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Structural breaks in the variance of the European market during the COVID-19 pandemic: a sectoral approach

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Abstract

This project aims to test for the presence of structural breaks in the volatility of the European markets during the covid-19 pandemic. A dataset composed by 19 sectoral indexes, and the methodology proposed by Kokoszka and Leipus are used. The results show that all the analyzed sectors besides two are going through multiple breaks. The breaks are more frequent during the beginning of the pandemic, and also the volatility is significantly higher during this period.

Keywords:

Covid

Volatility

Structural Breaks

Stop Europe 600

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Introduction

One of the main assumptions that we make when we estimate a model is that the model parameters will be constant over time. This might not be the case, especially when we are dealing with financial data. The reason behind this is that economic, social and political underlying assumptions are constantly threatened and rediscussed, and this is particularly true in times of crisis. When we are modeling volatility, for instance with a GARCH model, we are assuming that past volatility will be able to explain future volatility. This is usually true, as one of the main stylized facts that are observed about volatility is its persistency. However, when a shock affects the markets we need to pay attention to properly model the consequent impact. This has been shown by Lamoureux and Lastrapes (1990), who addressed the importance of understanding the persistency of the variance and the cruciality of the detection of structural breaks. Since volatility is often increasing following certain events, it is important to understand if the impact of a certain event is persistent, and if yes, then we also need to quantify how persistent it is. A significant role is played here by the market sentiment about the shock. Something that is perceived as temporary will have a steeply decreasing effect compared to an event that reshapes significantly the underlying assumptions of an economy. A significant difference exists between high persistency, that can be successfully modeled by using an IGARCH model, and the presence of a structural break. In this second case, wrong models may give the illusion of high persistency, when we are actually facing a variation of the model's parameters and the past volatility alone is not able anymore to explain future volatility. Poterba and Summers (1986) show that a shock in the volatility will not have statistically significant impact on stock prices unless there is a strong evidence that the shock is driven by a change in the fundamentals of the

market. This is coherent with the usual mean-reverting behavior of the volatility, as in normal conditions a slight spike in the volatility will quickly be reabsorbed. Hillebrand (2005) points out that the illusion of high persistence in the variance may also come from neglecting changes in the parameters of the model. Hillebrand also shows how in smaller samples parameter estimates of a GARCH which do not take into account structural breaks tend to sum up to one, indicating high persistence where we are maybe facing just a change in the parameters. The difference between a single temporary shock and a structural break, is better characterized by Wang and Moore (2009), according to who structural changes in the volatility are due to a shift in the market's behavior. Since current stock prices depend on expectations, we can say that a structural break might be driven by changes in macroeconomic conditions that threaten investors. In their study, they investigated the persistency of volatility of the European markets between 1994 and 2006, finding that when structural breaks in the volatility are detected and considered in a GARCH model, the estimated persistency decreases significantly. This is consistent with Tsuji (2018), who is concluding the same regarding the Japanese and Chinese markets. Strarica and Granger (2005) analyzed the returns of the SP500 between 1928 and 2000. They provide evidence about the presence of several changes in the unconditional variance, that determine shifts in the different levels of volatility over the years. Some papers already focused on the detection of structural breaks in the volatility during the covid crisis. Kusumahadi and Fikri (2021) found that almost all European and Asian markets increased the volatility levels in march 2020. They tested for the presence of structural changes in volatility and found that they are present in each of the countries analyzed. They also show that the shifts seem to be driven by the number of cases and deaths, the death rate and the government's responses.

Moreover, they point out that significant changes in exchange rates during covid affected the market volatility as well. In line with the above mentioned work, Baek, Mohanty and Glamborosky (2020), using a Markov switching model, show that the US market changed its volatility regime. Still on the US market, Hong, Bian and Lee (2021) tested for the presence of structural breaks in the volatility of American indexes, and found one break in the SP500 and DJIA at the beginning of the outbreak. Interestingly, the date of the break matches the sell-off by the senate committee members right before the market crashed. Just and Echaust (2020) observed also a break in the relationship between returns and implied volatility and correlation. The implied correlation appears to be more sensitive to the beginning of the outbreaks, but it is quickly followed by the implied volatility. Few to no works however focused on analyzing breaks in variance by sector instead of by nation. Despite all the markets reacted negatively to the pandemic, Buszko, Orzeszko and Stawarz (2021) identified five main clusters composed by sectors that are behaving in a similar way. The results are drawn in the context of the Warsaw stock exchange but they have a significant value for addressing other researches in different markets. Different sectors are indeed driven by different factors, and their behaviors might vary in a significant way. On top of this, it is worth mentioning that we had two different waves of contagions and the behavior of each industry varies also from one to the other. The aim of this project is to test for the presence of structural breaks during the covid pandemics in the volatility of 19 sector sub-indexes of the STOXX 600 Europe. This research covers a lack of papers focused on a sectoral based approach, as most of the other works are analyzing the impacts of the pandemic by country. The findings show that almost all sectors went through structural breaks in

the variance. Moreover, a decreasing trend in the volatility after the first break is detected in all sectors analyzed.

The remainder of this work is organized as follows. Section 2 contains a literature review of the most recent papers published about the financial and economic impacts of Covid. In section 3 I will describe the dataset and the methodology adopted for the analysis. In section 4 I will show the results of the analysis, with a particular focus on the underlying economic motivations for the behavior of each sector. Section 5 will contain the conclusions that I reached.

2 - Literature review

The official starting date of the pandemic, according the WHO, is the 11th of march 2020. Despite being a fairly recent event, an increasing number of researches already focused on the impact of Covid on the global economies, on the financial markets and on the volatility of financial markets. Boone, Haugh, Pain and Salins (2020) already before the formal declaration of the pandemic state, were forecasting an impact on the global economy in the order of trillions dollars. Their analysis was taking into consideration possible shocks on the supply chains, on demand and on peoples' confidence. Wójcik and Ioannou (2020) pointed out that although COVID-19 is not a native financial crisis, the implications on the financial sector are deep and ramified. This is in contrast to the 2008 crisis, which has been a purely financial event having an impact on all the other sectors. Even a comparison to previous crises triggered by epidemics might not be possible, as showed by Baker, Bloom, Davis, Kost, Sammon and Viratyosin (2020). They indeed underlined the significant differences that subsist between COVID and previous epidemics, in terms of impact on the stock markets and on the global economy. COVID had a

significantly more dramatic effect compared for instance to the Spanish Flu, despite not being quite as lethal. A possible explanation that they provide for this, refers to the wave of fear and herding behaviors triggered by news and measures implemented all over the world. The authors recognize how crucial all the measures have been to reduce the number of deaths and to slow contagion, but they show how they have actually increased the non-sanitary effects of the pandemic. Indeed, even if the existence of covid was already know, Chowdhury, Kalyan, Khan and Dhar (2021) showed that the discovery of the first patient in a country systematically triggered a sharp loss in the national indexes during the following trading day. The extreme severity of the shocks and the panic triggered by this crisis, pushed the analysis of Ahmada, Kutan and Smarth (2021) to the research of Black Swan events. They identified some of them in the US, UK and European markets, around the beginning of the pandemic and until the end of March 2020. Their findings are supported by the fact that the SEC had to trigger the market-wide circuit-breakers four times during March 2020 (Reuters - march madness). These procedures have been used before only once in the past since it was designed. As we can expect, COVID triggered a significative increase in the levels of volatility worldwide. This is coherent with Goswamy, Gupta and Wohar (2019) that are demonstrating how global crises have a bigger impact on volatility compared to local crises. However, the behavior of the volatility evolved during the pandemic. Duttilo, Gattone and Di Battista (2021) investigated this behavior on different national European stock markets, and they found that only the first wave had a significative impact, whereas only Belgium has been affected by the second wave. This allows us to conclude that stock markets somehow adapted to the presence of covid-related risk. Another dynamics that has to be taken into account are possible spillovers between different markets. Wang, Li and

Huang (2022) showed that spillovers are extremely significant for the whole month of March, but they tend to decline afterwards, and also that the main spillovers transmitters are the US and UK markets. In line with the previous study, also Moslehpour et Al. (2022) found that COVID increased the transmission of systematic risk across different countries, with particular regard to the links between the north American market and the European one. Albulescu (2021) shows that news coming from China had an impact on the VIX. In particular, VIX is more sensitive to new deaths rather than new cases in China. It is of no doubt that this crisis has been entirely live-covered on social networks and traditional media. The impact of the news has been tested by several studies, and also here we can observe a modification in the behavior of the markets. Moussi and Ouazza (2021) show how until the end of March 2020, both the European and the American markets are renting more promptly to the new data of contagions and deaths in Asia. In a later phase, occidental markets are then starting to show significant reactions to the data coming from the home countries. Badar (2020) finds a more significant response of the stock market to new cases rather than deaths, and that the impact of new confirmed cases on the stock market is strong until the first 60 days since the first case is confirmed in a country. In line with the above mentioned study, also Khanthavit (2020) is even demonstrating that markets are reacting more to the news rather than the effective evolution of the epidemic. Volatility has been also driven by news. Wang, Xu and Sharma (2021) addressed the relationship between investors' attention to the market and levels of volatility, and they detected the presence of some irrationality in the investor's behaviors. Volatility is indeed not reacting in a proportional way to the severity of the pandemic. In this sense, they distinguish between fundamental and realized volatility. The fundamental volatility is the one that is expected to move with

the actual epidemiological situation, whereas the realized volatility will be the one actually observed in the market. Since the first kind of volatility is not enough to fully explain the second one, the authors conclude that the market might have irrationally reacted. This is also confirmed by Haroon and Rizvi (2020) which are drawing the same conclusions about the reaction of volatility to the onslaught of the news. Zaremba et Al. (2020) investigates the impact of non-pharmaceutical measures such as event cancellations, their coverage from the news and the volatility on the market. They demonstrate that this kind of actions and their extremely high visibility that news gave to them, have a positive impact on the volatility. A significant role is played by the trust that people agreed to governments and institutions. Engelhardt et Al. (2021) are showing how the trust of the investors in governments significantly modifies the reaction of the markets. Countries with high-trusted institutions are showing lower levels of volatilities and more controlled reactions to outbreaks.

3 - Dataset and Methodology

The STOXX Europe 600 is a sub-index of the STOXX Europe Total Market Index (TMI). The stocks included in this index are quoting in the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland and the United Kingdom. It includes 600 companies among the most important large, mid and small caps in the European markets. Qontigo developed also sub-indexes that include the STOXX600 companies operating in specific sectors. In particular, 10 main industries are further split into 19 “super-sectors”, 41 sectors and 114 “sub-sectors”. I decided to conduct my analysis on the 19 super-sectors as in my opinion

this split offers the most reasonable level of detail needed for this kind of research. Table 1 shows the indexes considered and the respective tickers.

Table 1 - Indexes and Tickers	
STOXX Europe 600 Retail	SXRGR
STOXX Europe 600 Food and Beverage	SX3GR
STOXX Europe 600 Chemicals	SX4GR
STOXX Europe 600 Utilities	SX6GR
STOXX Europe 600 Banks	SX7GR
STOXX Europe 600 Technology	SX8GR
STOXX Europe 600 Real Estate	SX86GR
STOXX Europe 600 Automobiles & Parts	SXAGR
STOXX Europe 600 Health Care	SXDGR
STOXX Europe 600 Oil & Gas	SXEP
STOXX Europe 600 Financial Services	SXFGR
STOXX Europe 600 Insurance	SXIGR
STOXX Europe 600 Telecommunications	SXKGR
STOXX Europe 600 Media	SXMGR
STOXX Europe 600 industrial goods & services	SXNGR
STOXX Europe 600 Construction & materials	SXOGR
STOXX Europe 600 Basic Resources	SXPGR
STOXX Europe 600 Personal & household goods	SXQGR
STOXX Europe 600 Travel & Leisure	SXTGR
This table shows the indexes analyzed in this project, and the respective tickers	

The dataset includes observations between the end of 2019 and the end of 2021. The methodology that will be followed in this project is the one proposed by Kokoszka and Leipus (2000). They essentially corrected for the variance of the sample the usual CUSUM procedure. Rodrigues and Rubia (2011) show how this test is able to overcome the assumption of i.i.d Gaussian distribution of the proposed by Inlcàn and Tiao (1994). The main statistic of for the CUSUM procedure is

$$D_T(k) = \left[\left(\sum_{t=1}^{k} r_t^2 / \sum_{\tau=1}^{T} r_t^2 \right) - k/T \right] \qquad \text{k} = 1 \ldots \text{T}$$

and the breaks are detected by taking into consideration the maximum value of the sequence of this test. The significance level of each break will be then determined with a test statistic. The KL test can be written as

$$KL = T^{(-1/2)} \hat{M}_{4,T}^{(-1/2)} \operatorname{argmax}_{1 \leqslant k \leqslant T} \left| G_T(k) \right|$$

Where we define $G_T(k)$ is defined as

$$G_T(k) = \sum_{T=1}^{k} r_2^2 - (k/T) \sum_{T=1}^{T} r_T^2$$

And $\hat{M}_{4,T}$ is an estimator of the long run variance of the term $r^2 - E\left(r^2\right)$. This estimator is the limit of

$$(1/T) E \left[\sum_{t=1}^{\infty} \left(r_t^2 - E\left(r_t^2\right) \right)^2 \right]$$

The above mentioned Rodrigues and Rubia show also that $\hat{M}_{4,T}$ can be estimated in a model-fee setting and by using non-parametric techniques.

4 - Empirical Results

We can observe that for almost all indexes breaks during the period under examination are reported. Table 2 shows the date of the breaks detected. STOXX Europe 600 Financial Services, industrial goods & services and Travel & Leisure are the indexes showing the highest number of breaks, with 5 events detected. They are then followed by Chemicals, Technology, Health Care, Constructions & Materials

and Personal & household goods with 4 events. No breaks have been, surprisingly, detected for the Real Estate and Automobiles & Parts indexes. February and March 2020 are the months with the highest number of breaks (17 and 11 respectively). This

Table 2 - Break dates					
SXRGR	19/02/20	24/03/20			
SX3GR	19/02/20	26/03/20	12/11/20		
SX4GR	19/02/20	17/04/20	05/11/20	23/11/21	
SX6GR	19/02/20	30/03/20	19/03/21		
SX7GR	19/02/20	09/06/20			
SX8GR	19/02/20	20/04/20	09/11/20	17/11/21	
SX86GR					
SXAGR					
SXDGR	19/02/20	26/03/20	02/11/20	09/12/21	
SXEP	19/02/20	23/03/20	09/06/20		
SXFGR	19/02/20	25/03/20	23/06/20	05/11/20	18/11/21
SXIGR	19/02/20	23/03/20	09/06/20		
SXKGR	19/02/20	20/03/20	12/06/20		
SXMGR	19/02/20	28/04/20	05/11/20		
SXNGR	19/02/20	25/03/20	12/06/20	05/11/20	18/11/21
SXOGR	19/02/20	17/04/20	06/11/20	23/11/21	
SXPGR	19/02/20	14/05/20			
SXQGR	14/02/20	25/03/20	10/11/20	21/02/22	
SXTGR	19/02/20	09/03/20	03/04/20	09/06/20	23/11/21
This table shows the dates of the breaks detected for each of the 19 indexes					

was to be expected as they marked the beginning of the pandemic and we are here observing the initial panic-driven reaction of the markets. It is interesting to point out that the majority of the breaks are detected between February and June. After this, they become less frequent, and we are indeed observing them just in November 2020, and then in November 2021. The fact that breaks become less and less frequent

is a sign that the sentiment of investors is stabilizing, since they are already taking into account the presence of the pandemic. As mentioned above, from an economic point of view, a break should be driven by some kind of change in the underlying assumption of the market: if the presence of COVID or an increased number of cases was actually destabilizing in February 2020, it might not be significant in February 2021. This is consistent with Duttilo et Al, who enlightened a more significant impact of the first wave compared to the following ones. The initial breaks on the 19th of February can be treated as the natural reaction of the European markets to the beginning of the pandemic. Interestingly the date of this break matches the date of an extremely crowded public event in Italy - a football match - involving supporters from both Spain and Italy. This event will be afterwards considered as the root cause of many outbreaks in the north of Italy. Having breaks in this early phase is coherent with the above mentioned findings of Albulescu (2020), as in this phase the epicenter of the pandemic is still in China: the panic is starting to spread among the markets even before the virus. This is mainly driven by the higher uncertainty spread among the investors, and to the increasing measures being implemented around the world. Lack of available labour force and slowness in the supply chains have been the main drivers of the economic crisis triggered by COVID. The lockdown measures indeed prevented people from working and traveling, and therefore also goods to be imported from Asia. Table 3 shows the annualized standard deviations computed for the periods before, between and after the breaks, whereas Table 4 shows the annualized returns for the same time intervals.

Financial services (SXFGR) is among the most unstable sectors. In this category we do not find banks, but mainly asset managers, pension funds and other providers of financial services. The illiquidity of the markets together with a substantial increase

in the systematic risk of the whole market have been the main threatens for this sector. With a market going almost all down, asset managers, in particular, faced sharp losses, and transactions became expensive also on the OTC market, where margin accounts increased exponentially due to the increased counterparts risk. We observe an annualized standard deviation of 2.84% before the first break on the 19th of February 2020. What follows, is a period of extremely high volatility, with an annualized standard deviation of 16.52% lasting until the 25th of March. At this

Table 3 - Annualized Standard Deviation Between the Breaks

SXRGR	2,94%	10,61%	4,49%			
SX3GR	2,11%	10,94%	4,42%	2,42%		
SX4GR	2,77%	11,66%	5,07%	2,81%	3,84%	
SX6GR	2,85%	14,99%	4,27%	3,07%		
SX7GR	3,59%	13,81%	6,01%			
SX8GR	3,45%	12,64%	5,94%	4,30%	6,56%	
SX86GR						
SXAGR						
SXDGR	2,23%	10,70%	4,13%	2,80%	3,12%	
SXEP	3,19%	19,85%	12,71%	5,54%		
SXFGR	2,84%	16,52%	7,27%	4,57%	3,34%	4,48%
SXIGR	2,52%	15,82%	11,56%	4,30%		
SXKGR	2,47%	14,61%	6,11%	3,28%		
SXMGR	2,46%	11,75%	4,96%	3,47%		
SXNGR	2,77%	15,29%	8,94%	4,45%	3,23%	4,79%
SXOGR	2,53%	15,93%	5,72%	3,30%	4,46%	
SXPGR	4,63%	15,21%	5,84%			
SXQGR	2,80%	10,95%	4,75%	3,03%		
SXTGR	3,55%	7,80%	24,24%	11,76%	5,87%	8,65%

This table shows the annualized standard deviations of each index, during the periods delimited by the breaks. The first value is computed before the first break, whereas the last value is computed between the last break and the end of the sample.

stage, another break is detected and the volatility drops to 7.27%. This is possibly due to the measures announced to support the financial system. An increased trust of people towards government, might have calmed down the markets, and this would be consistent with the findings of Nils Engelhardt mentioned above. The following breaks happening on the 5th of November 2020 and the 18th of November are both bringing down the volatility, meaning that the confidence of investors is finally restored, at least in this sector. After the last break on the 18th of November 2021 we see a slight increase in the volatility, due to possible new measures following the 3rd wave.

Banks (SX7GR) on the other hand show a significantly more resilient behavior in terms of volatility and returns. We observe a longer period of increased volatility compare to most of the other sectors, that lasts until the 9th of June 2020. However, despite being threatened by several risks, banks show returns during the increased volatility period that are among the least negative compared to the other sectors analyzed.

Industrial goods & services (SXNGR) display five breaks within the sample period considered. We observe a standard deviation close of 2.77% before the initial break, followed by an increase to 15.29% between the first and the second break, happening on the 25th of March. Also in this case we observe a sharp decline of volatility after each of the following breaks besides the last one, that is bringing the volatility again up by 1.5 percentage points. This sector has been heavily impacted by labour and raw materials shortage, therefore after a framework to resume the activities has been designed, the recovery has been sharp. Indeed, the average annualized return of this

sector goes from 0.36% before the first break, to -5.91% between the first and second break and then up again to +1.38% after the second break.

Table 4 - Annualized Returns Between the Breaks						
SXRGR	0,48%	-4,96%	0,42%			
SX3GR	0,21%	-3,31%	0,38%	0,25%		
SX4GR	0,35%	-1,76%	0,51%	0,37%	0,06%	
SX6GR	0,90%	-3,69%	0,30%	0,23%		
SX7GR	0,37%	-1,45%	0,31%			
SX8GR	0,59%	-1,37%	0,33%	0,58%	-0,47%	
SX86GR						
SXAGR						
SXDGR	0,56%	-2,73%	0,16%	0,31%	0,80%	
SXEP	-0,29%	-8,95%	2,50%	0,11%		
SXFGR	0,67%	-5,74%	1,39%	0,15%	0,49%	-0,22%
SXIGR	0,43%	-8,44%	2,29%	0,21%		
SXKGR	0,07%	-4,35%	0,50%	0,14%		
SXMGR	0,22%	-2,06%	0,22%	0,49%		
SXNGR	0,36%	-5,91%	1,38%	0,47%	0,46%	0,03%
SXOGR	0,27%	-2,87%	0,57%	0,40%	0,39%	
SXPGR	0,09%	-1,56%	0,55%			
SXQGR	0,46%	-3,44%	0,57%	0,26%		
SXTGR	0,28%	-7,28%	-6,84%	2,63%	0,19%	-0,31%

This table shows the annualized average return of each index, during the periods delimited by the breaks. The first value is computed before the first break, whereas the last value is computed between the last break and the end of the sample.

Travel & Leisure (SXTGR) is perhaps the most impacted sector, and also here we observe five breaks. This is the only case in which the volatility increased both after the first and second break. We are going from an annualized value of 3.55% before the first event on the 19th of February to 7.80% right after, and up again to 24.24% after the third on the 3rd of April 2022. A sharp decrease is observed between the 4th

and the 5th break, but after the 5th break in November 2021 volatility raised again. Here, each new measure implemented by governments had a negative effect on the investor's sentiment as, inevitably, stricter and longer lockdowns will not be beneficial to this industry.

The Chemical sector (SX4GR) shows 4 breaks. The trend is consistent with the other indexes analyzed, as we observe an increase of the volatility between the first and the second break, then a decrease and a small increase after the last break. What is particular about this sector, is that production has been switched to crucial supplies for the sanitary emergency. Without mentioning the pharmaceutical part, a lot of industries managed to adapt to the current needs, and this results in lower losses compared to other sectors. A possible reason for this, is that the supply chain and labour force involved have been reorganized in a quicker way compared to other sectors.

The same reasoning applies to the Healthcare sector (SXDGR). Also here do we observe four breaks, and the same trend of the chemical sector in terms of volatility levels. Despite being the epicenter of the emergency, this sector did not show significantly lower returns in the periods between the breaks. This is due to the practically unlimited amount of resources allocated to the healthcare systems by all countries. Also, the losses suffered by the private players of the sector due to the lack of routine exams and treatments, have been compensated by the allocation of a significant portion of COVID patients to private structures paid by governments.

The Technology sector (SX8GR), especially for the production-focused part, suffered significantly due to COVID. In a context of trade war between USA and China, some of the main components and ores used by the industries of this sector became more expensive and hard to find. The supply chain of this sector is extremely shifted

towards east, as Asia is certainly the main producer of electrical and technological components. Trading with Asian partners has been extremely difficult during the first phase of the pandemic. The sector shows four breaks, with a peak in the volatility level of 12.64% after the first break. It is interesting to notice that the period of increased volatility is longer compared to other sectors, as it goes from the 19th of February to the 20th of April. The returns of the sector, however, have not been dramatical. COVID forced the world to a change in behavior, and new practice such as working from home and social distancing increased the overall demand for technological devices and services.

Oil and Gas (SXEP) went through the lowest level of their entire history. The lockdown measures triggered a substantial lack of demand for fuel for private and public transportation, and the slowness in the supply chains destroyed also the commercial demand. As we know oil prices went below zero, reaching settlement prices of -37$ for a barrel. For the first time in history, the storage cost was making not convenient to store and move oil. The volatility of this sector spiked on the 19th of February, reaching an annualized value of 19.85%, to slightly decrease to 12.71% on the 23rd of march. This level lasted until the 23rd of June, when a new break is observed and the level finally went back to normal. New lockdown measures did not create further breaks or significant increases in the volatility, as at least for the commercial demand no restrictions have ever been implemented again. The returns of the sector are significantly negative between the first and second break, to become again slightly positive afterwards.

The food and beverage sectors (SX3GR) has been perhaps the least impacted sector during the pandemic. Within this sector we indeed have to distinguish the hotel and restaurants related activities, from private consumptions: if the former partially

decreased, the latter increased substantially due to the increased number of consumers. The increased volatility after the first break is mostly due to the panic related to the shortage of supplies in supermarkets, caused both by the supply chain crisis and the common behavior of stockpiling goods. The situation we observe is a second break on the 26th of march 2020. At this stage the global situation of the supply chains had already improved, and the essential goods started to be shipped again. It is important to note that several players of this sector started to propose ad-hoc solutions for delivering food and food experience, so that the losses have been partially compensated.

Although it faced a severe crisis, the Retail sector (SXRGR) only shows two breaks. The behaviors of the consumers during the first part of the pandemic significantly changed. The traditional shopping has been impossible for almost two months and the online shopping experience has not been perceived as fully satisfying by the consumers, when allowed. The purchases simply shifted to the fundamental goods only. We observe a high volatility between the first and second break, reaching an annualized level of 10.61%. After the second break on the 24th of March 2020, the volatility goes back to lower values, as consumers got more used to so called new normal.

Utilities (SX6GR) are a relatively stable sector. We observe three breaks within the same, but only between the first and second break do we have significantly higher volatility. The losses due to the shutdown of companies around Europe have been compensated by the significantly higher domestic consumption. Lockdown measures in the first place, and also the need to work and study from home led to significantly higher private consumption. The high volatility between the first and second break is mostly a consequence on the energy commodities sector, as the supply of energy

sources has been the only threaten of the utilities sector during the pandemic. The volatility between the other breaks is lower compared to other sectors.

Insurances (SXIGR) as we can expect have been significantly threatened by the pandemic, with health insurances being the riskiest part of this sector. We observe three breaks. Between the first and the second event we reach the highest level of volatility, which however remains far above pre-pandemic levels also after the second event on the 23rd of March. The return of the insurance sector between the first and second break is the second lowest value observed.

Constructions & materials (SXOGR) shows four breaks. After the first break we observe an annualized volatility of 15.93%. This value decreases after the following breaks and slightly raises again after the last break observed in the sample, in November 23rd 2021. This sector has been considerably impacted by the supply chain crisis and by the lack of labour force.

Telecommunications (SXKGR) and Media (SXMGR) follow a similar path. They are both showing four breaks, but Media has a considerably lower volatility and less negative returns between the first and second break. We can attribute the better performance of the media sector to the less capital and infrastructure intensive activity that this sector is performing, compared to the telecommunications sector. The Media sector has been one of the most active sectors during the pandemic, from the news coverage to the increased amount of contents that the users demanded. On the other hand, telecommunications had to maintain infrastructures and services in a more difficult context.

Basic resources (SXPGR) include companies trading and producing commodities besides oil and gas. These players faced an extremely difficult period since, as mentioned above, moving goods became almost impossible. This sector shows just

two breaks, one at the beginning of the pandemic, and the other one on the 14th of May 2020. This is the longest period of increased volatility that we observe. This is due to the fact that while Oil and Gas have been considered fundamental goods, other commodities suffered more delays as the restoration of their chain has not been prioritized by all the countries. This is a clear example of a sector that has been "paused" by the measures and that, after the end of the lockdowns, recovered and went back to normal levels of returns and volatility.

Personal and household goods (SXQGR) show four breaks. The break points correspond to the first and second wave of contagions and measures, bur we clearly observe a lower impact of the second wave compared to the first one.

No breaks are detected for the Real Estate (SX86GR) and Automobiles & Parts (SXAGR) sectors. This is understandable as the real estate, at least for the private hosing part, has been stable during the pandemic. A shared feature between these two sectors is that the consumers - or buyers - usually plan the purchase months or years in advance. Therefore, the pandemic simply shifted by some months transactions that still happened. It would be interesting to investigate further the difference between the private and commercial part of the real estate sector, as several companies have been pushed to adopt different solutions in terms of working spaces during and after the pandemic. This is the case, for instance, of the increasing phenomenon of co-working spaces.

5 - Conclusion

This work project analyzed the behavior of the European stock markets' volatility during the pandemic. With a dataset composed by 19 sector-based indexes, the presence of structural breaks in the volatility has been tested with the methodology

proposed by Kokoszka and Leipus (KL) in 2000. Several studies focused on the impacts of the pandemic on the stock market and its volatility, but a sectoral approach has been adopted by very few of them. The main findings can be summarized as follow. All sectors analyzed show at least two breaks, except for Real Estate and Automobiles & Parts, that are not showing any structural change. All sectors went through a break at the beginning of the pandemic, when the epicenter of the covid emergency was still in China. February and March 2020 are the months with the highest numbers of breaks, as almost all the sectors show one break in these months. During the following months breaks became more sector-specific, as each sector faces different challenges and threats. The results provided are useful for further research aiming to model the volatility of this historical period. Several studies indeed provide evidence that ignoring the presence of structural breaks in the volatility when modeling it with a GARCH model, leads inevitably to the illusion of higher persistency, and biased estimators. Also from a risk management perspective, taking into account the presence of structural break is important. Hood (2018) showed that a VaR modeled by taking into account breaks in the variance performs better and is more reliable. Further research on this topic might be conducted in two different directions: the first one is a further split of the sectors, perhaps following the one proposed by Qontigo. As mentioned above, some sectors include businesses that for contingent reasons behaved in a significantly different way. This is usually the case of the split between commercial/industrial part and retail/private part of the sector. For instance, Food and Beverage and Real Estate might have behaved completely different. The other main direction of research could be further split the dataset by nations, while keeping the division by sector. This would be useful as not all the countries implemented the same measures, and this significantly differentiated

the behaviors of the consumers from county to country. Italy for instance implemented always a strict lockdown policy, and the economic sector might have reacted more, compared to countries such as Germany or UK.

Bibliography

Ahmad, Wasim, Ali M. Kutan, and Smarth Gupta. 2021. "Black Swan Events And COVID-19 Outbreak: Sector Level Evidence From The US, UK, And European Stock Markets". *International Review Of Economics &Amp; Finance* 75: 546-557. doi:10.1016/j.iref.2021.04.007.

Albulescu, Claudiu Tiberiu. 2021. "Coronavirus And Financial Volatility: 40 Days Of Fasting And Fear."

Ashraf, Badar Nadeem. 2020. "Stock Markets' Reaction To COVID-19: Cases Or Fatalities?". *Research In International Business And Finance* 54: 101249. doi:10.1016/j.ribaf.2020.101249.

Baek, Seungho, Sunil K. Mohanty, and Mina Glambosky. 2020. "COVID-19 And Stock Market Volatility: An Industry Level Analysis". Finance Research Letters 37: 101748. doi:10.1016/j.frl.2020.101748.

Baker, Scott, Nicholas Bloom, Steven Davis, Kyle Kost, Marco Sammon, and Tasaneeya Viratyosin. 2020. "The Unprecedented Stock Market Impact Of COVID-19". doi:10.3386/w26945.

Boone, Laurence, David Haugh, Nigel Pain, and Veronique Salins. 2020. "Tackling The Fallout From COVID-19". *Economics In The Time Of COVID-19*.

Buszko, Michał, Witold Orzeszko, and Marcin Stawarz. 2021. "COVID-19 Pandemic And Stability Of Stock Market—A Sectoral Approach". *PLOS ONE* 16 (5): e0250938. doi:10.1371/journal.pone.0250938.

Chowdhury, Emon Kalyan, Iffat Ishrat Khan, and Bablu Kumar Dhar. 2021. "Catastrophic Impact Of Covid-19 On The Global Stock Markets And Economic Activities". *Business And Society Review*. doi:10.1111/basr.12219.

Duttilo, Pierdomenico, Stefano Antonio Gattone, and Tonio Di Battista. 2021. "Volatility Modeling: An Overview Of Equity Markets In The Euro Area During COVID-19 Pandemic". *Mathematics* 9 (11): 1212. doi:10.3390/math9111212.

Engelhardt, Nils, Miguel Krause, Daniel Neukirchen, and Peter N. Posch. 2021. "Trust And Stock Market Volatility During The COVID-19 Crisis". *Finance Research Letters* 38: 101873. doi:10.1016/j.frl.2020.101873.

Goswami, Samrat, Rangan Gupta, and Mark E. Wohar. 2019. "Historical Volatility Of Advanced Equity Markets: The Role Of Local And Global Crises."

Haroon, Omair, and Syed Aun R. Rizvi. 2020. "COVID-19: Media Coverage And Financial Markets Behavior—A Sectoral Inquiry". *Journal Of Behavioral And Experimental Finance* 27: 100343. doi:10.1016/j.jbef.2020.100343.

Hillebrand, Eric. 2005. "Neglecting Parameter Changes In GARCH Models". *Journal Of Econometrics* 129 (1-2): 121-138.

Hong, Hui, Zhicun Bian, and Chien-Chiang Lee. 2021. "COVID-19 And Instability Of Stock Market Performance: Evidence From The U.S.". Financial Innovation 7 (1). doi:10.1186/s40854-021-00229-1.

Hood, Matthew, and Farooq Malik. 2018. "Estimating Downside Risk In Stock Returns Under Structural Breaks". *International Review Of Economics &Amp; Finance* 58: 102-112. doi:10.1016/j.iref.2018.03.002.

Just, Małgorzata, and Krzysztof Echaust. 2020. "Stock Market Returns, Volatility, Correlation And Liquidity During The COVID-19 Crisis: Evidence From The Markov Switching Approach". Finance Research Letters 37: 101775. doi:10.1016/j.frl.2020.101775.

Khanthavit, Anya. 2020. "World And National Stock Market Reactions To COVID-10". *ABAC Journal* 40 (2): 1 - 20.

Kokoszka, Piotr, and Remigiujus Leipus. 2000. "Change-Point Estimation In ARCH Models". *Bernoulli* 6 (3): 513 - 519.

Kusumahadi, Teresia Angelia, and Fikri C Permana. “Impact of COVID-19 on Global Stock Market Volatility.” Journal of Economic Integration 36, no. 1 (2021): 20–45. https://www.jstor.org/stable/26985574.

Lamoureux, Christopher G., and William D. Lastrapes. “Persistence in Variance, Structural Change, and the GARCH Model.” Journal of Business & Economic Statistics 8, no. 2 (1990): 225–34. https://doi.org/10.2307/1391985.

Moslehpour, Massoud, Ahmad Al-Fadly, Syed Ehsanullah, Kwong Wing Chong, Nguyen Thi My Xuyen, and Luc Phan Tan. 2022. "Assessing Financial Risk Spillover And Panic Impact Of Covid-19 On European And Vietnam Stock Market". *Environmental Science And Pollution Research* 29 (19): 28226-28240. doi:10.1007/s11356-021-18170-2.

Moussi, Abderrahmane, and Ahmed Ouazza. 2021. "Financial COVID-19 Crisis: An Empirical Study And Prediction Of Some Stock Market Indices". *IAENG International Journal Of Applied Mathematics* 51 (3).

Poterba, James M., and Lawrence H. Summers. “The Persistence of Volatility and Stock Market Fluctuations.” The American Economic Review 76, no. 5 (1986): 1142–51. http://www.jstor.org/stable/1816476.

Rodrigues, Paulo M. M., and Antonio Rubia. 2011. "The Effects Of Additive Outliers And Measurement Errors When Testing For Structural Breaks In Variance*". *Oxford Bulletin Of Economics And Statistics* 73 (4): 449-468. doi:10.1111/j.1468-0084.2010.00621.x.

Stărică, Cătălin, and Clive Granger. “Nonstationarities in Stock Returns.” The Review of Economics and Statistics 87, no. 3 (2005): 503–22. http://www.jstor.org/stable/40042945.

Tsuji, Chikashi. 2018. "How Are Structural Breaks Related To Stock Return Volatility Persistence? Evidence From China And Japan". Modern Economy 09 (10): 1635-1643. doi:10.4236/me.2018.910102.

Wang, Dong, Ping Li, and Lixin Huang. 2022. "Time-Frequency Volatility Spillovers Between Major International Financial Markets During The COVID-19 Pandemic". *Finance Research Letters* 46: 102244. doi:10.1016/j.frl.2021.102244.

Wang, Hua, Liao Xu, and Susan Sunila Sharma. 2021. "Does Investor Attention Increase Stock Market Volatility During The COVID-19 Pandemic?". *Pacific-Basin Finance Journal* 69: 101638. doi:10.1016/j.pacfin.2021.101638.

Wang, Ping, and Tomoe Moore. 2009. "Sudden Changes In Volatility: The Case Of Five Central European Stock Markets". Journal Of International Financial Markets, Institutions And Money 19 (1): 33-46. doi:10.1016/j.intfin.2007.08.006.

Wójcik, Dariusz, and Stefanos Ioannou. 2020. "COVID-19 And Finance: Market Developments So Far And Potential Impacts On The Financial Sector And Centres". *Tijdschrift Voor Economische En Sociale Geografie* 111 (3): 387-400. doi:10.1111/tesg.12434.

Zaremba, Adam, Renatas Kizys, David Y. Aharon, and Ender Demir. 2020. "Infected Markets: Novel Coronavirus, Government Interventions, And Stock Return Volatility Around The Globe". *Finance Research Letters* 35: 101597. doi:10.1016/j.frl.2020.101597.