameron & Trivedi, 2005). On the contrary of what happens in the OLS method, which has assumptions that the errors must not be autocorrelated and that they should have constant variance, the GLS method can be applied when serial correlation and heteroscedasticity are present (Pindyck & Rubinfeld, 1991).

The GLS method, according to Kariya & Kurata (2004), plays an important role in different theoretical and practical aspects of statistical inference in general linear regression models. The GLS technique uses data and prior information to get a best-fitting set of model parameters (Menke, 2015).

It is possible to say that the GLS is basically the OLS method on the transformed variables that satisfy the standard least-squares assumptions (Gujarati, 2003). According to this same author, the estimators that are obtained by this method are considered the Best Linear Unbiased Estimator (BLUE) and are most commonly known as GLS estimators.

We use the GLS method to analyse the impact of COVID-19 on the volatility of the European markets, but on the contrary to what happened in the OLS regression, this time it will be had in account the heteroscedasticity and autocorrelation of the errors – the GLS, as it was established before, will correct them.

We can describe the hypothesis test, such as it is presented above:

H_0: $The\ model\ doesn't\ explain\ the\ volatility\ of\ the\ European\ financial\ markets$

H_1: $The\ model\ explains\ the\ volatiity\ of\ the\ European\ financial\ markets$

It must be taken in account that only when the null hypothesis fails, we can use the variable to describe the behaviour of the dependent variable. Just as it had happened with the OLS regression, we aim to estimate the impact of each variable on the dependent variable – volatility index. So that, we estimate the models according to what is disposed on the equations (6), (7), (8) and (9).

We resourced to the same variables that were used in the OLS regression, so *VSTOXX* stands for the volatility index, α for the interception, *CovCases* for the reported daily cases of COVID-19, *DeathRatio* for the daily death ratio of the COVID-19, *EPU* for the Economic Policy Uncertainty index and, ϵ_t stands for the error term of the regression.

$$VSTOXX_t = \alpha + \beta_1 . CovCases^*_{t-1} + \epsilon_t \tag{6}$$

$$VSTOXX_t = \alpha + \beta_1 . DeathRatio^*_{t-1} + \epsilon_t \tag{7}$$

$$VSTOXX_t = \alpha + \beta_1 . CovCases^*_{t-1} + \beta_2 . DeathRatio^*_{t-1} + \epsilon_t \tag{8}$$

$$VSTOXX_t = \alpha + \beta_1 . CovCases^*_{t-1} + \beta_2 . DeathRatio^*_{t-1} + \beta_3 . EPU^*_{t-1} + \epsilon_t \tag{9}$$

For convenience, we will further refer to equations (6), (7), (8) and (9) as Model 5, Model 6, Model 7 and Model 8, respectively.

It should be noted that the difference between these variables and the variables of the OLS regression is that those are already transformed in order to be BLUE.

To summarize we used two different methodologies on this study: the OLS and the GLS. We decided to use the OLS methodology for our linear regression with the purpose of studying and measuring the impact of the pandemic on the volatility. Nevertheless, the

OLS regression must have homoscedastic errors and they also should not be autocorrelated. That is why we opted to add the GLS methodology on this study, attending the fact that the GLS methodology obtains unbiased estimators.

CHAPTER V – RESULTS

After presenting the variables used in the present study and the methodology applied to them, we are already able to present the results of the tests that were used.

As it was already mentioned, we used different timelines on this thesis. The first period where we applied the OLS and the GLS to get the regressions was comprehended between January 3rd of 2020 and December 14th of 2022. After this timeline we applied the regression in the period between January 3rd of 2020 and April 9th of 2020 and, only then, we verified if there was any difference between the beginning of the pandemics and the lockdown period of most European countries. For those three last periods we only analysed the models 3, 4, 7 and 8, presented in the Chapter IV – Methodology.

This chapter will be subdivided in two subchapters: 5.1 – Ordinary Least Squares, and 5.2 – Generalized Least Squares.

5.1 Ordinary Least Squares

With the aim to understand if the COVID-19 variables – New Cases and Death Ratio – we pretend to perform an OLS regression to the models 1, 2, 3 and 4, previously stated in chapter IV.

Nonetheless, the OLS must comply with the three assumptions presented in the chapter IV – Methodology. This way, we had to proceed to the Durbin-Watson and Breusch-Pagan tests to verify if there is no autocorrelation between the errors and if they are homoscedastic, as well. The results of the Breusch-Pagan tests are disposed in Appendix A, where it is possible to observe that it fails the homoscedastic errors assumption. In Appendix B is presented the Durbin-Watson table and in Appendix C the results of this test are offered. Resourcing to the tables presented in these two appendices, we can verify that the autocorrelation assumption has also failed.

The failing of these assumptions means that the estimators are biased and inefficient. Therefore, we must elaborate the GLS methodology.

In the Appendix D, it is possible to visualize the results of the OLS performance to the different models, in the different periods of time that are being studied in this dissertation.

5.2 Generalized Least Squares

As we have already mentioned, it is necessary to rectify the heteroscedasticity and the autocorrelation of the errors. To do that, we applied the GLS methodology to generate a new regression. In the Table 3, it is possible to visualize the GLS regression of the models 5 and 6 on the entire period of the pandemic.

Table 3. GLS applied in Models 5 and 6 – from January 3rd of 2020 to December 14th of 2022

Reject H_0 for a level of significance of 10% (*), 5% (**) and 1% (***)

	January 3, 2020 – December 14, 2022			
	Model 5		**Model 6**	
	B	**p-value**	**B**	**p-value**
(constant)	25,845	0,000***	20,527	0,000***
CovCases	0,000	0,000***	-	-
DeathRatio	-	-	194,86	0,000***
Model	**-**	**0,000*** **	**-**	**0,000*** **

In the table presented above, we are able to affirm that the reported new cases variable wasn't significant to the estimation of the volatility index, VSTOXX. On the other hand, the death ratio had affected the volatility index in a positive way, which means that the growth of the death ratio caused an augmentation in the volatility index.

That being said, we can acknowledge the fact that the announcement of new deaths is the one that caused more panic towards the investors, which affected the financial markets. The same thing did not happen with the announced daily cases of COVID-19, since the results show that the number of new cases had no impact on the European financial markets' volatility.

In what concerns with the analysis of the performance of the GLS on models 7 and 8, they are presented on the following Table 4.

Table 4. GLS applied in Models 7 and 8 – from January 3rd of 2020 to December 14th of 2022

Reject H_0 for a level of significance of 10% (*), 5% (**) and 1% (***)

	January 3, 2020 – December 14, 2022			
	Model 7		**Model 8**	
	B	**p-value**	**B**	**p-value**
(constant)	19,112	0,000***	17,124	0,000***
CovCases	0,000	0,002***	0,000	0,000***
DeathRatio	215,827	0,000***	-19,724	0,000***
EPU	-	-	0,043	0,000***
Model	**-**	**0,000*** **	**-**	**0,000*** **

In the Model 7, which doesn't have in account the EPU index, both death ratio and reported new cases are significant to the model, although the new cases have no impact on the VSTOXX, since the estimated parameter for this variable is null. In what concerns to the death ratio variable, we can say that the growth of the death ratio leads to an augmentation on the volatility index. The results established on the Table 4 are in compliance with what was contemplated in the analysis of the previous models – the number of new cases has, in fact, no impact on the volatility index.

The Model 8, which includes the EPU as an independent variable, is also significant. Nevertheless, the only variable that interacts with the volatility index is the EPU itself. The death ratio variable is not significant, and the estimator of the new cases variable is null.

According to what was exposed, we can conclude that the death ratio impacts the VSTOXX positively during the pandemic period. Nonetheless, when the EPU variable is added to the model, the death ratio has no longer importance to the estimation model. That can be explained by the fact that the EPU index has in account many other factors, besides the COVID-19 pandemic. An example of that is a more recent event that impacted the worldwide economy – the Russia-Ukraine war. According to authors like Umar *et al.* (2022), Kumari *et al*. (2023) and Ahmed *et al.* (2023), the war already had a massive impact on the financial markets, especially on the European ones. So, in that timeline – that goes from 2020 until 2022 –, we cannot forget that there were many other events that also had some consequences in the economy, so that the EPU index is a much better indicator to be used to measure the volatility of the financial markets during the period of

January 3rd of 2020 to December 14th of 2022, while the COVID-19 variables might be a better indicator for a more restricted period.

According to what was exposed, in the Table 5, the results for the Model 7 are presented in more restricted periods of time. Those periods correspond to the beginning of the pandemic – we assumed the period that goes from January 3rd of 2020 to May 29th of 2020. Alongside we use two periods – January 13th of 2020 to April 9th of 2020, and March 16th of 2020 to May 15th of 2020 –, with the aim to perceive if the COVID-19 variables had more influence on the volatility index in the beginning of the pandemic or if in the lockdown period.

Table 5. GLS applied in Model 7 in different timelines

Reject H_0 for a level of significance of 10% (*), 5% (**) and 1% (***)

	January 3, 2020 – May 29, 2020		**January 13, 2020 – April 9, 2020**		**March 16, 2020 – May 15, 2020**	
	B	**p-value**	**B**	**p-value**	**B**	**p-value**
(constant)	13,687	0,000***	-22,264	0,000***	94,580	0,000***
CovCases	0,000	0,000***	0,000	0,000***	0,000	0,000***
DeathRatio	590,361	0,000***	1808,349	0,000***	-310,782	0,000***
Model	-	**0,000*** **	-	**0,000*** **	-	**0,000*** **

In these different timelines the announcement of new cases still has no impact in the volatility index, on the contrary of what happens with the death ratio variable. Only with that information, we can acknowledge that the European financial markets, even by the beginning of the COVID-19 pandemic, only reacted to more dramatic news.

By the visualization of the Table 5 above, we can perceive that in the period that covers the lockdown and the beginning of the COVID-19 pandemic, all the variables are significant. Nonetheless, it is important to refer that the number of new cases of COVID-19 still has no impact on the volatility index. In the beginning of the pandemic (January 13th of 2020 – April 9th of 2020), we can observe similar results – all the variables are significant to the model, but even though the new cases' variable is significant, it doesn't have any influence on the VSTOXX. The biggest difference of these two periods is that in the period that is restricted to the beginning of the pandemic, the death ratio has a bigger impact on the volatility index of European markets – the double of the effect.

Finally, in the lockdown period, the results show that the COVID-19 variables do not have any influence in the volatility index.

According to what was exposed, it is possible to understand that, in fact, the period in which the COVID-19 announcements had more impact on the volatility of the European markets was in the beginning of the pandemic, time when the uncertainty about this new disease was extremely high, causing fear, which was reflected on the VSTOXX index. During the lockdown, the impact of the COVID-19 on the financial markets' volatility was not verified. This information leads us to the conclusion that the fear – reflected by the investors' behaviour – that the European population felt in the beginning of the pandemic – the time when Italy was the epicentre of the pandemic – was the period that affected the most the behaviour of the investors on the financial markets.

To understand if the EPU index shows any improvement in the model, we ran the GLS regression on Model 8. The results are presented on the Table 6.

Table 6. GLS applied in Model 8 in different timelines

Reject H_0 for a level of significance of 10% (*), 5% (**) and 1% (***)

	January 3, 2020 – May 29, 2020		**January 13, 2020 – April 9, 2020**		**March 16, 2020 – May 15, 2020**	
	B	**p-value**	**B**	**p-value**	**B**	**p-value**
(constant)	5,313	0,000***	-26,001	0,000***	93,834	0,000***
CovCases	0,000	0,000***	-0,001	0,000***	0,000	0,000***
DeathRatio	330,583	0,000***	1373,362	0,000***	-310,323	0,000***
EPU	0,095	0,000***	0,123	0,000***	0,002	0,437
Model	**-**	**0,000*** **	**-**	**0,000*** **	**-**	**0,000*** **

In the Table 6 above it is possible to observe that in the first period – from January 3rd of 2020 to May 29th of 2020 –, the model is significant. The variable of new cases, once again, has no effect on the volatility index. The other two variables – the death ratio and the EPU index, on the other hand, had a positive effect on the VSTOXX, which means that the increase of those both variables caused a growth on the volatility index.

In the period between January 13th of 2020 and April 9th of 2020, it is possible to verify that both EPU and death ratio had a positive impact on the VSTOXX. On the contrary, the number of new cases of COVID-19 had a slightly negative impact on the volatility index. According to this, we can understand that even in the beginning of the pandemic, the number of cases didn't have much impact on the volatility of the European financial markets, comparing to what happens with the death ratio.

In the remaining period, from March 16th of 2020 to May 15th of 2020 – the lockdown period –, is not reasonable, since the EPU is not significant, and the death ratio estimator is negative. According to that, we can acknowledge the fact that the lockdown period, on its own, did not influence the European financial markets.

Alongside with what was stated in the previous paragraphs, we are capable to realize that the EPU index did, in fact, add some quality to the model. This index is already known as a fundamental factor on the volatility of the financial markets analysis – according to authors such as Baker *et al.* (2016) and Hartwell (2018). This way, adding the economic uncertainty variable to the COVID-19, we were able to get a model with a higher degree of quality.

In sum, the results show that when analysing the period of the lockdown on its own, we do not obtain results that demonstrate that the COVID-19 impacted the volatility of the financial markets. In the two remaining periods, which include the beginning of the pandemic, we can see that the addition of the EPU variable improves the quality of the model. The new cases variable, though, has no impact in the volatility of the European markets, according to the models. In what respects to the period between January 3rd of 2020 and 14th December of 2022, we can see that the COVID-19 still has some impact on the volatility. Nonetheless, this period is too large, reflected by other variables having bigger influence in the volatility in different periods.

CHAPTER VI – CONCLUSION

To conclude, it should be stated that the financial markets are of remarkable importance, when it comes to economic development and growth. In what respects to the European financial markets, we can affirm that they have an exceptional connectedness and that the markets are highly correlated.

The volatility of the financial markets is an important subject and is studied by a lot of academics in the sphere of the financial matters. The fact is that volatility is a measure that reflects the behaviour of the participants of the financial markets – investors, companies, Government, and others – and the way they look through the market. Different authors have stated that the volatility is a way to quote options, stocks, and others. The fact is that, when we are towards efficient markets, the volatility is the reflex of unexpected changes in prices.

In periods of crisis the volatility typically registers higher values, since the prices practiced on the markets have great oscillations. It is also in times of crisis that there is a stronger relationship between the volatility of the financial markets and the economic policy uncertainty.

We should consider, as well, the fact that the COVID-19 pandemic caused a general crisis across different sectors, including the financial one. According to various authors, the COVID-19 had indeed impacted the financial markets around the world. On the present dissertation we studied the impact of this pandemic on the European financial markets, using the VSTOXX, the reported new daily cases of COVID-19, the daily death ratio of COVID-19 and the EPU as variables. In order to get into conclusions, we resourced to the GLS method once it deals better with serial autocorrelation of errors and heteroscedasticity.

With those variables, we divided them in different periods of time: the first went from January 3rd of 2020 until December 14th of 2022 and was designated as the whole period of the pandemic until the moment of this study, the second went from January 3rd of 2020 until May 29th of 2020 and it is the period that covers the beginning of the pandemic and the lockdown period, the third went from January 13th of 2020 until April 9th of 2020, only representing the period of the beginning of the pandemic, and the fourth, and last one went from March 16th of 2020 until May 15th of 2020, which comprises the period of the lockdown for most European countries.

With this study we got into different conclusions. The main conclusions are stated below.

In the period between January 3rd of 2020 and 14th December of 2022, the reported daily cases of COVID-19 had no impact on the volatility of the European financial markets, while the death ratio of COVID-19 had a positive impact. With the addition of the EPU to the model, the death ratio started to have a negative impact, which means that the growth of the ratio led to a decline in the volatility. The EPU, itself, had a positive impact. We concluded that in this timeline the EPU takes a better roll as an explanator of the behaviour of the volatility index, since this is a large period of time and the EPU index includes information of different events that impacted the financial markets throughout the two years in analysis.

The period that goes from January 3rd of 2020 and 29th May of 2020 has better results in what respects to the impact of the COVID-19 variables in the financial markets' volatility – both death ratio and EPU have positive impacts. That leads to the conclusion that it was in the beginning of the pandemic (including the first lockdown) that the COVID-19 had real impact on the financial markets. It should be noted that it was in that time that there was more uncertainty and fear, which are two factors that have a major influence in the volatility of the financial markets.

Separating the period that goes from January 3rd of 2020 to 29th May of 2020 in two – the beginning of the pandemic and the lockdown period –, we were able to see that the beginning of the pandemic showed results that indicated that the COVID-19 had impacted the volatility, while when we take only the period of the lockdown in account, it does not guide us to any conclusions. It provides us the image that the European investors were mainly affected by the uncertainty caused by the initial outbreak of the COVID-19 pandemic, while when it is only taken in account the lockdown period, there was no longer much impact.

To finish and comparing those results to the ones that Albulescu (2021) obtained for the United States' financial markets' volatility we can see that, while in the United States financial markets, the number of cases had impacted the markets, the same did not happen in Europe. Another comparison is that while the EPU had no significance in the United States financial markets, that same index had impacted the European markets. Despite that, the death ratio had a similar effect on the volatility of both markets.

In sum, we can conclude that even though the pandemic has impacted the volatility of European financial markets throughout two years in analysis, it had a wider effect in the first five months of 2020. The COVID-19 component that had a major consequence in the volatility of those markets was the daily death ratio in prejudice of the reported new daily cases of the coronavirus disease.

REFERENCES

Ahmed, S., Hasan, M. M., & Kamal, M. R. (2023). Russia–Ukraine crisis: The effects on the European stock market. *European Financial Management*, 29(4), 1078-1118. https://doi.org/10.1111/eufm.12386

Ahoniemi, K. (2008). Modeling and forecasting the VIX index. Available at SSRN. https://dx.doi.org/10.2139/ssrn.1033812

Albulescu, C. (2020). Coronavirus and financial volatility: 40 days of fasting and fear. Available at SSRN. http://doi.org/10.2139/ssrn.3550630

Albulescu, C. (2021). COVID-19 and the United States financial markets' volatility. *Finance Research Letters*, 38, 101699. https://doi.org/10.1016/j.frl.2020.101699

Aslam, F., Ferreira, P., Mughal, K. S., & Bashir, B. (2021). Intraday Volatility Spillovers among European Financial Markets during COVID-19. *International Journal of Financial Studies*, 9(1), 5. https://doi.org/10.3390/ijfs9010005

Assaf, A. (2016). MENA stock market volatility persistence: Evidence before and after the financial crisis of 2008. *Research in International Business and Finance*, 36, 222–240. https://doi.org/10.1016/j.ribaf.2015.09.003

Baele, L. (2005). Volatility Spillover Effects in European Equity Markets. *Journal of Financial and Quantitative Analysis,* 40(2), 373–401. https://doi.org/10.1017/S0022109000002350

Bailey, R. E. (2005). *The Economics of Financial Markets*. Cambridge University Press. https://doi.org/10.1017/CBO9780511817458

Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring Economic Policy Uncertainty. *The Quarterly Journal of Economics*, 131(4), 1593–1636. https://doi.org/10.1093/qje/qjw024

Baker, S. R., Bloom, N., Davis, S. J., & Terry, S. J. (2020). *COVID-Induced Economic Uncertainty*. NBER Working Papers 26983, National Bureau of Economic Research, Inc. https://doi.org/10.3386/w26983

Bartram, S. M., & Bodnar, G. M. (2009). No place to hide: The global crisis in equity markets in 2008/2009. *Journal of International Money and Finance*, 28(8), 1246–1292. https://doi.org/10.1016/j.jimonfin.2009.08.005

Bartram, S. M., Taylor, S. J., & Wang, Y.-H. (2007). The Euro and European financial market dependence. *Journal of Banking & Finance*, 31(5), 1461–1481. http://doi.org/10.2139/ssrn.673641

Bekaert, G., Harvey, C. R., Lundblad, C. T., & Siegel, S. (2013). The European Union, the Euro, and equity market integration. *Journal of Financial Economics*, 109(3), 583–603. https://doi.org/10.1016/j.jfineco.2013.03.008

Benzid, L., & Chebbi, K. (2020). The impact of COVID-19 on exchange rate volatility: Evidence through GARCH model. Available at SSRN. http://doi.org/10.2139/ssrn.3612141

Bhowmik, R., & Wang, S. (2020). Stock Market Volatility and Return Analysis: A Systematic Literature Review. *Entropy*, 22(5), 522. https://doi.org/10.3390/e22050522

Bodie, Z., Kane, A., & Marcus, A. J. (2018). *Investments* (11th Edition). McGraw Hill Education.

Bond, P., Edmans, A., & Goldstein, I. (2012). The Real Effects of Financial Markets. *Annual Review of Financial Economics*, 4, 339–360. https://doi.org/10.1146/annurev-financial-110311-101826

Breusch, T. S., & Pagan, A. R. (1979). A Simple Test for Heteroscedasticity and Random Coefficient Variation. *Econometrica: Journal of the econometric society*, 47, 1287–1294. https://doi.org/10.2307/1911963

Cameron, A. C., & Trivedi, P. K. (2005). *Microeconometrics: methods and applications*. Cambridge university press.

Caporale, G. M., Pittis, N., & Spagnolo, N. (2006). Volatility transmission and financial crisis. *Journal of Economics and Finance*, 30, 376–390. https://doi.org/10.1007/BF02752742

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), 208. https://doi.org/10.3390/jrfm13090208

Chicago Board Options Exchange (2018). *Cboe VIX FAQ*. https://www.cboe.com/tradable_products/vix/faqs/

Choi, S.-Y. (2022). Volatility spillovers among Northeast Asia and the US: Evidence from the global crisis and the COVID-19 pandemic. *Economic Analysis and Policy*, 73, 179–193. https://doi.org/10.1016/j.eap.2021.11.014

Chowdhury, E. K., & Abedin, M. Z. (2020). COVID-19 effects on the US stock index returns: An event study approach. Available at SSRN. https://doi.org/10.2139/ssrn.3611683

Chowdhury, E. K., Dhar, B. K., & Stasi, A. (2022). Volatility of the US stock market and business strategy during COVID-19. *Business Strategy & Development*, 5(4), 350-360. https://doi.org/10.1002/bsd2.203

Chumney, E. C. G., & Simpson, K. N. (2006*). Methods and Designs for Outcomes Research*. American Society of Health-System Pharmacists, Inc.

Chundakkadan, R., & Nedumparambil, E. (2022). In search of COVID-19 and stock market behavior. *Global Finance Journal*, 54, 100639. https://doi.org/10.1016/j.gfj.2021.100639

Danielsson, J., Valenzuela, M., & Zer, I. (2018). Learning from History: Volatility and Financial Crises. *The Review of Financial Studies*, 31(7), 2774–2805. https://doi.org/10.1093/rfs/hhy049

Dennis, P., Mayhew, S., & Stivers, C. (2006). Stock Returns, Implied Volatility Innovations, and the Asymmetric Volatility Phenomenon. *Journal of Financial and Quantitative Analysis*, 41(2), 381–406. http://www.jstor.org/stable/27647252

Diebold, F. X., & Yilmaz, K. (2012). Better to Give than to Receive: Predictive Directional Measurement of Volatility Spillovers. *International Journal of forecasting*, 28(1), 57–66. https://doi.org/10.1016/j.ijforecast.2011.02.006

Economic Policy Uncertainty (2012). *Methodology*. https://www.policyuncertainty.com/methodology.html

Elliot, L. (2020, March 15). *Prepare for the coronavirus global recession*. The Guardian. https://www.theguardian.com/business/2020/mar/15/prepare-for-the-coronavirus-global-recession

Engelhardt, N., Krause, M., Neukirchen, D., & Posch, P. N. (2021). Trust and stock market volatility during the COVID-19 crisis. *Finance Research Letters*, 38, 101873. https://doi.org/10.1016/j.frl.2020.101873

Fahling, E. J., Steurer, E., Ulbig, M., & Bamberger, B. (2019). Empirical analysis of VDAX and VSTOXX as major volatility indices in the EU including forecasting tools. *Journal of Financial Risk Management*, 8, 315-332. https://doi.org/10.4236/jfrm.2019.84022

Fleming, J., Ostdiek, B., & Whaley, R. E. (1995). Predicting Stock Market Volatility: A New Measure. *Journal of Futures Markets,* 15(3), 265–302. https://doi.org/10.1002/fut.3990150303

Granger, C. W. J., & Poon, S.-H. (2001). Forecasting Financial Market Volatility: A Review. Available at SSRN. https://doi.org/10.2139/ssrn.268866

Greenwood, J., & Smith, B. D. (1997). Financial markets in development, and the development of financial markets. *Journal of Economic Dynamics and Control*, 21(1), 145–181. https://doi.org/10.1016/0165-1889(95)00928-0

Gujarati, D. N. (2003). *Basic Econometrics* (4th Edition). McGraw-Hill Higher Education.

Haroon, O., Ali, M., Khan, A., Khattak, M. A., & Rizvi, S. A. R. (2021). Financial Market Risks during the COVID-19 Pandemic. *Emerging Markets Finance and Trade*, 57(8), 2407–2414. https://doi.org/10.1080/1540496X.2021.1873765

Haroon, O., & Rizvi, S. A. R. (2020). COVID-19: Media coverage and financial markets behavior-A sectoral inquiry. *Journal of Behavioral and Experimental Finance*, 27, 100143. https://doi.org/10.1016/j.jbef.2020.100343

Hartwell, C. A. (2018). The impact of institutional volatility on financial volatility in transition economies. *Journal of Comparative Economics*, 46(2), 598–615. https://doi.org/10.1016/j.jce.2017.11.002

Hendry, D. F. (1995). *Dynamic Econometrics*. Oxford University Press. https://doi.org/10.1093/0198283164.001.0001

Horowitz, J. (2020, March 16). *The global coronavirus recession is beginning*. CNN. https://edition.cnn.com/2020/03/16/economy/global-recession-coronavirus/index.html

Kalotychou, E. & Staikouras, S. K. (2009). Na Overview of the Issues Surrounding Stock Market Volatility. In G. N. Gregoriou (Ed.), *Stock Market Volatility* (pp. 3-29). CRC Press.

Kariya, T., & Kurata, H. (2004). *Generalized Least Squares*. John Wiley & Sons, Ltd. https://doi.org/10.1002/0470866993

Kumari, V., Kumar, G., & Pandey, D. K. (2023). Are the European Union stock markets vulnerable to the Russia–Ukraine war?. *Journal of Behavioral and Experimental Finance*, 37, 100793. https://doi.org/10.1016/j.jbef.2023.100793

Lúcio, F., & Caiado, J. (2022). COVID-19 and Stock Market Volatility: A Clustering Approach for S&P 500 Industry Indices. *Finance Research Letters*, 49, 103141. https://doi.org/10.1016/j.frl.2022.103141

Mazur, M., Dang, M., & Vega, M. (2021). COVID-19 and the march 2020 stock market crash. Evidence from S&P1500. *Finance Research Letters*, 38, 101690. https://doi.org/10.1016/j.frl.2020.101690

Mei, D., Zeng, Q., Zhang, Y., & Hou, W. (2018). Does US Economic Policy Uncertainty matter for European stock markets volatility? *Physica A: Statistical Mechanics and its Applications*, 512, 215–221. https://doi.org/10.1016/j.physa.2018.08.019

Menke, W. (2015). Review of the Generalized Least Squares Method. *Surveys in Geophysics*, 36, 1–25. https://doi.org/10.1007/s10712-014-9303-1

OPAS – Organização Pan-Americana da Saúde (2020). *Como estimar a mortalidade pela doença do novo coronavírus (COVID-19)*. https://iris.paho.org/bitstream/handle/10665.2/52650/OPASWBRACOVID-1920110_por%20%281%29.pdf?sequence=1&isAllowed=y

Pagano, M. (1993). Financial markets and growth: An overview. *European Economic Review*, 37(2–3), 613–622. https://doi.org/10.1016/0014-2921(93)90051-B

Pastor, L., & Veronesi, P. (2012). Uncertainty about Government Policy and Stock Prices. *The Journal of Finance*, 67(4), 1219–1264. https://doi.org/10.1111/j.1540-6261.2012.01746.x

Peters, E. E. (1996). *Chaos and Order in the Capital Markets: A New View of Cycles, Prices and Market Volatility* (2nd Edition). John Wiley & Sons, Inc.

Pindyck, R. S., & Rubinfeld, D. L. (1991). *Econometric Model and Economic Forecasts* (3rd Edition). McGraw-Hill International Editions.

Poon, S.-H. (2005). *A Practical Guide to Forecasting Financial Market Volatility*. John Wiley & Sons.

Qontigo (2023a). *STOXX ® STRATEGY INDEX GUIDE*. https://www.stoxx.com/document/Indices/Common/Indexguide/stoxx_strategy_guide.pdf

Qontigo (2023b). *EURO STOXX 50® INDEX*. https://www.stoxx.com/document/Bookmarks/CurrentFactsheets/SX5GT.pdf

Rastogi, S. (2015). The financial crisis of 2008 and stock market volatility–analysis and impact on emerging economies pre and post crisis. *Afro-Asian Journal of Finance and Accounting*, 4(4), 443–459. https://doi.org/10.1504/AAJFA.2014.067017

Reuters (2008, October 8). *Obama: U.S. in worst crisis since Depression*. Reuters. https://www.reuters.com/article/usa-politics-debate-economy-idUKN0749084220081008

Schwert, G. W. (2011). Stock Volatility during the Recent Financial Crisis. *European Financial Management*, 17(5), 789–805. https://doi.org/10.1111/j.1468-036X.2011.00620.x

Shezad, K., Xiaoxing, L., & Koçak, E. (2021). COVID-19 and Spillover Effect of Global Economic Crisis on the United States' Financial Stability. *Frontiers in Psychology*, 12, 632175. https://doi.org/10.3389/fpsyg.2021.632175

Shiller, R. J. (1988). Causes of changing financial market volatility. Proceedings, Federal Reserve Bank of Kansas City, 1-32.

Singhania, M., & Anchalia, J. (2013). Volatility in Asian stock markets and global financial crisis. *Journal of Advances in Management Research*, 10(3), 333–351. https://doi.org/10.1108/JAMR-01-2013-0010

Slimane, F. B., Mehanaoui, M., & Kazi, I. A. (2013). How does the financial crisis affect volatility behavior and transmission among European stock markets? *International Journal of Financial Studies*, 1(3), 81–101. https://doi.org/10.3390/ijfs1030081

So, M. K. P., Chu, A. M. Y., & Chan, T. W. C. (2021). Impacts of the COVID-19 pandemic on financial market connectedness. *Finance Research Letters*, 38, 101864. https://doi.org/10.1016/j.frl.2020.101864

The American Journal of Managed Care (2021, January 1). *A Timeline of COVID-19 Developments in 2020*. https://www.ajmc.com/view/a-timeline-of-covid19-developments-in-2020

Umar, Z., Polat, O., Choi, S. Y., & Teplova, T. (2022). The impact of the Russia-Ukraine conflict on the connectedness of financial markets. *Finance Research Letters*, 48, 102976. https://doi.org/10.1016/j.frl.2022.102976

Wang, D., Li, P., & Huang L. (2022). Time-frequency volatility spillovers between major international financial markets during the COVID-19 pandemic. *Finance Research Letters*, 46, 102244. https://doi.org/10.1016/j.frl.2021.102244

Wang, W., & Enilov, M. (2020). The Global Impact of COVID-19 on Financial Markets. Available at SSRN. https://doi.org/10.2139/ssrn.3588021

World Health Organization. (2023). *Coronavirus disease (COVID-19)*. https://www.who.int/health-topics/coronavirus#tab=tab_1

World Health Organization. (n.d.). *Timeline: WHO's COVID-19 response.* Retrieved January 28, 2023, from https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline

Yousef, I. (2020). Spillover of COVID-19: Impact on Stock Market Volatility. *International Journal of Psychosocial Rehabilitation*, 24(6), 18069–18081.

Zdaniuk, B. (2014). Ordinary Least-Squares (OLS) Model. In F. Maggino (Ed.), *Enciclopedia of Quality of Life and Well-Being Research* (pp. 4515–4517). https://doi.org/10.1007/978-94-007-0753-5_2008

Zhang, D., Hu, M., & Ji, Q. (2020). Financial markets under the global pandemic of COVID-19. *Finance Research Letters*, 36, 101528. https://doi.org/10.1016/j.frl.2020.101528

APPENDICES

LIST OF APPENDICES

Appendix A. Breusch-Pagan Tests

Reject H_0 for a level of significance of 5%

	P-value			
	Model 1	**Model 2**	**Model 3**	**Model 4**
January 3, 2020 - December 14, 2022	0,000	0,110	0,004	0,000
January 3, 2020 - May 29, 2020	-	-	0,003	0,005
January 13, 2020 - April 9, 2020	-	-	0,000	0,006
March 16, 2020 - May 15, 2020	-	-	0,019	0,031

Appendix B. Durbin-Watson table

Table A-2

Models with an intercept (from Savin and White)

Durbin-Watson Statistic: 5 Per Cent Significance Points of dL and dU

	k'*=1		k'=2		k'=3		k'=4		k'=5		k'=6		k'=7		k'=8		k'=9		k'=10	
n	dL	dU	dL	dU	dL	dU	dL	dU	dL	dU	dL	dU	dL	dU	dL	dU	dL	dU	dL	dU
6	0.610	1.400	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
7	0.700	1.356	0.467	1.896	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
8	0.763	1.332	0.559	1.777	0.367	2.287	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
9	0.824	1.320	0.629	1.699	0.455	2.128	0.296	2.588	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
10	0.879	1.320	0.697	1.641	0.525	2.016	0.376	2.414	0.243	2.822	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
11	0.927	1.324	0.758	1.604	0.595	1.928	0.444	2.283	0.315	2.645	0.203	3.004	-----	-----	-----	-----	-----	-----	-----	-----
12	0.971	1.331	0.812	1.579	0.658	1.864	0.512	2.177	0.380	2.506	0.268	2.832	0.171	3.149	-----	-----	-----	-----	-----	-----
13	1.010	1.340	0.861	1.562	0.715	1.816	0.574	2.094	0.444	2.390	0.328	2.692	0.230	2.985	0.147	3.266	-----	-----	-----	-----
14	1.045	1.350	0.905	1.551	0.767	1.779	0.632	2.030	0.505	2.296	0.389	2.572	0.286	2.848	0.200	3.111	0.127	3.360	-----	-----
15	1.077	1.361	0.946	1.543	0.814	1.750	0.685	1.977	0.562	2.220	0.447	2.471	0.343	2.727	0.251	2.979	0.175	3.216	0.111	3.438
16	1.106	1.371	0.982	1.539	0.857	1.728	0.734	1.935	0.615	2.157	0.502	2.388	0.398	2.624	0.304	2.860	0.222	3.090	0.155	3.304
17	1.133	1.381	1.015	1.536	0.897	1.710	0.779	1.900	0.664	2.104	0.554	2.318	0.451	2.537	0.356	2.757	0.272	2.975	0.198	3.184
18	1.158	1.391	1.046	1.535	0.933	1.696	0.820	1.872	0.710	2.060	0.603	2.258	0.502	2.461	0.407	2.668	0.321	2.873	0.244	3.073
19	1.180	1.401	1.074	1.536	0.967	1.685	0.859	1.848	0.752	2.023	0.649	2.206	0.549	2.396	0.456	2.589	0.369	2.783	0.290	2.974
20	1.201	1.411	1.100	1.537	0.998	1.676	0.894	1.828	0.792	1.991	0.691	2.162	0.595	2.339	0.502	2.521	0.416	2.704	0.336	2.885
21	1.221	1.420	1.125	1.538	1.026	1.669	0.927	1.812	0.829	1.964	0.731	2.124	0.637	2.290	0.546	2.461	0.461	2.633	0.380	2.806
22	1.239	1.429	1.147	1.541	1.053	1.664	0.958	1.797	0.863	1.940	0.769	2.090	0.677	2.246	0.588	2.407	0.504	2.571	0.424	2.735
23	1.257	1.437	1.168	1.543	1.078	1.660	0.986	1.785	0.895	1.920	0.804	2.061	0.715	2.208	0.628	2.360	0.545	2.514	0.465	2.670
24	1.273	1.446	1.188	1.546	1.101	1.656	1.013	1.775	0.925	1.902	0.837	2.035	0.750	2.174	0.666	2.318	0.584	2.464	0.506	2.613
25	1.288	1.454	1.206	1.550	1.123	1.654	1.038	1.767	0.953	1.886	0.868	2.013	0.784	2.144	0.702	2.280	0.621	2.419	0.544	2.560
26	1.302	1.461	1.224	1.553	1.143	1.652	1.062	1.759	0.979	1.873	0.897	1.992	0.816	2.117	0.735	2.246	0.657	2.379	0.581	2.513
27	1.316	1.469	1.240	1.556	1.162	1.651	1.084	1.753	1.004	1.861	0.925	1.974	0.845	2.093	0.767	2.216	0.691	2.342	0.616	2.470
28	1.328	1.476	1.255	1.560	1.181	1.650	1.104	1.747	1.028	1.850	0.951	1.959	0.874	2.071	0.798	2.188	0.723	2.309	0.649	2.431
29	1.341	1.483	1.270	1.563	1.198	1.650	1.124	1.743	1.050	1.841	0.975	1.944	0.900	2.052	0.826	2.164	0.753	2.278	0.681	2.396
30	1.352	1.489	1.284	1.567	1.214	1.650	1.143	1.739	1.071	1.833	0.998	1.931	0.926	2.034	0.854	2.141	0.782	2.251	0.712	2.363
31	1.363	1.496	1.297	1.570	1.229	1.650	1.160	1.735	1.090	1.825	1.020	1.920	0.950	2.018	0.879	2.120	0.810	2.226	0.741	2.333
32	1.373	1.502	1.309	1.574	1.244	1.650	1.177	1.732	1.109	1.819	1.041	1.909	0.972	2.004	0.904	2.102	0.836	2.203	0.769	2.306
33	1.383	1.508	1.321	1.577	1.258	1.651	1.193	1.730	1.127	1.813	1.061	1.900	0.994	1.991	0.927	2.085	0.861	2.181	0.796	2.281
34	1.393	1.514	1.333	1.580	1.271	1.652	1.208	1.728	1.144	1.808	1.079	1.891	1.015	1.978	0.950	2.069	0.885	2.162	0.821	2.257
35	1.402	1.519	1.343	1.584	1.283	1.653	1.222	1.726	1.160	1.803	1.097	1.884	1.034	1.967	0.971	2.054	0.908	2.144	0.845	2.236
36	1.411	1.525	1.354	1.587	1.295	1.654	1.236	1.724	1.175	1.799	1.114	1.876	1.053	1.957	0.991	2.041	0.930	2.127	0.868	2.216
37	1.419	1.530	1.364	1.590	1.307	1.655	1.249	1.723	1.190	1.795	1.131	1.870	1.071	1.948	1.011	2.029	0.951	2.112	0.891	2.197
38	1.427	1.535	1.373	1.594	1.318	1.656	1.261	1.722	1.204	1.792	1.146	1.864	1.088	1.939	1.029	2.017	0.970	2.098	0.912	2.180
39	1.435	1.540	1.382	1.597	1.328	1.658	1.273	1.722	1.218	1.789	1.161	1.859	1.104	1.932	1.047	2.007	0.990	2.085	0.932	2.164
40	1.442	1.544	1.391	1.600	1.338	1.659	1.285	1.721	1.230	1.786	1.175	1.854	1.120	1.924	1.064	1.997	1.008	2.072	0.952	2.149
45	1.475	1.566	1.430	1.615	1.383	1.666	1.336	1.720	1.287	1.776	1.238	1.835	1.189	1.895	1.139	1.958	1.089	2.022	1.038	2.088
50	1.503	1.585	1.462	1.628	1.421	1.674	1.378	1.721	1.335	1.771	1.291	1.822	1.246	1.875	1.201	1.930	1.156	1.986	1.110	2.044
55	1.528	1.601	1.490	1.641	1.452	1.681	1.414	1.724	1.374	1.768	1.334	1.814	1.294	1.861	1.253	1.909	1.212	1.959	1.170	2.010
60	1.549	1.616	1.514	1.652	1.480	1.689	1.444	1.727	1.408	1.767	1.372	1.808	1.335	1.850	1.298	1.894	1.260	1.939	1.222	1.984
65	1.567	1.629	1.536	1.662	1.503	1.696	1.471	1.731	1.438	1.767	1.404	1.805	1.370	1.843	1.336	1.882	1.301	1.923	1.266	1.964
70	1.583	1.641	1.554	1.672	1.525	1.703	1.494	1.735	1.464	1.768	1.433	1.802	1.401	1.838	1.369	1.874	1.337	1.910	1.305	1.948
75	1.598	1.652	1.571	1.680	1.543	1.709	1.515	1.739	1.487	1.770	1.458	1.801	1.428	1.834	1.399	1.867	1.369	1.901	1.339	1.935
80	1.611	1.662	1.586	1.688	1.560	1.715	1.534	1.743	1.507	1.772	1.480	1.801	1.453	1.831	1.425	1.861	1.397	1.893	1.369	1.925
85	1.624	1.671	1.600	1.696	1.575	1.721	1.550	1.747	1.525	1.774	1.500	1.801	1.474	1.829	1.448	1.857	1.422	1.886	1.396	1.916
90	1.635	1.679	1.612	1.703	1.589	1.726	1.566	1.751	1.542	1.776	1.518	1.801	1.494	1.827	1.469	1.854	1.445	1.881	1.420	1.909
95	1.645	1.687	1.623	1.709	1.602	1.732	1.579	1.755	1.557	1.778	1.535	1.802	1.512	1.827	1.489	1.852	1.465	1.877	1.442	1.903
100	1.654	1.694	1.634	1.715	1.613	1.736	1.592	1.758	1.571	1.780	1.550	1.803	1.528	1.826	1.506	1.850	1.484	1.874	1.462	1.898
150	1.720	1.747	1.706	1.760	1.693	1.774	1.679	1.788	1.665	1.802	1.651	1.817	1.637	1.832	1.622	1.846	1.608	1.862	1.593	1.877
200	1.758	1.779	1.748	1.789	1.738	1.799	1.728	1.809	1.718	1.820	1.707	1.831	1.697	1.841	1.686	1.852	1.675	1.863	1.665	1.874

*k' is the number of regressors excluding the intercept

Source: University of Notre Dame

Appendix C. Durbin-Watson test results

January 3, 2020 – December 14, 2022

Models	**Durbin-Watson**	**dL**	**dU**
Model 1	0,070	1,758	1,779
Model 2	0,080	1,758	1,779
Model 3	0,082	1,748	1,789
Model 4	0,255	1,728	1,799

March 16, 2020 – May 15, 2020

Models	**Durbin-Watson**	**dL**	**dU**
Model 3	0,901	1,634	1,715
Model 4	0,864	1,613	1,736

January 13, 2020 – April 9, 2020

Models	**Durbin-Watson**	**dL**	**dU**
Model 3	0,296	1,514	1,652
Model 4	0,937	1,480	1,689

January 3, 2020 – May 29, 2020

Models	**Durbin-Watson**	**dL**	**dU**
Model 3	0,075	1,391	1,600
Model 4	0,485	1,338	1,659

Appendix D. OLS regression results

Table D1. OLS applied in Models 1 and 2 – from January 3rd of 2020 to December 14th of 2022

Reject H_0 for a level of significance of 10% (*), 5% (**) and 1% (***)

	January 3, 2020 – December 14, 2022			
	Model 1		**Model 2**	
	B	**p-value**	**B**	**p-value**
(constant)	25,852	0,000***	20,526	0,000***
CovCases	0,000	0,200	-	-
DeathRatio	-	-	194,934	0,000***
Model	**-**	**0,200**	**-**	**0,000*****
Adjustment Quality	R^2 adj. = 0,001		R^2 adj. = 0,120	

Table D2. OLS applied in Models 3 and 4 – from January 3rd of 2020 to December 14th of 2022

Reject H_0 for a level of significance of 10% (*), 5% (**) and 1% (***)

	January 3, 2020 – December 14, 2022			
	Model 3		**Model 4**	
	B	**p-value**	**B**	**p-value**
(constant)	18,979	0,000***	17,156	0,000***
CovCases	0,000	0,004***	0,000	0,004***
DeathRatio	218,267	0,000***	-21,624	0,436
EPU	-	-	0,043	0,000***
Model	**-**	**0,000*****	**-**	**0,000*****
Adjustment Quality	R^2 adj. = 0,129		R^2 adj. = 0,265	

Table D3. OLS applied in Model 3 in different timelines

Reject H_0 for a level of significance of 10% (*), 5% (**) and 1% (***)

	January 3, 2020 – May 29, 2020		**January 13, 2020 – April 9, 2020**		**March 16, 2020 – May 15, 2020**	
	B	**Sig.**	**B**	**p-value**	**B**	**p-value**
(constant)	13,665	0,007***	-23,149	0,040**	93,050	0,000***
CovCases	0,000	0,069*	0,000	0,033**	0,000	0,000***
DeathRatio	592,577	0,001***	1856,182	0,000***	-288,875	0,008***
Model	**-**	**0,000*** **	**-**	**0,000*** **	**-**	**0,000*** **
Adjustment Quality	R^2 adj. = 0,152		R^2 adj. = 0,402		R^2 adj. = 0,882	

Table D4. OLS applied in Model 4 in different timelines

Reject H_0 for a level of significance of 10% (*), 5% (**) and 1% (***)

	January 3, 2020 – May 29, 2020		**January 13, 2020 – April 9, 2020**		**March 16, 2020 – May 15, 2020**	
	B	**p-value**	**B**	**p-value**	**B**	**p-value**
(constant)	6,444	0,099*	-26,904	0,001***	91,837	0,000***
CovCases	0,000	0,000***	-0,001	0,000***	0,000	0,000***
DeathRatio	309,025	0,031**	1432,813	0,000***	-283,754	0,011**
EPU	0,097	0,000***	0,120	0,000***	0,002	0,769
Model	**-**	**0,000*** **	**-**	**0,000*** **	**-**	**0,000*** **
Adjustment Quality	R^2 adj. = 0,504		R^2 adj. = 0,693		R^2 adj. = 0,879	

UNIVERSIDADE DOS AÇORES
Faculdade de Economia e Gestão

Rua da Mãe de Deus
9500-321 Ponta Delgada
Açores, Portugal

A pandemia COVID-19 e o seu impacto na volatilidade dos mercados financeiros europeus

Inês Teves Santos

DM

2023